

Application Note- Maximizing Luminaire Efficacy

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Background

Xicato modules have been designed with the goal of maximizing overall efficacy while delivering industry leading quality of light. When designing a LED based luminaire, there are three main areas that need to be considered in order to maximize luminaire efficacy. These focus areas are:

- Optical design
- Driver selection
- Thermal management

Efficacy is the ratio of luminous flux (lumen) to power (watts), and is commonly referred to as lumen per watt (lm/W). Efficiency on the other hand is unit less and expressed as a percentage. For example a luminaire that has a 30lm/W “efficacy” but uses a LED source that is 60lm/W, has a fixture “efficiency” of 50%.

Optical Design

Luminaire optical design is the most important, but also the most difficult aspect of designing a luminaire that targets high efficacy. One of the biggest misconceptions is if an 85% efficient reflector is used then the optical efficiency or Light Output Ratio (LOR) of the luminaire will be 85% (LOR 0.85). While this can be a valid statement, in reality this is not the case for most luminaires. Controlling the light output from a luminaire is usually where the largest system efficacy losses occur. Accessories such as trims, snoots, bezels, diffusers, and glass lenses play a huge role in system level optical efficiencies.

Snoots, Barn Doors, and Trims

“Snoots” and “Barn Doors” can be classified as accessories that clip light coming out of the reflector. A snoot’s design can have a large impact on overall optical efficiencies. Most people think of a snoot as an elongated barrel that is positioned in front of a light source to control light, but a trim that is 2mm thick can act as a snoot as well. Figure 1 shows a typical MR-16 fitting that has been designed with a snoot feature that is 20mm long.



Figure 1- Snoot feature

The length and finish of a snoot, barn door, or trim can determine the amount of light that is lost through absorption in the system. Figure 2 shows the optical efficiencies of a 60 degree reflector as a function of length, when a black snoot is introduced in front of the reflector.

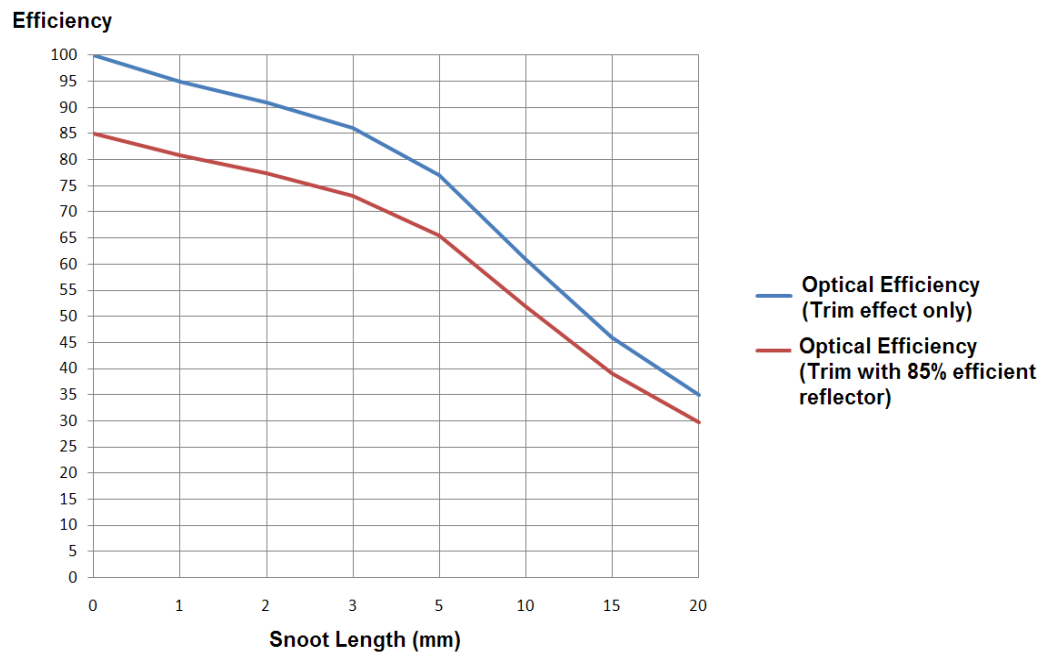


Figure 2- Optical Efficiencies vs. Snoot Length

Design Considerations

When trying to maximize a luminaire's efficacy keep snoot or trim lengths to a minimum. If the aesthetic design calls for a feature of this type, design the snoot or trim to be outside the optical path of the reflector. Another option is to design this feature as an accessory, that can be fitted to the luminaire as needed and not part of the general luminaire (which is used for efficacy testing). Keep in mind that snoots or trim features will have less of a negative impact when using a tighter beam optic since more of the light is concentrated towards the center of the beam.

Snoot Calculation Example

Fixture Assumptions: 85% efficient 60 degree reflector
 Snoot Length: 20mm
 Snoot Finish: Black

Module Assumptions: XSM-1300 operated at 700mA: 1000 lm (68 lm/W)

Optical Calculations: After reflector losses (15%): 850 lm (57.8 lm/W)
 After snoot and reflector losses: 300 lm (20.4 lm/W)

Diffuser and Glass Lenses

Using a diffuser, glass, or plastic lens over a fixture can also have a large and negative impact on the optical efficiencies of the luminaire. The definition of a diffuser is a device that spreads or scatters light in some manner. These devices are used for both functional and aesthetic reasons in luminaire designs. For example, a glass lens can be used to seal an outdoor fixture from the elements. Another example is adding a diffuser to spread or soften light. Optical losses occur when a light ray gets scattered back into the reflector, LED source, or into the diffuser itself. A portion of these light rays ultimately get absorbed and lost.

In most cases light scatters due to the surface texture or profile of the diffuser or lens. Depending on these factors as well as the refractive index of the diffuser, glass, or plastic and the angle of incidence, a light ray will travel through the material or be reflected. Optical losses of 6-50% can occur depending on the type of diffuser or glass used in front of the primary reflector. Expect a loss of roughly 10% when using high quality, optically clear, borosilicate glass such as BK7.

Design Considerations

Avoid using diffusers or glass lenses in fittings. In cases where a diffuser is used to soften a beam, work on softening the beam within the reflector itself. If a glass lens is required to seal a fixture, be sure to select the most efficient and reflective optic (i.e. reflector) available along with a high quality optical glass. If luminaire efficacy levels are still too low you can use an anti-reflective (AR) coated glass lens. This will reduce reflections and improve optical efficiencies when compared to non-AR coated glass.

Primary Reflectors

Using a high quality, efficient primary optic should be considered when designing a luminaire. Table 1 shows typical efficiencies for different reflector manufacturing processes. Table 2 shows tested optical efficiencies (LOR values) for reflectors compatible with Xicato.

Rating	Average	Good	Better	Best
Manufacturing Method	Unfinished stamped, drawn, or hydroformed	Polished or anodized spun, stamped, or drawn	Metalized coated injection molded, spun, drawn or stamped	Folded coated aluminum i.e. Alanod, Almeco
Typical Efficiencies	68-80%	78%-86%	80%-88%	90-97%
Sample				

Table 1 – Common Reflector Type

Manufacture	Manufacture P/N	Xicato Internal P/N	Xicato Accessory P/N	Reflector Efficiency	LOR
Alux Luxar	30208 XLC 900	N/A	N/A	97.3%	0.97
Alux Luxar	30205 XLC 600	N/A	N/A	97.1%	0.97
Alux Luxar	30016 XLC 800	N/A	N/A	96.6%	0.97
Alux Luxar	30013 XLC 500	N/A	N/A	95.8%	0.96
Top Lighting Company	X00211	X00211	XSA-14	90.0%	0.90
Diffraction Optics	P6762 (Non UL) P7022 (UL rated)	X00349	XSA-20	89.8%	0.90
Top Lighting Company	X00210	X00210	XSA-13	89.8%	0.90
Top Lighting Company	X00212	X00212	XSA-15	89.5%	0.90
Diffraction Optics	P6643 (Non UL) P6953 (UL rated)	X00195	XSA-10	89.4%	0.89
Diffraction Optics	P8279 (Non UL)	X00428	XSA-23	89.1%	0.89
Alux Luxar	30015 XLC 700	N/A	N/A	88.8%	0.89
Diffraction Optics	P6680 (Non UL) P6955 (UL rated)	X00196	XSA-11	88.7%	0.89
Diffraction Optics	P8277 (Non UL) P8235 (UL rated)	X00430	XSA-22	87.1%	0.87
Jordan	1.12991.501.101 Order No 2841	N/A	N/A	85.8%	0.86

Table 2-Reflector Efficiency Matrix

Manufacture	Manufacture P/N	Xicato Internal P/N	Xicato Accessory P/N	Reflector Efficiency	LOR
Jordan	1.13140.S01.000 Order No 2854	N/A	N/A	85.8%	0.86
Alux Luxar	30012 XLC 400	N/A	N/A	85.6%	0.86
Diffractive Optics	P6645 (Non UL) P6957 (UL rated)	X00197	XSA-12	85.2%	0.85
Diffractive Optics	P6764 (Non UL) P7024 (UL rated)	X00481	XSA-21	84.6%	0.85
ACL Reflektoren	5851-0-00-01 5851-A-01-01	N/A	N/A	83.7%	0.84
Jordan	1.13239.S01.101 Order No. 2845	N/A	N/A	83.1%	0.83
Jordan	1.13238.S01.101 Order No 2843	N/A	N/A	83.1%	0.83
ACL Reflektoren	5850-0-00-01 5850-A-01-01	N/A	N/A	82.2%	0.82
ACL Reflektoren	5849-0-00-01 5849-A-01-01	N/A	N/A	80.9%	0.81
ACL Reflektoren	5852-0-00-01 5852-A-01-01	N/A	N/A	78.0%	0.78
Diffractive Optics	P7076 (Non UL) P7613 (UL rated)	X00175	XSA-17	72.8%	0.73

Table 2 – Reflector Efficiency Matrix cont.

Driver Selection

Xicato modules operate via a constant current DC supply which is usually in the form of a “driver”. The function of a driver is to convert voltage regulated electrical power into a constant current regulated DC source. For example, converting mains line voltage (e.g. 220VAC) to a 700mA constant current source with an output voltage range of 10-32VDC. The process of doing this is inherently inefficient and requires additional power beyond what is required for the LED. Driver efficiencies range dramatically from 55-95%. There are a number of parameters that affect driver efficiencies (e.g. input voltage/current, output voltage/current, source type, power factor, etc). Most “mains line” AC drivers fall within a 70-88% efficiency range.

The following example shows a detailed breakdown of system efficacies. In both cases the module, optic and trim stay constant but the driver is changed.

Light Source	XSM-1300 1000lm, 68 lm/W (assume 700mA driver current) 14.7 Watts	
Reflector	Coated Spun Reflector 88% Efficient 880 lm, 59lm/W (performance w/ just reflector)	
Trim	Matte Silver Trim 5% Optical reduction 836 lm, 57lm/W (performance w/ reflector and trim)	
Driver	Driver "1" 85% Efficient 17.3 Watts 836 lm, 48.3 lm/W (performance w/ reflector, trim and driver 1)	Driver "2" 79% Efficient 18.6 Watts 836 lm, 44.9 lm/W (performance w/ reflector, trim and driver 2)

Table 3– Driver and System Efficacies Example

Design Considerations: Driver Selection

Xicato provides a driver compatibility matrix that states tested driver efficiencies when paired with a specific Xicato module. These efficiencies are denoted as a percentage in the compatibility box. If a percentage number is not stated, Xicato has not physically tested the driver's efficiency.

When choosing a driver, if possible select one that has the highest stated efficiency. If a particular driver is not listed on the driver compatibility matrix or does not have a stated efficiency number make sure to test the driver's efficiency in house or send a sample to Xicato for testing. In most cases, driver data sheets specify efficiency at "full load", meaning a 36W driver is paired with a 36W Xicato module. In reality most drivers have a large enough voltage range that the same 36W driver will also operate a lower power module (e.g. a 22W XSM). Efficiencies can change depending on the driver's electrical architecture when the driver is not at full load (in most cases efficiency drops). For example a 36W driver that has a stated efficiency of 88% at full load could be 82% efficient when paired with a 22W device.

Thermal Considerations

In general LEDs become more efficient as their junction temperature (T_j) is reduced; thus thermal design is another area that can be optimized in order to increase a luminaires' efficacy. Since a LED junction temperature (T_j) is directly related to its case temperature (T_c), it is important to design a luminaire and heatsink solution that keeps the XSM T_c below the max specification of 90C. Designing a luminaire that has a lower T_c point, for example 65C, will not only improve its lifetime but also slightly improve the modules efficiency. The performance curve below (Figure 3), shows the module efficacy vs. temperature (T_c) of a typical 1300lm XSM. Although the data for Figure 3 is shown for the 1300lm module, the percent reduction in lm/W over temperature is typical for all Xicato modules. Efficacy improvements that result from thermal optimization will be smaller on average than improvements from optical or driver optimization.

See the "Application Note - Heatsink Design" for more information regarding thermal management in luminaire design.

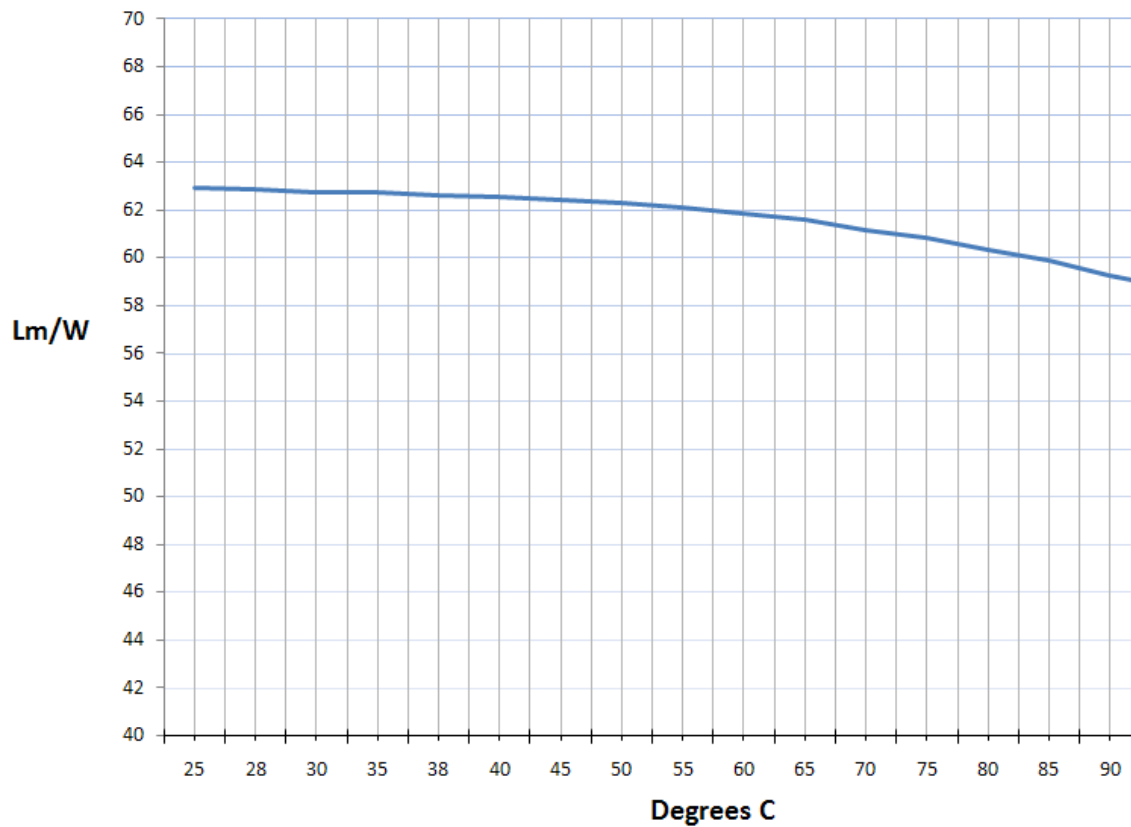


Figure 3
Efficacy vs. Temperature
1300lm XSM

Energy Codes and Standards

The following section will outline how to meet the current 2011 energy codes using Xicato technology. Since optical losses such as snoots, trims, lens, etc vary to such a large extent, these losses are not included in the following Tables. If large optical losses are expected from the luminaire design the easiest way to increase system efficacy is to reduce the drive current to the Xicato module.

Standard	Luminaire Efficacy
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Energy Star (Downlights)	42 lm/W
Energy Star (Directional Heads Surface Mount)	35 lm/W
Title 24 5-15 Watt system power	40 lm/W
Title 24 15-40 Watt system power	50 lm/W
Park L (UK)	55 lm/W

Table 4: 2011 Energy Codes and Standards

Standard	Xicato Module	Reflector *	Driver**	Heatsink	Total Efficacy lm/W
Energy Star (Downlights) ≥42 lm/W	XSM-1000 (700mA)	≥90%	Harvard CL700S-UNI-B ≥86%	XSA-03	42.6
	XSM-1300 (1000mA)	≥85%	Magtech LF1028E-136 ≥85%	XSA-03	44
	XSM-2000 (1000mA)	≥91%	Magtech LF1048-48- C1000 ≥85%	XSA-27 or XSA-28	42.5
Energy Star (Directional Heads Surface Mount)	XSM-1000 (700mA)	≥75%	Harvard CL700S-UNI-B ≥86%	XSA-03	35.4
	XSM-1300 (1000mA)	≥70%	Magtech LF1028E-136 ≥85%	XSA-03	36.3
	XSM-2000 (1000mA)	≥77%	Magtech LF1048-48- C1000 ≥85%	XSA-27 or XSA-28	36

Table-5

Energy Star Luminaire Design Guide

* Refer to *Reflector Efficiency Matrix* for specific part numbers

** Refer to Driver Matrix for other driver options

Standard	Xicato Module	Reflector *	Driver**	Heatsink	Total Efficacy lm/W
Title 24 5-15 Watt	XSM-700 (700mA)	≥85%	Harvard CL700S-UNI-B ≥84%	XSA-03 or XSA-27	40.6
	XSM-1000 (500mA)	≥77%	Magtech LP1025-36- C0500 ≥83%	XSA-03 or XSA-27	40.9
	XSM-1300 (500mA)	≥75%	500mA Driver ≥85%	XSA-03 or XSA-27	44.6
Title 24 15-40 Watt	XSM-2000 (500mA)	≥95%	500mA Driver ≥85%	XSA-27 or XSA-28	50.8

Table-6
Title 24 Luminaire Design Guide

Standard	Xicato Module	Reflector *	Driver**	Heatsink	Total Efficacy lm/W
Park L (UK)	XSM-1300 (500mA)	≥94%	500mA Driver ≥85%	XSA-27 or XSA-28 or XSA-31	55.9
	XSM-1300 (350mA)	≥87%	Harvard CL700S-UNI-B ≥83%	XSA-27 or XSA-28 or XSA-31	56.3

Table-7
Part L (United Kingdom)

* Refer to *Reflector Efficiency Matrix* for specific part numbers

** Refer to Driver Matrix for other driver options

Conclusion

Optical design, driver selection and thermal performance are all key areas that need to be considered when designing a luminaire to maximize system efficacy. New legislation and energy codes are beginning to impact what lighting fixtures end users and lighting designers can and cannot use. Therefore, meeting or exceeding these codes is an important part of a lighting company's portfolio. XSM or XLM selection, optical design, and driver selection are the most important aspects when designing to a particular

performance goal, but in the end a luminaire is a lighting system and everything in that system should to be optimized.

For additional questions, contact your Xicato technical support representative, or email support@xicato.com