Cree® XLamp® CXA2530 LED Retail Track Light Reference Design

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INTRODUCTION

This application note details the design of a 39-watt equivalent retail track light using Cree's XLamp CXA2530 LED. The CXA2530 is optimized to simplify designs and lower system cost and can enable system-level performance of 2000 to 5000 lumens. The XLamp CXA2530 LED delivers high lumen output and high efficacy in a single, easy-to-use package that eliminates the need for reflow soldering.

The XLamp CXA2530 LED highlighted in this reference design is optimized to enable applications that traditionally use halogen, ceramic metal halide (CMH) and compact fluorescent lamp (CFL) technology. In this reference design, the XLamp CXA2530 LED is used in a retail track light that operates on direct line 120-VAC input. The goal of the design is to enable a retail track light with a narrow beam, based on a single XLamp CXA2530 LED, delivering performance equivalent to a 39-watt CMH lamp.

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DESIGN APPROACH/OBJECTIVES

In the "LED Luminaire Design Guide" application note, Cree advocates a 6-step framework for creating LED luminaires.[1] All Cree reference designs use this framework, and the design guide's summary table is reproduced below.

Step		Explanation
1.	Define lighting requirements	• The design goals can be based either on an existing fixture or on the application's lighting requirements.
2.	Define design goals	• Specify design goals, which will be based on the application's lighting requirements. • Specify any other goals that will influence the design, such as special optical or environmental requirements.
3.	Estimate efficiencies of the optical, thermal & electrical systems	• Design goals will place constraints on the optical, thermal and electrical systems. • Good estimations of efficiencies of each system can be made based on these constraints. • The combination of lighting goals and system efficiencies will drive the number of LEDs needed in the luminaire.
4.	Calculate the number of LEDs needed	• Based on the design goals and estimated losses, the designer can calculate the number of LEDs to meet the design goals.
5.	Consider all design possibilities and choose the best	• With any design, there are many ways to achieve the goals. • LED lighting is a new field; assumptions that work for conventional lighting sources may not apply.
6.	Complete final steps	• Complete circuit board layout. • Test design choices by building a prototype luminaire. • Make sure the design achieves all the design goals. • Use the prototype to further refine the luminaire design. • Record observations and ideas for improvement.

Table 1: Cree 6-step framework

THE 6-STEP METHODOLOGY

The goal for this project is to demonstrate an easy-to-implement, high-output lamp that can better the performance of 39-W CMH lamps currently on the market, showing that a narrow-beam 39-watt equivalent retail track light is possible using a single XLamp CXA2530 LED.[2]

1. DEFINE LIGHTING REQUIREMENTS

Table 2 shows a ranked list of desirable characteristics to address in a track light.

Importance	Characteristics	Units
Critical	Luminous flux	lumens (lm)
	Light intensity - center beam candle power (CBCP)	candelas (cd)
	Beam angle - full width half maximum (FWHM)	degrees (°)
	Luminaire efficacy	lm/W
	Electrical power	watts (W)
Important	Lifetime	hours
	Operating temperatures	°C
	Correlated color temperature (CCT)	K
	Color rendering index (CRI)	100-point scale
	Power factor	

Table 2: Ranked design criteria for a track light

1 LED Luminaire Design Guide, Application Note AP15, www.cree.com/xlamp_app_notes/luminaire_design_guide

2 Production and cost-optimized implementations are beyond the scope of this document.

Table 3 and Table 4 summarize the ENERGY STAR® requirements for directional commercial and residential luminaires.[3]

Luminaire Type	Luminaire Efficacy (Initial)	ENERGY STAR REQUIREMENTS	
		Luminaire Minimum Light Output (Initial)	Luminaire Zonal Lumen Density Requirement
Accent Lights • includes line voltage track heads • includes directional ceiling fan light kits	35 lm/W	Luminaire shall deliver a minimum of 200 lumens per head.	Luminaire shall deliver a minimum of 80% of total initial lumens within the 0-40° zone (axially symmetric about the center of the beam).

Table 3: ENERGY STAR luminous efficacy, output and zonal lumen density requirements

Characteristic	Requirements
Light source life requirements: all luminaires	The LED package(s) / LED module(s) / LED array(s), including those incorporated into LED light engines or GU24 based integrated LED lamps, shall meet the following L70 lumen maintenance life values (refer to Lumen Maintenance Requirements in the next section): • 25,000 hours for residential grade indoor luminaires • 35,000 hours for residential grade outdoor luminaires • 35,000 hours for commercial grade luminaires Lumen maintenance life projection claims in excess of the above requirements shall be substantiated with a TM-21 lumen maintenance life projection report.
Lumen maintenance requirements: directional and non-directional luminaires	The LED package(s) / module(s) / array(s), including those incorporated into LED light engines or GU24 based integrated LED lamps, shall meet the following L_{70}(6k) rated lumen maintenance life values, in situ: • L_{70}(6k) ≥ 25,000 hours for residential indoor • L_{70}(6k) ≥ 35,000 hours for residential outdoor, or commercial Compliance with the above shall be documented with a TM-21 lumen maintenance life projection report as detailed in TM-21, section 7. The report shall be generated using data from the LM-80 test report for the employed LED package/module/array model ("device"), the forward drive current applied to each device, and the in situ TMP_{LED} temperature of the hottest LED in the luminaire. In addition to LM-80 reporting requirements, the following information shall be reported: • sampling method and sample size (per LM-80 section 4.3) • test results for each T_S and drive current combination • description of device including model number and whether device is an LED package, module or array (see Definitions) • ANSI target, and calculated CCT value(s) for each device in sample set • Δ u'v' chromaticity shift value on the CIE 1976 diagram for each device in sample set • a detailed rationale, with supporting data, for application of results to other devices (e.g. LED packages with other CCTs) Access to the TMP_{LED} for the hottest LED may be accomplished via a minimally sized hole in the luminaire housing, tightly resealed with a suitable sealant if created for purposes of testing. All thermocouple attachments and intrusions to luminaire housing shall be photographed.
CCT requirements: all indoor luminaires	The luminaire (directional luminaires), or replaceable LED light engine or GU24 based integrated LED lamp (non-directional luminaires) shall have one of the following nominal CCTs: • 2700 Kelvin • 3000 Kelvin • 3500 Kelvin • 4000 Kelvin • 5000 Kelvin (commercial only) The luminaire, LED light engine or GU24 based integrated LED lamp shall also fall within the corresponding 7-step chromaticity quadrangles as defined in ANSI/NEMA/ANSLG C78.377-2008.

3 ENERGY STAR Program Requirements, Product Specification for Luminaires (Light Fixtures), Eligibility Criteria, Version 1.2, www.energystar.gov/ia/partners/product_specs/program_reqs/Final_Luminaires_V1_2.pdf?7b7d-2473

Characteristic	Requirements
Color rendering requirements: all indoor luminaires	The luminaire (directional luminaires), or replaceable LED light engine or GU24 based integrated LED lamp (non-directional luminaires) shall meet or exceed Ra ≥ 80.
Color angular uniformity requirements: directional solid state indoor luminaires	Throughout the zonal lumen density angles detailed above, and five degrees beyond, the variation of chromaticity shall be within 0.004 from the weighted average point on the CIE 1976 (u',v') diagram.
Color maintenance requirements: solid state indoor luminaires only	The change of chromaticity over the first 6,000 hours of luminaire operation shall be within 0.007 on the CIE 1976 (u',v') diagram, as demonstrated by either: • the IES LM-80 test report for the employed LED package/array/module model, or • as demonstrated by a comparison of luminaire chromaticity data in LM-79 reports at zero and 6,000 hours, or • as demonstrated by a comparison of LED light engine or GU24 based integrated LED lamp chromaticity data in LM-82 reports at zero and 6,000 hours.
Source start time requirement: directional and non-directional luminaires	Light source shall remain continuously illuminated within one second of application of electrical power.
Dimming requirements	The luminaire and its components shall provide continuous dimming from 100% to 35% of total light output. Step dimming, if employed, shall provide at least two discrete light output levels ≥ 35% of total light output and not including 100% output.
Power factor requirements: directional and non-directional luminaires	Total luminaire input power less than or equal to 5 watts: PF ≥ 0.5 Total luminaire input power greater than 5 watts: Residential: PF ≥ 0.7 Commercial: PF ≥ 0.9
Transient protection requirements: all luminaires	Ballast or driver shall comply with ANSI/IEEE C62.41.1-2002 and ANSI/IEEE C62.41.2-2002, Class A operation. The line transient shall consist of seven strikes of a 100 kHz ring wave, 2.5 kV level, for both common mode and differential mode.
Operating frequency requirements: directional and non-directional luminaires	Frequency ≥ 120 Hz Note: This performance characteristic addresses problems with visible flicker due to low frequency operation and applies to steady-state as well as dimmed operation. Dimming operation shall meet the requirement at all light output levels.
Noise requirements: directional and non-directional luminaires	All ballasts & drivers used within the luminaire shall have a Class A sound rating. Ballasts and drivers are recommended to be installed in the luminaire in such a way that in operation, the luminaire will not emit sound exceeding a measured level of 24 BA.

Table 4: ENERGY STAR luminaire requirements

The DesignLights™ Consortium (DLC) provides requirements for track or mono-point directional lighting fixtures, summarized in Table 5.[4]

Characteristic	Unit	DLC Value
Minimum light output	lm	250
Zonal lumen density		≥ 85%: 0-90°
Minimum luminaire efficacy	lm/W	40
Allowable CCTs (ANSI C78.377-2008)	K	≤ 5000
CRI		80
L70 lumen maintenance	hours	50,000
Minimum luminaire warranty	years	5

Table 5: DLC track light requirements

4 Technical Requirements Table v1.7, DesignLights Consortium Qualified Products List - Non-Residential Applications, www.designlights.org/solidstate.manufacturer.requirements.php

2. DEFINE DESIGN GOALS

In addition to the requirements given in the above tables, we examined existing 39-W CMH lamp data sheets to develop the goals shown in Table 6. We found that the input power for luminaires using 39-W CMH lamps is 44 to 45 W, so we targeted this reference design to be at least equivalent.

Table 6 shows the design goals for this project.

Characteristic	Unit	Minimum Goal	Target Goal
Light output	lm	3200	> 3200
Light intensity - CBCP	cd	20,000	> 20,000
Beam angle - FWHM	degrees	15	15
Luminaire efficacy	lm/W	75	> 75
Lifetime	hours	35,000	50,000
CCT	K	3000	3000
CRI	100-point scale	80	80
Power	W	44	< 44
Power factor		0.9	> 0.9

Table 6: CXA2530 retail track light design goals

3. ESTIMATE EFFICIENCIES OF THE OPTICAL, THERMAL & ELECTRICAL SYSTEMS

We used Cree's Product Characterization Tool (PCT) tool to determine the drive current for the design.[5] Figure 1 shows basic electrical data and optical output from the PCT. We estimated 90% optical efficiency, 85% driver efficiency and a solder point temperature (T_{SP}) of 70 °C.

Current (A)	LED 1			
	Model	Cree XLamp CXA2530 {EZW}		
	Flux	T2 [3200]	Tsp (°C)	70
	Price	$ -		
	SYS # LED	SYS lm tot	SYS W	SYS lm/W
0.900	1	3073.91	37.617	81.7
0.950	1	3184.98	39.959	79.7
1.000	1	3290.86	42.326	77.8
1.100	1	3483.93	47.126	73.9
1.200	1	3653.5	52.025	70.2

Figure 1: PCT output with CXA2530 flux data

The PCT output shows that, at 1 A, a single XLamp CXA2530 LED produces the desired lumen output and efficacy.

Thermal Requirements

Proper thermal management is a key component of any successful LED-based lamp or luminaire design. Operating at 42 W of power in this retail track light design, the XLamp CXA2530 LED requires a heat sink to dissipate this thermal

5 PCT is available at: pct.cree.com

load. The heat sink in this design must not only dissipate the heat generated by the LED, but also provide the mechanical frame for the LED, optic, driver and base. We used a market-ready heat sink/housing assembly, shown in Figure 2.[6] The heat sink is made of anodized aluminum alloy, AA 6063, and is part of a kit that includes a cover glass, screw-on base and front optic cover ring.

Figure 2: CXA2530 retail track light heat sink/housing assembly

We performed thermal simulation to verify that this thermal design is sufficient.[7] Figure 3 shows thermal images of the lamp assembly. The simulated peak solder point temperature (T_{SP}) is 64 °C, or 39 °C above ambient. The thermal resistance of the XLamp CXA2530 LED is 0.8 °C/W, so at 42 W the junction temperature (T_J) will be approximately 98 °C.

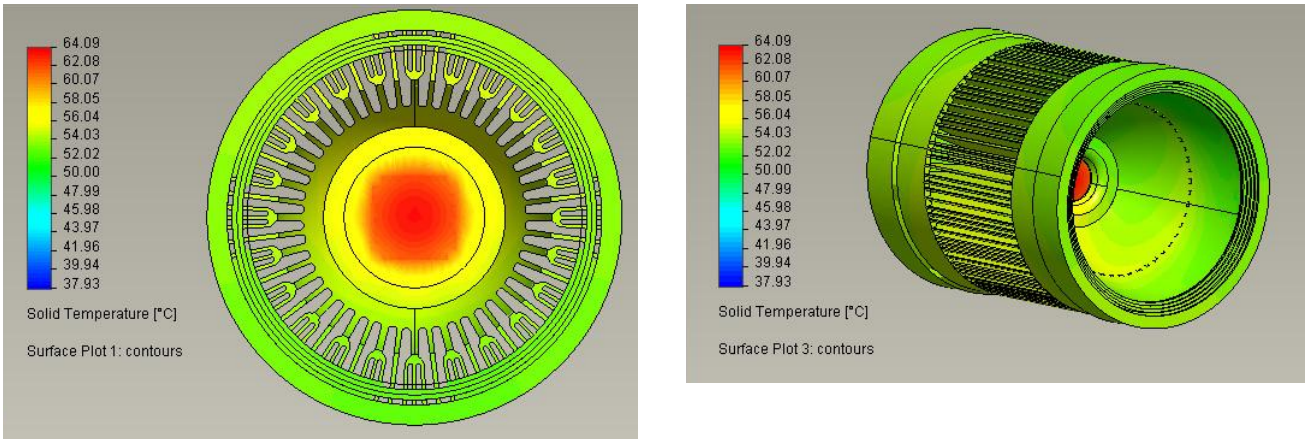


Figure 3: CXA2530 retail track light thermal simulation

Drive Electronics

Cree selected a dimmable, universal input voltage driver to supply power to the retail track light.[8] The driver is a slightly modified version of a commercially available driver model. The driver, shown in Figure 4, is located off the track and is attached to the heat sink/housing assembly.

6 Model GD120-01, Losiwang, www.Losiwang.com.cn

7 For additional information on thermal management, refer to the Thermal Management of Cree XLamp LEDs Application Note, AP05, www.cree.com/xlamp_app_notes/thermal_management

8 Model ERP040W-1000-39, Energy Recovery Products (ERP), www.erppowerllc.com/

Figure 4: CXA2530 retail track light driver

Secondary Optics

It is a challenge to create a narrow-beam optic for a relatively large light source such as the XLamp CXA2530 LED. This design meets the challenge with a custom reflector that is about 89% optically efficient and produces a 16° beam angle.[9] The reflector, shown in Figure 5, fits within the heat sink/housing assembly.

Figure 5: CXA2530 retail track light reflector

4. CALCULATE THE NUMBER OF LEDS NEEDED

The dual purpose of this reference design is to show that a single LED package can deliver equivalent lighting utility and superior performance compared to existing 39-W CMH lamps on the market and show that it is possible to produce a narrow-beam retail track light based on the XLamp CXA2530 LED. The CXA2530 LED is a multi-chip LED package that can offer the required CBCP with new levels of LED-to-LED color consistency and efficiency. The new XLamp CXA2530 LED is 34% brighter than the original CXA2011,[10] which can enable superior LED lighting designs even more quickly.

We selected a Warm White LED for this reference design, shown highlighted in yellow in Table 7. By choosing an LED from a mid-level flux bin, we ensured that the design uses an LED that is readily available.

9 Model 4-1361-1, Nata Lighting Company Limited, www.nata.cn/

10 Measured at 1 A, junction temperature (T_J) = 85 °C

Color	CCT Range	Base Order Codes Min. Luminous Flux @ 800 mA			2-Step Order Code		4-Step Order Code	
		Group	Flux (lm) @ 85 °C	Flux (lm) @ 25 °C*	Chromaticity Region		Chromaticity Region	
EasyWhite	4000K	T2	3200	3609	40H	CXA2530-0000-000N00T240H	40F	CXA2530-0000-000N00T240F
		T4	3440	3879		CXA2530-0000-000N00T440H		CXA2530-0000-000N00T440F
		U2	3680	4150		CXA2530-0000-000N00U240H		CXA2530-0000-000N00U240F
	3500K	S4	2990	3372	35H	CXA2530-0000-000N00S435H	35F	CXA2530-0000-000N00S435F
		T2	3200	3609		CXA2530-0000-000N00T235H		CXA2530-0000-000N00T235F
		T4	3440	3879		CXA2530-0000-000N00T435H		CXA2530-0000-000N00T435F
	3000K	S4	2990	3372	30H	CXA2530-0000-000N00S430H	30F	CXA2530-0000-000N00S430F
		T2	3200	3609		CXA2530-0000-000N00T230H		CXA2530-0000-000N00T230F
	2700K	S2	2780	3135	27H	CXA2530-0000-000N00S227H	27F	CXA2530-0000-000N00S227F
		S4	2990	3372		CXA2530-0000-000N00S427H		CXA2530-0000-000N00S427F
		T2	3200	3609		CXA2530-0000-000N00T227H		CXA2530-0000-000N00T227F

Table 7: CXA2530 LED order codes

5. CONSIDER ALL DESIGN POSSIBILITIES

The design possibilities for an LED-based track light are multitudinous. There are many ways to design the necessary heat sink that can dissipate the heat and fit within the desired envelope. One such heat sink is demonstrated in this reference design. There are also many ways to drive the LED and design the reflector and optics. Carefully selecting a driver and working with a reflector manufacturer to create an appropriate reflector provided the performance necessary for a true 39-W CMH-equivalent retail track light.

There are a number of desirable performance-related benefits in this design, which are results of the XLamp CXA2530 LED package. Because the CXA2530 LED uses EasyWhite™ technology, LED-to-LED color consistency can be held to within two or four McAdam ellipses for any given CCT, depending on the order code. The CXA2530 LED is binned at 85 °C, so the CCT will be as faithful as possible to the system operating environment. These component features allow for new levels of specification accuracy.

However, the primary purpose of this reference design is to show how simple and straightforward it is to design with Cree's XLamp CXA2530 LED. This application note is not intended to show the only way to do this, but instead demonstrate the ease of implementation with this set of engineering constraints. Certainly numerous other successful solutions are possible.

Track light manufacturers typically design a reflector for a particular beam angle and install the light source and reflector in multiple housings. This reference design supports such a process and in addition, the performance range of the XLamp CXA2530 LED enables a wide variety of luminaires that all use a single CXA2530 LED. For demanding retail applications, the CXA2530 LED is offered in a 90-minimum CRI option, providing even better color rendering than this reference

design. CCTs from 2700 K to 5000 K and lumen output up to 5900 lm[11] are possible, providing the flexibility to offer a variety of luminaires that use a single LED light source and reflector. This flexibility is enhanced by the XLamp CXA2520 LED, which has the same physical dimensions and optical source size as the CXA2530 and offers even more design possibilities.

6. COMPLETE THE FINAL STEPS

This section describes the techniques used to create a working retail track light using the XLamp CXA2530 LED and shows the results of the design.

Prototyping Details

The essence of the design is to attach a Cree XLamp CXA2530 LED to a heat sink and assemble the necessary optics and driver around this to create a true 39-W CMH-equivalent LED luminaire. The assembly steps are detailed below.

1. We verified the component dimensions to ensure a correct fit.
2. We attached the CXA2530 LED to the heat sink with a small amount of thermally conductive compound.[12] Thermally conductive epoxy can also be used.[13]
3. We fed the driver output wires through the heat sink and, following the recommendations in Cree's Soldering and Handling Application Note for the CXA family of LEDs[14], soldered them onto the CXA2530 LED.
4. We tested the connection by applying power to the LED and verified that the LED lit up.
5. We placed a plastic alignment ring[15] over the LED and positioned the ring so the LED was centered on the heat sink.
6. We secured the plastic alignment ring to the heat sink with screws.

7. We secured each end of the driver to the heat sink with a bracket and screw.

11 At 61 W, 85 °C
12 Dow Corning Thermally Conductive Compound, TC-5026, www.dowcorning.com/content/publishedlit/11-1689a-01.pdf
13 Refer to Cree's Chemical Compatibility application note for compounds that are safe to use with Cree LEDs.
Cree XLamp LED Chemical Compatibility Application Note, AP63, www.cree.com/products/pdf/XLamp_Chemical_Comp.pdf
14 Cree XLamp CXA Family LEDs Soldering and Handling, Application Note AP74, www.cree.com/xlamp_app_notes/CXA_SH
15 Model PC, Mekoda Optical Co., Ltd., www.mekoda.cn

8. We fed the driver input wires through the center hole in the screw-in base.
9. We screwed the base to the heat sink, enclosing the driver.
10. We placed the reflector in the heat sink so the opening aligned with the LED.
11. We placed the cover glass on the reflector and screwed the front optic cover ring to the heat sink to secure the cover glass and the reflector to the heat sink.
12. We attached the track adaptor bracket to the lamp assembly with decorative screws.
13. We connected the driver input wires to the track adaptor.
14. We performed final testing.

Results

Thermal Results

We measured the thermal performance of the retail track light by attaching a thermocouple to the XLamp CXA2530 LED mounted to the heat sink. The T_{SP} of the CXA2530 retail track light was 63.5 °C.

Based on the measured solder point temperature, the T_J can be calculated as follows.

$T_J = T_{SP}$ + (LED power * LED thermal resistance)
T_J = 63.5 °C + (42 W * 0.8 °C/W)
T_J = 97 °C

This thermal performance is in line with the thermal simulation.

Estimated LED Lifetime

Based on thousands of hours of long-term testing of the XLamp CXA2011 LED at higher temperatures than the measured 63.5 °C T_{SP} in this reference design, Cree expects an L70 lifetime for this retail track light significantly longer than the 50,000-hour goal. 39-W CMH lamps typically have lifetimes ranging from 10,000 to 12,000 hours, so the 4 to 5 times longer lifetime of the CXA2530 retail track light offers compelling maintenance cost savings.

Optical and Electrical Results

We obtained the results in Table 8 by testing the retail track light in a 1.5-meter sphere and a Type A goniometer after a 60-minute stabilization time.[16] The performance meets or exceeds the project goals and accomplishes this using a single XLamp CXA2530 LED to produce a symmetric 16° beam with CBCP exceeding 20,000 cd.

16 Testing was performed at Cree's Shenzhen Technology Center. An IES file for the retail track light is available on the Cree website: www.cree.com/xlamp_app_notes/CXA2530_track_ies

Characteristic	Unit	Result
Light output	lm	3211
Light intensity - CBCP	cd	20,470
Beam angle - FWHM	degrees	16
Luminaire efficacy	lm/W	75.5
CCT	K	3048
CRI	100-point scale	80
Power	W	42.6
Power factor		0.95

Table 8: CXA2530 retail track light results

We also tested the intensity distribution of the CXA2530 retail track light. As shown in Figure 6, the retail track light has an even intensity distribution for the narrow beam angle.

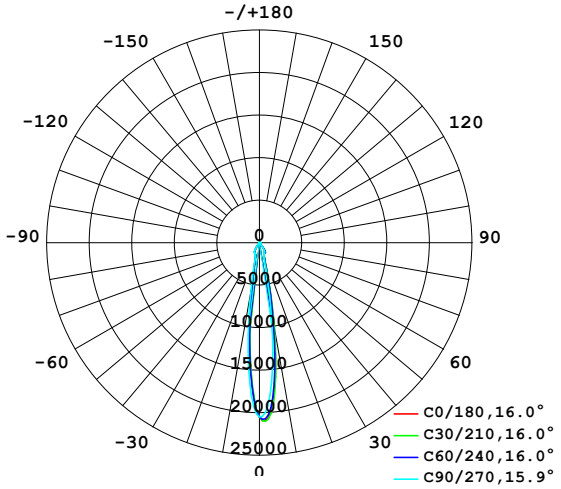


Figure 6: Goniometric intensity polar plot of CXA2530 retail track light

Table 9 shows the center beam illuminance of the CXA2530 retail track light at various distances from the light source.

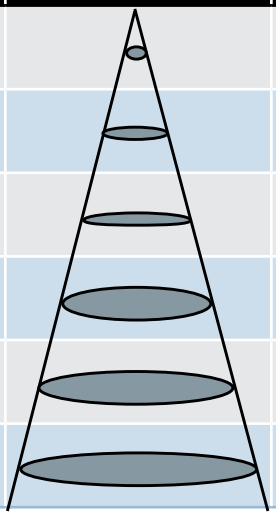
Height		Center Beam Illuminance			Beam Width			
					Vertical Spread		Horizontal Spread	
0.5 m	1.7 ft	7,371 fc	79,337 lx		15.2 cm	0.5 ft	15.2 cm	0.5 ft
1.0 m	3.3 ft	1,843 fc	19,834 lx		30.5 cm	1.0 ft	27.4 cm	0.9 ft
1.5 m	5.0 ft	819 fc	8,815 lx		42.7 cm	1.4 ft	42.7 cm	1.4 ft
2.0 m	6.6 ft	461 fc	4,959 lx		57.9 cm	1.9 ft	57.9 cm	1.9 ft
2.5 m	8.3 ft	295 fc	3,173 lx		73.2 cm	2.4 ft	73.2 cm	2.4 ft
3.0 m	9.9 ft	205 fc	2,204 lx		88.4 cm	2.9 ft	88.3 cm	2.8 ft

Table 9: CXA2530 retail track light center beam illuminance – 16° beam angle

CONCLUSIONS

This reference design demonstrates the ease of integrating the Cree XLamp CXA2530 LED into a retail track light with excellent results. Such a luminaire is useful in both retail and residential spot light applications, where enhancing the appearance of merchandise or artwork is desirable. The performance of this retail track light makes it an attractive alternative to CMH-based luminaires and could form the basis for a broad product line of CXA2530 LED based track lights. This document is meant to show that this level of performance is achievable with a single XLamp CXA2530 LED component, and is meant to suggest that the CXA2530 LED can be the basis of numerous successful track light designs.

SPECIAL THANKS

Cree would like to acknowledge and thank the following partner companies for collaborating in the successful prototyping of this track light.

- Energy Recovery Products - www.erppowerllc.com
- Nata Lighting Company Limited - www.nata.cn

BILL OF MATERIALS

Component	Order Code/Model Number	Company	Web Link
Alignment ring	PC	Mekoda Optical Co., Ltd.	www.mekoda.cn
Driver	ERP040W-1000-39	Energy Recovery Products, Inc.	www.erppowerllc.com
Heat sink/housing, cover glass, screw-on base, front optic cover ring kit	GD120-01	Losiwang	www.Losiwang.com.cn
LED	CXA2530-0000-000N00T230H	Cree, Inc.	www.cree.com/cxa2530
Reflector	4-1361-1	Nata Lighting Company Limited	www.nata.cn
Thermally conductive compound	TC-5026	Dow Corning Corporation	www.dowcorning.com/content/publishedlit/11-1689a-01.pdf

Table 10: Bill of materials for CXA2530 retail track light