XLamp® CX Family LED Design Guide

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INTRODUCTION

This guide simplifies the CX family luminaire design effort by providing basic information on the requirements to use XLamp® CX family LEDs successfully in luminaire designs, with appropriate consideration for mechanical, electrical, thermal and optical design and chemical compatibility.

In this document, the term CX family LEDs refers to Cree LED's ceramic substrate CXA and CXB LEDs, i.e., all the CXA and CXB LEDs except the out-of-production CXA2011.

CX family LEDs deliver high lumen output and efficacy in a family of single, easy-to-use components. CX family LEDs enable lighting manufacturers to quickly add LED products to their product portfolio. With CX family LEDs, lighting manufacturers can have performance, reliability and ease-of-use in a single LED.

This design guide explains how CX family LEDs and assemblies containing these LEDs should be handled during manufacturing. Please read this entire document to understand how to properly design with and handle CX family LEDs.

ABOUT THIS DESIGN GUIDE

This design guide provides critical design guidelines, principles and best practices for successfully integrating the XLamp CX family LED into new and existing luminaire designs.

- For additional product information or samples, please contact your Cree LED sales representative.
- For technical information and support, please e-mail us at productsupport@cree-led.com.

Consult the CX family soldering and handling document for additional information on the proper procedures to solder and handle CX family LEDs.

THANK YOU

Thank you for choosing to incorporate the XLamp CX family LED into your luminaire designs.

CX FAMILY PRODUCT CAUTIONS

- XLamp CX family LEDs must be electrically connected to an unenergized driver before applying power. “Hot plugging,” i.e., making a connection from a CX family LED to an energized driver, may cause irreparable damage and will void the product warranty.
- All installations and applications of CX family LED-based luminaires are subject to the electrical, construction and building codes in effect in the final installation location. Installation by professionals having experience in the area of electrical lighting and formal inspection by the Authorities Having Jurisdiction (AHJ) is strongly recommended.
- Thermal characteristics of CX family LEDs are affected by the luminaire and by the conditions in which the luminaire is installed. All final luminaire products should be evaluated in actual worst case installation conditions. Thermal limits of the CX family LED must be maintained for warranty consideration.

⚠ CX family LED surfaces may be hot during operation. Take care during handling to avoid burns.

⚠ Do not look directly at an energized CX family LED without proper eye safety precautions or diffusive shielding.

Failure to follow the design guidelines in this document may void the product warranty and may present a hazard to property or personnel.

STORAGE & HANDLING

Store XLamp CX family LEDs in their original packaging to minimize potential for unintended contact and contamination.

CX family LEDs must be handled with proper electrostatic discharge (ESD) handling protocols. Remove CX family LEDs from their package at an ESD-safe workstation and use appropriate handling protocols and precautions when handling and soldering connections to the CX family LED.

- Handle CX family LEDs in a clean environment, i.e., free from particulates, oil residues, etc.
- Do not touch the light-emitting surface (LES) of a CX family LED with tools or fingers. The LES is the part of the LED from which light is emitted. In the pictures on the cover page of this guide, the yellow or orange circle on each CX family LED is the LES.
- Do not allow foreign material to touch the LES of a CX family LED.
- Do not assemble CX family LED-based luminaires in an environment in which foreign material can come in contact with the LED.
- Material should be cleaned from a CX family LED by gently blowing the material off the LED with clean dry air (CDA) or by wiping the LED with a lint-free swab dipped in isopropyl alcohol (IPA).

MECHANICAL DESIGN

Typical Assembly

CX family LEDs are generally attached directly to a heat sink and discrete wires are used to deliver power to the LED, as illustrated in Figure 1. A thermal interface material (TIM) must be applied between the CX family LED and the heat sink to properly maintain thermal performance.

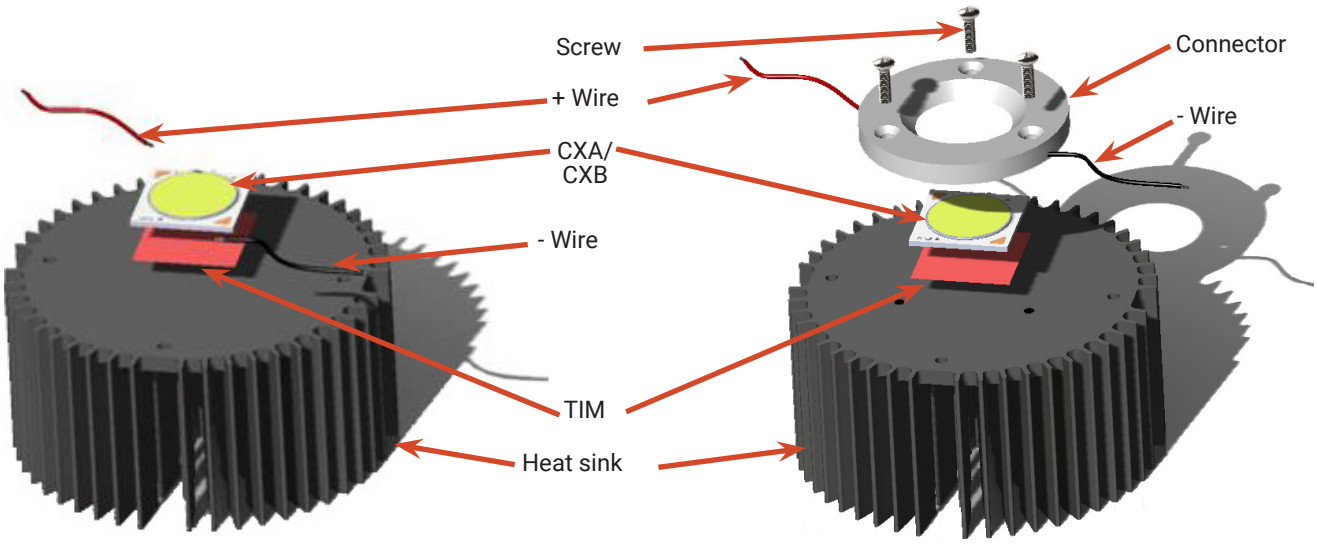


Figure 1: CX family LED connected to heat sink, left: without a connector, right: with a connector

Connectors

The use of a connector to attach a CX family LED to a heat sink simplifies the mechanical fastening of the CX family LED to the heat sink and can help with aligning a secondary optic with the LES. The use of a connector can also ensure proper clamping force is applied to the CX family LED, minimizing the potential for damage. Additionally, because a connector covers the LED's electrical connections, use of a connector simplifies the safety and regulatory certification process.

Connector Resources

Table 1 contains model numbers and characteristics for connectors. Each supplier name and model number is a link to additional information on the connector. These suppliers can provide assistance with connectors and connector information.

Table 1: CX family connector model numbers

CX Family LED/ Characteristic	Supplier Model Number					
	BJB	Ideal	Kang Rong	Molex	SMK	TE Connectivity
CXA13XX CXB13XX	47.319.6120.50	50-2000CR				2-2154857-2
CXA15XX CXB15XX	47.319.6101.50	50-2001CR	K905A	180560-0001		2-2154857-3 5-2154874-2
CXA18XX CXB18XX	47.319.2130.50	50-2101CR	K905C K905R			2-2154857-2 22131401-1 22131401-2
CXA1830 CXB1830		50-2101CR	K905R			2-2154857-2 22131401-1 22131401-2
CXA25XX CXB25XX	47.319.2140.50	50-2102CR	K905B 90409	180720-0002 180810-0001	CLE9902-0791F	2-2154857-2 5-2154874-3 2213107-1 2213107-2
CXA30XX CXB30XX	47.319.2150.50	50-2234C			CLE9902-1391F	2-2154857-2
CXA35XX CXB35XX CXA2 Studio		50-2303CR				
Screw size	M3	#4, #5, M3	M2.5, M3	M2.5, M3	M3	No. 4 or M3x6-mm (minimum)
Maximum torque for screw (Nm)	0.5	0.3-0.5	0.5	0.4-0.8	0.3 ±10%	0.28-0.45
Reflectivity	97%		96%			
Zhaga Book 3 compliant	Yes	Yes	No	No	No	No

Cree LED recommends following the connector manufacturer's recommendations for both the amount of torque to apply to the connector and the TIM thickness.

Table 2 shows some of the optics available for CX family LED connectors. For more optics solutions, see Table 8.

Table 2: CX family LED connectors and optics

CX Family LED	Connector Vendor	Connector Part Number	Optic Part Number				
			Carclo	Gaggione	Khatod	LEDiL	Ideal LEDiL Adaptor
CXA13XX CXB13XX	BJB	47.319.6120.50	10755.00 10754.00				
	Ideal	50-2000CR					
	Kang Rong						
	Molex						
	SMK						
	TE Connectivity	2-2154857-2					

CX Family LED	Connector Vendor	Connector Part Number	Optic Part Number				
			Carclo	Gaggione	Khatod	LEDiL	Ideal LEDiL Adaptor
CXA15XX CXB15XX	BJB	47.319.6101.50	10755.00 10754.00				
	Ideal	50-2001CR				Mirella	
	Kang Rong						
	Molex	180560-0001					
	SMK						
	TE Connectivity	2-2154857-3					
CXA18XX CXB18XX	BJB	47.319.2130.50		LLC56N LLR05N		F13659_ANGELINA-S-B F13660_ANGELINA-M-B F13661_ANGELINA-W-B F13839_ANGELINA-XW-B F13662_ANGELA-S-B F13663_ANGELA-M-B F13664_ANGELA-W-B F13841_ANGELA-XW-B	
	Ideal	50-2101CR				Mirella-PF Lena Angela	50-2100MR 50-2100LN 50-2100AN
	Kang Rong						
	Molex						
	SMK						
	TE Connectivity	2-2154857-2					
CXA1830 CXB1830	BJB						
	Ideal	50-2101CR					
	Kang Rong						
	Molex						
	SMK						
	TE Connectivity	2-2154857-2					
CXA25XX CXB25XX	BJB	47.319.2140.50		LLC56N LLR05N		F13659_ANGELINA-S-B F13660_ANGELINA-M-B F13661_ANGELINA-W-B F13839_ANGELINA-XW-B F13662_ANGELA-S-B F13663_ANGELA-M-B F13664_ANGELA-W-B F13841_ANGELA-XW-B	
	Ideal	50-2102CR				Lena Angelina	50-2100LN 50-2100AN
	Kang Rong						
	Molex	180720-0001					
	SMK	CLE9902-0791F					
	TE Connectivity	2-2154857-2					

CX Family LED	Connector Vendor	Connector Part Number	Optic Part Number				
			Carclo	Gaggione	Khatod	LEDiL	Ideal LEDiL Adaptor
CXA30XX CXB30XX	BJB	47.319.2150.50		LLC56N LLR05N		F13659_ANGELINA-S-B F13660_ANGELINA-M-B F13661_ANGELINA-W-B F13839_ANGELINA-XW-B F13662_ANGELA-S-B F13663_ANGELA-M-B F13664_ANGELA-W-B F13841_ANGELA-XW-B	
	Ideal	50-2234C				Lena Angelina	50-2100LN 50-2100AN
	Kang Rong						
	Molex						
	SMK	CLE9902-1391F					
	TE Connectivity	2-2154857-2					
CXA35XX CXB35XX CXA2 Studio	BJB						
	Ideal	50-2303CR				Angelina	50-2300AN
	Kang Rong						
	Molex						
	SMK						
	TE Connectivity						

Mechanical Damage to Light-Emitting Surface

At no time should anything (tools, optics, hands) come in contact with the LES of a CX family LED. Such contact will damage the LED.

Cree LED performed tests to replicate handling that can damage the CX family LED LES. Figure 2 shows downward force being applied to a CX family LED LES. Figure 3 shows bent (blue arrows) and broken (red arrows) bond wires in a CX family LED due to force applied to the LES. Figure 4 shows a CX family LED that is only partially illuminated due to handling that damaged bond wires in the LED.

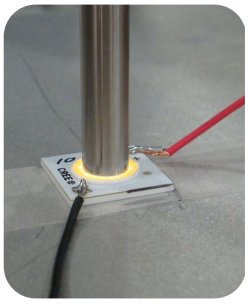


Figure 2: Force applied to CX family LED

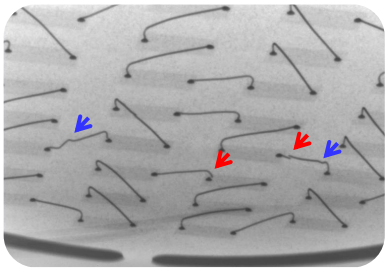


Figure 3: Damaged bond wires due to improper handling of CX family LED

Figure 4: Partially illuminated CX family LED due to damaged bond wires

Preventing Damage to CX Family LEDs

The force needed to fracture a CX family LED depends on many factors including the flatness of the material onto which the LED is pressed, the hardness and thickness of the material, how the CX family is stressed and where on the LED the stress is applied.

Cree LED recommends a maximum force of no more than 75 pound-force (334 Newtons) be applied to a CX family LED on a flat surface.

It takes less force to damage a CX family LED on a non-flat surface. The amount of force depends on the geometry of the non-flat surface, how the force is applied and where on the LED the force is applied. As recommended in the Heat Sink Flatness and Cleanliness section on page 14, attaching a CX family LED to a flat heat sink surface is advised. This not only enables good thermal contact, but also supports the CX family LED uniformly so the ceramic will not break under normal force conditions. Using a thick, soft TIM or a non-flat surface reduces the allowable force on a CX family LED and application-specific testing is strongly advised in such a situation.

Handling/Assembly

Do not attach screws directly to a CX family LED, not even with the use of plastic washers. Doing so will damage the LED. Figure 5 is an example of improperly attaching a CX family LED to a heat sink.

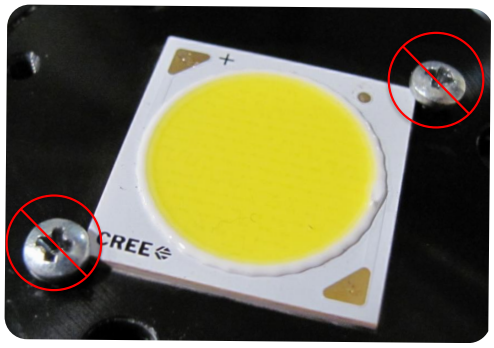


Figure 5: Do not attach CX family LED with screws

Figure 6 shows proper and improper handling of CX family LEDs with fingers and tweezers. Wear clean, lint-free gloves when handling CX family LEDs. Doing so helps to keep the LES clean. Do not touch the LES with fingers, gloved fingers or tools.

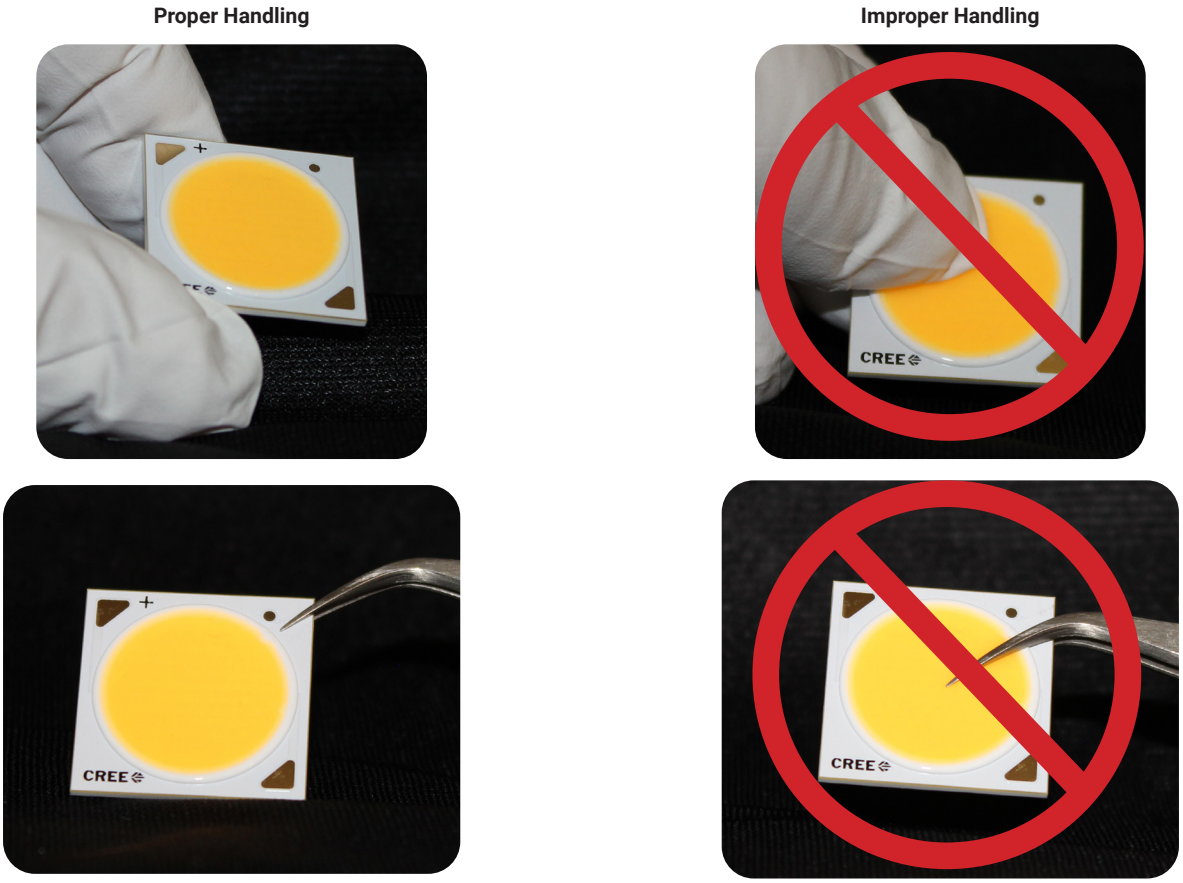


Figure 6: Correct and incorrect handling of CX family LED with fingers and tweezers

If wires are to be manually soldered to a CX family LED, Cree LED recommends using wire of the gauge shown in Table 3. These gauges apply when operating the CX family LED at its maximum current. If a lower current is used, a smaller gauge wire can be used. The wire strip length depends on the size of the CX family LED and should be no longer than the length of the solder pad, as shown in Table 3.

Table 3: CX family manual soldering wire gauge and wire strip length

LED		Wire Gauge		Wire Strip Length	
		AWG	mm^2	in	mm
CXA1304 CXB1304	9 V	21	0.41	0.075	1.9
	18 V	24	0.205	0.075	1.9
	36 V	27	0.102	0.075	1.9
CXB1310	18 V	21	0.41	0.075	1.9
	36 V	24	0.205	0.075	1.9
CXA1507 CXB1507	18 V	22	0.326	0.075	1.9
	36 V	25	0.162	0.075	1.9
CXA1510	18 V	21	0.41	0.075	1.9
	36 V	23	0.258	0.075	1.9
CXA1512 CXB1512	18 V	21	0.41	0.075	1.9
	36 V	23	0.258	0.075	1.9
CXB1520	36 V	22	0.326	0.075	1.9
CXA1816 CXB1816	36 V	22	0.326	0.075	1.9
CXA1820 CXB1820	36 V	21	0.41	0.075	1.9
CXA1830 CXB1830	36 V	20	0.518	0.075	1.9
CXA2520	36 V	20	0.518	0.106	2.7
CXA2530 CXB2530	36 V	19	0.653	0.106	2.7
CXA2540 CXB2540	36 V	18	0.823	0.106	2.7
CXA3050 CXB3050	36 V	17	1.04	0.106	2.7
CXA3070 CXB3070	36 V	17	1.04	0.106	2.7
CXA3590 CXB3590 CXA2 Studio	36 V	17	1.04	0.126	3.2
	72 V	19	0.653	0.126	3.2

As illustrated in Figure 7, wire should not protrude outside the contact pad to minimize the potential to damage the LES or short around the ceramic dielectric. Any residual flux should be cleaned with IPA to minimize the potential for contamination or degradation of the silicone.

Figure 7: Left: Wires improperly attached to CX family LED, center: wires should not protrude beyond solder pads, right: excessive solder flux should be cleaned

THERMAL DESIGN

Heat & Lifetime

XLamp CX family LEDs are designed to perform over a range of operating temperatures. As with all LEDs, their expected lifetimes depend on their operating temperature. When designing a luminaire that incorporates CX family LEDs, careful consideration must be taken to ensure a sufficient thermal path to ambient is provided. Verification of a proper thermal path is done on the finished luminaire in the intended application by attaching a thermocouple at the Tc measurement point indicated in Figure 8 for each CX family LED.

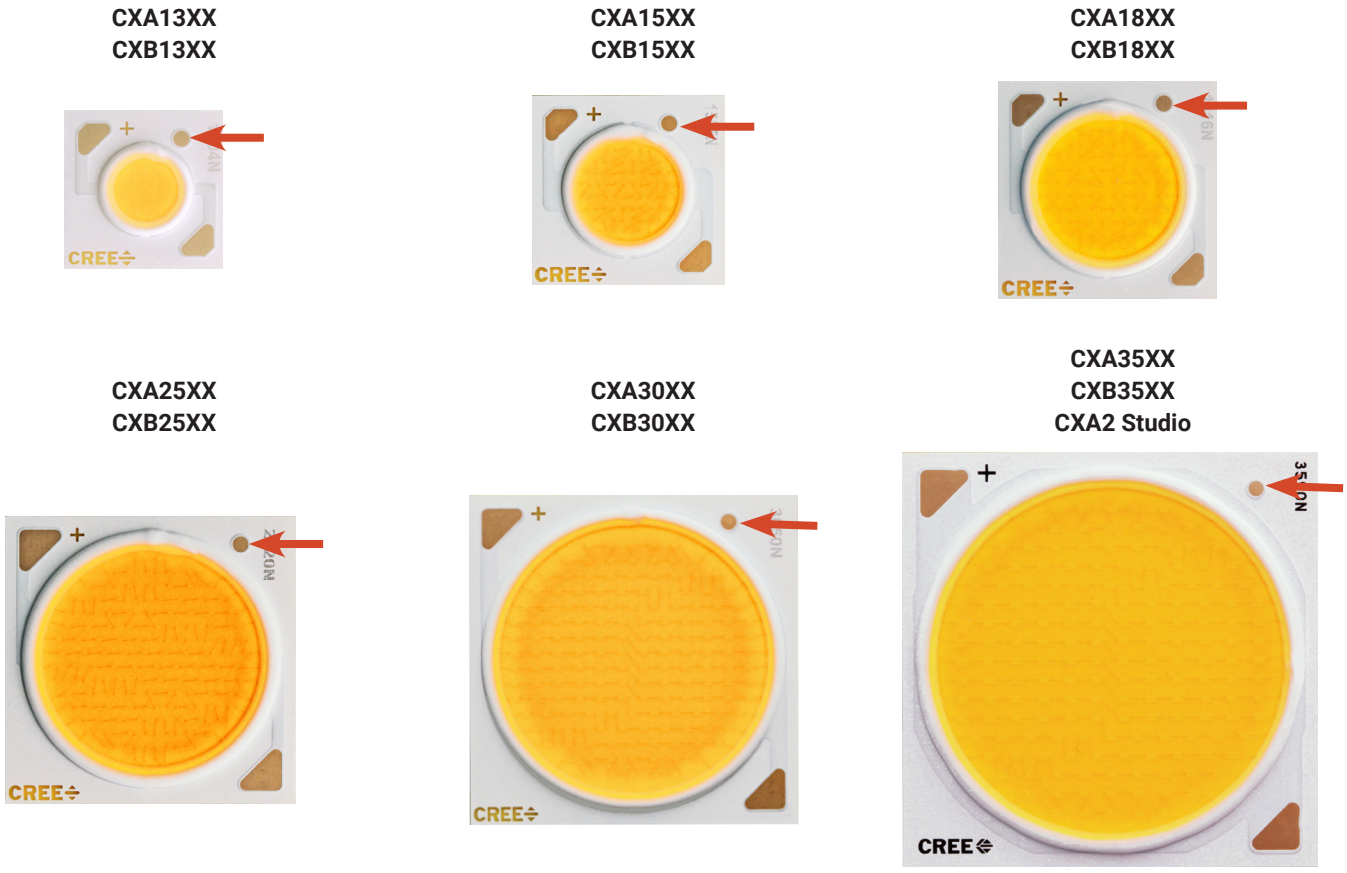


Figure 8: Tc measurement point for CX family LEDs

A summary of the LM-80 test results with reported TM-21 lifetimes is available on the Cree LED website. Contact your Cree LED sales representative to request an LM-80 report for a CX family LED. Contact your Cree LED Field Applications Engineer (FAE) to request TM-21 projections.

Heat & Light Output

All CX family LEDs are rated for their nominal lumen output at a Tc of 85 °C. Temperature change from this point inversely affects the lumen output of the CX family LED.

The Operating Limits section of each CX family LED's data sheet gives the maximum current and Tc conditions under which the LED operates successfully. At operating temperatures above a certain point, different for different LEDs, the current level must be de-rated, i.e., lowered, to allow the LED to operate at peak effectiveness. See the Operating Limits section on page 14 for more information.

Ambient Temperature Measurement

The ambient temperature of the test environment must be monitored and recorded with the required data during a temperature test. The preferred ambient temperature measurement apparatus is described in UL1598-2008 Rev January 11, 2010, Section 19.5. The intent of this requirement is to ensure that the temperature monitored does not fluctuate. Note that bare thermocouple wires in open air is not an acceptable method of recording the ambient temperature.

Thermocouple Attachment

Attach a thermocouple to the Tc point indicated in Figure 8. The attachment method described in UL1598-2008 Rev January 11, 2010, Section 19.7.4 is preferred; using silver-filled thermal epoxy is an acceptable alternative. Ensuring that the tip of the thermocouple properly contacts the LED at the Tc location and that the attachment method does not add thermal resistance to the test is critical to correct and acceptable testing. A thin (>30 AWG, 0.05 mm^2) Type T thermocouple can be easily and quickly soldered directly to the Tc point. Type J and K thermocouples are also very popular, however, they cannot be soldered and must be attached with an adhesive.

Do not place the thermocouple tip directly on the LES. A temperature measured at the LES will be inaccurate and taking a measurement this way can damage the LED. Figure 9 shows a thermocouple properly attached to a CX family LED.

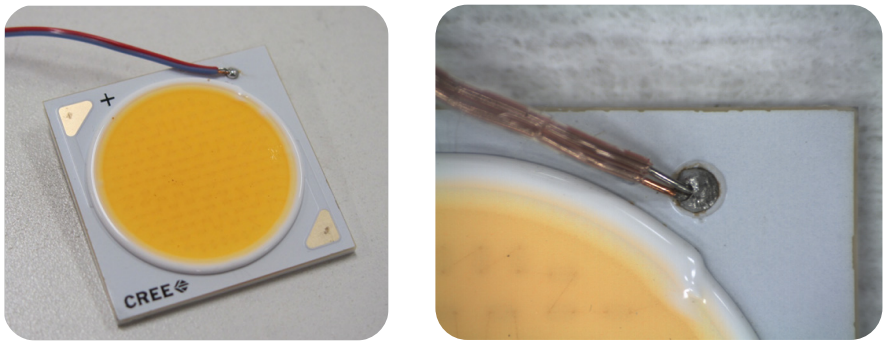


Figure 9: Thermocouple properly attached to CX family LED, left: thermocouple wire does not cross the LES, right: thermocouple attachment in close-up

> **Note** - Quick-drying adhesives and other cyanoacrylate-based products are known to be destructive, over time, to the components and adhesives used in solid-state lighting products. The use of cyanoacrylate-based products is at the discretion of the testing organization. Cyanoacrylate adhesives should not be used in any luminaire design or for any long-term testing.

Luminaire Case Temperature Measurement

Once the thermocouple is properly attached at the Tc location, assemble the CX family LED into the luminaire. The luminaire must then be tested in its intended environment or that environment which will result in the highest recorded temperature. Take care during assembly to ensure that the thermocouple remains properly attached and that the thermocouple wire is not in the light emission path from the LED. One precaution to ensure the thermocouple remains attached to the LED is to use tape to provide strain relief. Energize the luminaire and allow the assembly to reach thermal equilibrium. Thermal stabilization may require several hours, depending on the mechanical design. Once thermal equilibrium is achieved, record the room ambient and case temperatures. Measure the CX family LED case temperature at the designated case temperature measurement point, adjacent to the anode or plus (+) solder pad. This measurement point is shown in Figure 8.

There is no need to calculate for T_J inside the package, as the thermal management design process, specifically from T_{SP} to ambient (T_a), remains identical to any other LED component. For additional information on Tc measurement, refer to the Solder-Point Temperature Measurement application note.

Operating Limits

The Operating Limits section of each CX family LED data sheet has a graph similar to Figure 10. The plotted line is the maximum operating condition for the LED. The operating conditions, i.e., LED drive current and Tc, must be below the line. In the example graph in Figure 10, the CX family LED can be operated at 375 mA as long as the Tc remains at or below 100 °C. When the Tc exceeds 100 °C, the CX family

LED must be operated at a lower drive current level and Tc, i.e., a drive current level and Tc in the green area below the plotted line in the graph. Each such graph in the CX family LED data sheets assumes that the system design employs good thermal management (thermal interface material and heat sink) and may vary when poor thermal management is employed.

Another important factor in good thermal management is the LES temperature. Cree LED recommends a maximum LES temperature of 135 °C to ensure optimal LED lifetime.

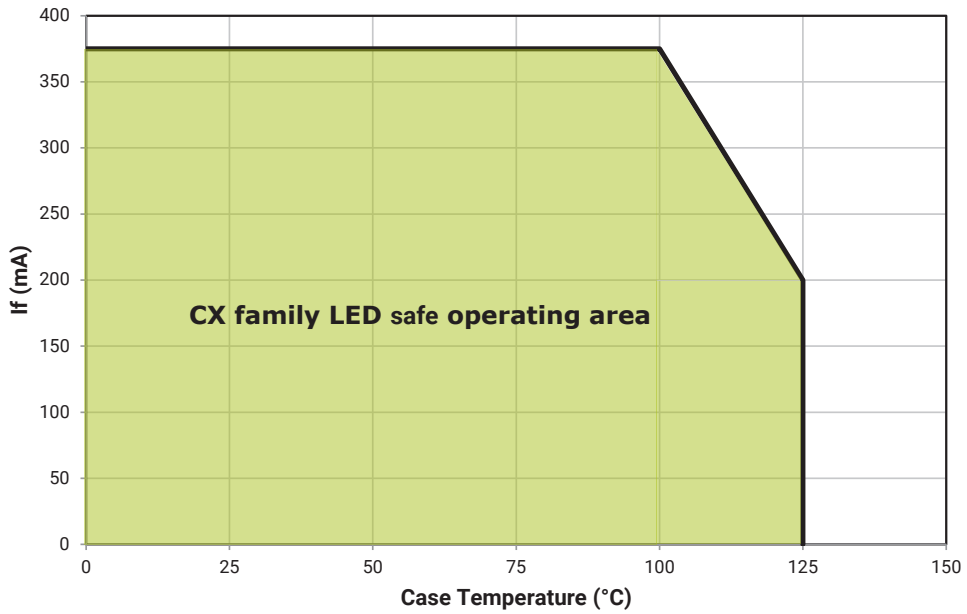


Figure 10: Example CX family LED operating limit graph

Light-Emitting Surface Temperature Measurement

LES temperatures are measured using an infrared (IR) thermal imaging camera. IR cameras detect the infrared wavelength thermal emission from an object's surface, which is correlated to the surface temperature using the surface's thermal emissivity. CX family LES thermal emissivity is 0.98. Please consult the IR camera's operating instructions for proper measurement settings and guidelines. Factors that can affect the accuracy of IR thermal measurement include the distance to the object's surface, image focus and ambient conditions.

Making accurate LES temperature measurements requires the IR camera to have a direct line-of-sight view of the LES. Remove all lenses, diffusers and baffles that cover the LES before making a measurement. Measure LES temperatures when the LED has reached thermal equilibrium under steady-state operation. An example IR thermal image of a CX family LED in a luminaire is shown in Figure 11. The LES temperature at the position of the crosshairs is reported in the upper left corner of the image.

Cree LED recommends a maximum LES temperature of 135 °C to ensure optimal LED lifetime.

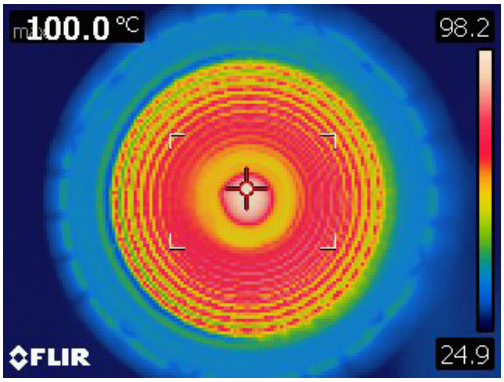


Figure 11: Example LES temperature measurement

Low Temperature Operation

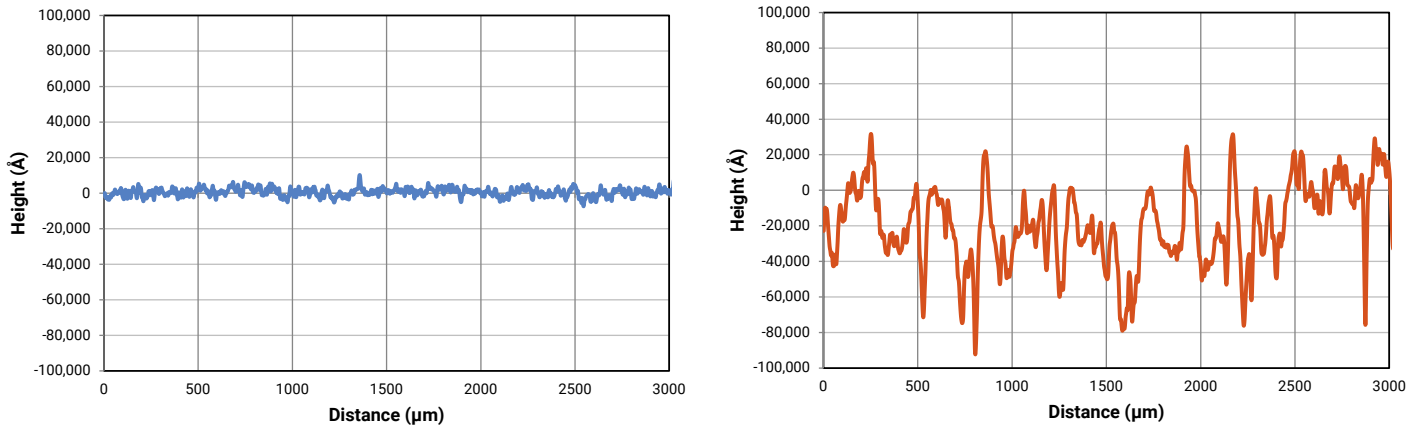
The minimum operating temperature of CX family LEDs is -40 °C. To maximize CX family LED lifetime, Cree LED recommends avoiding applications where the lamps are cycled on and off more than 10,000 cycles at temperatures below 0 °C.

Heat Sink Flatness and Cleanliness

The use of an appropriate heat sink will improve thermal performance in LED-based luminaire designs and help maximize the LED lifetime. A heat dissipation path is required; CX family LEDs should not be operated without a properly tested heat dissipation path. Luminaire designs with a direct thermal path to ambient are desired and will provide the best results. Attaching a CX family LED to a clean, flat, smooth heat sink is required for good thermal transfer. The use of a TIM between the CX family LED and the heat sink is required.

The back of a ceramic substrate CX family LED is ten times smoother than the back of the aluminum substrate often used by other chip-on-board (COB) LEDs. A ceramic substrate enables a better thermal contact with a flat, clean heat sink. Figure 12 demonstrates the flatness difference between a CX family LED and a metal-core printed circuit board (MCPCB).

Pictorial comparison of flatness of CX family LED (left) and MCPCB (right)



Graphical comparison of measured flatness of CX family LED (left) and MCPCB (right)

Figure 12: Flatness comparison of CX family LED and MCPCB

A quick way to check the flatness of a heat sink is to use a razorblade as a straight edge and touch the edge to the heat sink. Look for any gaps between the razorblade edge and heat sink. Figure 13 shows the procedure.

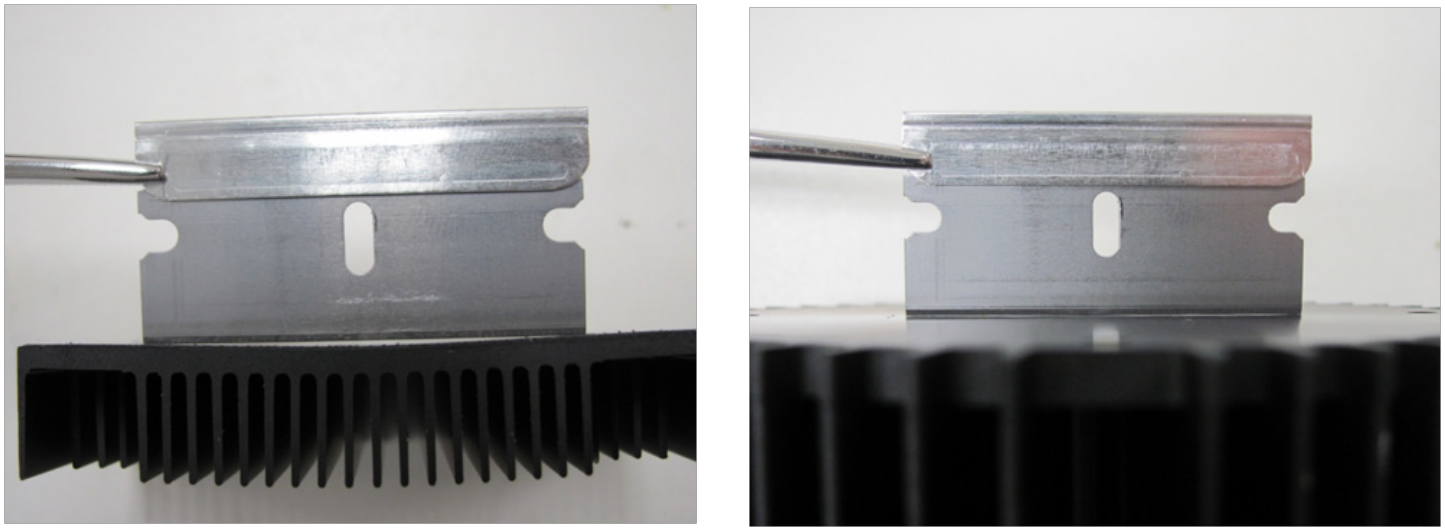
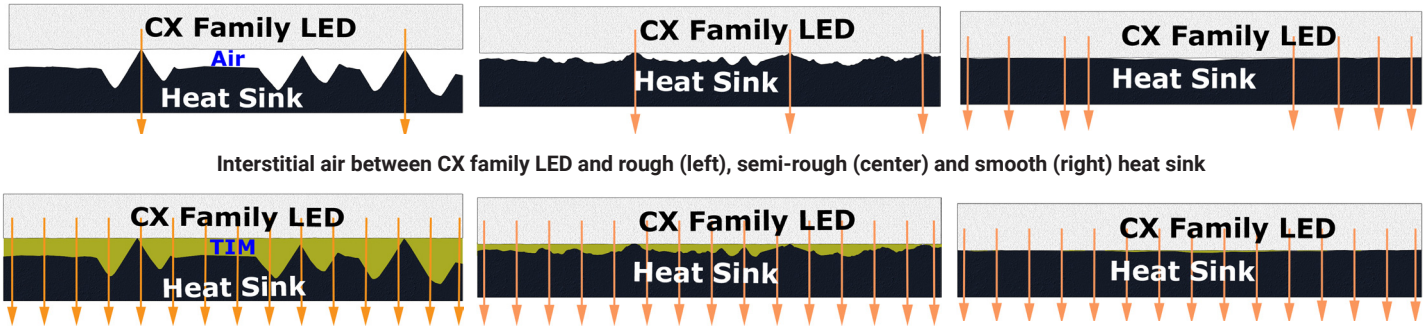


Figure 13: Checking heat sink flatness, left: a gap below the razorblade edge, right: no gap below the razorblade edge

Thermal Interface Materials

A good thermal connection between the CX family LED and the heat sink is critical for successful designs. A TIM is required for optimal performance. Air is a thermal insulator so a TIM is needed to fill any voids between the CX family LED and the heat sink, as shown in Figure 14. Without a TIM, there are a limited number of spots for heat transfer from the CX family LED to the heat sink to occur. With the voids filled by a TIM, heat flows much more freely from a CX family LED to the heat sink.



Interstitial air between CX family LED and rough (left), semi-rough (center) and smooth (right) heat sink

TIM between CX family LED and rough (left), semi-rough (center) and smooth (right) heat sink

Figure 14: TIM fills the voids between CX family LED and heat sink

Electrically isolated TIMs are not needed with CX family LEDs because the ceramic substrate acts as electrical isolation.

Make sure the TIM does not come into contact with the LES. There is a risk of failure of the CX family LED if this occurs.

The thermal resistance calculation is as shown in Equation 1. Cree LED's Thermal Management application note provides additional information.

$$\Theta_{TIM} = \frac{L}{k\ A}$$

Equation 1: TIM thermal resistance calculation

where:

Θ_{TIM} is the thermal resistance of the TIM
L is the thickness of the TIM (m)
k is the thermal conductivity of the TIM (W/m K)
A is the contact area (m^2)

At the high power levels at which many of the CX family LEDs operate, it is necessary to use a TIM to ensure proper thermal operating conditions. The higher the power, the more critical this interface is. If the Tc is too high, i.e., above the CX family LED's operating limit, a better thermal solution needs to be found. Cree LED recommends thermal grease or thermal pads as the first choice for a TIM, with other TIMs as an alternative when circumstances make the use of thermal grease or thermal pads not viable.

Figure 15 shows the Tc of a CXA2540 LED connected to a Cree LED heat sink designed for use with the LMH2 LED module[1] for various power levels with several TIMs. Note that thermal grease and a thermal pad allow the LED to operate well within its operating limit. With other TIMs, the LED's Tc rises to beyond the LED's operating limit.

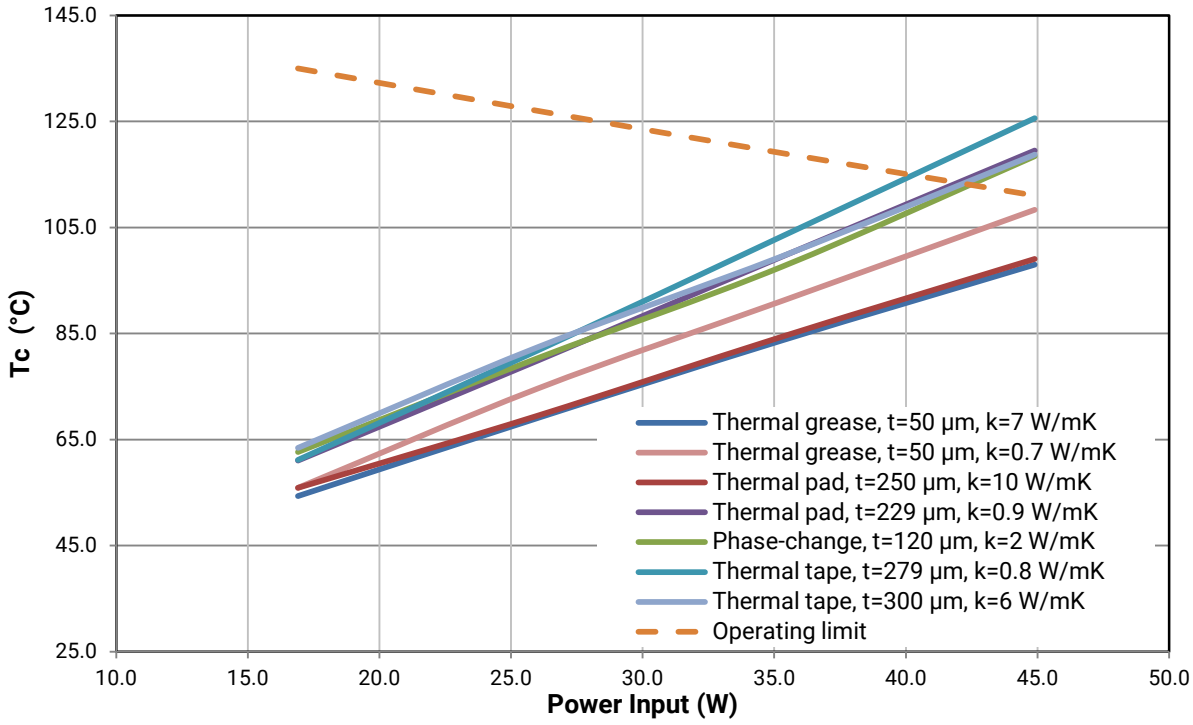


Figure 15: CXA2540 Tc vs. power

Figure 16 shows the relative lumen output from a CXA2540 LED connected to the same Cree LED heat sink and operated at various power levels with various TIMs. The lumen output percentages are calculated relative to the output with thermal grease as the TIM. Note that a

1 Order code LMH020-HS00-0000-0000001

thermal pad allows the LED to operate at nearly the same lumen level as does thermal grease, but with the other TIMs the lumen level is initially lower than with thermal grease and decreases as the power increases.

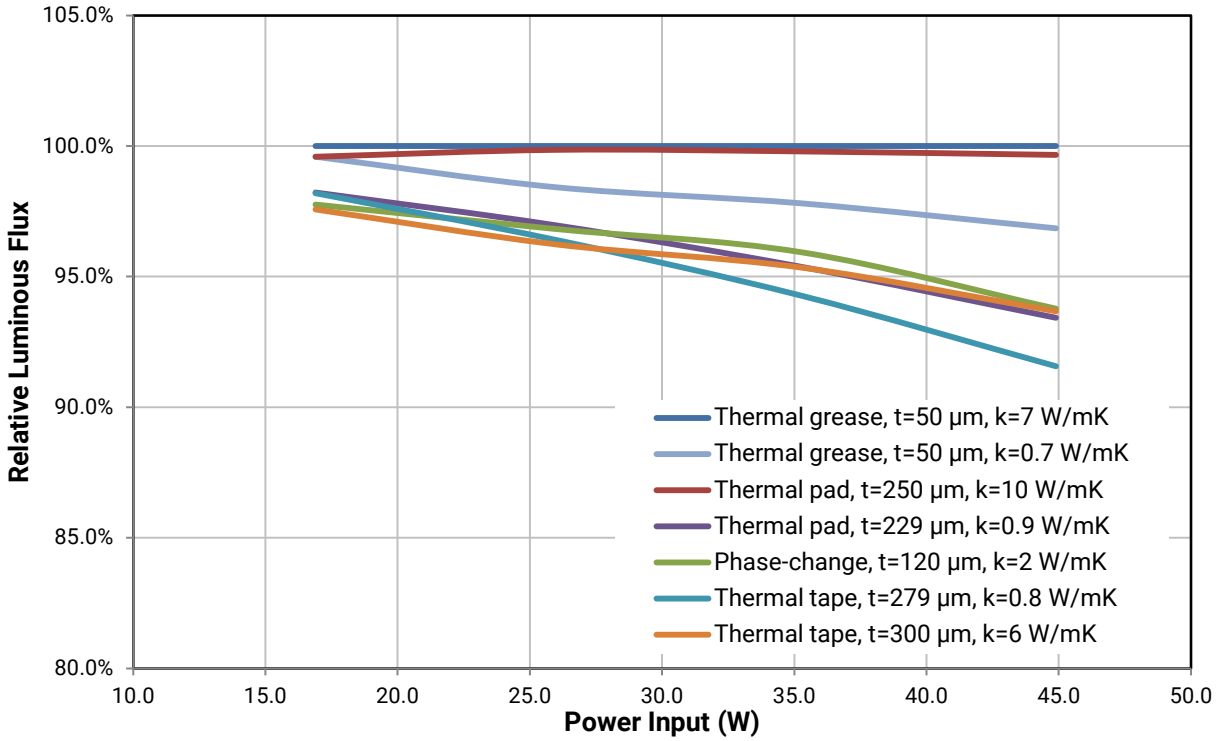


Figure 16: CXA2540 relative luminous flux vs. power

Using a TIM helps deal with process variations in heat sink manufacturing and ensures that differences in heat sink flatness/roughness can be accommodated. Figure 17 shows examples of the change in Tc when various TIMs are used on heat sinks with varying roughness.

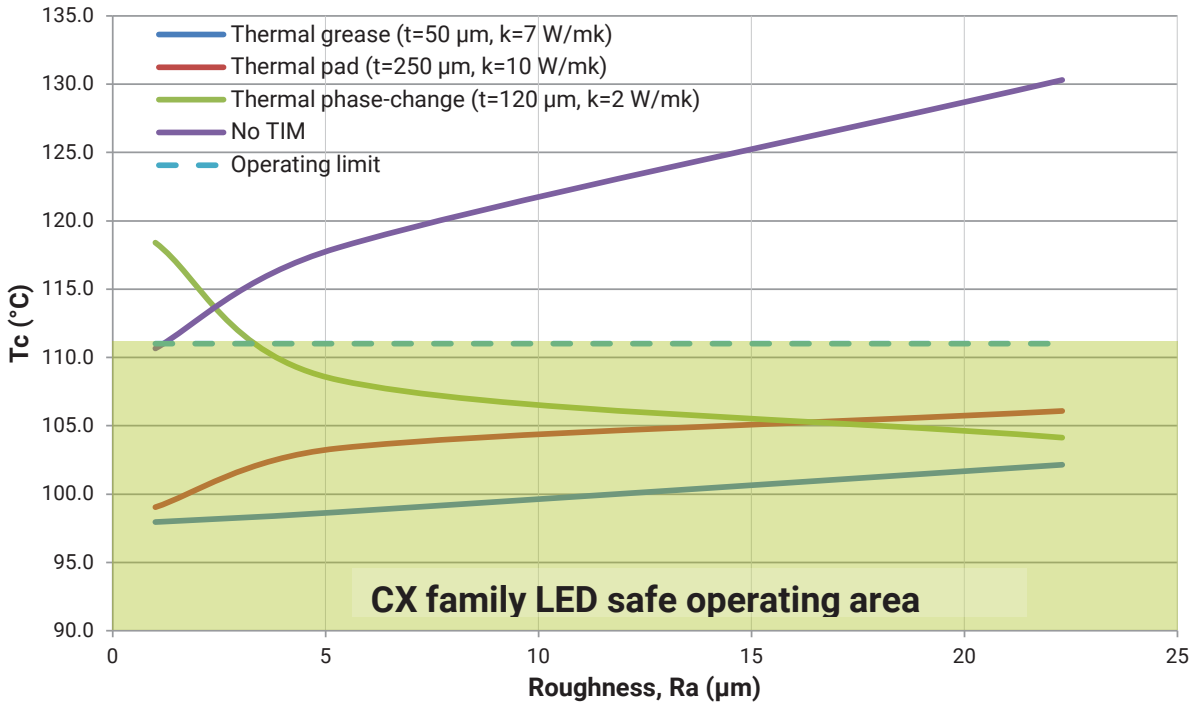


Figure 17: Tc vs. roughness

Cree LED recommends that the heat sink used with a CX family LED has an average roughness value (Ra) less than 10 µm. Figure 18 shows typical roughness values resulting from various manufacturing processes.[2] Once a heat sink is manufactured, finishing the heat sink by polishing or milling, for example, is important to achieve a smooth, flat surface. For comparison purposes, Table 4 contains size measurements for several grit sizes in several standards systems.[3]

2 E. Paul DeGarmo, J.T. Black and Ronald A. Kohser, *DeGarmo's Materials and Processes in Manufacturing,* Ninth Edition, John Wiley & Sons, Inc. (2003)
3 Orivs, Kenneth H. and Grissino-Mayer, Henri D., *Standardizing the Reporting of Abrasive Papers Used to Surface Tree-Ring Samples*, Tree-Ring Bulletin, Volume 58 (2002)

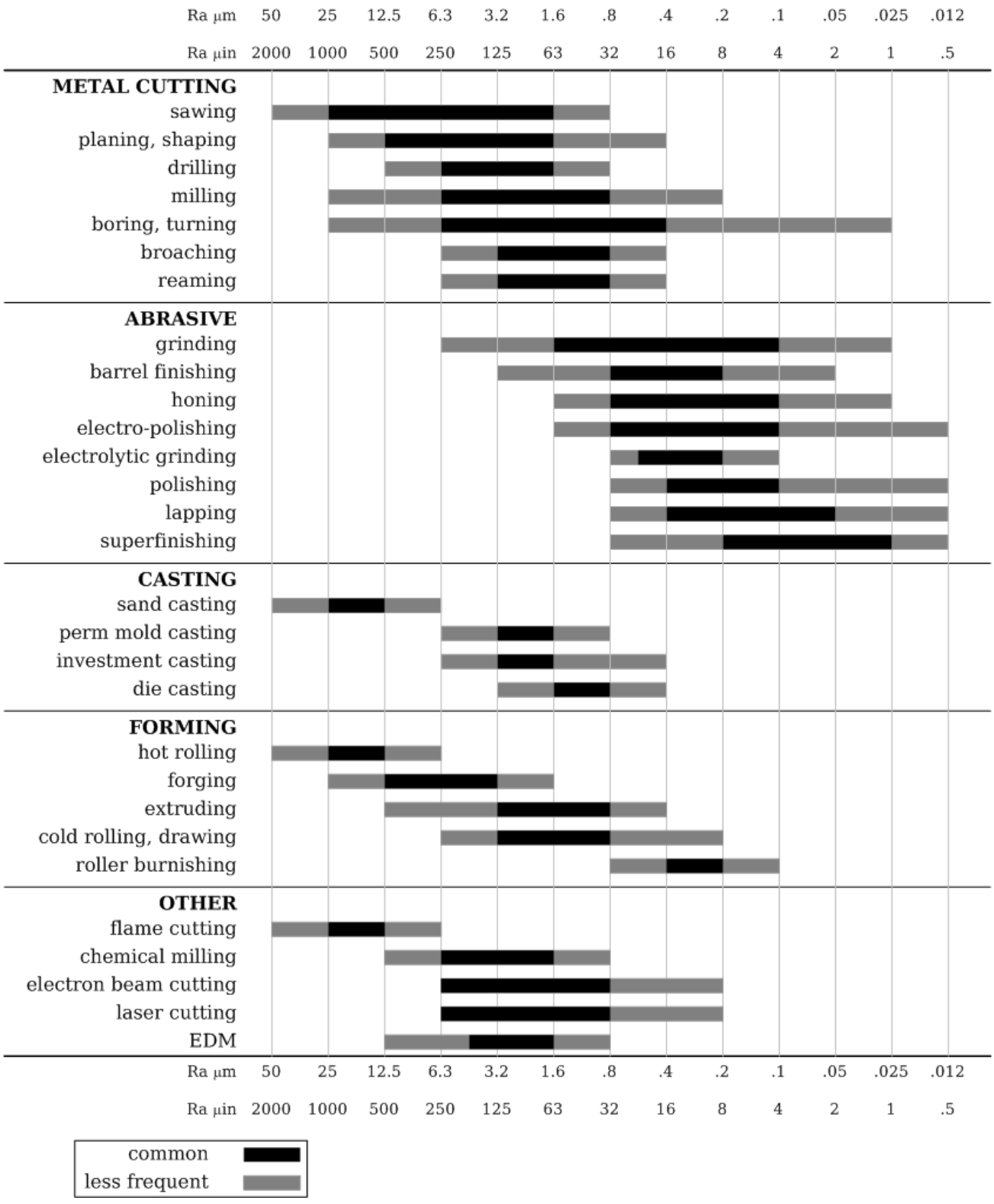


Figure 18: Roughness values from various manufacturing processes

Table 4: Sandpaper grit sizes

International		US		Europe		Japan		China	
ISO (86)	µm	ANSI (74)	µm	FEPA (93)	µm	JIS (87)	µm	GB2478 (96)	µm
P100	125-150	100	125-149	P100	162	100	125-150	100	125-150
P220	53-75	220	53-74	P220	68	220	53-75	220	53-75
P400	33.5-36.5	320	32.5-36.0	P400	33.5-36.5	400	32.0-36.0	W40	28.0-40.0
P1000	17.3-19.3	500	16.7-19.7	P1000	17.3-19.3	800	17.0-19.0	W20	14.0-20.0
P2500	7.9-9.1	1000	6.8-9.3	P2500	7.9-8.9	2000	7.8-9.2	W10	7.0-10.0

Thermal Design Resources

Table 5 contains examples of recommended TIMs from several suppliers. This is not an all-inclusive list of available TIMs. The presence of a TIM in the table is not a guarantee or warranty of the TIM's performance in any particular installation. The absence of a TIM from the table does not necessarily imply non-performance. Contact your Cree LED Field Applications Engineer or the TIM supplier for help with specific case-by-case recommendations.

Table 5: TIM examples

Supplier	Thermal Grease	Thermal Pad	Thermal Phase-Change	Thermal Gap Filler
3M	TCG-2035 Grease	5590H		
Bergquist	TIC1000A	Q-Pad® II	Hi-Flow 565UT	Gap Filler 4000
Dow Corning	TC-5629	TC-4025		TC-4025
GrafTech		HITHERM 1205/1210		
Henkel	LOCTITE® TG100		LOCTITE® PSX-D	
Lord	TC-426			

ELECTRICAL CONSIDERATIONS

Multiple CX Family LEDs

If multiple CX family LEDs are used in a luminaire, it is best to configure the LEDs in series, not parallel, or use a multi-channel driver.

Electrical Overstress/Hot-Plugging

Electrical overstress (EOS) occurs when an LED is exposed to any current exceeding the maximum current specified in the LED's data sheet. The effect on the LED varies in severity depending on the duration and amplitude of the exposure, however, any single EOS event has the potential to damage an LED. This damage can result in an immediate failure or in a gradual failure many hours after the event. A number of EOS protection devices are available to absorb electrical energy that would otherwise be dissipated in the LED or to block current from flowing in the reverse direction if the load is connected backwards. A good way to avoid EOS is to use a good quality driver.

Cree LED recommends adding EOS protection to luminaires that do not include an on-board power supply. The use of a simple, low-cost protection circuit can dramatically reduce the rate of returns from lighting customers. EOS, and hot-plugging in particular, is the most common problem Cree LED has observed in returned LEDs. In addition, Cree LED recommends extensive testing of LED luminaires that includes surge immunity, power cycling and electromagnetic compliance.

Some steps to prevent EOS events at a work station or assembly line include:

- Connecting a metal table to a common ground point

- Anti-static wrist straps for personnel
- ESD table mats
- ESD floor mats

Additional information on EOS can be found in the EOS and Pulsed Over-Current application notes.

Dielectric Voltage Withstand Testing

CX family LEDs do not require special handling for luminaire assembly line dielectric voltage withstand testing. The ceramic substrate of the CX family LED provides a high level of electrical isolation. Cree LED conducted dielectric voltage withstand testing to confirm this. Figure 19 shows the test setup. For the component test, the LED was resting on an isolating ESD mat. For the system test, the LED was connected to a heat sink using an electrically non-insulating TIM.[4] With two leads connected as shown in Figure 19 and separated to prevent arcing, and a dielectric voltage withstand tester set to 1 second and 5 mA limit, voltages starting at 1000 V and increasing to 5000 V in 1000-V increments were applied.

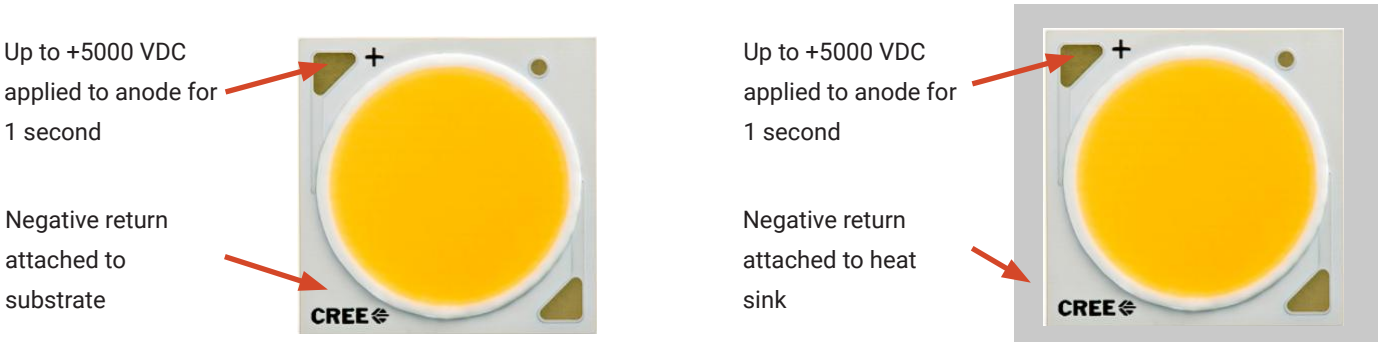


Figure 19: CX family LED dielectric voltage withstand test setup, left: component test, right: system test

Multiple individual CX family LEDs of each model were tested. The test results are shown in Table 6. A check mark (√) indicates the test passed. An **X** indicates a test failure.

4 The system test is a creepage and clearance test. If the CX family LED is placed on top of an electrically conductive surface, there will eventually be a breakdown as the electricity finds the path of least resistance and there is an arc.
The creepage distance is shortest distance between two conductive parts or between a conductive part and the outer edge of the LED, measured along the surface of the insulation. The clearance is the shortest distance between two conductive parts or between a conductive part and the outer edge of the LED, measured through air.

Table 6: Dielectric voltage withstand test results

LED	Component Test					System Test
	1000 V	2000 V	3000 V	4000 V	5000 V	Average Breakdown Voltage (V)
CXA1304 CXB1304	√	√	√	√	√	4332
CXA1507 CXB1507	√	√	√	√	√	3790
CXA1512 CXB1512	√	√	√	√	√	4302
CXA1816 CXB1816	√	√	√	√	√	4127
CXA1820 CXB1820	√	√	√	√	√	4095
CXA1830 CXB1830	√	√	√	√	√	4263
CXA2520	√	√	√	√	√	3837
CXA2530 CXB2530	√	√	√	√	√	4139
CXA2540 CXB2540	√	√	√	√	√	4096
CXA3050 CXB3050	√	√	√	√	√	4252
CXA3590 CXB3590	√	√	√	√	√	4512

The results of this testing gives luminaire manufacturers confidence.

- The CX family LED does not require an electrically insulating TIM, however the use of an electrically insulating TIM can be expected to yield a higher system-level breakdown voltage.
- The CX family LED will comply with any testing to UL8750 section 8.4 Dielectric Voltage Withstand Test standards.
- The CX family will pass production system-level dielectric voltage withstand testing.

Reverse Voltage

CX family LEDs must not be energized with reverse voltage or catastrophic damage will occur. The LED can be protected by placing a barrier diode in series with the LED. Observe correct polarity when connecting a CX family LED to a driver.

CHEMICAL COMPATIBILITY

Consult Cree LED's Chemical Compatibility application note for lists of recommended chemicals, conformal coatings and harmful chemicals and materials to be used or avoided in LED manufacturing activities. Consult your regional Cree LED Field Applications Engineer for assistance in determining the compatibility of materials considered for use in a particular application.

Avoid getting material, e.g., thermal grease or solder, on the LES of the CX family LED. Material contacting the LES will compromise the lumen output and can negatively react with the materials in the CX family LED to shorten the component's lifetime.

Hermetically Sealing Luminaires

For proper LED operation and to avoid potential lumen depreciation and/or color shift, LEDs of all types must operate in an environment that contains oxygen. Simply allowing the LEDs to ventilate to air is sufficient; no extraordinary measures are required. Hermetically sealing LEDs in an enclosed space is not recommended.

OPTICAL CONSIDERATIONS

Optical Design

All CX family LEDs have a Lambertian light distribution. The optical center and mechanical center is same on CX family LEDs. The small LES allows for easier optical control, particularly for narrow beam applications. The small LES and high luminous flux of the CX family high-density (HD) series LEDs provide unrivaled lumen density for spotlight applications.

Cree LED provides optical source models and ray files for CX family LEDs on the Cree LED website. All rays are originated on a plane. As shown in Figure 20, the Z = 0 point is on top of the LED substrate.

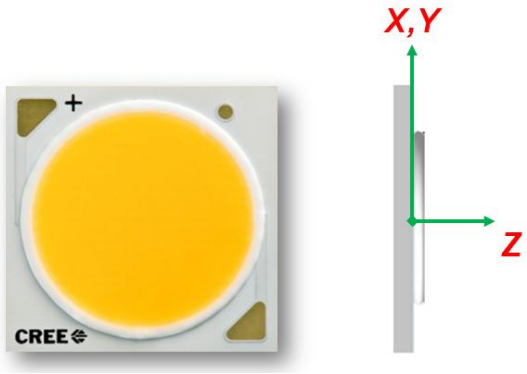


Figure 20: X, Y and Z axes in CX family LED ray files

When applying secondary optics to CX family LEDs, make sure the optics opening matches the LES. All light coming from the CX family LED needs to be collected by optics. Be sure there are no gaps between the optic and the LES that allow light to not be collected by the optics and that the optic does not obstruct the LES.

There are several ways to add secondary optics to CX family LEDs:

- Incorporate optics with the luminaire housing and directly add optics on top of the CX family LED.
- Connect the optics on the top of a connector and use the connector lock feature to attach the optics.
- Some optics are supplied with the connector and the optics and connector can be directly applied to the CX family LED.

Figure 21 shows examples of secondary optics and connectors.

Ideal® Chip-Lok® connector

Khatod LYRA reflector system

LEDiL® reflector with connector

Tyco® connector with Carclo Newton reflector

Figure 21: Secondary optics and connectors

CX Family Lens Material Considerations

Polymers, i.e., plastics and polymethyl methacrylate (PMMA), and glass are the most common materials used for optical lenses. Although glass typically has better optical properties than plastic, glass is used less frequently because it is heavier, more expensive and more fragile than plastic. The light absorption, reflection and transmission properties of plastics can vary considerably, even within the same class of material, e.g., polycarbonate. Cree LED recommends the use of optical grade plastics for lenses used with CX family LEDs to ensure good optical efficiency and long-term reliability. The use of non-optical grade plastics is to be avoided. This includes materials used as a luminous opening, i.e., a window, in a luminaire. The flammability rating of a polymer material should also be taken into consideration when designing and specifying optical components. UL 94, the Standard for Safety of Flammability of Plastic Materials for Parts in Devices and Appliances Testing, can be helpful in providing guidance.

CX family LEDs transmit no significant IR light, but, as do all high-powered light sources, do transmit significant photonic energy that, if absorbed by the lens material, can cause the material to heat up. The focusing effect of the lens material can cause the lens to reach a temperature higher than the Tc of the CX family LED producing the light.

CX Family LEDs and Silicone

All LED components should be designed into a lighting application that allows the LEDs to ventilate. Silicone is a gas-permeable polymer material that is commonly used as an encapsulant and primary optic in LED packaging and can absorb volatile organic compounds (VOCs) during operation of the LED. VOCs, in the presence of thermal and photonic energy, may cause charring near the phosphor layer, changes in chromaticity, or a reduction in light quality and intensity of the LED. Silicone optics are often molded into various shapes and sizes utilizing light and/or heat to cure the polymer. LED sources produce light and heat, so both these characteristics can contribute to further curing of the silicone while the LED device is operating.

XLamp CX family LEDs have a much larger LES and therefore utilize more silicone than many other LED types. Outgassing of VOCs and advancement of the polymer cure must be considered during the design stages of an LED luminaire. Ventilation of the LED is recommended for all LED-based luminaire designs, including those utilizing the XLamp CX family LED series.

CX Family Light Emitting Surface Comparison

Table 7 shows simulated performance data for CX family LEDs with the same reflector. This shows that the small LES size of CX family LEDs enables small beam angles and intense light. Note that the beam angle increases and the cd/lm decreases as the LES size increases.

Table 7: CX family LES comparison

Characteristic	CXA13XX CXB13XX	CXA15XX CXB15XX	CXA18XX CXB18XX	CXA25XX CXB25XX	CXA30XX CXB30XX
LES (mm)	6	9	12	19	23
Optics size - depth X height (mm)	120 x 60	120 x 60	120 x 60	120 x 60	120 x 60
Beam angle - full width half maximum (degrees)	5.6	6.7	7.1	13.2	13.8
cd/lm	38.0	26.0	23.0	10.3	9.5
Intensity at 400 lm (cd)	15,200	10,400	9,200	4,120	3,800
Intensity at 700 lm (cd)	26,600	18,200	16,100	7,210	6,650
Intensity at 1000 lm (cd)	39,000	26,000	23,000	10,300	9,500
Intensity at 2000 lm (cd)		52,000	46,000	20,600	19,000
Intensity at 5000 lm (cd)			115,000	51,500	47,500

Optical Design Resources

Cree LED works with all major LED optical companies around the world to offer different types of optics for CX family LEDs. The check marks (√) in Table 8 show the optics available from secondary optics solution providers.

Table 8: Optics for CX family LEDs

Optics Solution Provider	LED	Beam Angle			Web Link
		< 15 °	15 - 30°	> 30°	
Bicom	CXA13XX CXB13XX				en.baikang.cn
	CXA15XX CXB15XX		√	√	
	CXA18XX CXB18XX			√	
	CXA25XX CXB25XX		√	√	
	CXA30XX CXB30XX		√	√	

Optics Solution Provider	LED	Beam Angle			Web Link
		< 15 °	15 - 30°	> 30°	
Carclo	CXA13XX CXB13XX				www.carclo-optics.com/optics-for-leds/cree/
	CXA15XX CXB15XX		√	√	
	CXA18XX CXB18XX				
	CXA25XX CXB25XX				
	CXA30XX CXB30XX				
DBM Reflex	CXA13XX CXB13XX				www.dbmlighting.com/cree-optics/
	CXA15XX CXB15XX	√	√	√	
	CXA18XX CXB18XX				
	CXA25XX CXB25XX				
	CXA30XX CXB30XX				
Gaggione	CXA13XX CXB13XX	√	√	√	www.lednlight.com
	CXA15XX CXB15XX	√	√	√	
	CXA18XX CXB18XX		√	√	
	CXA25XX CXB25XX		√	√	
	CXA30XX CXB30XX		√	√	
Kathod	CXA13XX CXB13XX				www.khatod.com/Khatod/Search.aspx?4
	CXA15XX CXB15XX	√	√	√	
	CXA18XX CXB18XX				
	CXA25XX CXB25XX		√	√	
	CXA30XX CXB30XX		√	√	
LEDiL	CXA13XX CXB13XX	√	√	√	ledil.fi/cree
	CXA15XX CXB15XX	√	√	√	
	CXA18XX CXB18XX		√	√	
	CXA25XX CXB25XX	√	√	√	
	CXA30XX CXB30XX		√	√	

Optics Solution Provider	LED	Beam Angle			Web Link
		< 15 °	15 - 30°	> 30°	
Ledlink	CXA13XX CXB13XX	√	√	√	www.ledlink-optics.com/ProductsHomeLED.aspx
	CXA15XX CXB15XX	√	√	√	
	CXA18XX CXB18XX	√	√	√	
	CXA25XX CXB25XX		√	√	
	CXA30XX CXB30XX		√	√	
Nata	CXA13XX CXB13XX	√	√		www.nata.cn/miniCatalog.php?lan=en&level1=CA_0000009
	CXA15XX CXB15XX	√	√	√	
	CXA18XX CXB18XX	√	√		
	CXA25XX CXB25XX	√	√	√	
	CXA30XX CXB30XX		√	√	
Optosource	CXA13XX CXB13XX		√	√	www.opto-source.net/product/product.asp?classid=66
	CXA15XX CXB15XX		√	√	
	CXA18XX CXB18XX				
	CXA25XX CXB25XX		√	√	
	CXA30XX CXB30XX		√	√	

CX FAMILY LED HOW-TO

The following section provides instructions to assist in combining CX family LEDs with the other components of a lighting system.

How to Assemble a CX Family LED into a Lighting System

Following are the basic steps to assemble a CX family LED into a lighting system.

1. Heat sink preparation
   a. Select a flat, smooth heat sink with proper thermal properties for the application.
      i. For more information on selecting a heat sink, see the Heat sink Flatness and Cleanliness section on page 14.
   b. If using a connector to attach the CX family LED to the heat sink, drill and tap any holes necessary according to the connector supplier's specifications. For more information on connectors, see the Connector Resources section on page 3.
   c. Clean and wipe the heat sink to remove any foreign materials such as cutting fluid, fingerprints or foreign particles.
      i. To clean the heat sink, Cree LED recommends gently blowing the material off the heat sink with CDA or using IPA and/or water applied with a lint-free wipe.

2. TIM application

a. Select a proper TIM depending upon the application and power level. For more information on selecting and using a TIM, see the Thermal Interface Materials section on page 15.
b. Follow the supplier's recommendations to apply the TIM.
    i. If a grease or gel is being used, Cree LED recommends applying it using a stencil printer to ensure uniform, controlled application.
    ii. If a pad is being used, it is important to keep both sides of the material clean and free from foreign contamination when handling and placing the pad.
c. Follow the supplier's recommendations for curing, pre-conditioning and pressure requirements after applying the material.

3. CX family LED application
    a. If the CX family LED has been exposed to a dirty environment or to possible contamination of the backside of the substrate, clean the LED by gently blowing the material off the LED with CDA or by using IPA applied with a lint-free swab before assembly.
    b. If manually soldering wires to the CX family LED, Cree LED recommends pre-tinning the contact pads to ease the soldering process prior to assembly on the heat sink, if possible. Refer to the CX family soldering and handling document for more information on soldering wires to the CX family LED.
    c. Place the CX family LED on the TIM on the heat sink, aligned such that a connector can be used appropriately. Refer to the connector supplier documentation for more information on proper LED location.

4. Connector application (if applicable)
    a. Refer to the connector's instructions for proper handling and application instructions.
    b. Once the connector is aligned around the LED, secure the connector with screws, as specified by the supplier. Tighten the screws according to the recommended screw torque, as shown in Table 1 or the specific connector data sheet.

5. Optic assembly
    a. If a secondary optic is being used, follow the supplier's recommendations for attachment.
        i. Typically, the optic is simply snapped into place in the holder. For more information on compatible holders and optics, see the Optical Design section on page 23.

6. Electrical connection
    a. Make a proper electrical connection from the LED driver to the CX family LED. Common methods to connect are to solder the wires, use quick-connect terminal blocks, or directly connect the wire to the LED connector.
        i. Use caution to avoid hot-plugging the CX family LED to prevent premature LED failure.

For more help with CX family assembly, contact your local Cree LED Field Applications Engineer.

SAFETY & COMPLIANCE

As a matter of course, CX family LEDs are submitted for safety and compliance testing to standards such as European Union (EU) Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) and such organizations as UL®.

CX family LEDs that have completed UL testing have a Level 4 enclosure consideration. The LED package or a portion thereof has been investigated as a fire and electrical enclosure per ANSI/UL 8750 so a luminaire based on a CX family LED does not need to cover the LED. Level 4 CX family LEDs are recognized to be able to operate in damp environments and with non-isolated or isolated LED drivers.

Information on UL certification of CX family LEDs is available on the UL website. Contact your Cree LED sales representative for the UL Conditions of Acceptability (COA) document for a CX family LED.

SUMMARY

Observe the following practices to maximize the performance of CX family LEDs.

- Work with CX family LEDs in a clean environment, free from any foreign material that could come into contact with and damage the LED.
- Do not touch the LES of a CX family LED.
- Wear clean, lint-free gloves when handling CX family LEDs.
- Use a connector to attach the CX family LED to a flat, smooth and clean heat sink.
- Apply a TIM, preferably thermal grease or thermal pad, between the CX family LED and the heat sink.
- Use optical grade plastics for lenses used with CX family LEDs.
- Operate a CX family LED within its operating limits, as shown in the LED's data sheet, to maximize light output and LED lifetime.
- If multiple CX family LEDs are being used, connect them in series.

DESIGN EXAMPLES

This section contains design proposals for luminaires that incorporate CX family LEDs and are suggestive of luminaires that can be produced using CX family LEDs.

> Note - The examples depicted below are conceptual only. The inclusion of a concept in this group does not imply agency approval. The exclusion of any concept from this group should not be seen as a limitation. These examples are not proprietary or protected and may be reproduced wholly or in part as desired by a luminaire manufacturer. Final agency approval(s) and confirmation of acceptable operating parameters is solely the responsibility of the luminaire manufacturer.

Decorative

Downlight

Pendant

Track Light