Cree® XLamp® MT-G MR16 Reference Design

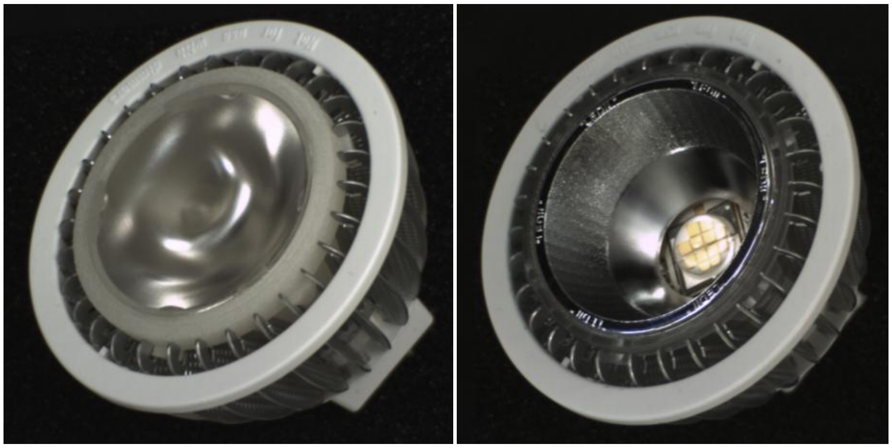

Figure 1: MR16 assembly (left: Carclo TIR optic, right: Ledil reflector optic)

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INTRODUCTION

The design and production of high-lumen, small-form, point-source illumination has been one of the more challenging solid-state lighting applications. Requirements for high lumen density combined with limited space for drive electronics and thermal dissipation have limited the adoption of LED illumination in applications like MR16 bulbs.

In addition to being an interesting exercise in systems development, we are presenting a multi-vendor, multi-disciplinary approach to solving the MR16-lamp constraints. The successful solution has required collaborative design and innovation in LED packaging, power supply, optics and heat-sink development. In order to bring a series of industry-leading practices to bear on a tricky problem, we believe this kind of collaboration will become increasingly common in the solid-state lighting arena. Just as traditional lamp and ballast manufacturers have engaged in symbiotic development, so too

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must companies working on LED illumination components work together to solve problems in a mutually beneficial way.

This application note details the design of an MR16 bulb with Cree's XLamp® MT-G component. The goal of the design is to enable an LED-based MR16 replacement retrofit bulb that delivers equivalent performance to 35W – 50W halogen MR16s and conforms to the latest Energy Star requirements.[1]

In early 2011, many MR16 replacements currently available on the market underperform when compared to standard halogen bulbs and several misrepresent their halogen equivalency on datasheets and packaging. The DOE's CALIPER testing program corroborates this, most recently with the CALIPER Round 11 tests.[2]

The design in this application note will show that a highly efficient, high lumen output multi-die LED array such as the XLamp MT-G, when designed with the proper heat sink, optics and driver, can enable a true 35W – 50W MR16 bulb replacement, delivering superior product repeatability, efficacy and longevity.

In presenting this design, our team set out to create a luminaire with 50,000 hour L70 longevity, created through a low power/high efficacy instrumentation of the LED. Cree created these MR16 prototypes using an elegant MR-form heat sink design from Neng Tyi Precision Industries Co., Ltd.,[3] and collaborated with multiple industry-leading driver and optic partners to create an integrated, optimized system with multiple components and combinations to function with the MT-G LED. This reference design shows only a few possible implementations of an MR16 bulb with the MT-G LED and is meant to demonstrate increasing value of multi-disciplinary design to bring segment leading products to market.

1 As specified in the Integral LED Lamps specification version 1.1 http://www.energystar.gov/ia/partners/manuf_res/downloads/IntegralLampsFINAL.pdf and the Energy Star Integral LED Lamp Center Beam Intensity Benchmark Tool (ed 7/6/2010) http://www.energystar.gov/ia/partners/manuf_res/downloads/EIQ_Form_All_Categories.xls
2 http://www1.eere.energy.gov/buildings/ssl/caliper.html
3 http://www.nengtyi.com.tw/eindex.aspx

DESIGN APPROACH/OBJECTIVES

In the "LED Luminaire Design Guide"[4] Cree advocates a six step framework for creating LED luminaires and lamps. We use this framework, with the design guide's summary table 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 effiiciencies 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.

4 LED Luminaire Design Guide, Application Note APO000015, www.cree.com/products/pdf/LED_Luminaire_Design_Guide.pdf

THE 6-STEP METHODOLOGY

The major requirement and goal for this project was to demonstrate an easy-to-implement, high efficiency lamp that could replace the current halogen MR16 bulbs on the market, showing that a true 35W-50W equivalent MR16 LED lamp is possible at a reasonable cost. Cree framed the project as a retrofit, so the MR16 bulb designed in this application note could take advantage of the installed base of track lighting and fixtures.[5,6]

1. DEFINE LIGHTING REQUIREMENTS

The table below lists important characteristics to consider for the design of the MR16 in this reference design.

Importance	Characteristics	Units
Critical	light intensity	CBCP (foot-candles)
	beam angle (FWHM)	degrees
	electrical power	watts (W)
	luminous flux	lumens (lm)
	form factor	
Important	price	$
	lifetime (L70)	hours
	operating temperatures	°C
	operating humidity	% RH
	color temperature	K
	CRI	100-pt scale
	bulb-to-bulb consistency	
	driver power factor	
	manufacturablilty	

Table 1: Important characteristics of target MR16 luminaire

Examination of existing halogen MR16 lamp data sheets gives basic benchmark data:[7]

Source	Luminaire Power (W)	Luminous Flux (Lm)	Efficacy (Lm/W)	CBCP (cd)	Beam Angle (°)	Lifetime (hours)[8]
35W halogen wide flood	35	540	15.4	1000	36°	3000
50W halogen narrow flood	50	800	16.0	2500	24°	3000
50W halogen indoor flood	50	850	17.0	1600	36°	3000

Table 2: Halogen MR16 data-sheet information

5 Track Lighting markets are documented in a recently release report from the US Department of Energy, Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/nichefinal-report_january2011.pdf

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

7 Source: http://www.lighting.philips.com/us_en/browseliterature/download/p-5755.pdf

8 Rated average life is the length of operation (in hours) at which point an average of 50% of the lamps will still be operational and 50% will not.

Measurement of MR16 halogen lamps as purchased from retail stores shows that the consistency of the beam angle is poor. This application note will show that with proper design of an LED system, an MT-G-based MR16 will significantly improve this and create a much more repeatable beam with equivalent intensity. The graphs below shows the measured data, normalized to show the light distribution for various types of halogen MR16s. The data shows a significant variation of peak intensity locations and beam shape.

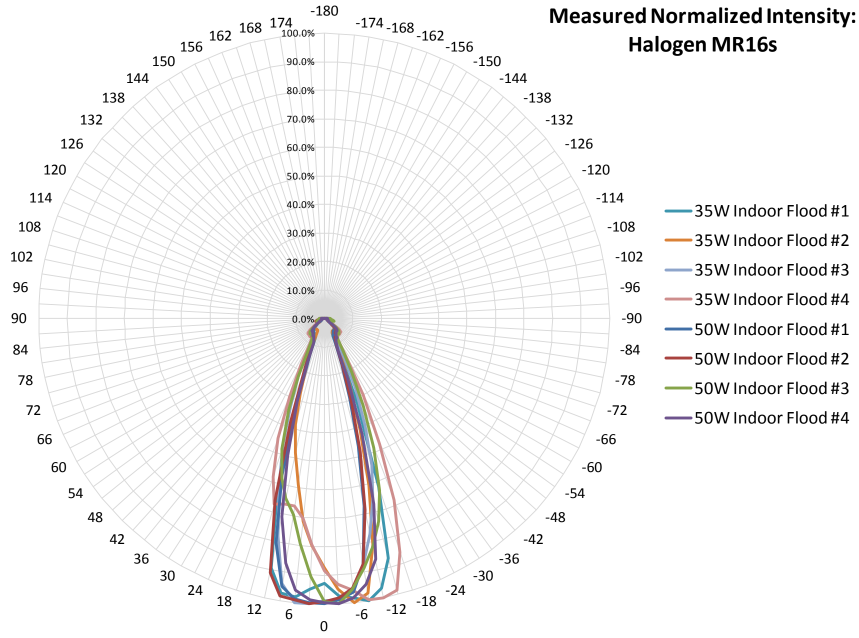

Figure 2: Measured goniometric intensity polar plot of halogen MR16

Data from the Energy Star *Program Requirements for Integral LED Lamps* gives us additional performance requirements.[9]

General Energy Star Luminaire Requirements:		
Correlated Color Temperature (CCT)	The luminaire must have one of the following designated CCTs and fall within the 7-step chromaticity quadrangles as defined in the Appendix.	
Nominal CCT	**Target CCT (K) and tolerance**	**Target Duv and tolerance**
2700 K	2725 ± 145	0.000 ± 0.006
3000 K	3045 ± 175	0.000 ± 0.006
3500 K	3465 ± 245	0.000 ± 0.006
4000 K	3985 ± 275	0.001 ± 0.006
Color Maintenance	The change of chromaticity over the minimum lumen maintenance test period (6000 hours) shall be within 0.007 on the CIE 1976 (u′,v′) diagram.	
Color Rendering Index (CRI)	Minimum CRI (Ra) of 80. In addition, the R9 value must be greater than 0.	
Dimming	Lamps may be dimmable or nondimmable. Product packaging must clearly indicate whether the lamp is dimmable or not dimmable. Manufacturers qualifying dimmable products must maintain a Web page providing dimmer compatibility information. Minimum efficacy, light output, CCT, CRI, and power factor of dimmable lamps will be confirmed with the lamp operated at full power.	
Warranty	A warranty must be provided for lamps, covering material repair or replacement for a minimum of three (3) years from the date of purchase.	
Allowable Lamp Bases	Must be a lamp base listed by ANSI.	
Power Factor	For lamp power ≤5 W and for low voltage lamps, no minimum power factor is required For lamp power >5 W, power factor must be ≥ 0.70 Note: Power factor must be measured at rated voltage.	
Minimum Operating Temperature	Integral lamp shall have a minimum operating temperature of -20°C or below.	
LED Operating 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.	
Electromagnetic and Radio Frequency Interference	Integral LED lamps must meet the appropriate FCC requirements for consumer use (FCC 47 CFR Part 15).	
Audible Noise	Integral lamp shall have a Class A sound rating.	
Transient Protection	Power supply shall comply with IEEE C.62.41-1991, 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 Voltage	Lamp shall operate at rated nominal voltage of 120, 240 or 277 VAC, or at 12 or 24 VAC or VDC.	

9 http://www.energystar.gov/ia/partners/product_specs/program_reqs/ILL_prog_reqs.pdf

And MR16-specific data:[10]

Application Requirements:	
Criteria Item	**ENERGY STAR Requirements**
Definition	Directional lamp means a lamp having at least 80% light output within a solid angle of *π* sr (corresponding to a cone with angle of 120°)
Minimum luminous efficacy - Lamp diameter ≤ 20/8 inch	40 lm/W
Color Spatial Uniformity	The variation of chromaticity within the beam angle shall be within 0.006 from the weighted average point on the CIE 1976 (u',v') diagram.
Maximum lamp diameter	Not to exceed target lamp diameter
Maximum overall length (MOL)	Not to exceed MOL for target lamp
Minimum center beam intensity - MR16 lamps	Link to online tool at http://www.drintl.com/htmlemail/Energystar/Dec09/ESIntLampCenterBeamTool.zip Enter the following information into the online tool: Target lamp nominal wattage Target lamp beam angle in degrees (Note: maximum allowable beam angle = 50°.)
Lumen Maintenance	≥ 70% lumen maintenance (L70) at 25,000 hours of operation
Rapid-Cycle Stress Test	Cycle times must be 2 minutes on, 2 minutes off. Lamp will be cycled once for every two hours of required minimum L70 life.

10 Ibid. p13-14

2. DEFINE DESIGN GOALS

The design goals for this project:

Characteristic	Unit	Minimum Goal	Target Goal
Luminaire Light Output	Lm	500	600
Illuminance Profile		Identical	Better
Power	W	<<50	<8
Beam Angle	°	25°-40°	25°-40°
Center Beam Candle Power: 27° Beam	Cd	1409	>2044
Center Beam Candle Power: 38° Beam	Cd	791	>1147
Lifetime	Hours	25,000	50,000
CCT	K	3,000	3,000
CRI		80	85
Max ambient temperature	ºC	30	40

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

Component Efficiency

The MT-G EasyWhite LED has a variety of efficacies depending upon color temperature, bin, and drive conditions. Based on the preliminary data of the MT-G, Cree chose to work with the MTGEZW-00-0000-0B00G030F, highlighted in yellow below, to give the closest possible CCT equivalent to a halogen bulb and the highest efficiency. These components, when attached to a proper heat sink and fit with an appropriate secondary optic and driven with the correct conditions, will deliver the sufficient center beam candle power (CBCP) to be considered a 35W – 50W equivalent MR16 bulb as specified by Energy Star.

Color	CCT Range	Base Order Codes Min Luminous Flux (lm) (Tj =85° C)		Order Code
		Group	Flux (lm)	
EasyWhite 4-Step	4,000 K	F0	480	MTGEZW-00-0000-0B00F040F
		G0	520	MTGEZW-00-0000-0B00G040F
		H0	560	MTGEZW-00-0000-0B00H040F
	3,500 K	E0	440	MTGEZW-00-0000-0B00E035F
		F0	480	MTGEZW-00-0000-0B00F035F
		G0	520	MTGEZW-00-0000-0B00G035F
	3,000 K	E0	440	MTGEZW-00-0000-0B00E030F
		F0	480	MTGEZW-00-0000-0B00F030F
		G0	520	MTGEZW-00-0000-0B00G030F
	2,700 K	D0	400	MTGEZW-00-0000-0B00D027F
		E0	440	MTGEZW-00-0000-0B00E027F
		F0	480	MTGEZW-00-0000-0B00F027F

Basic LED (not system) electrical data and optical output from Cree's Product Characterization tool is listed below in Figure 4.[11]

Compare: LED lm | LED lm/W | LED Vf | LED W

System: Target Lumens : 600 Optical

LED 1

Model: Cree XLamp MT-G {EZW} prelim

Flux: G0 [620] 620.0

Price: $ - Tj (°C) 85

LED Multiple: x1

Current (A)	LED lm	LED lm/W	LED Vf	LED W
0.700	350	91.4	5.47	3.83
0.750	373	90.5	5.49	4.12
0.800	396	89.8	5.51	4.41
0.850	419	89.1	5.53	4.7
0.900	442	88.4	5.55	5
0.950	464	87.7	5.57	5.29
1.000	487	87.3	5.58	5.58
1.100	531	85.9	5.62	6.18
1.200	574	84.7	5.65	6.78
1.300	617	83.4	5.69	7.4
1.400	658	82.1	5.72	8.01
1.500	700	81.1	5.75	8.63
1.600	740	80	5.78	9.25
1.700	780	78.9	5.81	9.88
1.800	819	77.9	5.84	10.51
1.900	857	76.9	5.87	11.15
2.000	895	76	5.89	11.78

Figure 4: Cree's Product Characterization Tool with Preliminary XLamp MT-G minimum flux data

11 The analysis came from Cree's Product Characterization Tool. http://pct.cree.com/

After some basic calculations and use of the PCT, we determined to drive the MT-G at 1.10A in order to generate the sufficient system luminous output and efficacy. The choice was constrained by our desire to use less than 6.5 Watts of LED power while delivering more than the minimum required CBCP from the EnergyStar specification. We chose the lumen output based on historical data and our experience in the conversion of lumens to candela for standard secondary optics in the desired beam angle range.

Thermal Requirements

The XLamp MT-G operates at just over 6 watts of power, at steady state temperature, when running at the chosen 1.10-A input current and requires a heat sink to dissipate this thermal load. In an LED-based MR16 design, the heat sink must not only dissipate the heat generated by the LED but also provide the mechanical frame for the LED, optic, driver and base. Additionally, to be considered a true MR16 retrofit, the overall footprint must fit into the ANSI-standard envelope as defined in ANSI C78.24-2001.[12] We chose to find an off-the-shelf heat sink for this reference design instead of creating a custom heat sink. A benefit of this approach is to show how easy it can be to create a high-quality MR16 retrofit bulb with the MT-G component.

After evaluating designs from several heat-sink manufacturers, we decided to focus on a single heat sink from Neng Tyi Precision Industries Co., Ltd.,[13] which met the necessary requirements of thermal dissipation for this project. We measured a thermal resistance of 4.5°C/W heat sink to ambient (Θ_{hs-a}) for the Neng Tyi "Diamond" heat sink.

Figure 5: The Neng Tyi "Diamond" MR16 heat sink

12 http://www.nema.org/stds/c78-24.cfm
13 http://www.nengtyi.com.tw

To verify the performance, thermal simulations were executed with ANSYS, Inc. simulation software.[14] Shown below are the simulation results showing images of the assembly and a cross section of the heat sink running at 6.5W input power in a 25°C ambient environment. The peak solderpoint temperature calculated by the software is 79°C, or 54°C above ambient. The thermal effective resistance of the MT-G component is 1.5°C/W, so the junction temperature will thus be 89 °C. Since the XLamp MT-G LED is a new component, based on our experience with similar LED systems (e.g. XLamp MP-L), we expect this design with this heat sink to attain both the minimal goal of an Energy Star-compliant L70 rating of 25,000 hours and the target design goal of an L70 rating of 50,000 hours.[15]

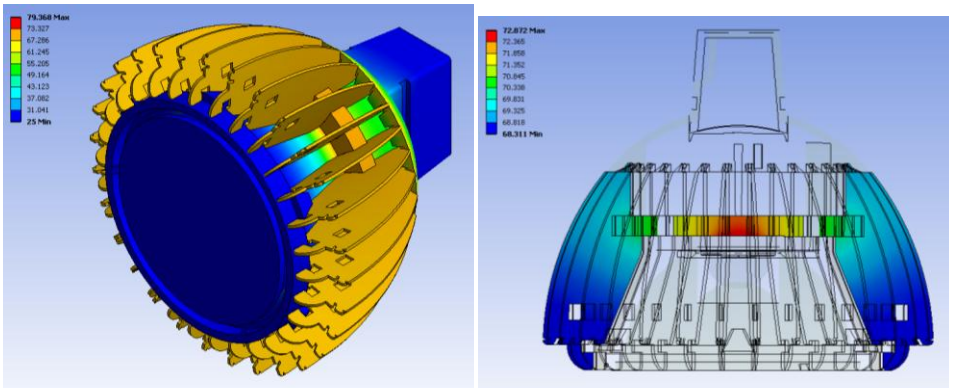

Figure 6: Ansys thermal simulations

Data collected (below) from an MT-G mounted to the MR16 heat sink, running at 6.5 W, shows thermal performance in line within a few degrees with the thermal simulations above.

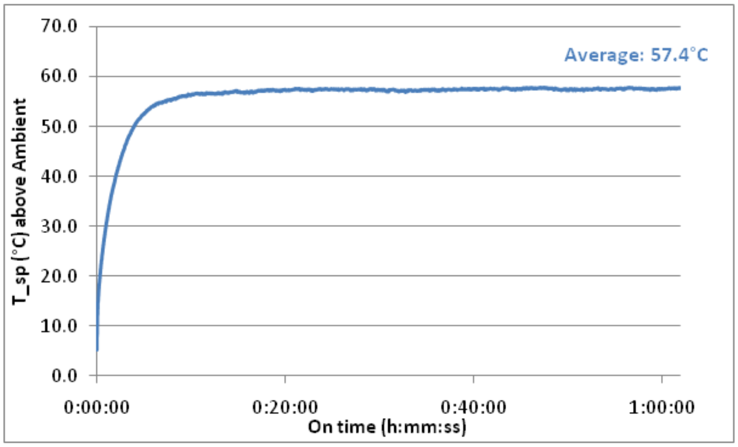

Figure 7: Measured solder-point temperature above ambient of XLamp MT-G MR16 at 6.5-W input power

14 Cree used Ansys DesignSpace, http://www.ansys.com/products/structural-mechanics/products.asp

15 That is, after 50,000 hours of operation, the LED will still deliver at least 70% of its initial luminous flux.

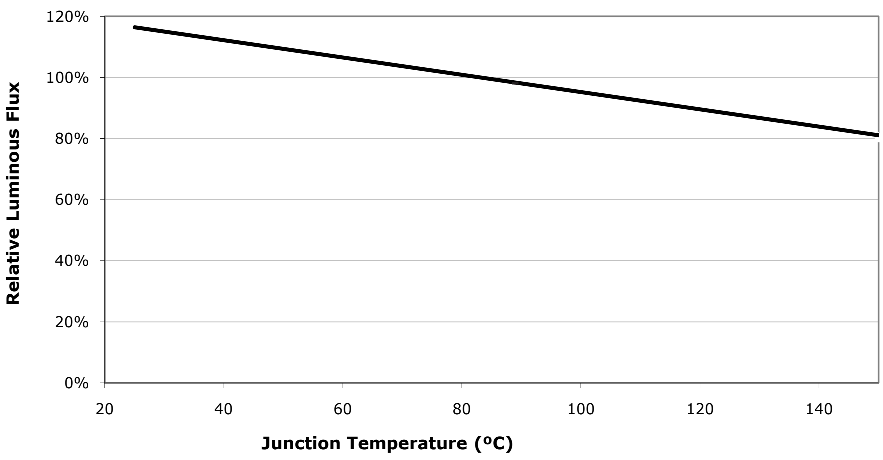

Figure 8: XLamp MT-G Data Sheet: Relative Luminous Flux vs. Junction Temperature

Looking at either the PCT or information in the MT-G data sheet,[16] a MT-G LED operating with a 90°C junction temperature will have a brightness of just less than 100% of the 85°C pulsed binning data, which is confirmed in our measurements.

Drive Electronics

One of the biggest challenges of this design was fitting the necessary drive electronics into the small area of the MR16 base. Numerous types of transformers are on the market, including magnetic and electronic. Full compatibility with all transformers will depend significantly on driver design and is not in the scope of this document. For this reference design, Cree focused on the more-common electric transformers, such as the Lightech[17] LET 60 LW, a low-wattage transformer compatible with both LED and halogen MR16s. Standard MR16 track lighting transformers supply 12 VAC to the bulbs, so the internal driver must convert the 12 VAC from the transformer to a 1.10-A current source for the MT-G component, running at approximately 6.0 V. We determined the driver would have to be 80% efficient in order to minimize the total load to under 8 W and not generate excess heat.

Working with several driver partners, we identified and characterized three solutions for this reference design. Drivers from Diodes Incorporated,[18] National Semiconductor,[19] and Texas Instruments[20] were fabricated by each company to fit the required form factor and deliver the necessary current.

16 www.cree.com/products/pdf/XLampMTG-EZW.pdf
17 Lightech Electronic Industries, Ltd. website: http://lightechinc.com
18 Diodes Incorporated's website: http://www.diodes.com/zetex/cree.html
19 National Semiconductor Corporation's website: http://www.national.com/analog/partner/cree
20 Texas Instruments, Incorporated's website/reference design link/etc. http://www.ti.com/led

Schematics and reference designs of the specific drivers used can be found on each of the driver suppliers' websites. The driver from National Semiconductor was based on their LM3401 controller. The driver from Diodes, Inc. was based on their AL8806 controller. The driver from Texas Instruments was based on their TPS54260 controller. All of these drivers were ~80% efficient and had a power factor of 0.6-0.9.

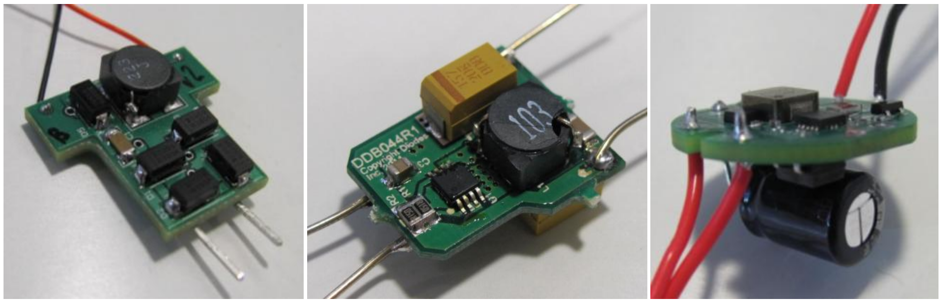

Figure 9: Driver image (from left: National Semiconductor, Diodes Incorporated, Texas Instruments)

Secondary Optics

Another challenge was to tailor the secondary optic for the MT-G component to fit within the standard MR16 envelope and produce the proper beam angle and center-beam candle power (CBCP). The baseline performance for CBCP was established from the Energy Star Integral LED Lamp Center Beam Intensity Benchmark Tool (ed 7/6/2010). The footprint of the optic had to fit within the heat-sink opening as provided by Neng Tyi, as well as comply with the ANSI standard dimensions.

Cree collaborated with optical partners to create or select secondary optics for the XLamp MT-G LED that fit the form factor requirements and cd/lum conversion in the design goals. Carclo Technical Plastics Ltd, a division of Carclo plc[21] provided three versions of a 30-mm TIR lens compatible with the XLamp MT-G component that fit within the Neng Tyi heat sink. A custom holder was engineered to fix the optic to the heat sink at the correct optical height. LEDIL OY[22] provided an innovative reflector solution that fit around the MT-G component and snapped into the existing optic holder provided by Neng Tyi for their Diamond heat sink. Photometric results for both of these solutions are shown below.

21 Carclo http://www.carclo-optics.com/
22 Ledil http://www.ledil.com/index.php?page=cree

Figure 10: Top: Neng Tyi optic holder and Ledil reflector; bottom: Prototype SLS optic holder and Carclo TIR optic

4. CALCULATE THE NUMBER OF LEDS

One.

The purpose of this reference design is to show that a single LED package can deliver equivalent lighting utility and superior efficacy compared to the existing bulbs on the market. The XLamp MT-G EasyWhite LED is a multi-chip LED package that can offer the required CBCP of a replacement bulb with new levels of LED-to-LED color consistency and efficiency.

5. CONSIDER ALL DESIGN POSSIBILITIES

The design possibilities for a retrofit LED MR16 bulb are endless. There are countless ways to design the necessary heat sink that can dissipate the heat and fit within the standard MR16 envelope. One such heat sink was the existing design from OEM bulb manufacturer Neng Tyi. There are also many ways to both drive the LED and design the optics. Working with driver companies to create reference design and optics companies to create and/or select appropriate optics, provided the performance necessary for a true 35W – 50W halogen MR16 replacement bulb.

There are a number of desirable performance-related benefits in this design, which are part of the XLamp MT-G package. Because the MT-G uses EasyWhite technology, LED-to-LED color consistency can be guaranteed to within four or two McAdam ellipses (for any given CCT and depending on the order codes). The MT-G has an 80 CRI minimum and is binned at 85° C, so the tested/binned CCT will be as faithful as possible to the system operating environment. These are all component features that allow for new levels of specification accuracy.

However, the primary purpose of this reference design is to show how straightforward it is to design with Cree's XLamp MT-G EasyWhite LED. This application note is not intended to show the only way to do this but rather to demonstrate the ease of implementation within a difficult set of engineering constraints. With a dedicated design team and resources, the solution space is large!

6. COMPLETE THE FINAL STEPS: IMPLEMENTATION AND ANALYSIS

In this section, Cree illustrates some of the techniques used to create a working prototype MR16 lamp using the XLamp MT-G EasyWhite. Additionally, the photometric results of the XLamp MT-G EasyWhite-based MR16 with comparison to classic halogen lamps will be shown.

Prototyping Details

The essence of the design is to attach a Cree XLamp MT-G EasyWhite component to a heat sink and assemble the necessary optics and driver around this to create a true 35W-50W halogen MR16 replacement. The steps of the assembly will be detailed below.

1. Per the details given in the MT-G data sheet, we soldered a single MT-G LED to a star-shaped metal core printed circuit board (MCPCB) designed for the MT-G.
2. Once the LED is soldered to the MCPCB, wire connectors are soldered to the star board for contact with the driver.
3. A thermal epoxy is placed on the back of the MCPCB to attach to the heat sink. In this reference design, we used Arctic Silver thermal adhesive.[23]
4. The MCPCB is placed onto the heat sink with the leads placed through the thru-holes of the heat-sink base plate, and the thermal paste is allowed to cure (allow at least 15 minutes to cure).
5. Insert the driver board into the plastic base.
6. The wires from the MCPCB are soldered to the driver.
7. Depending on the optic used, there are two methods for attaching the optic to the heat sink.
    a. The Carclo optic is assembled by snapping the optic to the custom holder.
    b. The Ledil optic is snapped into the optic holder from Neng Tyi.
    c. These assemblies can then be snapped into the heat sink over the MT-G, aligning around the MCPCB.
8. The assembly is now finished, and the lamp can now be powered by 12 VAC.

23 http://www.arcticsilver.com/arctic_silver_thermal_adhesive.htm

Results

Optic results:

Optic	Optic Type	Beam Angle	Cd/Lum	Efficiency
Carclo 10756 Narrow Frosted	TIR	27°	3.2	88%
Carclo 10757 Medium Frosted	TIR	31°	1.9	84%
Carclo 10758 Wide Frosted	TIR	42°	1.1	81%
Ledil Minnie	Reflector	38°	1.4	91%

Table 4: Optic test data

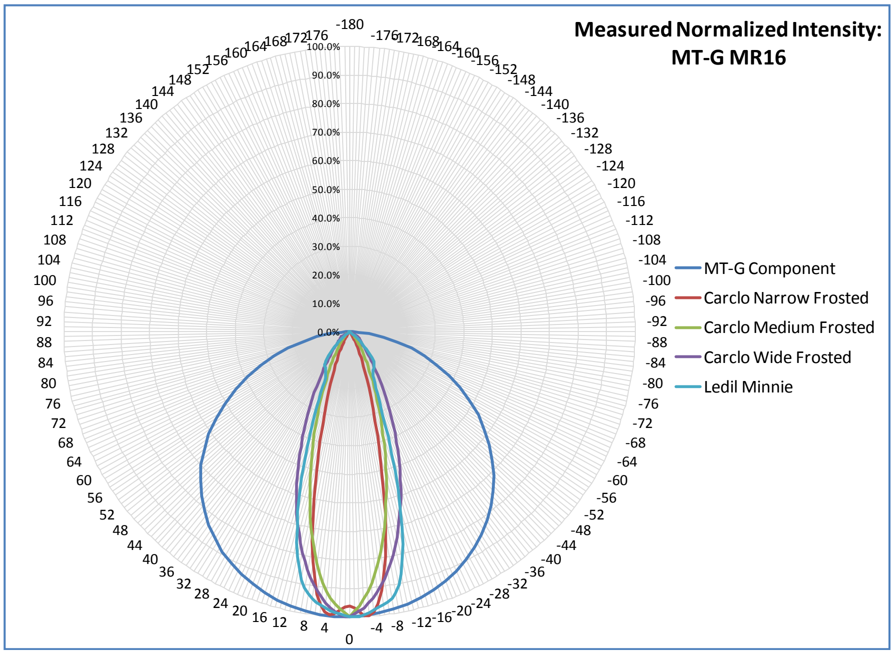

Figure 11: Goniometric-intensity polar plot of XLamp MT-G MR16

Description	Wattage	Current Output (A)	T_sp (°C)	Lumen	CBCP (cd)	Beam Angle (°)	Energy Star Equivalence
MT-G MR16, Carclo Narrow Frosted Optic, Diodes Inc. Driver @ 1.1 A	7.2 W	1.08	84°C	497	1755	27°	>35 W (~43 W)
MT-G MR16, Carclo Narrow Frosted Optic, Diodes Inc. Driver @ 1.5 A	10.1 W	1.50	103°C	611	2250	27°	>50 W (~57 W)
MT-G MR16, Ledil Minnie Reflector, Diodes Inc. Driver @ 1.1 A	7.2 W	1.08	82°C	515	794	38°	35 W
MT-G MR16, Ledil Minnie Reflector, Diodes Inc. Driver @ 1.5 A	10.1 W	1.50	100°C	636	973	38°	>35 W (~42 W)

Table 5: System test data, steady state

We chose the driver from Diodes Incorporated because it was easy to modify so as to deliver 1.5 A. In this configuration, the solder-point temperature measured ~103°C: hot, but manageable. With this driver configuration, we were able to achieve 50W halogen equivalency based on the Energy Star requirements. Using the Carclo Narrow Frosted TIR optic, we demonstrated a 50W equivalent MR16 lamp. The measured CBCP was 2250 cd, above the minimum 2044 cd required for a 27° beam. At the 1.5-A drive level, the lumen output was 620 lumens at steady state, with a 12.0 VAC input. See below for the beam profile and luminous intensity data.

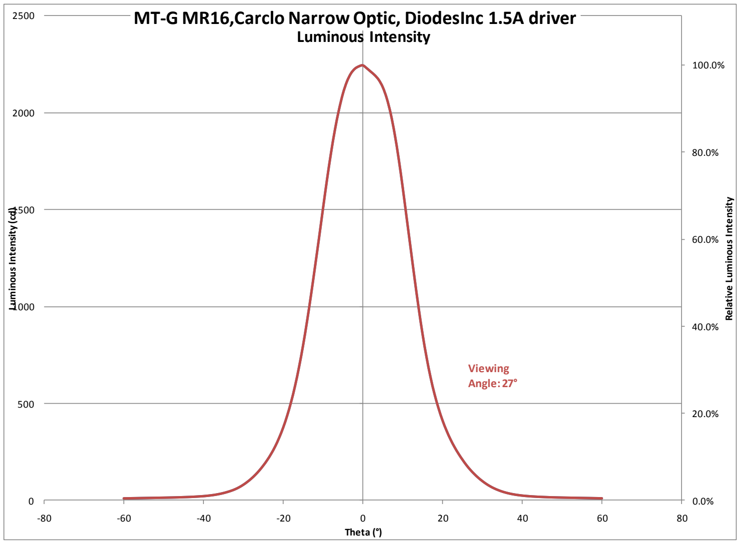

Figure 12 Measured luminous intensity of 50W equivalent MT-G MR16

CONCLUSIONS

This reference design demonstrates the ease of integration of a Cree XLamp MT-G component into a conventional MR16 housing with great results. The design here utilized proper heat sinking, optical control and driver design in order to efficiently and effectively hit the targets outlined by Energy Star as a true 35W – 50W equivalent MR16. We chose driver current and heat sink to achieve a minimum L70 25,000-hour designation. This document is meant to show that this level of performance is achievable and attainable with a single MT-G component but is not meant to be interpreted as the only way that a good LED MR16 can be designed.

SPECIAL THANKS

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