Application Note

Guidelines for Luminus Dynamic COBs — Warm Dimming and Tunable White

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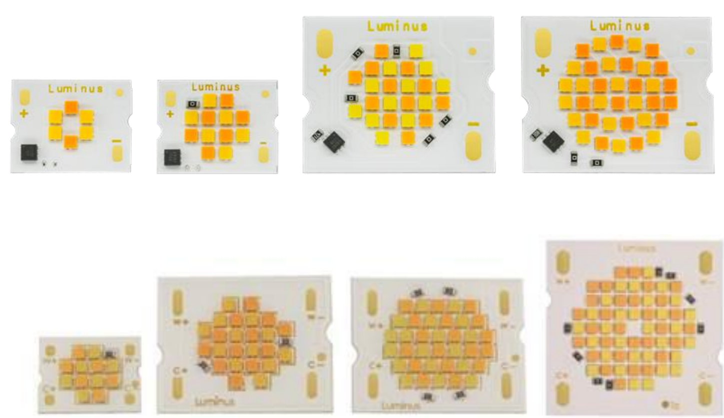
1. Introduction

This document contains application information for the Luminus Dynamic COB modules — Warm Dimming and Tunable White COBs. The contents include an overview of the products, general handling and soldering tips, guidelines for mounting and connecting, secondary optics, power supplies and driving dynamic COBs, and thermal management associated with the COBs. Additionally, this application note provides an Ecosystem section that helps designers choose a variety of compatible components used to optimize Luminus Dynamic COB module performance.



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2. Product Overview

Warm Dimming and Tunable White COBs are designed to provide adjustable Correlated Color Temperatures (CCTs) when driving them at different currents. They have high lumen density and give great performance for directional lighting. Although they all serve the same purpose of providing various CCTs in directional lighting, there are differences between them in design, functionality, and applications which are explained below.

2.1 Warm Dimming COBs

A Warm Dimming COB consists of MP-1616 Cube LEDs and an IC chip on a metal PC board. Figure (1). The beam angle of Cube LEDs is optimized for high density tight array modules. The warm white and cool white Cubes on the same board mix light together to provide flexible CCTs. The unique design allows light mixing and recycling for high uniformity.

Figure 1: An Example of Warm Dimming COB

Luminus delivers four lighting emission surface (LES) sizes for Warm Dimming COBs: CDM-6, CDM-9, CDM-14 and CDM-18. CDM-6 and CDM-9 share the same footprint of 12x15mm with LES of 6.5mm and 9.5mm, while CDM-14 and CDM-18 have a footprint of 20x24mm with LES of 14.5mm and 17.5mm. Standard Warm Dimming COBs have two ranges of CCTs, from 3000K to 1800K and from 4000K to 2700K. Other dim-to-warm CCT change ranges are possible, but would involve customer-specific development and NRE. Targeted applications include residential lighting, hospitality and well-being or human centric lighting. Warm Dimming COBs have a defined measurement point of case temperature (T_C) marked on each board to monitor board temperature.

Warm Dimming COBs only require a single channel dimmable driver. The IC on board controls the warm dimming function. The dimming curve is adjusted in the Luminus factory by the selection of an on board resistor. Luminus Dynamic COB warm dimming solutions provide the most simple and economic dim-to-warm COB modules with a choice of two dimming curves, linear and halogen-like, as shown in the diagrams below.

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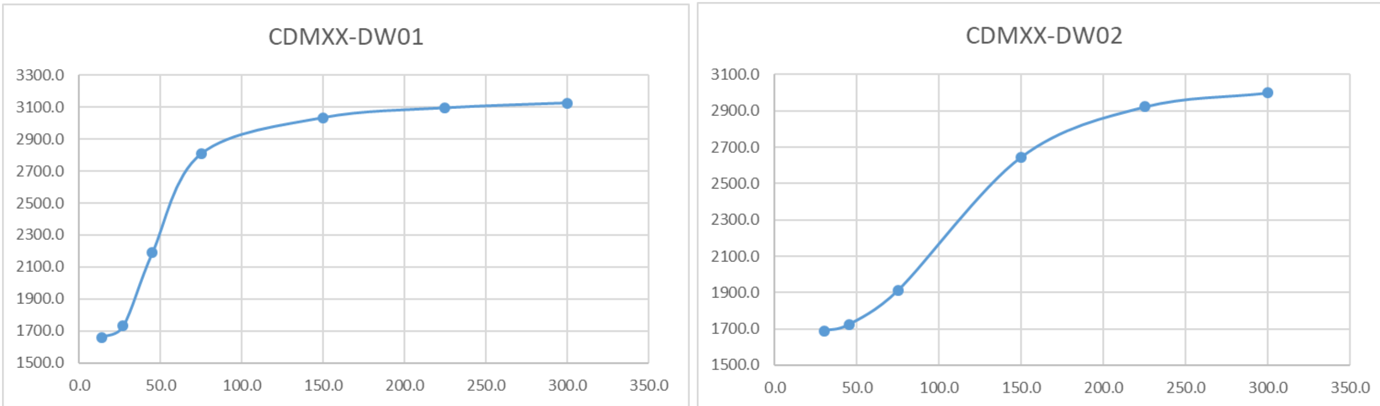

Figure 2: Dimming Curves for Warm Dimming COBs

Figures 2 shows the dimming curves at different driving current for the Warm Dimming series. Additionally, there are two dimming curve options for each Warm Dimming COBs. One with suffix "-DW01" is "halogen-like" (left graph above) and the other one with suffix "-DW02" is "linear-style" (right graph above).

2.2 Tunable White COBs

A Tunable White COB consists of MP-1616 Cube LEDs on a metal PC board. See Figure 3. Similar to Warm Dimming COBs, warm white and cool white LED cubes on metal PC board mix light to provide flexible CCTs. The unique design allows light mixing and recycling for highly uniform narrow beam spot lights.

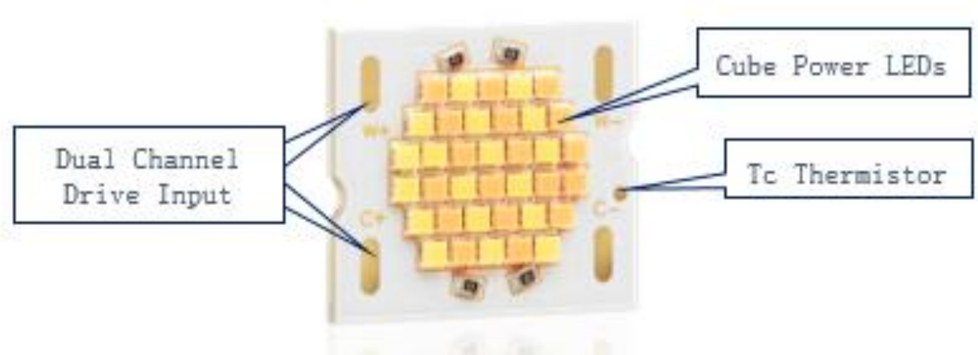

Figure 3: An Example of a Tunable White COB Module

Luminus offers four LES sizes for Tunable White COBs including the CTM-9, CTM-14, CTM-18 and CTM-22. The CTM-14 and CTM-18 share the same substrate size (20x24mm). The CTM-9 has a substrate size of 12x15mm with a LES diameter of 9.5mm, and the CTM-22 has a substrate size of 28x28mm with an LES of 22mm. Different from Warm Dimming series, Tunable White COBs have two separate channels and require dual channel drivers to control the CCT ranges, from 4000K to 1800K or from 6500K to 2700K in the standard product portfolio. Other CCT ranges are available as custom orders. The CCT tunable range of all CTM series COB module products are re-configurable with a programmable driver by controlling the output current ratio of dual-channel drivers. For example, with CTM-4018, the tunable CCT range can be re-configured to any range within 4000K to 1800K; with CTM-6522, the tunable CCT range can be re-configured to any range within 6500K

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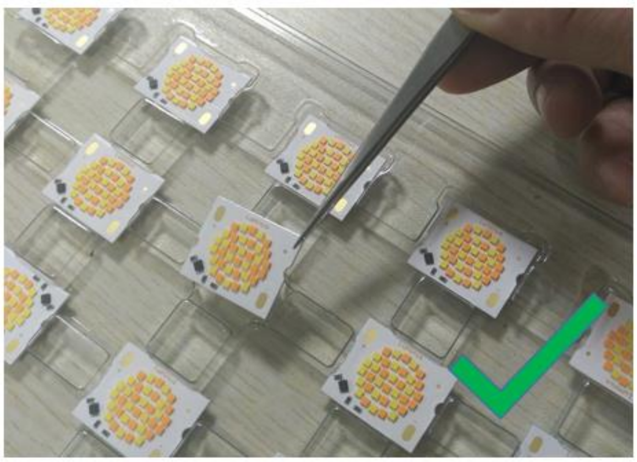
to 2700K, such as 4000K/3500K/3000K in commercial lighting applications. Targeted areas of applications are human centric lighting, shop and retail, and commercial. Tunable White COBs also have a Tc measurement point to monitor board temperature.

3. General Handling and Soldering

Luminus products are designed for robust performance in general lighting applications; however, care must be taken when handling and soldering COBs. To avoid damaging the products, please follow the tips below.

3.1 Holding the COBs

Devices are made to be lifted or carried with tweezers on proper locations as shown in Figure 4A. At no time should the devices be handled by or should anything come in contact with electrical pads, IC, or LES area as shown in Figure 4 B, C and D. Incorrect handling will damage the device and cause it to fail.



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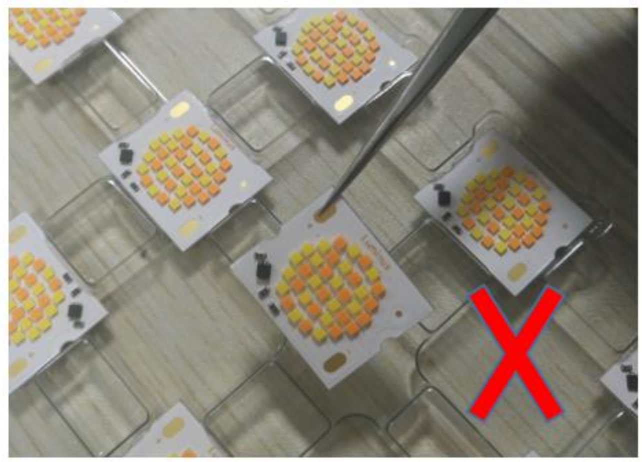

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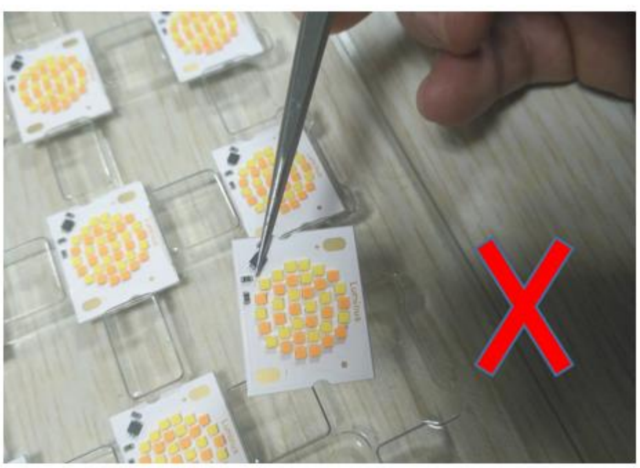


C

D

Figure 4: Correct and Incorrect Handling of Dynamic COBs

3.2 Chemical Compatibility

The resin material used to form the emitters inside the LES can absorb hydrocarbons from the surrounding environment. As a result, certain chemical compounds are not recommended for use with Luminus products. Use of these compounds can cause damage to the light output of the device and may permanently damage the device. Below is a partial list of chemicals which need to be avoided with Luminus COBs.

Common Chemicals Known To Adversely Affect Luminus COBs	
Acetates	Liquid hydrocarbons
Acetic acid	Phosphoric acid
Acrylates	Potassium hydroxide
Aldehydes	Siloxanes, fatty acids
Amines	Sodium Hydroxide
Benzene	Sulfur compounds
Cl, F,or Br containing compounds	Sulfuric Acid
Dienes	Toluene
Ethers	Xylenes
Hydrochloric Acid	Nitric Acid
Ketones	

Table 1: List of Chemicals to Be Avoided with Dynamic COBs

3.3 Static Electricity

LEDs are electronic devices which can be damaged by electrostatic discharge (ESD). Please use appropriate measures to assure the devices do not experience ESD during their handling and/or storage. ESD protection guidelines should be used at all times when working with LEDs.

Storage: Luminus products are delivered in ESD shielded bags and should be stored in these bags until used.

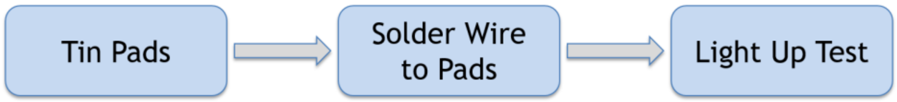
Assembly: Individuals handling LEDs during assembly should be trained in ESD protection practices. Assemblers should maintain constant conductive contact with a path to ground by means of a wrist strap, ankle straps, mat, or other ESD protection system.

Transporting: When transporting the devices from one assembly area to another, ESD shielded cards and carriers should be used.

4. Soldering and Light Up Test

In general, a solderless connector is recommended for mounting, but if designers choose not to use a solderless connector, they can solder wire leads to the electrically conductive pads on the core board of COB devices. The devices may be soldered by hand or by use of a reflow oven.

Flow Diagram for General Steps:



Soldering Procedures:

1. Place device on thermal non conductive surface.
2. Use a soldering iron set at 400~450°C depending on the solder and work station in the manufacturing line.
3. Tin the pads with SAC305 flux-core solder wire.
4. Strip 2-3 mm of wire and tin with SAC305 flux-core solder wire.
5. Solder wire to pad.
6. Remove the soldering iron from the device.

Precautions:

1. Avoid any contact with emitting LED surfaces during soldering. A hot soldering iron can cause permanent damage and catastrophic failure. Luminus recommends the use of a solder stencil in order to prevent solder from contacting areas of the device other than the solder pads.
2. Do not attach COB to heat sink prior to soldering.
3. ESD protection is required when soldering.
4. Choose soldering iron with proper shape and size of the iron tip similar to pads. Make sure that they have full contact when soldering by keep soldering iron and pad in contact for 1~2 seconds.
5. Make sure the tin points are smooth and not too big or too high to block the light.

Light Up Test:

Apply constant current mode output to the device using a DC power supply. Use output current about 10 to 20mA for the light up lest. Note:

1. For Warming Dimming COBs, only warm white string LEDs will light up when operating at such small current levels, and one LED in each warm string will not light up visually, which is normal. All LEDS will turn on when operating at typical/nominal driving current.

2. For Tunable White COBS, all LEDs will light up when driving at low current.

5. Mounting and Connecting

Warm Dimming and Tunable White COBs need to be securely mounted so that the entire COB board is in contact with the thermal interface material and heat sink.

Through Holes: There are two "mouse bite" holes provided through the COB board for the purpose of using thread screws for mounting. The screws feature a flat surface where the screw head contacts the COB board. (Figure 5) Screw head sizes should be selected so that no portion of the screw head or washer contacts the

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solder pads, IC, resistors or LES. Make sure the proper moderate torque is applied to the mounting screws to avoid breaking the solder mask layer which may short-circuit the electrical trace of the COB to the heat sink. An electrical isolated plastic screw or adding isolation washer/layer when using metal screw is recommended if using screws to mount dynamic COB modules onto the heat sink.

Figure 5: Screw Head Types and Screw Mounting

Using Connectors or Holders: We recommend the use of solderless connectors and COB holders to hold down the Dynamic COB in place and maintain thermal contact with the heat sink. A solderless connector has electrical connections (pins) in contact with conductive pads so it doesn't require soldering. A COB holder does not provide any electrical connection so wire leads must be soldered to the pads. Dynamic COBs holders are available from major reflector/lens venders like Darkoo, Shinland, Herculux, and others. Dynamic COBs connectors are available from Bender & Wirth, TE, Widegerm, Optosource and others.

When mounting a connector/holder to a Warm Dimming COB, pay attention to the correct connector orientation when clipping it onto the COB. See figure 6A. If the orientation is rotated incorrectly by 180°, the connector will break the IC and resistors on board. See figure 6B.

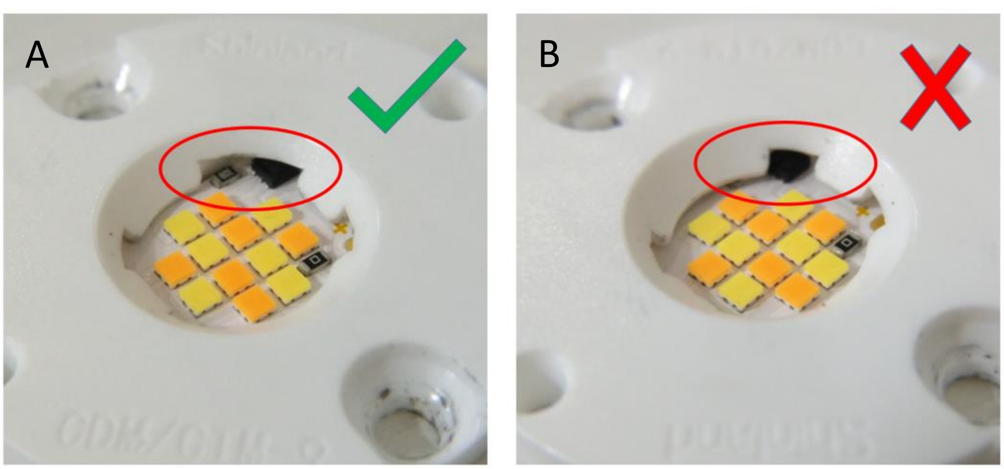

Figure 6: Connector Orientation

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A few notes when using a connector or holder to mount the Dynamic COBs onto the heat sink:

• Connectors and holders must not touch the LEDs. The aperture of the connector must have a larger diameter than the LES diameter.

• Holder clamps should not contact the solder pads or wire leads.

• Conductive contacts of solderless connectors should be in firm contact with the solder pads and be held in place securely enough so that the conductivity is always maintained. Conductive contacts should only touch the solder pads.

• Screws used to fasten the solderless connector or clamp holder should be seated with a thread sealant such as Loctite 220 or equivalent in order to prevent loosening due to thermal cycling of the system.

• Connectors and holders should not interfere with the thermal path between COB board, TIM, and heat sink.

• Operators should make sure that the connector or channel marked positive (+) coincides with the solder pad marked positive (+) on the COB board. Likewise, the negative connector (-) or channel marked negative (-) should coincide with the solder pad marked negative (-) on the COB board. Failure to insure that the connectors are contacting the proper pole could lead to reverse biasing of the device after assembly.

• Solderless connectors must be sized so that the COB board and LES fit within the connector without interference or allowing the part to move freely. If the pocket for the holder is too small or too large this may interfere with the connectivity between the lead contacts and conductive pads on the COB.

• Make sure the LES of COBs is centered inside the aperture of the solderless connector or COB holder. If the LES is not properly centered in the opening of the connector, then the LES may be damaged or the light output may become partially obscured.

6. Secondary Optics

6.1 General Guideline

Typically, COBs have a Lambertian viewing angle which needs secondary optics to change its distribution angle for different applications. Because Warm Dimming and Tunable White COBs have both cool white and warm white LEDs packaged on board, it's important to mix the color to achieve better color uniformity.

Multi-faceted reflectors can provide good color uniformity for large beam angles (>25^{o}) when used on dynamic COBs. But in order to generate a spot beam less than 20^{o}, the optic needs stronger mixing features. When a reflector is used as a secondary optic, a diffusive lens needs to be added either on top of the COB or on top of the reflector to eliminate the color separation around the edge due to spatial separation of cool white LEDs and warm white LEDs, as well as to provide better uniformity. If a designer wants to use a TIR lens, an effective color mixing feature is required when selecting or designing the lens. Some suggestions in TIR lens design for Luminus Dynamic COBs are 1). Lens array or other diffusive feature on output surface of TIR lens, 2). Multi-faceted TIR reflection surface, and 3). Diffusive input surface. Luminus provides a list of existing optics from

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several manufacturers for designers to choose from. Please refer to the Ecosystem tables in the last section of this document.

When mounting an optic to a COB, it is important to avoid any contact with the LEDs.

For designers who need to run ray trace simulations in software to model their own optics before prototyping, Luminus provides the design files including mechanical files and ray data files. The mechanical files are in IGES or STEP format and can be imported into CAD modeling software such as SolidWorks or ProE. Ray data files are provided in various formats for optical simulation software such as ASAP, LightTools, TracePro or Zemax. These files can be downloaded from the Luminus website.

One key of using ray files is to understand the source alignment according to the geometry of COB. In each folder of the ray file, Luminus provides a slide of PPT explaining where the ray data should be located. Using CDM-9 as an example, Luminus provides images to illustrate the xyz coordinates on the COB. (Figure 7)

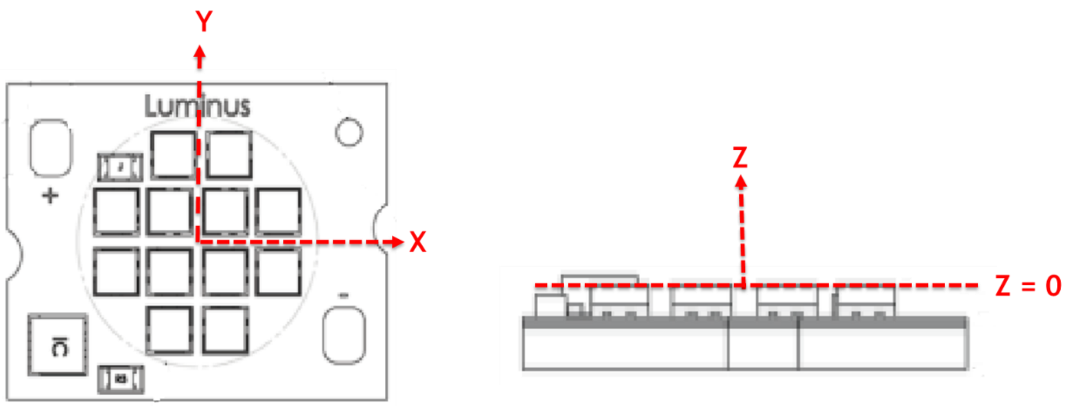

Figure 7: Source Alignment for Ray Data

When designers load both the mechanical file and ray file of the CDM-9 into the optical software, the ray file should be located in the center of light emitting surface in the X-Y plane and the top surface of the LEDs in the X-Z or Y-Z plane. Properly located ray data is critical in optical simulation.

6.2 Narrow beam optics for Dynamic COBs

Special consideration is needed to design optics for Dynamic COBs at narrow beam angles less than 24° . Due to spatial separation of cool white LEDs and warm white LEDs, Dynamic COBs may have some color separation and pattern distribution at the near-field emitting surface. In order to achieve a narrow beam angle, secondary optics may project this near-field color separation or pattern onto the wall or may project slight de-focusing of this pattern, which may result in a color non-uniformity phenomenon.

For narrow beam optics design, it is key to solve this color separation issue on the wall, which involves a couple of techniques in the following:

1. Using actual ray files or a LED model source with the spatial color LED pattern when designing narrow beam optics

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2. A free-form design approach may be needed when designing a reflection surface or TIR surface, so the beam pattern on the wall is independent of the spatial location of the multi-color LED source.
3. A diffusive lens can be added on top of the Dynamic COBs for a better spatial color uniformity source.
4. A multi-facet reflector is usually helpful to mix the light for better uniformity
5. A lens array or diffusive plate can be added on top of the reflector or TIR lens to provide better uniformity.

One example of adding a diffusive lens to get better light uniformity is in Fig. 8. The diffusive lens has a dome shape with micro-lens array features to mix the light from the LED source. The diffusive lens can be snapped into the connector of Dynamic COBs.

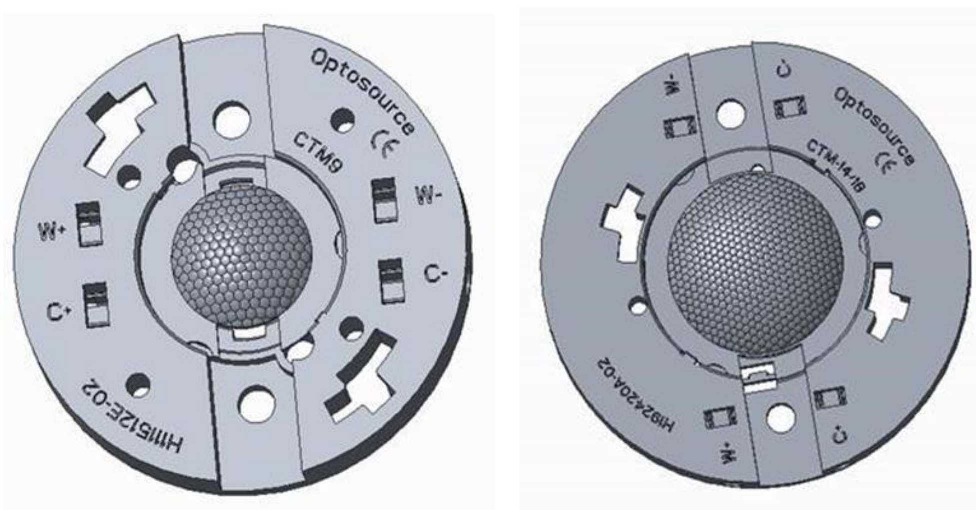


Figure 8: Diffusive lens snapped into COB Connector

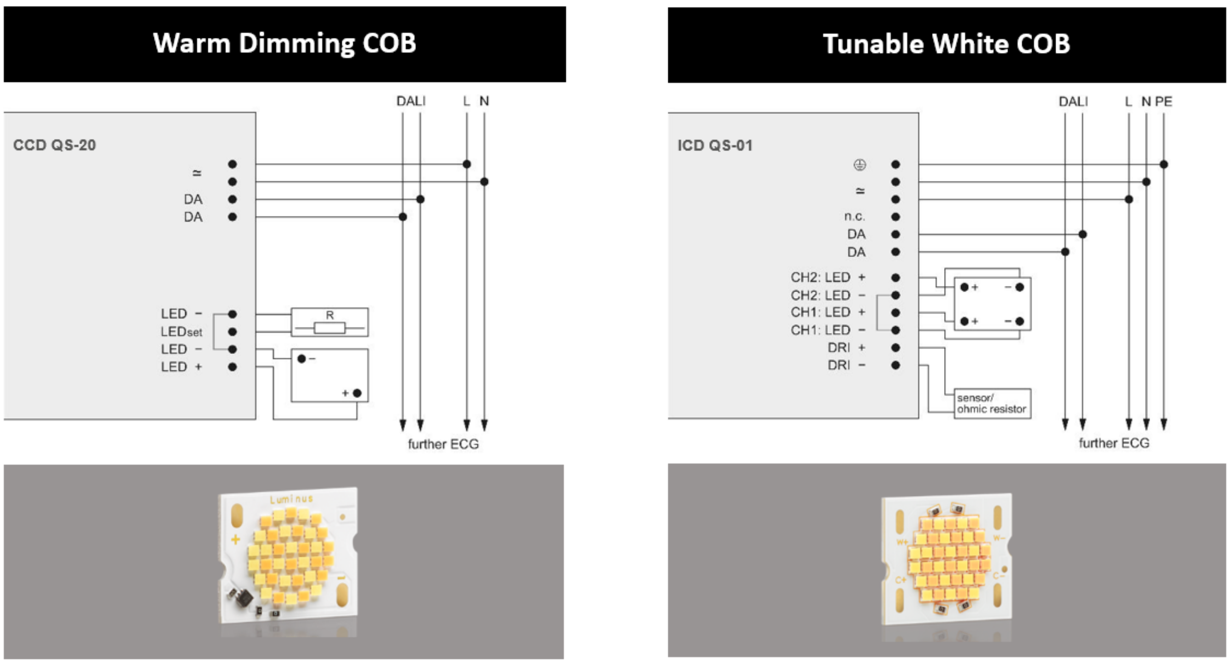
7. Driving Dynamic COBs

7.1 Driving warm dimming(WD) COBs

LED drivers are used to supply power to make COBs emit light. Proper dimable drivers need to be selected to control the dimming function. Some types of driver controllers may or may not work with Luminus Dynamic COBs, which are listed in the next paragraph. For specific part numbers of suggested drivers, please refer to the Ecosystem table in last section of the application note.

Warm Dimming COBs use a single channel dimmable driver. The on-board IC senses the input current or voltage change and adjusts the current ratio running through the cool white and warm white channels, so the CCT will change during dimming. General speaking, most Triac/0-10V dimmable drivers which work well with regular/standard COBs(single CCT) will also work with warm dimming COBs. Figure 9A shows how a Warm Dimming COB is connected to a single channel dimmable driver in a DALI control system. There are other control systems available for dim-to-warm adjustment, such as Triac or 0~10V dimmers, WIFI remotes, etc.

1. TRIAC: YES. It's a three terminal bidirectional semiconductor switching device which can control alternating current in a load.
2. 0-10V: YES. It's one of the earliest and simplest system for controlling dimming function.
3. Digital dimmable driver: Yes, if has current, or voltage change during dimming operation.
4. PWM (Pulse-width modulation): NO. This is inappropriate for Warm Dimming COBs. It is used to vary duty cycles of a constant current.



A B

Figure 9: Wire Diagrams for Dynamic COBs

7.2 Driving tunable white(TW) COBs

Tunable White COBs need dual channel dimmable drivers. Figure 9B shows how a Tunable White COB is connected to a dual channel driver in a DALI control system. Tunable white COB driver control schemes may include DALI, wireless and 0~10V.

By adjusting the current input to the cool white channel and warm white channel of tunable white CTM COBs from a dual channel driver, the mixing white color will have color points falling onto the line between the cool white color point and warm white color point. See figure 10A and figure 10B below which show the typical current ratio input to CW/WW channels to create various CCTs using the CTM-4018 and CTM-6527 COBs.

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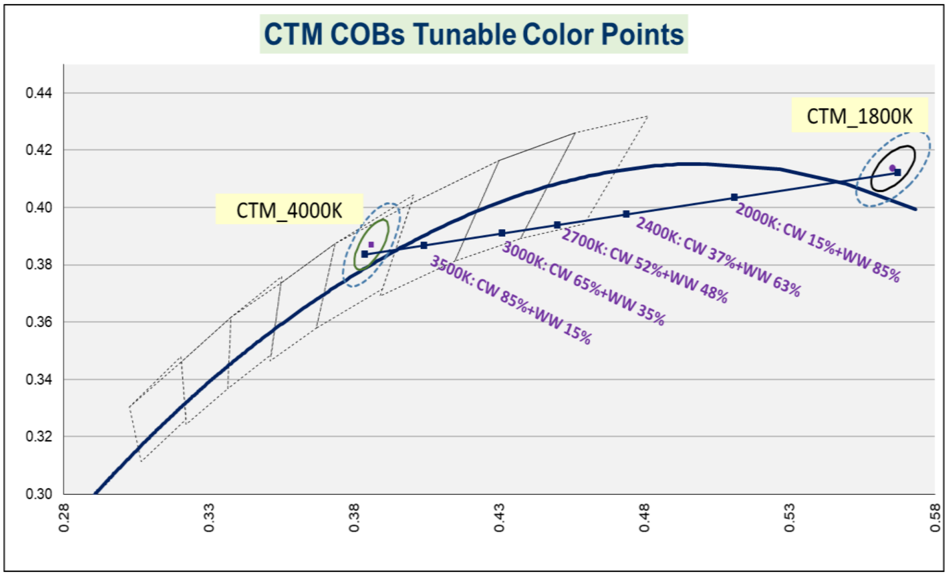

Figure 10A. CW/WW channel current ratio of CTM4018 at different tunable CCTs

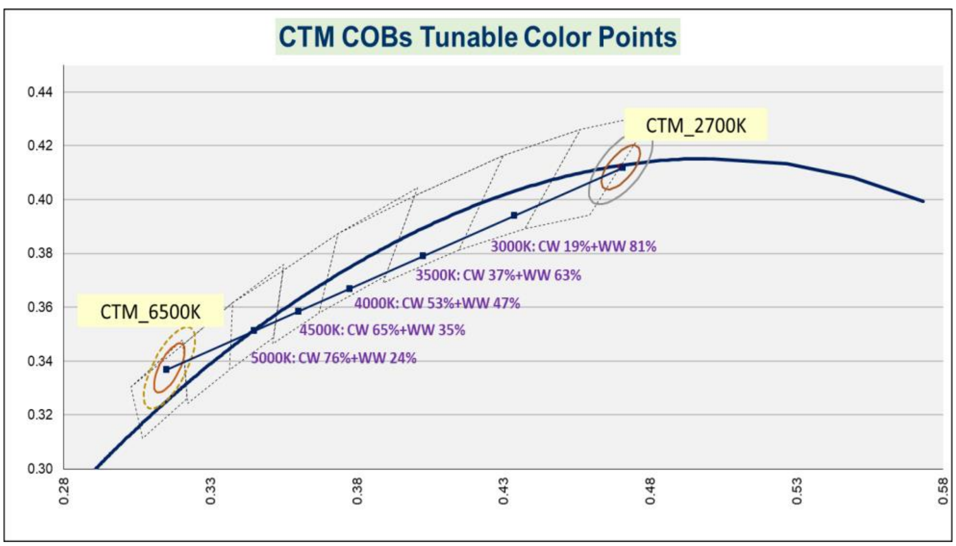

Figure 10B. CW/WW channel current ratio of CTM6527 at different tunable CCTs

The CCT tunable range could be re-configured to be narrower than the maximum change range by re-configuring the dual channel current output range of the single driver. For example, users can reduce the maximum range of 4000~1800K for the CTM4018 or the 6500~2700K range for the CTM6527. In such a case, the CW or WW channel may not be completely turned off during CCT tuning and CTM COBs could be driven at higher input power. Figure 11 shows the maximum power for different CCT tunable ranges of a CTM14-6527 COB. At the extreme limits of the full CCT tunable range of 2700K~6500K, one CCT channel will turn off. The maximum driving current from a dual-channel single driver is around 440mA and maximum input power will be around 17W. For CCT tunable range of 3000K~5000K, both CCT channels will remain on during CCT tuning, so the maximum total output current from a single driver could be 550mA and the maximum total input power

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can be 21W. If the CTM14-6527 is used for a CCT tunable range of 3300~4500K, then the maximum total output current of the driver can be 675mA and the maximum total input power to the COB can be 25W.

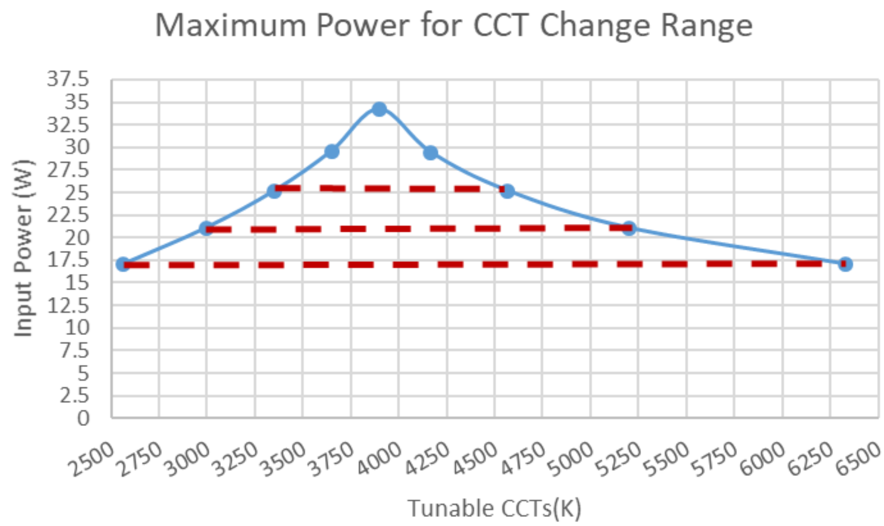

Figure 11. Maximum power for various CCT tunable range of CTM14-6527

8. Thermal Management

Proper thermal management is one of the key requirements for optimal COB operation. Heat generated in the COB can be very substantial and needs to be managed properly, otherwise it could lead to a significant drop in light output and shorten the COB's lumen maintenance dramatically.

Luminus provides sufficient information in the product datasheet to help designers perform thermal calculations for controlling the substrate temperature. The important information in the datasheet is the maximum LED junction temperature ($T_{j\text{-}max}$) and the typical thermal resistance from LED junction to substrate ($R_{\theta j\text{-}c}$). Luminaire designers need to calculate T_j based on case temperature (T_c) and make sure the value is lower than the maximum allowed $T_{j\text{-}max}$. The relationship between T_j and T_c is described below:

$$T_j = R_{\theta j-c} \times P_{Diss} + T_c$$

where, T_j: Temperature at LED junction

$R_{\theta j-c}$: Thermal resistance from LED junction to case

P_{Diss}: Dissipated Power, which is assumed as the LED input power

T_c: Case temperature measured on LED coreboard

Note: The amount of power dissipated optically is neglected in the calculation.

As a first step, designers need to measure T_c and make sure this value is lower than $T_{c\text{-}max}$, which is normally given in the datasheet. To measure T_c, use a thermocouple to connect the little round dot on the COB core board and the temperature of the substrate can be read on the other end with a meter. Then, designers can use the equation above to calculate T_j based on measured T_c and parameters $R_{\theta j-c}$ and LED power obtained

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from the datasheet at certain driving conditions. As long as the calculated T_j is not exceeding allowed $T_{j\text{-}max}$, the LED is operating at a safe temperature without overheating. Therefore, designers can control T_c and input power to properly manage potential thermal issue in LEDs.

In order for heat energy to move from LED junction to heat sink, thermal interface material (TIM) must be filled in between to eliminate thermally resistive air gaps that occur on a microscopic scale. A TIM increases the surface contact by a significant degree and thereby allows for the efficient removal of heat from the LED package. When applying TIM on Warm Dimming and CCT Tunable LEDs, make sure it is in complete contact with the entire back surface of the aluminum core board on one side and also the heat sink on the other side. Voids, poor adhesion, or insufficient amount of TIM can result in low light output and failure of the device. A table of TIM options is provided for reference in the last section of this document.

Once heat is removed from the LED package to the heat sink, it needs to be dissipated quickly and efficiently in order to prevent the junction temperature from rising to levels that could be destructive to the device. A properly designed (or chosen) heat sink is the key in exchanging heat to the ambient environment. When the heat sink has a constraint on its footprint, adding a fan or thermo-electric cooler with the heat sink is a practical way to minimize its size and further dissipate the heat out into the environment.

For additional information for thermal management, see refer to APN-001443 on Luminus website.

9. Dynamic COB LM-80 and Life Time Estimation

Luminus Dynamic COBs are level-2 LED assemblies consisting of multiple units of 6Volt MP-1616 LEDs surface mounted on a metal core board. LEDs are arranged in strings of 6 LEDs in series in order to create a nominal forward voltage of 36V on the board. In the CDM-6, the LEDs are arranged in strings of 3 LEDs to produce a nominal forward voltage of 18 volts. Please refer to the tables below to see the number of parallel strings in each product.

CCT Tunable Two Channel Dynamic COBs

Part number	Nominal forward current per channel	Number of LED strings in parallel per channel	Forward current per LED @ nominal channel current	Absolute maximum forward current per channel	Forward current per LED @ max current per channel
CTM-9-xxxx-90-36-TW01	200mA	1	200mA	220mA	220mA
CTM-14-xxxx-90-36-TW01	400mA	2	200mA	440mA	220mA
CTM-18-xxxx-90-36-TW01	550mA	3	183mA	660mA	220mA
CTM-22-xxxx-90-36-TW01	875mA	5	175mA	1100mA	220mA

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Warm Dimming Dynamic COBs

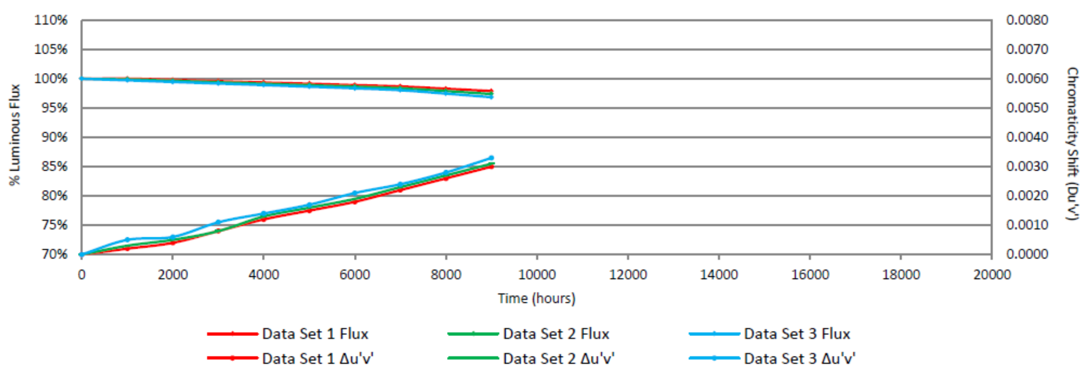
Part Number	Nominal current applied to board	Number of LED strings in parallel	Forward current per LED @ nominal board current	Absolute maximum current applied to board	Forward current per LED @ max current per channel
CDM-6-xxxx-90-18-DW0x	300mA	2	150mA	440mA	220mA
CDM-9-xxxx-90-36-DW0x	300mA	2	150mA	440mA	220mA
CDM-14-xxxx-90-36-DW0x	600mA	4	150mA	800mA	200mA
CDM-18-xxxx-90-36-DW0x	900mA	6	150mA	1080mA	180mA

With this "level-2" packaged light source module, the LM-80 test of MP1616 LEDs will be used for Dynamic COB modules, which tests the light output change over time at different driving currents and MCPCB board temperatures.

The MP-1616 LEDs have been tested for 9000 hours at forward current of 250mA at 3 temperatures (Tc=55°C, 85°C and 105°C). LM-80 test data is summarized below:

2700K, I_f=250mA, Data Set 1: Tc=55°C; Data Set 2: Tc=85°C; Data Set: Tc=105°C

Data Set:	Sample Size	Failures Observed:	Test Interval	Test Duration	α:	β:	Reported TM-21 L_{70} Lifetime
1	25	0	1000hrs	9000hrs	2.919E-06	1.006	>54000hrs
2	25	0	1000hrs	9000hrs	3.473E-06	1.006	>54000hrs
3	25	0	1000hrs	9000hrs	4.131E-06	1.007	>54000hrs



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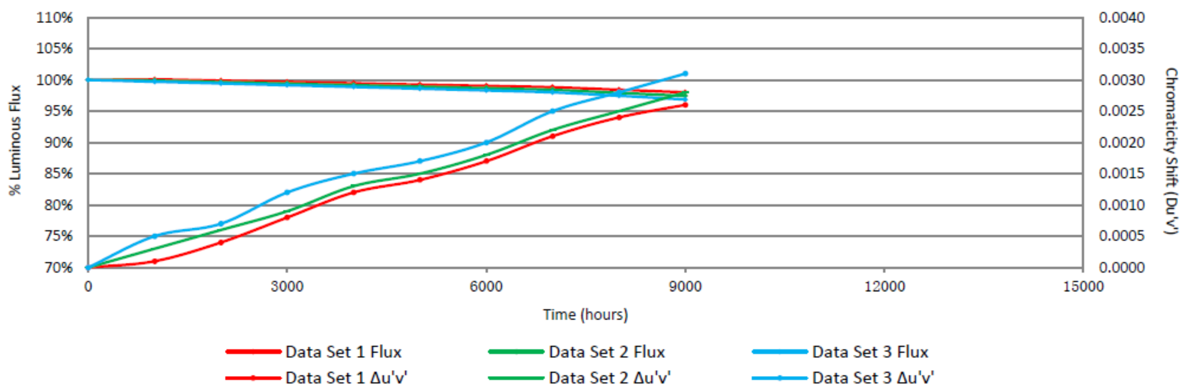
1800K, I_f=250mA, Data Set 1: Tc=55°C; Data Set 2: Tc=85°C; Data Set: Tc=105°C

Data Set:	Sample Size	Failures Observed:	Test Interval	Test Duration	α:	β:	Reported TM-21 L_{70} Lifetime
1	25	0	1000hrs	9000hrs	2.858E-06	1.007	>54000hrs
2	25	0	1000hrs	9000hrs	3.446E-06	1.006	>54000hrs
3	25	0	1000hrs	9000hrs	4.013E-06	1.006	>54000hrs



When a luminaire designer uses the MP1616 LM-80 test report to estimate the lumen maintenance of Dynamic COB modules, they should measure the Tc point of Dynamic COBs in their typical field application conditions then decide which test is the best match to those conditions.

10. Ecosystem Tables

Luminus provides the ecosystem suppliers and components in tables below for reference. These include information on connectors and holders, optics, drivers and thermal interface materials from various manufacturers. Designers can simply choose the proper component to use in conjunction with Luminus Dynamic COBs, or use this information as a guideline for your own design if necessary. While we strive to provide an extensive list here of optical or drive components, we also encourage designers to contact relative Ecosystem partners for details and updated information.

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10.1 Connectors/Holders

<table>
<tr><th colspan="4">LUMINUS COBs</th><th colspan="5">CONNECTORS/HOLDERS</th></tr>
<tr><th>FUNCTION</th><th>COB PARTS NUMBER</th><th>LES</th><th>BOARD SIZE</th><th>BJB</th><th>BENDER + WIRTH</th><th>MOLEX</th><th>WIDEGERM</th><th>OPTOSOURCE</th></tr>
<tr><td rowspan="4">TUNABLE WHITE</td><td>CTM-9-XXXX-90-36-TW01</td><td>9.5mm</td><td>12X15mm</td><td>WIP</td><td>495/46651</td><td></td><td>WC-CTM9</td><td>H111512E-02</td></tr>
<tr><td>CTM-14-XXXX-90-36-TW01</td><td>14.5mm</td><td>20X24mm</td><td rowspan="2">47.319.2051</td><td rowspan="2">442/46648</td><td></td><td rowspan="2">WC-CTM-14-18</td><td>H192420A-02</td></tr>
<tr><td>CTM-18-XXXX-90-36-TW01</td><td>17.5mm</td><td>20X24mm</td><td></td><td>H192420A-02</td></tr>
<tr><td>CTM-22-XXXX-90-36-TW01</td><td>22mm</td><td>28X28mm</td><td></td><td>494/46618</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">WARM DIMMING</td><td>CDM-6-XXXX-90-18-DW0X</td><td>6.5mm</td><td>12X15mm</td><td rowspan="2">47.319.618X</td><td rowspan="2">490/46552-2</td><td rowspan="2">1803900002</td><td rowspan="2">WC-CDM6-9</td><td>H111512F-02</td></tr>
<tr><td>CDM-9-XXXX-90-36-DW0X</td><td>9.5mm</td><td>12X15mm</td><td>H111512F-02</td></tr>
<tr><td>CDM-14-XXXX-90-36-DW0X</td><td>14.5mm</td><td>20X24mm</td><td rowspan="2">47.319.201X</td><td rowspan="2">491/46555-2</td><td rowspan="2">1803300002</td><td rowspan="2">WC-CDM14-18</td><td>H192420B-02</td></tr>
<tr><td>CDM-18-XXXX-90-36-DW0X</td><td>17.5mm</td><td>20X24mm</td><td>H192420B-02</td></tr>
</table>

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10.2 Secondary Optics

Luminus COBs				Optics		
Function	COB Part Number	LES	Board Size	Ledil	LEDLink	Darkoo
Tunable White	CTM-9-xxxx-90-36-TW01	9.5mm	12x15mm	CN12483_Mirella-50-S-DL CN12484_Mirella-50-M-DL CN12485_Mirella-50-W-DL	LL01ED-ACA24L14 LL01ED-ACA38L14	DK4524-REF-K DK4536-REF-K DK5024-REF-K DK5036-REF-K
	CTM-14-xxxx-90-36-TW01	14.5mm	20x24mm	FC13977_Angelina-RZ-S-B FC13978_Angelina-RZ-M-B FC13979_Angelina-RZ-W-B C13085_Mirella-50-S-PF C13086_Mirella-50-XW-PF C13087_Mirella-50-W-PF	LL01CR-CFE24L02-P LL01CR-CFE38L02-P LL01CR-CEN24L02 LL01CR-CEN38L02	DK6924-REF-K DK6940-REF-K DK7524-REF-K DK7540-REF-K DK8525-REF-K DK8540-REF-K
	CTM-18-xxxx-90-36-TW01	17.5mm	20x24mm			
	CTM-22-xxxx-90-36-TW01	22mm	28x28mm			
Warm Dimming	CDM-6-xxxx-90-18-DW0x	6.5mm	12x15mm	CN12483_Mirella-50-S-DL CN12484_Mirella-50-M-DL CN12485_Mirella-50-W-DL	LL01ED-ACA24L14 LL01ED-ACA38L14	DK4524-REF-K DK4536-REF-K
	CDM-9-xxxx-90-36-DW0x	9.5mm	12x15mm			DK5024-REF-K DK5036-REF-K
	CDM-14-xxxx-90-36-DW0x	14.5mm	20x24mm	FC13977_Angelina-RZ-S-B FC13978_Angelina-RZ-M-B FC13979_Angelina-RZ-W-B C13085_Mirella-50-S-PF C13086_Mirella-50-XW-PF C13087_Mirella-50-W-PF	LL01CR-CFE24L02-P LL01CR-CFE38L02-P LL01CR-CEN24L02 LL01CR-CEN38L02	DK6924-REF-K DK6940-REF-K DK7524-REF-K DK7540-REF-K DK8525-REF-K DK8540-REF-K
	CDM-18-xxxx-90-36-DW0x	17.5mm	20x24mm			

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10.3 Drivers

LUMINUS COBS				DRIVERS		
FUNCTION	COB PARTS NUMBER	LES	BOARD SIZE	ECG(DALI)	ELDOLED(DALI)	MOONS(0~10V)
TUNABLE WHITE	CTM-9-XXXX-90-36-TW01	9.5mm	12X15mm	2X CCD1105-18QS-20/DALI		
	CTM-14-XXXX-90-36-TW01	14.5mm	20X24mm	ICD290-100LS-02/DALI	DULADRIVER 560/U1 DALI DUALDRIVER 560/A2 DALI DUALDRIVER 560/L2 DUALDRIVER 560/S2	MU050S150BQI201 MU050I105DQI5 MU050I105DQI81
	CTM-18-XXXX-90-36-TW01	17.5mm	20X24mm	ICD290-100LS-02/DALI		
	CTM-22-XXXX-90-36-TW01	22mm	28X28mm	ICD290-100LS-02/DALI		
WARM DIMMING	CDM-6-XXXX-90-18-DW0X	6.5mm	12X15mm	CCD1105-18QS-20/DALI		
	CDM-9-XXXX-90-36-DW0X	9.5mm	12X15mm	CCD1105-18QS-20/DALI		
	CDM-14-XXXX-90-36-DW0X	14.5mm	20X24mm	CCD1105-35QS-20/DALI		
	CDM-18-XXXX-90-36-DW0X	17.5mm	20X24mm	CCD1105-35QS-20/DALI		

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10.3 Drivers (continue)

LUMINUS COBS				DRIVERS			
FUNCTION	COB PARTS NUMBER	LES	BOARD SIZE	BAG	HELVAR	TIGI DIGITAL (WIRELESS REMOTE)	LITETRACE (APP CONTROL)
TUNABLE WHITE	CTM-9-XXXX-90-36-TW01	9.5mm	12X15mm			TGSC-IH12-42-B1-0280	LT-G-03-2215035
	CTM-14-XXXX-90-36-TW01	14.5mm	20X24mm		LL35/2-E-DA-iC LC35/2-DA-iC	TGPC-IH25-42-B1-0480	LT-G-03-2215035
	CTM-18-XXXX-90-36-TW01	17.5mm	20X24mm			TGPC-IH40-42-B1-0600 TGPC-IH40-42-A1-0700	LT-S-03-2230070
	CTM-22-XXXX-90-36-TW01	22mm	28X28mm				
WARM DIMMING	CDM-6-XXXX-90-18-DW0X	6.5mm	12X15mm	CCD1105-18QS-20-220~224/DALI CCD170-27QS-20/220~240/DALI			
	CDM-9-XXXX-90-36-DW0X	9.5mm	12X15mm	CCD1105-18QS-20-220~224/DALI CCD170-27QS-20/220~240/DALI		TGPD-IH25-42-B1-0320	
	CDM-14-XXXX-90-36-DW0X	14.5mm	20X24mm	CCD1105-35QS-20/220~240/DALI		TGPD-IH25-42-B1-0600	
	CDM-18-XXXX-90-36-DW0X	17.5mm	20X24mm	CCD1140-55QS-20/220~240/DALI		TGPD-IH40-42-B1-0950 TGPD-IH40-42-A1-0900	

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10.4 Thermal Interface Materials

MANUFACTURER	PART NUMBER	TYPE	DESCRIPTION	PERFORMANCE
3M	8805	Acrylic	Thermally conductive adhesive transfer tape	Excellent
3M	5590h	Acrylic	Thermally conductive acrylic interface pad	Good
GrafTech	eGraph HiTherm	Graphite	Flexible graphite	Good
GrafTech	eGraph HiTherm	Adhesive	flexible graphite with adhesive	Good
Berquist	Liqui-form 2000	Grease	Shear-thinning, conformable	Excellent
Arctic Silver	Arctic Silver 5	Grease	High Density Polysynthetic Silver Thermal Compound	Excellent
Panasonic	PGS	Graphite +Acrylic	Thermal Graphite Sheets	Excellent
Omega	OmegaTHERM	Grease	High Temp Thermally Conductive Paste	Excellent
Rathburn	8805	Graphite + Adhesive	Thermally Conductive Transfer Pad	Good
Rathburn		Graphite + PET	Thermally Conductive Transfer Pad	Good

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