IEEE Meeting – Central Tennessee Section

LED Lighting Overview

Bobby Brooks

11-8-2018

STREETWORKS

McGRAW-EDISON

LUMARK

INVUE

EATON
Powering Business Worldwide

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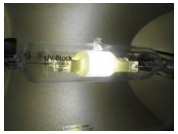
A History of Light Sources

- ~400,000 BCE - Fire is discovered.
- ~3000 BCE - Oil lamps are open bowls with a spout to hold the wick.
- ~400 - The candle is invented.
- 1809 - Sir Humphrey Davey demonstrates electrical discharge lighting to the Royal Institution in London, using an open-air arc between two carbon rods. The result is a very intense, and very pure white light. Unfortunately, as the arc runs, carbon boils off and the rods wear away: constant attention must be paid to readjusting the arc, feeding more carbon in.
- 1841 - Frederick DeMoleyns patented incandescent lamp using filaments of platinum and carbon, protected by a vacuum.
- 1880 - Thomas Edison receives U.S. patent #223,898 for the carbon filament incandescent lamp.
- 1932 - Low pressure sodium lamps are first used commercially.
- 1934 - The high-pressure mercury lamp is introduced.
- 1938 - First commercial sale of the fluorescent lamp
- 1957 - The quartz halogen lamp (A.K.A. tungsten halogen lamp) is invented. In conventional tungsten lamps, the filament metal slowly evaporates and condenses on the glass envelope, leaving a black stain. In this case, the halogen removes the deposited tungsten and puts it back on the filament.
- 1962 - First light emitting diode (LED)
- 1966 - Commercial introduction of the high pressure sodium lamp
- 1969 - A new form of metal halide lamp, the HMI lamp (mercury medium arc iodides) is introduced. The H stands for mercury (atomic symbol "Hg"), M is for Metals and the I is for halogen components (iodide, bromide). It provides a daylight type spectrum.



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LED vs Traditional Light Sources

Strengths

- No filaments like incandescent lamps.
- No electrodes like gas discharge lamps (HPS, Metal Halide, and Fluorescent).
- No Mercury in the Light Source
- Instant On, Full Color, 100% Light, dimming options
- Promise of Long Life – Reduced Maintenance Costs

Weakness

- Higher initial cost compared to traditional light sources.
- Electronic LED driver life can be drastically reduced if exposed to high heat levels.
- Electronic LED drivers provide only a fraction of the surge protection that is offered by HID core and coil ballasts.

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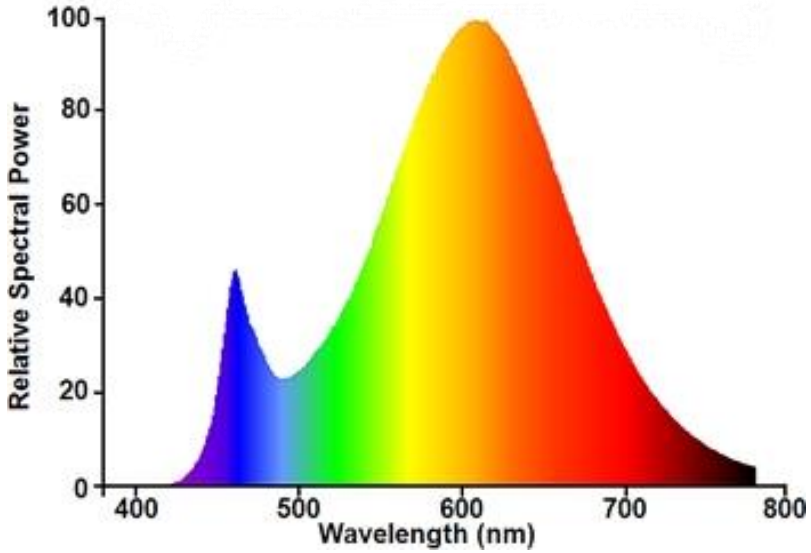
What is an LED?

Light-Emitting

White light is generated through a *phosphor* conversion process of the blue wavelength emitted from the *die*



Color spectrum for LEDs contains a **peak in the blue wavelength** and causes objects to look more blue than other sources

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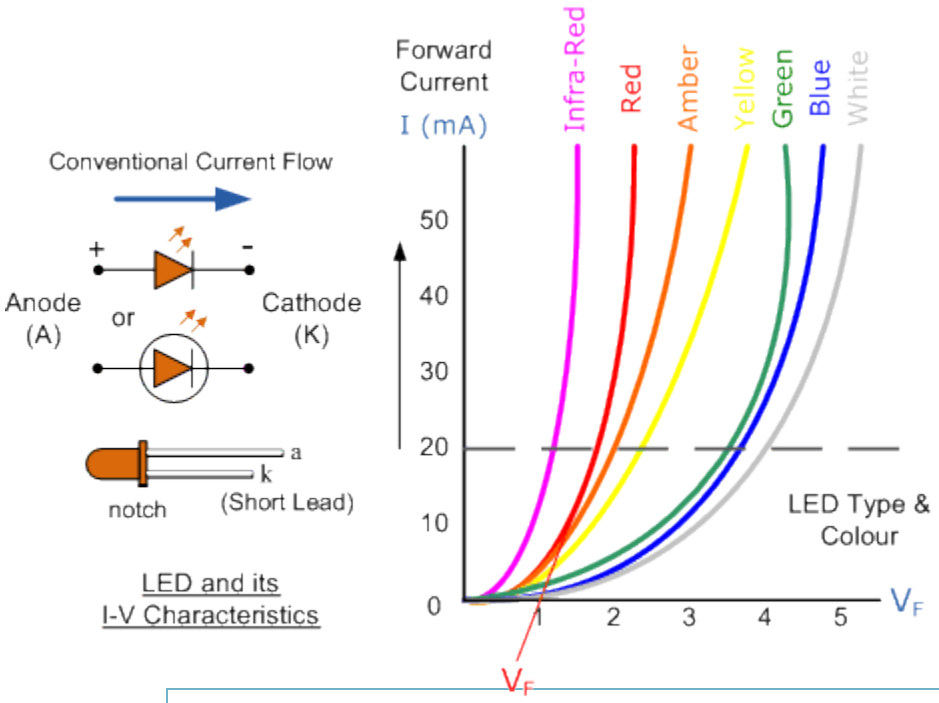
What is an LED?

LEDs are semiconductor components which exhibit an exponential I-V characteristic, DC current/voltage



Characteristics:

Polarized (Anode +)(Cathode -)

Typical Voltage ~ 3V

DC current-driven

(more current = more light, little change in Vf)

Power = Heat + Light

ESD & Dust Sensitive devices

Careful attention to polarity and current applied

Reverse polarity or too much current can permanently damage an LED

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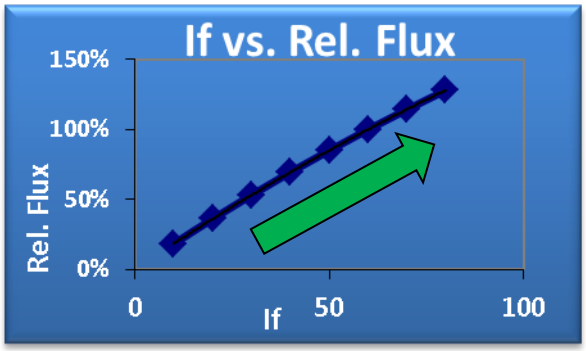
LED Characteristics

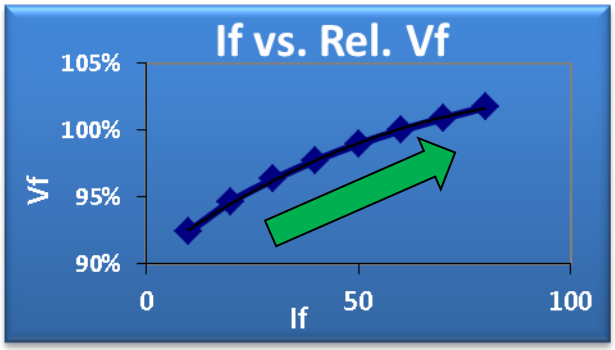
LEDs are primarily impacted by *drive current* and *temperature*.

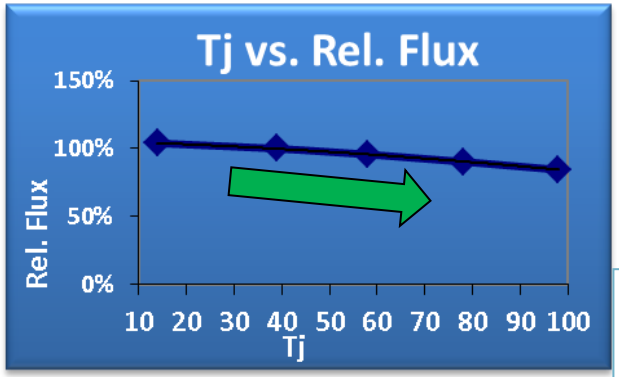


As current changes

- ***Voltage changes little***
- ***Light output changes significantly***

LEDs are more efficient at lower current

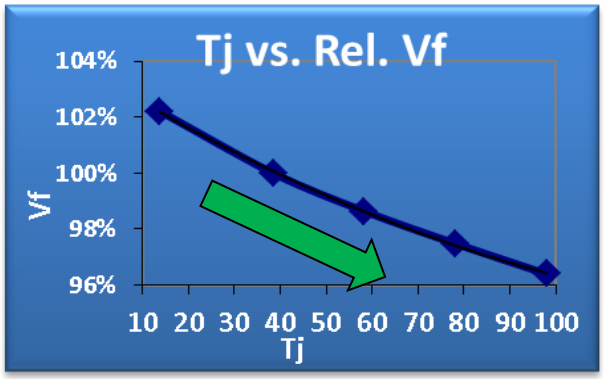




As temp changes

- ***Voltage changes little***
- ***Light output changes little***

LEDs are more efficient at lower temperatures



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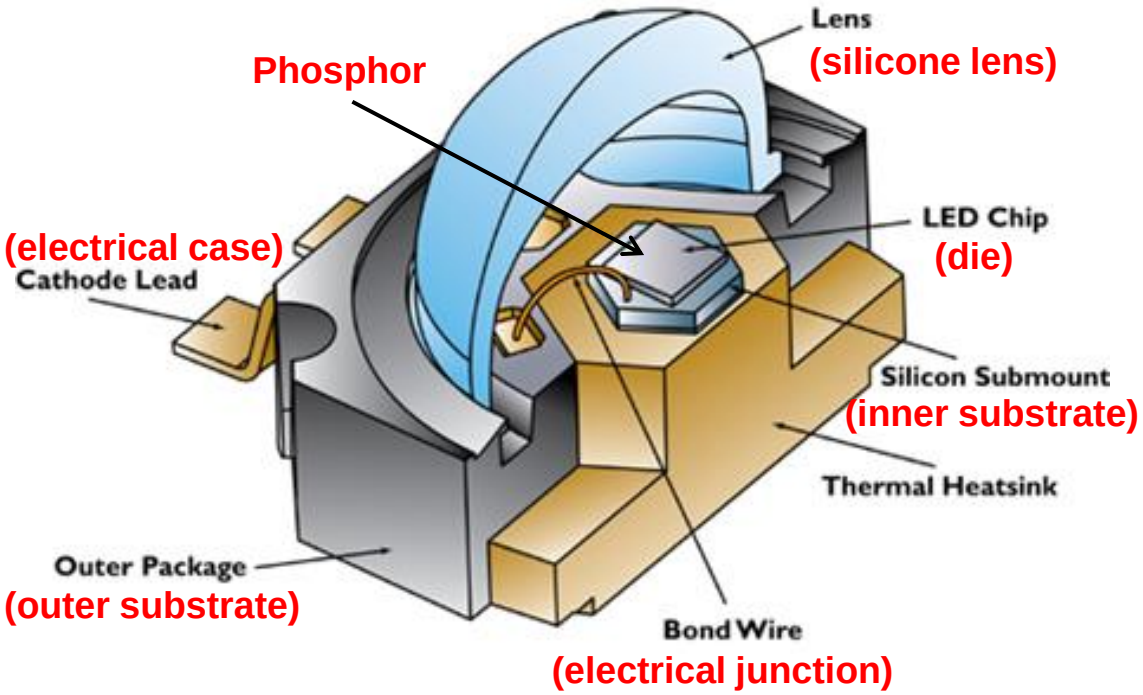
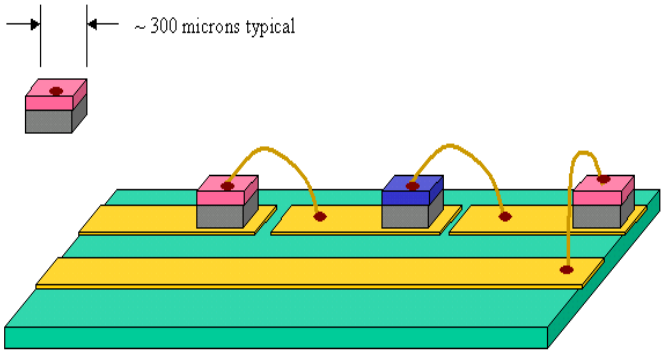
LED Package

A white LED package consists of die/dice, phosphor, electrical connections, substrate, and lens



An LED package may contain one or more LED die to increase amount of light in a smaller area.



Example: Chip on Board (COB) – Wire bonding

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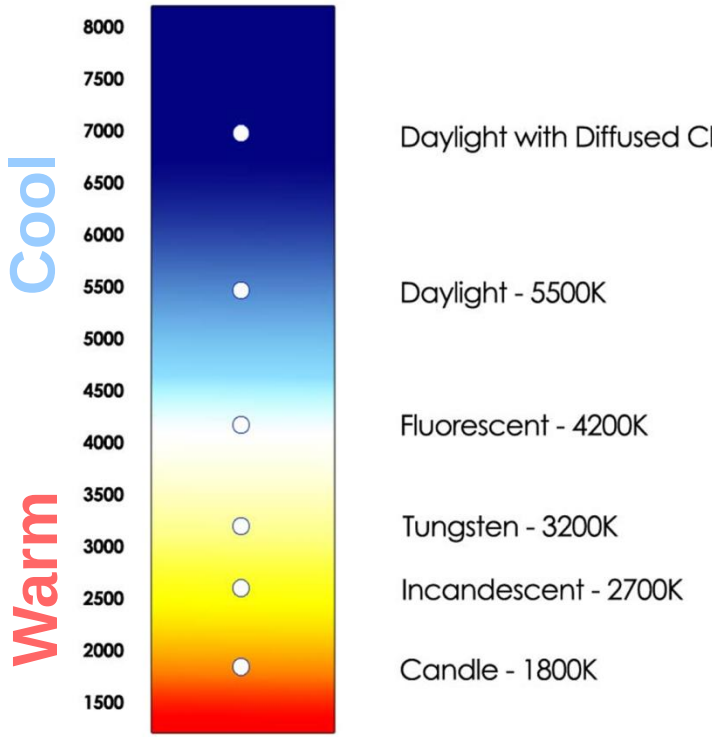
Color and Binning

An LED can be made into different *color temperatures (CCT)* and *color rendering indices (CRI)* by using a different mix of *phosphors*.



Common CCTs:
2700K, 3000K, 3500K, 4000K, 5000K

Differences in CCT can be challenging to visually distinguish

Common CRI:
70, 80, 90

Extremely difficult to determine CRI
Higher CRI = larger color gamut
Incandescent Lamp = 100 CRI (Ref)

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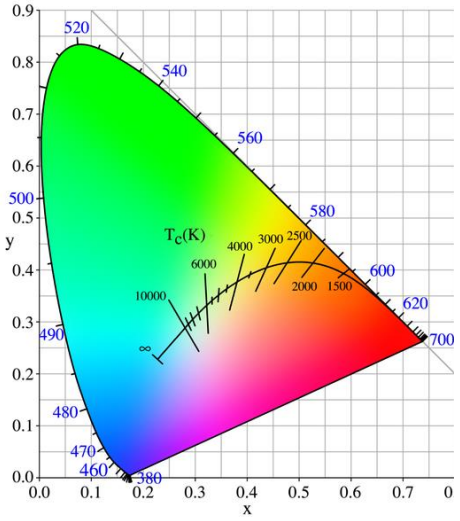
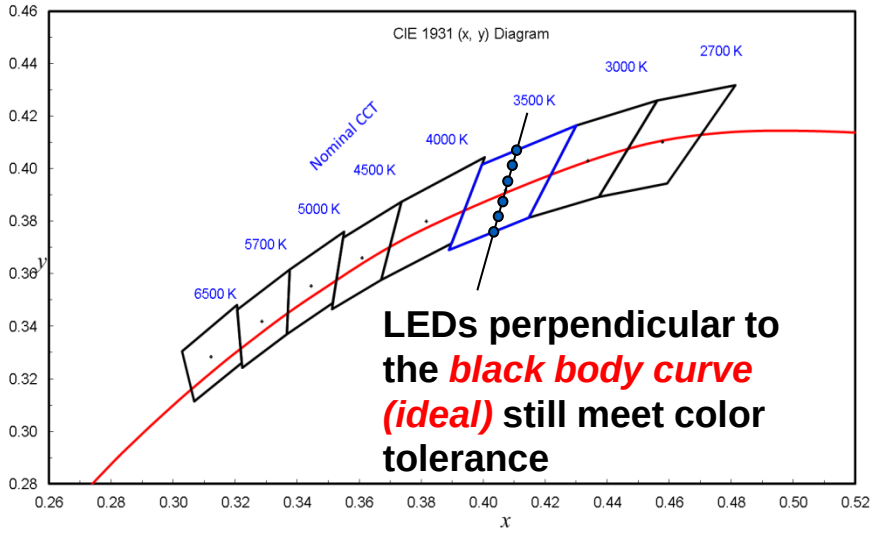
Color and Binning

The human eye is sensitive to color contrasts. This is why the color tolerance is critical to LED applications. Even though an LED may measure 3500K, it can look different depending on the *x-y chromaticity coordinate*.





Always pay attention to brightness and color of LEDs

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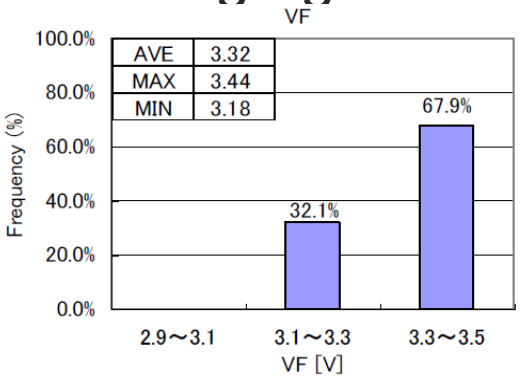
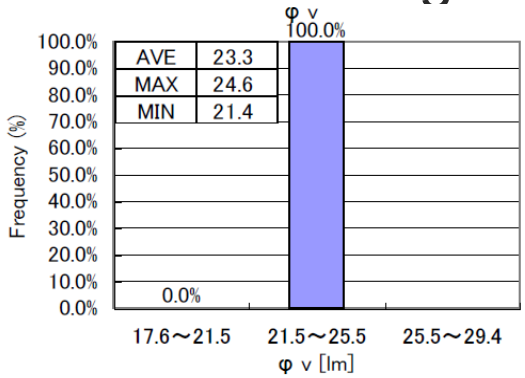
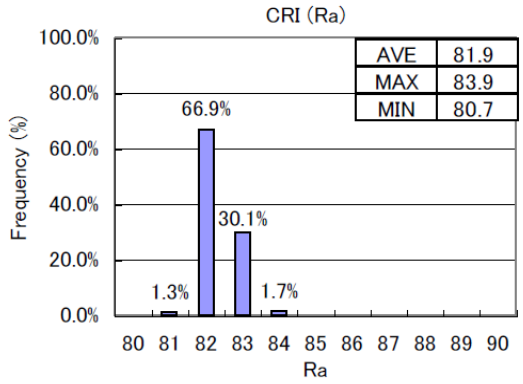
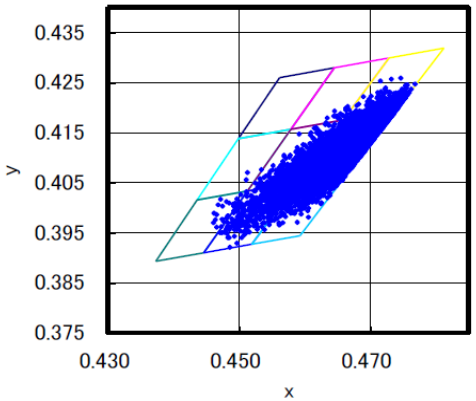
Color and Binning

Binning is a sorting process for LED manufacturers to utilize all parts made in production. Shipments are arranged by CCT, Vf, and lumens. If more than one LED is used in a fixture, it becomes challenging to maintain consistent light output and color.



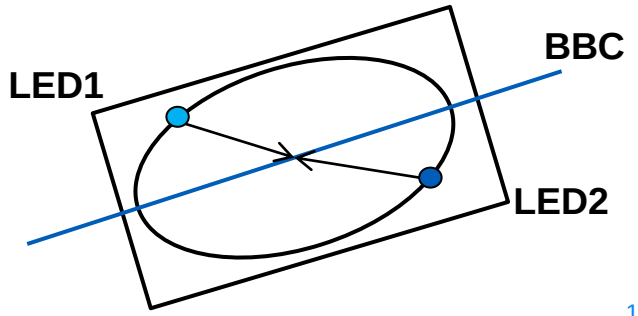






Recipe Binning (Color):

A technique to fully utilize LED yield by arranging parts of opposing color coordinates to create an **average** which falls on the ***black body curve***.



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LED Boards and Modules

An LED module consists of one or more LEDs electrically connected and mounted on a heatsink (which can be the fixture). Sometimes a PCB (Printed Circuit Board) is used.

Ensure good attachment of LEDs to heatsink/fixture for performance and lifetime.

Circuit Boards:

PCBs are used with discrete LED packages to arrange the components electrically. FR-4 (glass-epoxy) and Metal Core (aluminum with dielectric) are common materials used.

Color Coding:

Typically the LED positive(+) is a **RED** wire
And the negative(-) is a **BLACK**/**BLUE** wire

LEDs can be easily damaged during the mounting process

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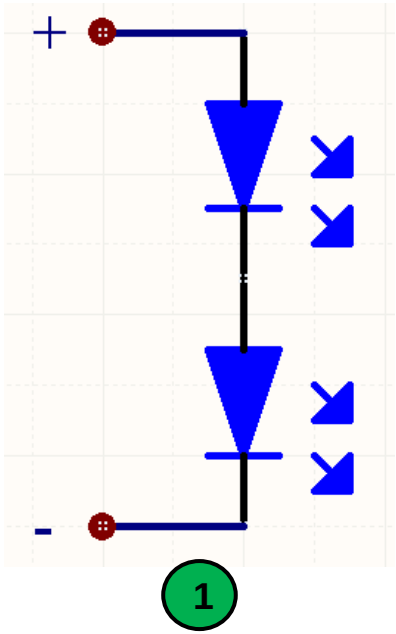
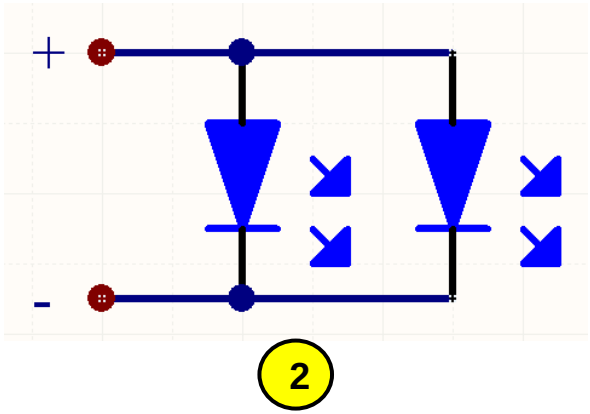
Light Engine

LEDs can be arranged in many ways to achieve design voltage and current configurations. They can be wired in series, parallel, or a combination of series/parallel.

Series

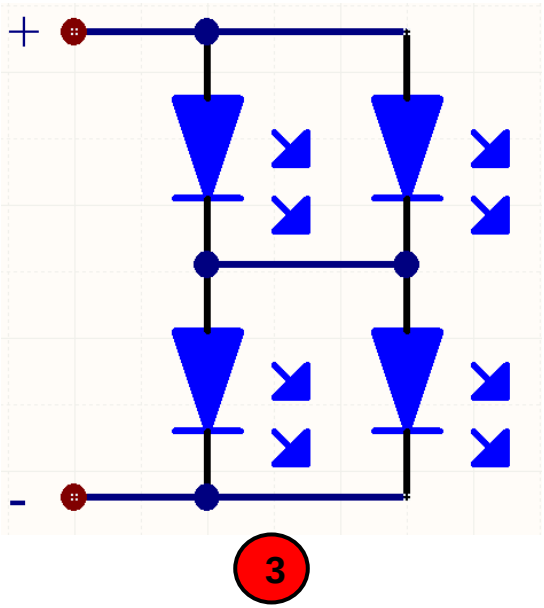


Parallel



Levels of complexity

Combination



There are advantages and disadvantages of each configuration

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Types of LEDs

High Power Discrete

Advantages:
Design flexibility
Large supply base

Disadvantages:
Pixilation
Cost

Chip on Board (COB)

Advantages:
Easy to use optically
High lumen density
Cost
Flexibility

Disadvantages:
Lower LM-80

Mid Power Discrete

Advantages:
Design flexibility
Largest supply base
Lowest Cost

Disadvantages:
Optically complex

Chip Scale Package (CSP)

Advantages:
Design flexibility
Cost improving
Easy array (color tuning)

Disadvantages:
Five sided emitter
Cross talk

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Life Rating of Light Source

Note regarding life ratings:

- **Life for HID is calculated when 50% of lamps are burned out.**
- **Life for LED is calculated via IESNA TM-21, limits life claim to 6 x the number of hours tested. Typical is 60,000hours. Life is then given as the lumen depreciation estimated at that life number.**

For example, $L_{90}60$ is 90% lumen depreciation at 60,000 hours.

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IESNA LM-80 Test Report on the Philips Lumileds Luxeon TX LED

Luminous flux depreciation information

Normalized Flux Statistics for If = 1000mA (L1T2-4070000000000)

		0hrs	24hrs	168hrs	500hrs	1000hrs	2000hrs	3000hrs	4000hrs	5000hrs	6000hrs	7000hrs	8000hrs	9000hrs	10000hrs	alpha	B	L70
DATASET 59	median =	1.0000	0.9956	1.0010	1.0154	1.0268	1.0369	1.0405	1.0387	1.0293	1.0211	1.0139	1.0161	1.0219	1.0156			
Ts=Tair=105°C	average =	1.0000	0.9955	1.0008	1.0158	1.0268	1.0365	1.0368	1.0361	1.0302	1.0179	1.0111	1.0168	1.0214	1.0166	1.4576e-06	1.0302	265,099
	st dev =	0.0000	0.0028	0.0038	0.0060	0.0056	0.0079	0.0098	0.0123	0.0154	0.0179	0.0154	0.0154	0.0147	0.0148	TM-21 L70(10k) > 60,000hrs		
	min =	1.0000	0.9909	0.9922	1.0069	1.0172	1.0199	1.0162	1.0073	1.0032	0.9733	0.9747	0.9842	0.9902	0.9808			
	max =	1.0000	1.0025	1.0106	1.0335	1.0419	1.0505	1.0521	1.0544	1.0560	1.0454	1.0355	1.0441	1.0455	1.0365			
DATASET 60	median =	1.0000	0.9935	0.9909	1.0138	1.0153	1.0147	1.0157	1.0107	1.0119	1.0093	1.0057	1.0105	1.0087	1.0072			
Ts=Tair=85°C	average =	1.0000	0.9927	0.9894	1.0136	1.0144	1.0138	1.0145	1.0104	1.0112	1.0095	1.0055	1.0096	1.0081	1.0063	6.9519e-07	1.0136	532,523
	st dev =	0.0000	0.0032	0.0055	0.0064	0.0054	0.0065	0.0058	0.0067	0.0067	0.0081	0.0088	0.0099	0.0094	0.0106	TM-21 L70(10k) > 60,000hrs		
	min =	1.0000	0.9815	0.9697	0.9946	0.9968	0.9933	0.9966	0.9903	0.9933	0.9889	0.9855	0.9858	0.9864	0.9828			
	max =	1.0000	0.9973	0.9971	1.0296	1.0205	1.0210	1.0213	1.0211	1.0252	1.0272	1.0251	1.0302	1.0292	1.0272			
DATASET 61	median =	1.0000	0.9951	0.9924	1.0121	1.0137	1.0117	1.0112	1.0102	1.0063	1.0056	1.0015	1.0026	1.0029	1.0016			
Ts=Tair=55°C	average =	1.0000	0.9947	0.9909	1.0118	1.0109	1.0103	1.0103	1.0087	1.0036	1.0035	0.9985	1.0007	0.9998	0.9994	8.5027e-07	1.0073	428,057
	st dev =	0.0000	0.0029	0.0066	0.0093	0.0089	0.0107	0.0115	0.0114	0.0108	0.0121	0.0124	0.0127	0.0125	0.0135	TM-21 L70(10k) > 60,000hrs		
	min =	1.0000	0.9853	0.9693	0.9893	0.9860	0.9838	0.9822	0.9810	0.9771	0.9758	0.9700	0.9719	0.9709	0.9692			
	max =	1.0000	0.9982	0.9967	1.0318	1.0219	1.0281	1.0251	1.0222	1.0155	1.0183	1.0136	1.0164	1.0146	1.0157			

After 10,000 hours of testing the Luxeon Tx LED has actually increased at the 85°C and 105°C temperatures with only a .0006 decrease at 55°C

The unparalleled lumen maintenance of the Luxeon TX leads to superior maintained light levels even after 85,000 hours of operation.

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IESNA LM-80 Test Report on the Philips Lumileds Luxeon TX LED

Color or kelvin temperature shift information

Delta u'v' for If = 1000mA (L1T2-4070000000000)

		0hrs	24hrs	168hrs	500hrs	1000hrs	2000hrs	3000hrs	4000hrs	5000hrs	6000hrs	7000hrs	8000hrs	9000hrs	10000hrs
DATASET 59	median =	0.0000	0.0002	0.0002	0.0004	0.0003	0.0006	0.0007	0.0009	0.0011	0.0009	0.0024	0.0031	0.0031	0.0029
Ts=Tair=105°C	average =	0.0000	0.0002	0.0002	0.0004	0.0004	0.0007	0.0008	0.0010	0.0011	0.0009	0.0025	0.0031	0.0031	0.0029
	st dev =	0.0000	0.0001	0.0001	0.0002	0.0002	0.0004	0.0004	0.0004	0.0004	0.0004	0.0005	0.0004	0.0004	0.0004
	min =	0.0000	0.0001	0.0000	0.0001	0.0001	0.0001	0.0002	0.0004	0.0004	0.0001	0.0016	0.0023	0.0022	0.0020
	max =	0.0000	0.0004	0.0005	0.0008	0.0008	0.0017	0.0018	0.0018	0.0018	0.0019	0.0035	0.0043	0.0041	0.0040
DATASET 60	median =	0.0000	0.0004	0.0003	0.0004	0.0004	0.0005	0.0005	0.0005	0.0005	0.0006	0.0006	0.0005	0.0005	0.0003
Ts=Tair=85°C	average =	0.0000	0.0004	0.0003	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004
	st dev =	0.0000	0.0001	0.0001	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003	0.0002	0.0003
	min =	0.0000	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000
	max =	0.0000	0.0005	0.0005	0.0010	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0009	0.0008	0.0008	0.0008
DATASET 61	median =	0.0000	0.0003	0.0005	0.0007	0.0010	0.0010	0.0009	0.0007	0.0008	0.0009	0.0011	0.0010	0.0009	0.0010
Ts=Tair=55°C	average =	0.0000	0.0003	0.0005	0.0007	0.0009	0.0009	0.0008	0.0006	0.0007	0.0008	0.0009	0.0008	0.0007	0.0008
	st dev =	0.0000	0.0001	0.0001	0.0002	0.0003	0.0004	0.0004	0.0003	0.0003	0.0004	0.0004	0.0004	0.0003	0.0004
	min =	0.0000	0.0002	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001	0.0000	0.0001	0.0001
	max =	0.0000	0.0004	0.0007	0.0010	0.0013	0.0013	0.0013	0.0010	0.0011	0.0012	0.0013	0.0012	0.0011	0.0012

In-situ case operating temperature of 86°C the NVN LED at 25C ambient at 86°C shows minimal color shift over the 10,000 hour test period.

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TM-21-11

- LM-80 -- only an LED testing standard
- IES TM-21-11 -- mathematical framework for LM-80 data and making useful LED lifetime projections

Key points of TM-21:

- Developed by major LED suppliers with support of NIST, PNNL
- Projection limited to 6x the available LM-80 data set
- Projection algorithm: least squares fit to the data set
- L_{70}, L_{80}, L_{90}, L_{xx} projections easily possible
- Nomenclature: L_p(Yk)where p is Lumen Maintenance percentage and Y is length of LM-80 data set in thousands of hours ie: L_{85}(10k)

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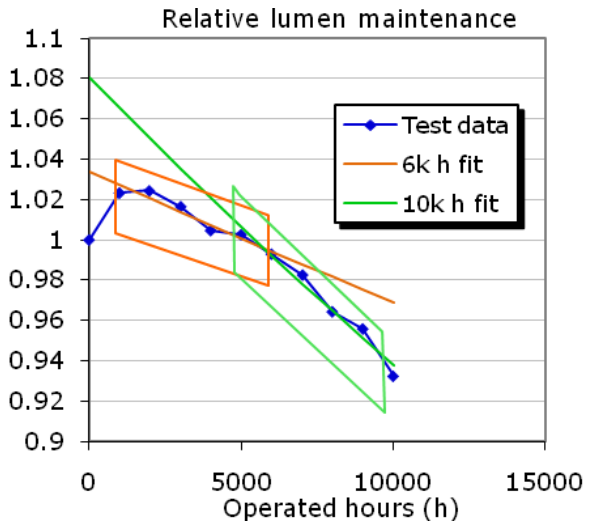
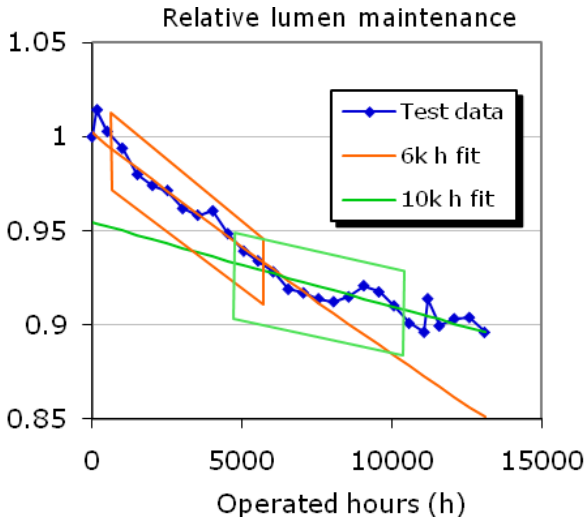
TM-21 – Use the latest data

- **Initial data variability (i.e. "hump") is difficult for models to evaluate (0-1000 hr)**
- **Later data exhibits more characteristic decay curve of interest**
  - **Non-chip decay (encapsulant, etc.) occurs early and with varying effects on decay curve**
  - **Later decay is chip-driven and relatively consistent with exponential curve**
  - **Verification with long duration data sets (>10,000 hr) shows better model to reality fit with last 5,000 hours of 10,000 hour data**
- **For 6,000 hours of data (LM-80 minimum) and up to 10,000 hours: Use last 5,000 hours**
- **For > 10,000 hours: Use the last ½ of the collected data**





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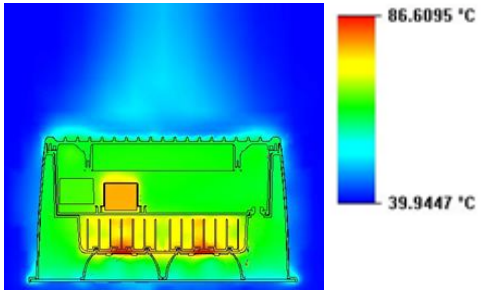
Thermal report to confirm driver TC and COB operating temperature at 40°C ambient

#	Location	Meas.	Norm	Lim.
1	DRIVER Tc	64.74	**65**	80
4	LED 1 CATHODE	72.75	**73**	105
5	LED 2 CATHODE	68.94	**69**	105
40	Ambient	**38.98**	**40**	40



Electrical Data	Volts	Amps	Watts
Initial	119.60	1.10	130.50
Final	119.70	1.05	125.90

Test Time	Start	Stop	Duration
Date	2017-03-17	2017-03-17	
Time	3:22:20 PM	10:52:23 PM	7.50

Test Station: 08 Test duration (Hours:Minutes) 7:30 Voltage type AC

The above thermal report was performed at 120V in a 40C (104F) ambient environment for 7 hours and 30 minutes. The hottest running COB will be used in the TM-21 calculator.

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Excellent lumen maintenance at both 25C and 40C (93% at 60,000 hours at 40C)

TM-21 Inputs

Instructions
Yellow fields are completed by the user. Fields not used should be left blank. Cyan fields are calculated based on user entries. First, enter a description of the LED light source tested. Then complete the fields labeled "LM-80 Testing Details". Test duration must be at least 6,000 hours. If only one case temperature data set is to be used (no interpolation), complete only "Tested case temperature 1". For only two case temperature data sets, complete 1 and 2. Next, further to the right, in the corresponding box(es) for each tested case temperature, enter the test data along with the time (in hours) at which each measurement was taken. Data entered must be normalized then averaged measured data (per TM-21 sections 5.2.1 and 5.2.2). Enter drive current, *in-situ* temperature data and the percentage of initial lumens to project to in the fields labeled "*In-Situ* Inputs". Results can be tailored to estimate lumen maintenance at a specific time by entering a value (t) in the yellow field. A complete TM-21 report will appear on the next tab labeled "Report".

LM-80 Test Inputs

Description of LED Light Source Tested (manufacturer, model, catalog number)
Two Citizen CLL042-1818 in Verdeon (grey heat sink/reflector), 40C ambient environment

LM-80 Testing Details	
Total number of units tested per case temperature:	20
Number of failures:	0
Number of units measured:	20
Test duration (hours):	7000
Tested drive current (mA):	2160
Tested case temperature 1 (T_c, °C):	55
Tested case temperature 2 (T_c, °C):	85
Tested case temperature 3 (T_c, °C):	105

Test Data for 55°C Case Temperature		Test Data for 85°C Case Temperature		Test Data for 105°C Case Temperature	
Time (hours)	Lumen Maintenance (%)	Time (hours)	Lumen Maintenance (%)	Time (hours)	Lumen Maintenance (%)
0	100.00%	0	100.00%	0	100.00%
1000	99.80%	1000	99.20%	1000	97.70%
2000	99.00%	2000	98.20%	2000	97.20%
3000	98.80%	3000	97.90%	3000	97.30%
4000	98.30%	4000	97.90%	4000	97.20%
5000	98.50%	5000	98.10%	5000	96.60%
6000	98.20%	6000	97.90%	6000	95.80%
7000	98.00%	7000	97.50%	7000	95.10%

In-Situ Inputs

Drive current for each LED package/array/module (mA):	1150
In-situ case temperature (T_c, °C):	84
Percentage of initial lumens to project to (e.g. for L_{70}, enter 70):	70

Results

Time (t) at which to estimate lumen maintenance (hours):	60,000
Lumen maintenance at time (t) (%):	93.16%
Calculated L70 (hours):	350,000
Reported L70 (hours):	>42000

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Energy Star TM-21 Report

TM-21 Report

Table 1: Report at each LM-80 Test Condition						Table 2: Interpolation Report (projection based on in-situ temperature entered)	
Description of LED Light Source Tested (manufacturer, model, catalog number)	LumiLeds Rebel ES					$T_{s,1}$ (ºC)	55.00
						$T_{s,1}$ (K)	328.15
Test Condition 1 - 55ºC Case Temp		Test Condition 2 - 85ºC Case Temp		Test Condition 3 - 105ºC Case Temp		α_1	8.528E-07
Sample size	25	Sample size	25	Sample size	25	B_1	1.007
Number of failures	0	Number of failures	0	Number of failures	0	$T_{s,2}$ (ºC)	85.00
DUT drive current used in the test (mA)	1000	DUT drive current used in the test (mA)	1000	DUT drive current used in the test (mA)	1000	$T_{s,2}$ (K)	358.15
Test duration (hours)	10,000	Test duration (hours)	10,000	Test duration (hours)	10,000	α_2	6.966E-07
Test duration used for projection (hour to hour)	5,000 - 10,000	Test duration used for projection (hour to hour)	5,000 - 10,000	Test duration used for projection (hour to hour)	5,000 - 10,000	B_2	1.014
Tested case temperature (ºC)	55	Tested case temperature (ºC)	85	Tested case temperature (ºC)	105	E_a/k_b	-7.93E+02
α	8.528E-07	α	6.966E-07	α	1.444E-06	A	7.617E-08
B	1.007	B	1.014	B	1.030	B_0	1.010
Calculated L70(10k) (hours)	427,000	Calculated L70(10k) (hours)	531,000	Calculated L70(10k) (hours)	268,000	$T_{s,i}$ (ºC)	74.00
Reported L70(10k) (hours)	>60000	Reported L70(10k) (hours)	>60000	Reported L70(10k) (hours)	>60000	$T_{s,i}$ (K)	347.15
						α_i	7.472E-07
						Projected L70(10k) at 74ºC (hours)	491,000
						Reported L70(10k) at 74ºC (hours)	>60000

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Superior thermal management results in long life

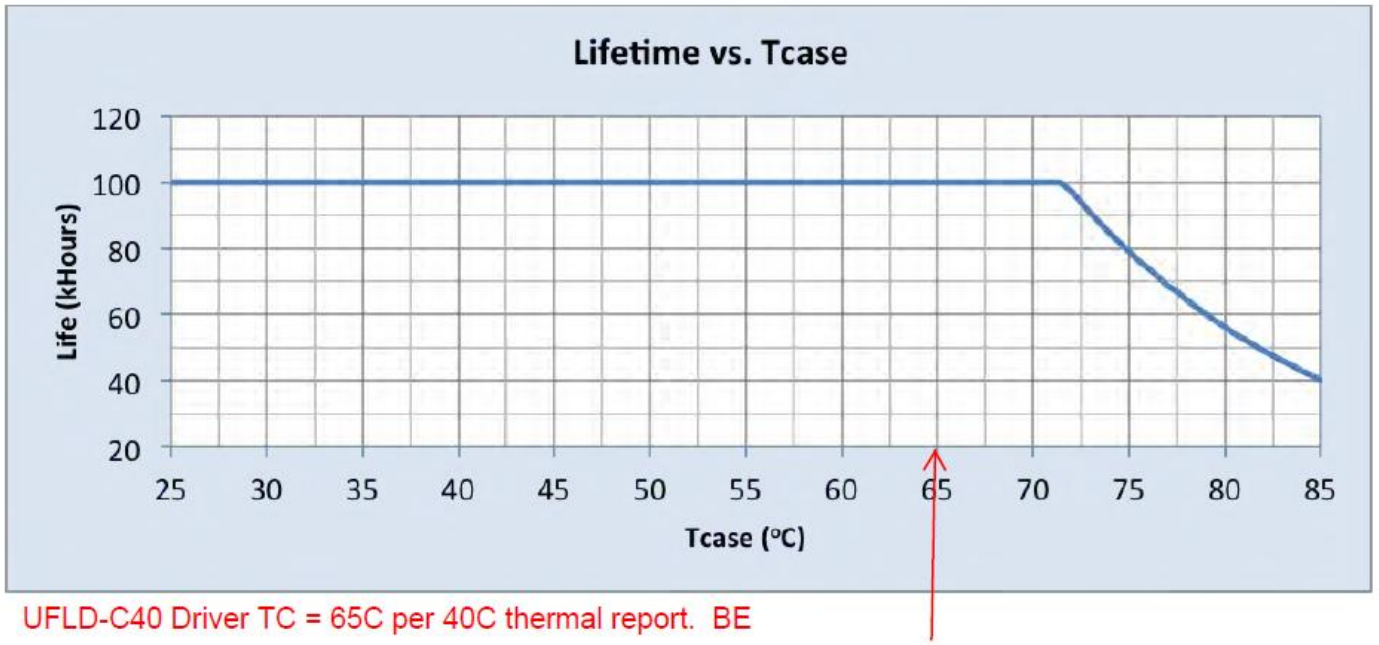
PHILIPS
ADVANCE

LED Driver

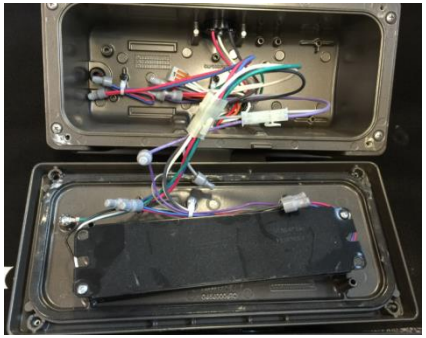
Xitanium

150W 120-277V 1.05A 0-10V
XI150C105V140CNF1

Driver Lifetime vs. Driver Case Temperature:



UFLD-C40 Driver TC = 65C per 40C thermal report. BE



The above driver data sheet indicates that the driver lifetime is 100,000 hours with a Tcase operating temperature of 72C or lower. The UFLD-C40 thermal report had a Tcase temperature of 65°C when operating in a 40°C ambient environment.

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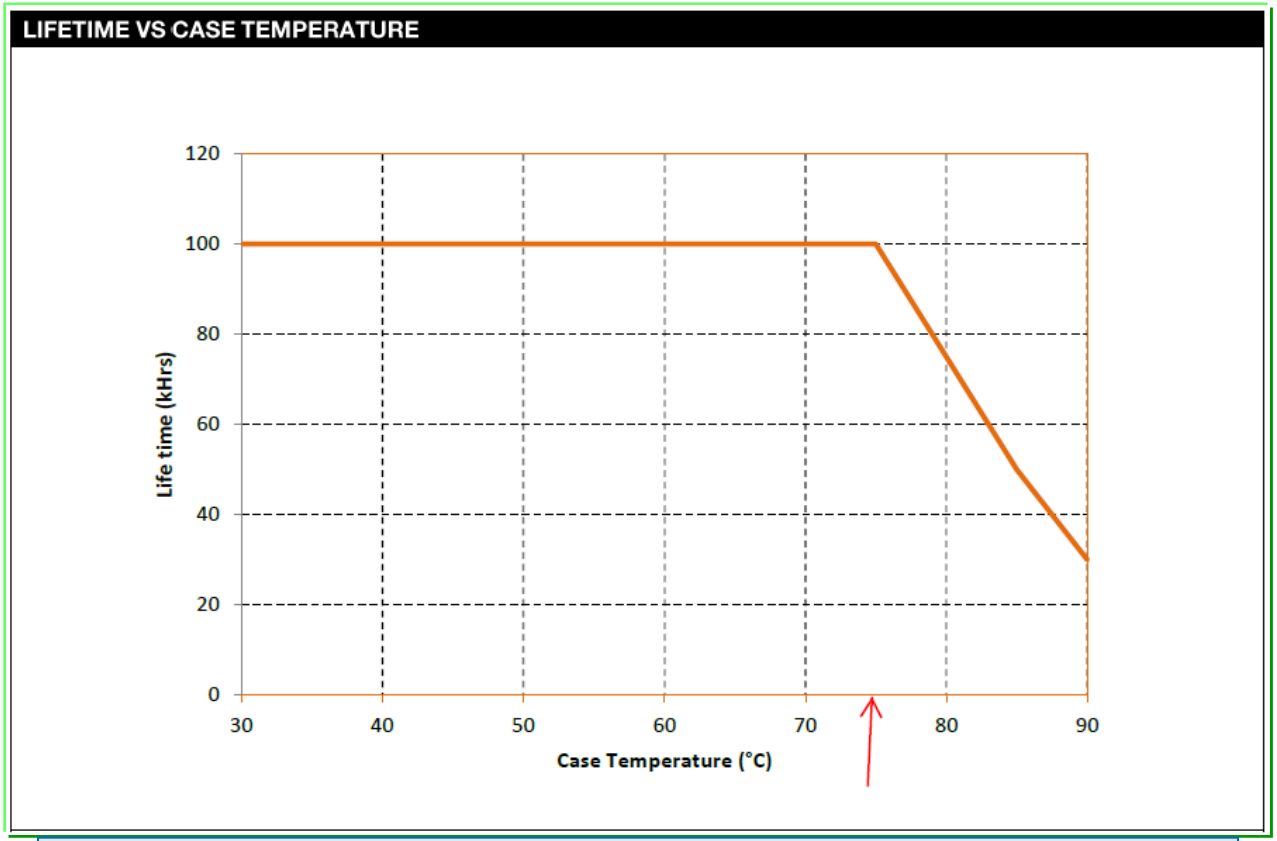
Superior thermal management results in long life

GENERAL INFORMATION	
Item Number	79369
Type	Constant Current
Output Power	100W (Max.)
Programming tool	51645; Software
Programmable features	Output current Dimming level LED thermal protection AstroDIM LEDSet Gen2 Constant Lumen output End of life indicator



The above driver data sheet indicates that the driver lifetime is 100,000 hours with a Tcase operating temperature of 75C or lower. The UFLD-C40 thermal report had a Tcase temperature of 75°C when operating in a 50°C ambient environment.

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Absolute and Relative Photometry

Absolute Photometry

- LED luminaires LM-79-08
- Lamps integral to luminaire
- No lamp seasoning, calibrated to lamp of known output
- Actual lumen output measured
- Unique results for each product

Relative Photometry

- **Bare lamps measured separately.**
  - **Seasoned (aged) lamps**
  - **Output stabilization**
  - **Raw output measured**
- **Luminaire test**
  - **Same lamps and ballast**
  - **Identical electrical and thermal characteristics**
  - **Results scaled to initial rated lamp lumens**
- **Same results with different lamps**

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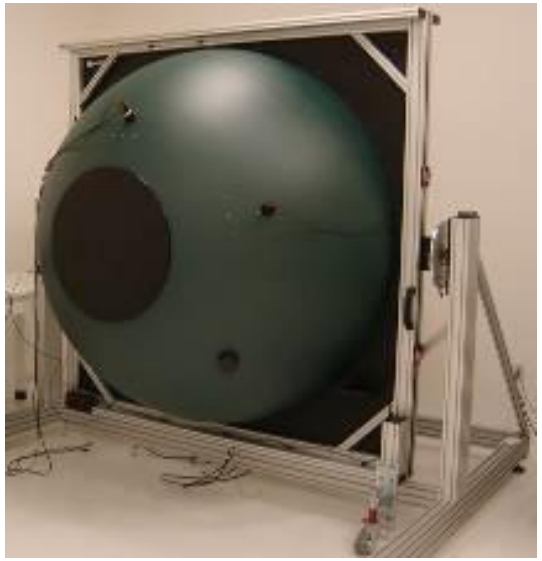
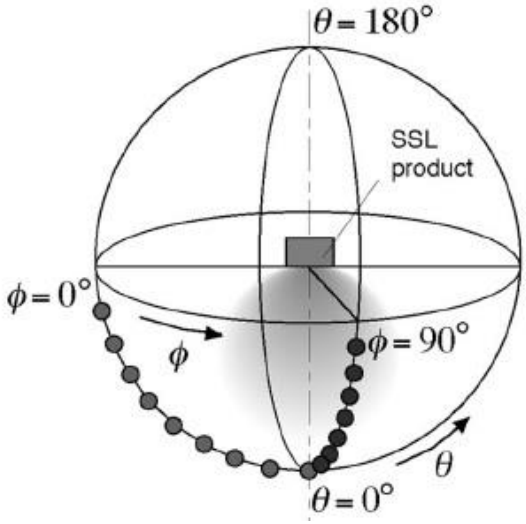
Photometric Testing per IES LM-79-08

- **Electrical and Photometric Measurements of Solid-State Lighting Products**
  - **Luminaire based absolute photometry**
    - **Total Luminous Flux**
    - **Luminous Intensity Distribution**
    - **Electrical Power**
    - **Luminous Efficacy (LPW - calculated)**
    - **Color Characteristics**
    - **Chromaticity**
    - **CCT**
    - **CRI**

Integrating Sphere





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Integrating Sphere Report

COOPER Lighting

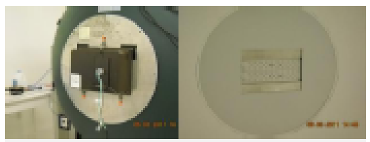
Photometric Color Report
IL– R5.10.2 Rev. C
1/4/2011
Originator: Mike Kallas

Customer First Center
1121 Highway 74 South
Peachtree City, GA 30269
770-486-4800

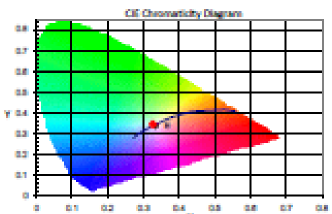
************* This test was performed using procedures based on IES LM-79-08 except where noted in the Test Notes *************

TEST#:	SP10175	DATE:	6-Jun-11
PREPARED FOR:	PHILIP WINTERS REQ. 567	TECHNICIAN:	ANUSZKIEWICZ
TEST UNIT:	120V RIDGEVIEW 6000K LED	ROOM TEMP.(°C):	25.3
TEST UNIT CAT.#:	LDRV-T35-A03-6-7060	OPERATION TIME:	1HR
LAMP/LED CAT#:	PHILIPS REBEL 21 LED		
TEST SETUP DESCRIPTION(BURNING POSITION ETC.)	120V RIDGEVIEW LED FIXTURE WITH (1) 21 LED LIGHTBAR MOUNTED TO ALUMINUM PLATE (3015 CSS) AND MAGTECH LP1040 ELECTRONIC DRIVER (LP1040-36-C1050).		

SOURCE VOLTAGE (V)	SOURCE CURRENT (A)	SOURCE POWER (W)	FREQUENCY (HZ)
120.03	0.2173	25.5	60
Power Factor	SPHERE TEMPERATURE (C°)	STABILITY TIME (MIN)	MEASUREMENT GEOMETRY
0.977	24.8	30	2π
REFERENCE STANDARD	PHOTOMETER	CORR. COLOR TEMPERATURE (K)	PEAK WAVELENGTH
IC0105	SP1	5765	446
DOMINANT WAVELENGTH	u'	v'	PURITY
513	0.2019	0.4778	2.2
CIE x	CIE y	CIE z	
0.3264	0.3433	0.3304	
Luminous Flux (lumen)	EFFICACY (LUMEN/WATT)		
1899.84648	74.59448021		

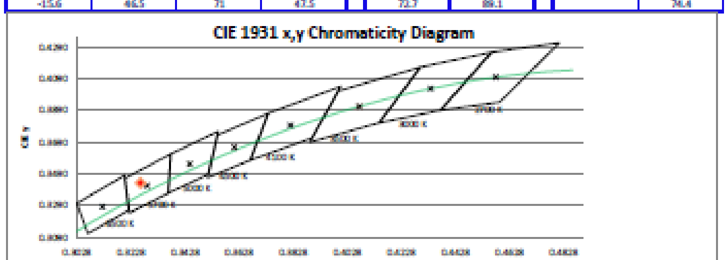


PHOTO



COLOR RENDERING INDEX DETAIL

R1	R2	R3	R4	R5	R6	R7	R8
72	78.2	81	74.9	73.8	69.7	83.3	63.2
R9	R10	R11	R12	R13	R14		COLOR RENDERING INDEX
-15.6	46.5	71	47.5	73.7	89.1		74.4



COOPER Lighting

Photometric Color Report
IL– R5.10.2 Rev. C
1/4/2011
Originator: Mike Kallas

Customer First Center
1121 Highway 74 South
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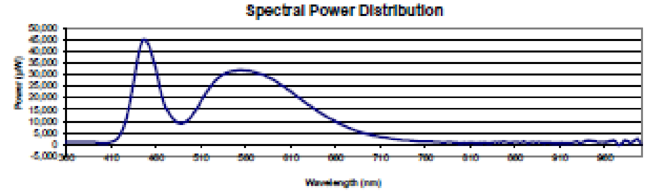
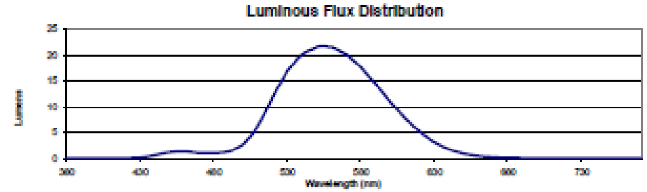
770-486-4800



Wavelength In nm	Spectral Flux In µW/nm	Wavelength In nm	Spectral Flux In µW/nm	Wavelength In nm	Spectral Flux In µW/nm	Wavelength In nm	Spectral Flux In µW/nm
360	1068.2333	510	18552.7852	660	9637.5986	810	911.8410
370	974.1728	520	24675.4004	670	7971.9789	820	791.8229
380	1081.9813	530	28762.1270	680	6279.6306	830	617.8943
390	991.3050	540	30076.7188	690	5010.8140	840	582.4680
400	648.5253	550	31719.3047	700	3990.4965	850	1134.2954
410	1036.7045	560	31737.0820	710	3290.5129	860	1097.8821
420	4009.4478	570	30963.4238	720	2667.7940	870	1180.2180
430	16532.1698	580	29750.5234	730	2137.5239	880	1049.5085
440	30290.7500	590	27665.8211	740	1756.7147	890	893.2429
450	43524.8594	600	25404.8496	750	1391.8079	900	782.9670
460	31706.0723	610	22702.8836	760	1221.9578	910	528.7772
470	16467.5156	620	19779.9414	770	1019.6700	920	698.7424
480	10554.4480	630	17033.8211	780	893.7003	930	1117.9186
490	9147.2779	640	14247.8891	790	833.7979	940	1798.2911
500	12488.3441	650	11687.8183	800	855.9769	950	1222.7917



Wavelength In nm	Spectral Flux In Lm/nm	Wavelength In nm	Spectral Flux In Lm/nm	Wavelength In nm	Spectral Flux In Lm/nm	Wavelength In nm	Spectral Flux In Lm/nm
380	0.0000	480	1.0022	580	17.8682	680	0.0728
390	0.0001	490	1.2996	590	14.4074	690	0.0281
400	0.0002	500	2.7502	600	10.9488	700	0.0112
410	0.0009	510	6.3736	610	7.7992	710	0.0047
420	0.0118	520	11.8178	620	5.1464	720	0.0018
430	0.1310	530	18.0036	630	3.0698	730	0.0008
440	0.8015	540	20.1181	640	1.7030	740	0.0003
450	1.1296	550	21.5546	650	0.8688	750	0.0001
460	1.2993	560	21.5880	660	0.4098	760	0.0001
470	1.0245	570	20.1328	670	0.1742	770	0.0000

TEST NOTES:
PERFORMED CHARACTERIZATION OF HORIZONTAL TO VERTICAL (2pi) POSITIONING.

ROOM THERMOMETER ID: IN0046
SPHERE THERMOMETER ID: IN0085

CHECKED: Paul A. Tech
APPROVED: M.Kallas/Sr. Tech.

EQUIPMENT

METER MANUFACTURER:	XTRON 2801
METER ID NUMBER:	IN0071
SUPPLY MANUFACTURER:	CHROMA 6420
SUPPLY ID NUMBER:	IN0063
Aux. Lamp	
METER MANUFACTURER:	XTRON 2801
METER SERIAL NUMBER:	IN0071
STANDARD LAMP:	IN0003
SUPPLY MANUFACTURER:	AGILENT E3634A
SUPPLY ID NUMBER:	IN0010

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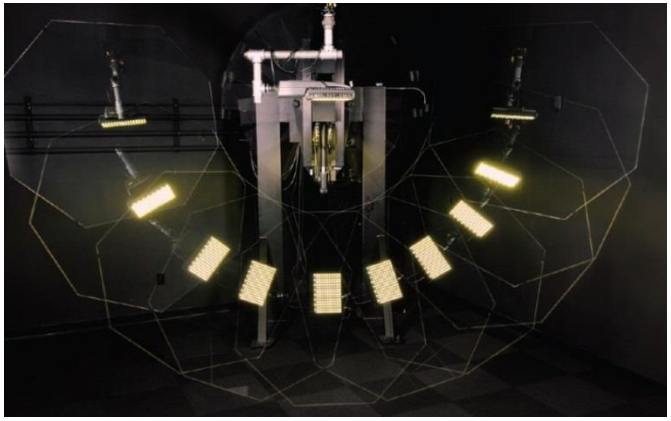
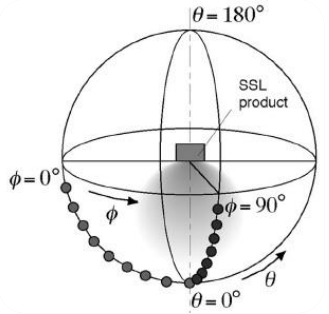
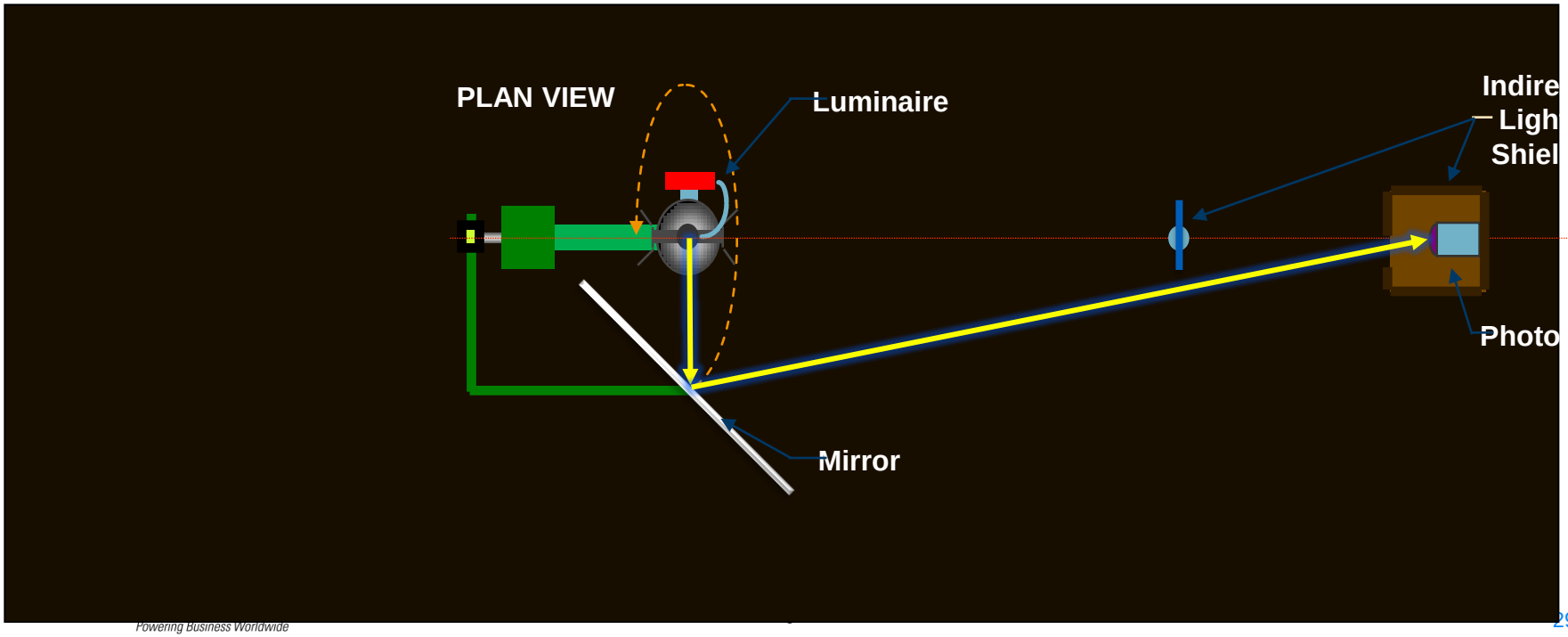
Measuring Luminaire Performance



Goniophotometer

An apparatus for measuring the directional light distribution characteristics of light sources, luminaires, media, and surfaces.





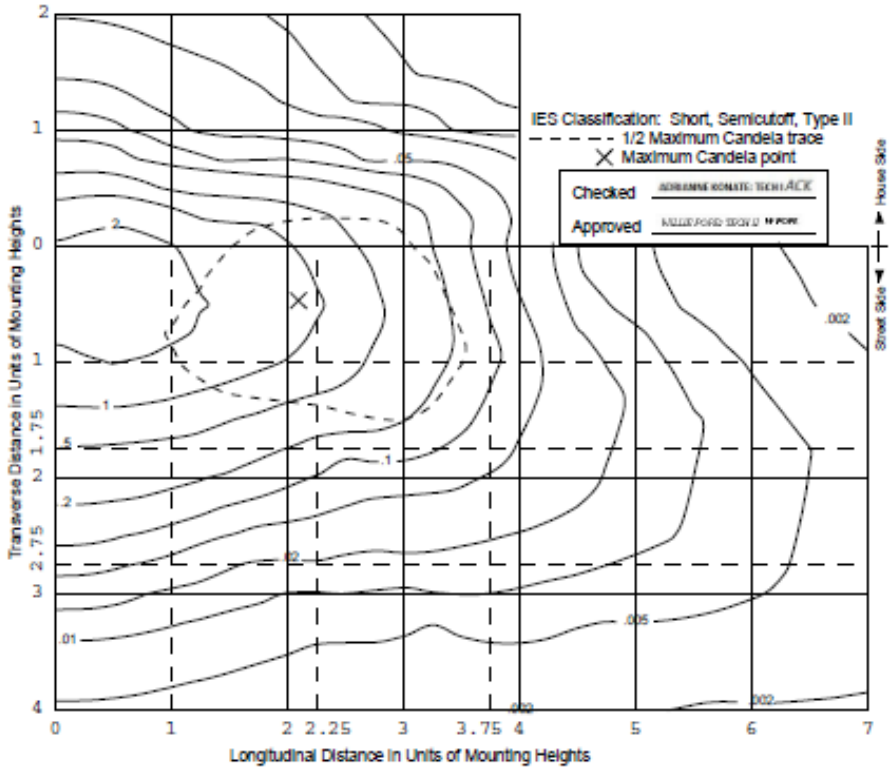
Absolute IES file information from Goniophotometer

Cooper Lighting
Photometric Lab
1121 HWY 74 South
Peachtree City, Ga 30269
PHOTOMETRIC TEST REPORT

COOPER Lighting

ISOFOOTCANDLE LINES OF HORIZONTAL ILLUMINATION
Values based on 20 foot mounting height.

REPORT NUMBER: P92850
ISSUE DATE: 7/13/2012 PAGE: 1 OF 7
CATALOG NUMBER: NVN-AA-02-E-U-SL2
LUMINAIRE: NAVION LED ROADWAY LUMINAIRE
(2) LIGHTSQUARES WITH 14 LEDs EACH
AND TYPE 2 WITH SPILL CONTROL OPTICS
ELECTRONIC DRIVER
ABSOLUTE DATA SHOWN IS ABSOLUTE FOR
THE SAMPLE PROVIDED ABSOLUTE
PHOTOMETRY IS BASED ON CALIBRATION
FACTORS CREATED USING LAB LUMEN
STANDARDS IN GONIOPHOTOMETER WITH
TEST DISTANCE OF 28.75 FEET



THIS REPORT IS BASED ON IES PUBLICATION LM-79-08. FIELD PERFORMANCE MAY DIFFER FROM LABORATORY PERFORMANCE.

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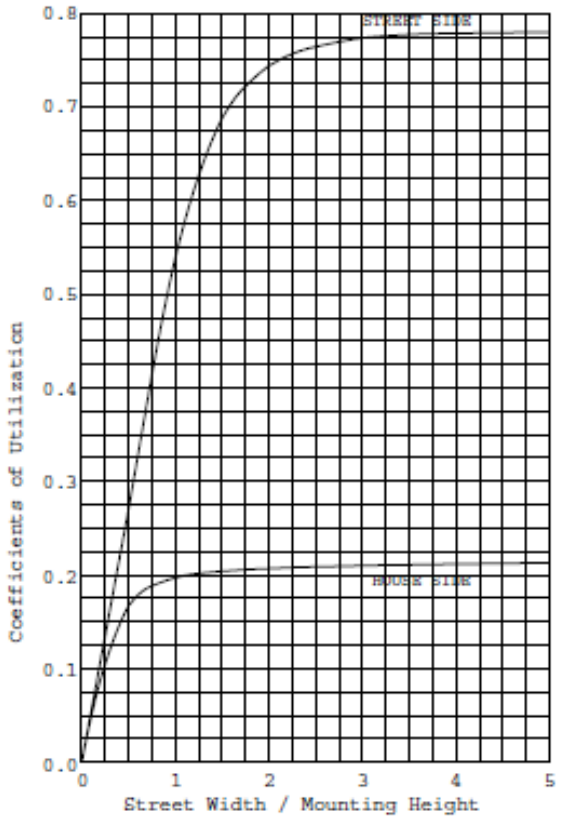
Cooper Lighting
Photometric Lab
1121 HWY 74 South
Peachtree City, Ga 30269
PHOTOMETRIC TEST REPORT

COOPER Lighting

REPORT NUMBER: P92850 PAGE: 3 OF 7
ISSUE DATE: 7/13/2012
CATALOG NUMBER: NVN-AA-02-E-U-SL2

COEFFICIENTS OF UTILIZATION AND FLUX DISTRIBUTION



	LUMENS	PERCENT OF FIXTURE
DOWNWARD STREET SIDE	5821.	78.4
DOWNWARD HOUSE SIDE	1601.	21.6
DOWNWARD TOTAL	7423.	100.0
UPWARD STREET SIDE	0.	0.0
UPWARD HOUSE SIDE	0.	0.0
UPWARD TOTAL	0.	0.0
TOTAL FLUX	7423.	100.0

TOTAL INPUT WATTS = 103
EFFICACY = 72.1 Lm/W

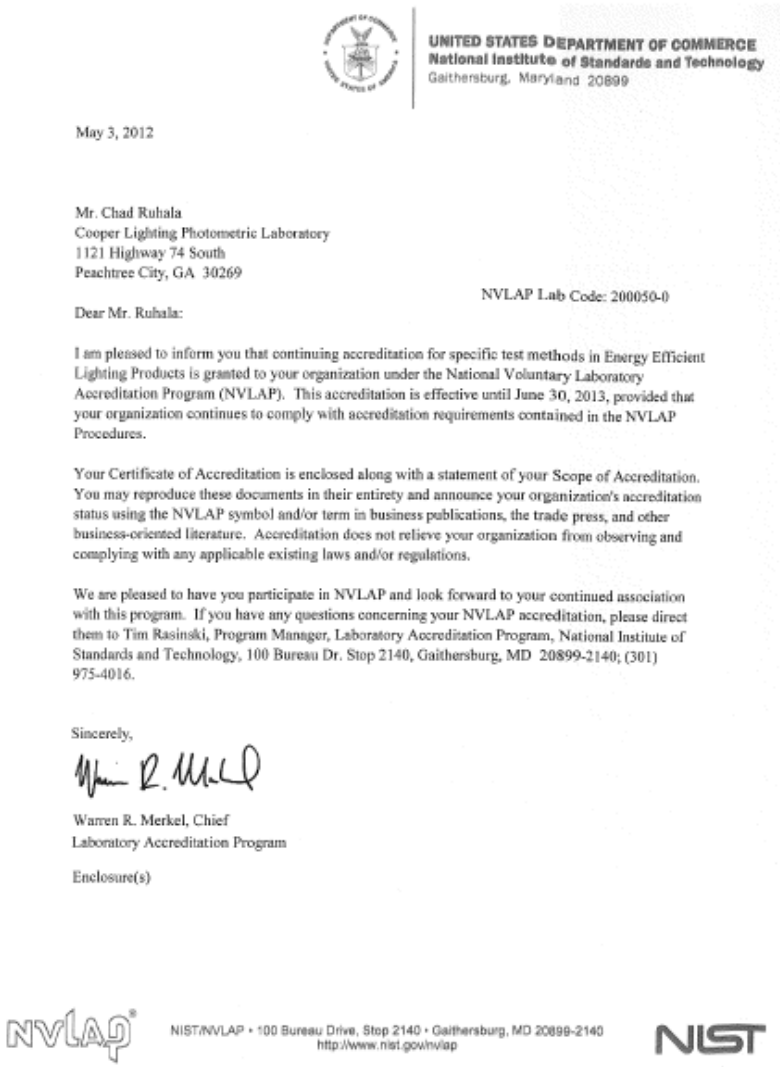
ALL CANDELA AND LUMENS IN THIS REPORT ARE BASED ON ABSOLUTE PHOTOMETRY. THE COEFFICIENT OF UTILIZATION VALUES ARE BASED ON THE TOTAL ABSOLUTE LUMEN OUTPUT OF THIS LUMINAIRE SAMPLE.

THIS REPORT IS BASED ON IES PUBLICATION LM-79-08. FIELD PERFORMANCE MAY DIFFER FROM LABORATORY PERFORMANCE.

National Voluntary Laboratory Accreditation Program - NVLAP

The National Voluntary Laboratory Accreditation Program (NVLAP) provides third-party accreditation to testing and calibration laboratories.

NVLAP operates an accreditation system that is compliant with ISO/IEC 17011, *Conformity assessment — General requirements for accreditation bodies accrediting conformity assessment bodies*, which requires that the competence of applicant laboratories be assessed by the accreditation body against all of the requirements of ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories.*



UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

May 3, 2012

Mr. Chad Ruhala
Cooper Lighting Photometric Laboratory
1121 Highway 74 South
Peachtree City, GA 30269

NVLAP Lab Code: 200050-0

Dear Mr. Ruhala:

I am pleased to inform you that continuing accreditation for specific test methods in Energy Efficient Lighting Products is granted to your organization under the National Voluntary Laboratory Accreditation Program (NVLAP). This accreditation is effective until June 30, 2013, provided that your organization continues to comply with accreditation requirements contained in the NVLAP Procedures.

Your Certificate of Accreditation is enclosed along with a statement of your Scope of Accreditation. You may reproduce these documents in their entirety and announce your organization's accreditation status using the NVLAP symbol and/or term in business publications, the trade press, and other business-oriented literature. Accreditation does not relieve your organization from observing and complying with any applicable existing laws and/or regulations.

We are pleased to have you participate in NVLAP and look forward to your continued association with this program. If you have any questions concerning your NVLAP accreditation, please direct them to Tim Rasinski, Program Manager, Laboratory Accreditation Program, National Institute of Standards and Technology, 100 Bureau Dr. Stop 2140, Gaithersburg, MD 20899-2140; (301) 975-4016.

Sincerely,

Warren R. Merkel, Chief
Laboratory Accreditation Program

Enclosure(s)

NVLAP® NIST/NVLAP • 100 Bureau Drive, Stop 2140 • Gaithersburg, MD 20899-2140 http://www.nist.gov/nvlap NIST

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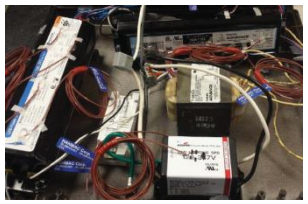
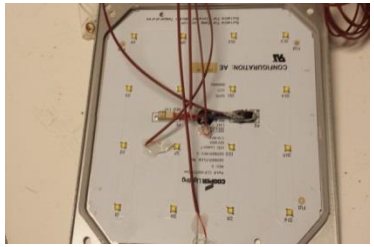
Thermal Test Information

At right is a sample thermal test report on an outdoor LED luminaire. Note readings are taken on many parts of the luminaire including the LED case, driver and surge module.





	Description	RAW	Adj.	3 Hr	Up	Td	St
1	L- SQR (1) LED SLUG	95.4	94	0	0	☑	☐
2	L- SQR (1) OPTIC	86.3	85	0	0	☑	☐
3	L- SQR (1) GASKET	79.8	78	0	0	☑	☐
4	L- SQR (1) WIRE GROMMET	85.4	84	0	0	☑	☐
5	L- SQR (1) LINE LEAD (INSIDE)	86.9	85	0	0	☑	☐
6	L-SQR (1) SOLDER PAD	88.3	87	0	0	☑	☐
7	L- SQR (2) LED SLUG	91.9	90	0	0	☑	☐
8	L- SQR (2) OPTIC	70.9	69	0	0	☑	☐
9	L- SQR (2) GASKET	70.8	69	0	0	☑	☐
10	L- SQR (2) WIRE GROMMET	72.4	71	0	0	☑	☐
11	L- SQR (2) LINE LEAD (INSIDE)	71.2	69	0	0	☑	☐
12	L-SQR (2) SOLDER PAD	72.1	70	0	0	☑	☐
13	ADVANCE LED Driver Center (not required	77.1	75	0	0	☑	☐
14	ADVANCE DRIVER Case marked HOTSPOT	67.9	66	0	0	☑	☐
15	ADVANCE DRIVER - 0.5 in from INPUT	72.7	71	0	0	☑	☐
16	ADVANCE DRIVER - 0.5 in from OUTPUT	71.1	69	0	0	☑	☐
17	SURGE PROTECTOR (TOP)	65.9	64	0	0	☑	☐
18	SURGE PROTECTOR (SIDE-1)	68.4	67	0	0	☑	☐
19	GASKET - SIDE	51.3	50	0	0	☑	☐
20	WIRE CONNECTOR	69.7	68	0	0	☑	☐
21	QUICK DISCONNECT WIRING HARNESS	73.9	72	0	0	☑	☐
22	GASKET - DOOR	58.8	57	0	0	☑	☐
23	TERMINAL BLOCK	66.8	65	0	0	☑	☐
24	MOTION / WIRELESS SENSOR (INSIDE)	48.3	47	0	0	☑	☐
25	MOTION / WIRELESS SENSOR (GASKET)	57.7	56	0	0	☑	☐

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UV testing on Polycarbonate Plaques

Note: Proper installation of the Navion luminaire will not expose the optical square to direct sunlight.

Background – Polycarbonate is a resilient material that can be used for optical elements in outdoor lighting products. An undesirable aspect of this material is that it will become yellow and lose light transmission over time when exposed to ultraviolet radiation. To minimize this effect the light square polycarbonate material was infused with an ultraviolet inhibitor.

Purpose – To provide a summary of measurements on the polycarbonate plaques (used on the light square products) that have been exposed to high intensity ultraviolet radiation.

Test – Five plaques were selected for testing with one plaque being untreated and four infused with the UV stabilizer. Each plaque as cut in half so that one half of each plaque could be placed in the UV chamber while the other half could be retained as a control sample. The UV chamber emitted radiation in the wavelength between 300 and 340 nanometers and also cycled through heat, humidity and water exposure to simulate real world conditions. Total lumen output and color characteristics were recorder for each of the samples in an integrating sphere calibrated and maintained under NVLAP accredited program and in conformance with IESNA standards of photometric testing.

Results – After more than 6,000 hours of exposure to high intensity UV radiation the transmittance of the untreated plaque was reduced from 90.4% to 79.2% with a color shift of 600 degrees kelvin. The treated samples showed no reduction in transmittance and less than 1% shift in kelvin temperature (consistent with the LED LM-80 DUV). This test would equal 8.2 years of direct sunlight exposure at 12 hours per day.

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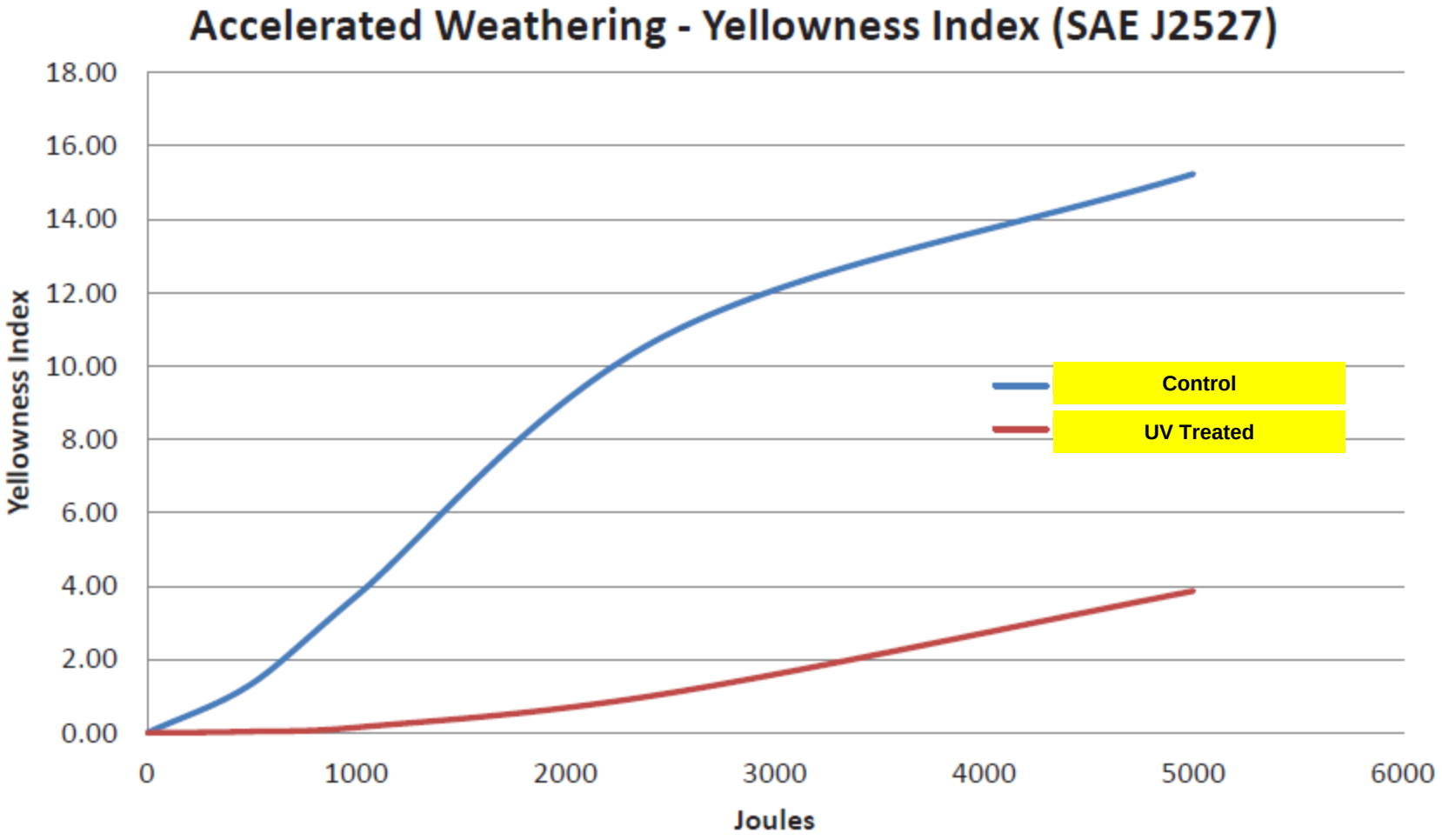
UV stabilizers greatly reduce the rate of yellowing on plastic materials



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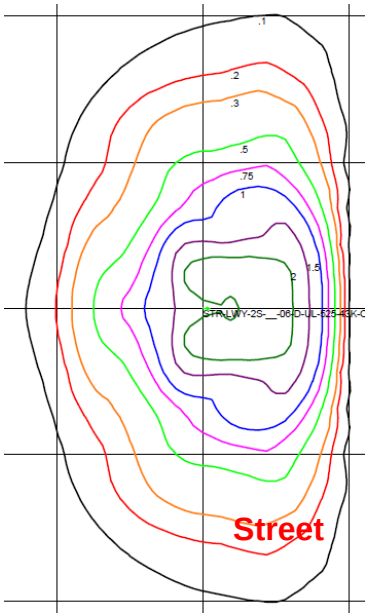
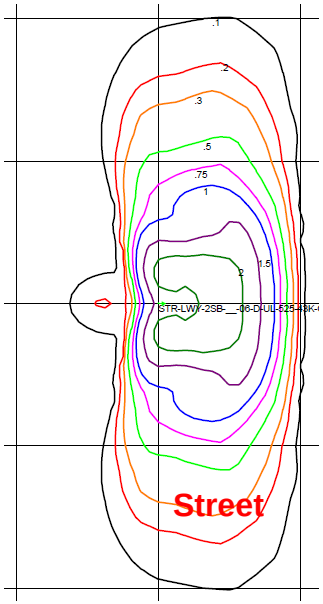
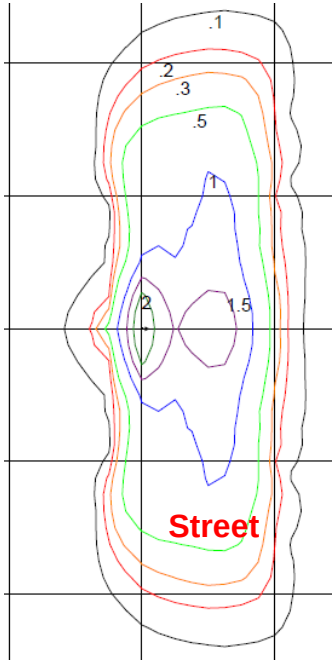
Optical Control Advantage Over External Shields







40’ Grid

25’ MH

Type 2 Short , 7928 lumens, 78 lumens per watt, with light more than 40’ behind the pole.

Type 2 Short with an external shield, 6090 lumens, 60 lumens per watt, light reduced to 20’ behind the pole.

Type 2 Medium mirror imbedded optics, 7523 lumens, 105 lumens per watt with light evenly dispersed 10’ to 20’ behind the pole for sidewalk illumination.

External shields can reduce luminaire efficiency by as much as 23%. precision optics maintain luminaire efficiency by re-directing the light evenly along the roadway.

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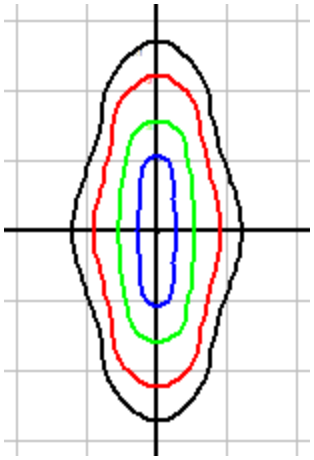
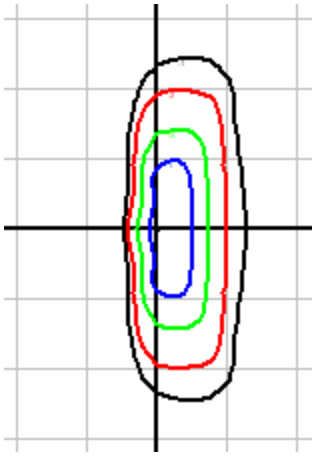
VERD Optics

Distribution Pattern Comparison



T1

T2

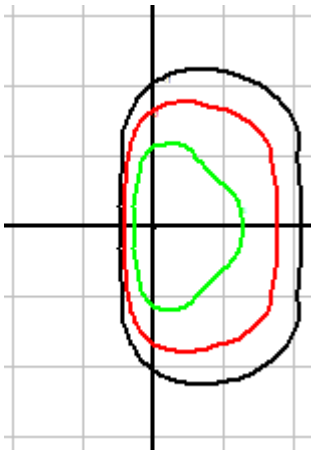


T2-HSS

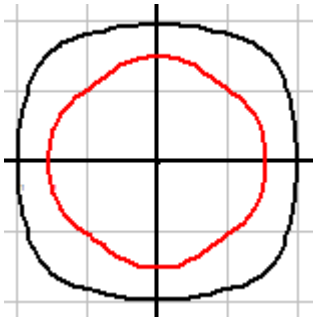
T3

T2-HSS

T4



T4-HSS



T5

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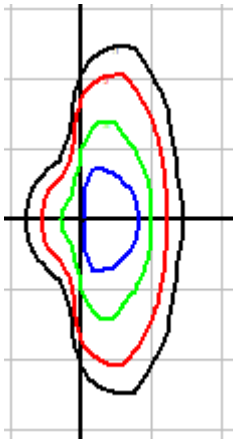
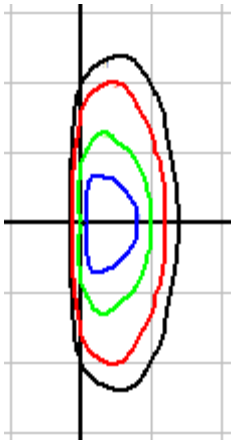
ARCH Optics

Distribution Pattern Comparison

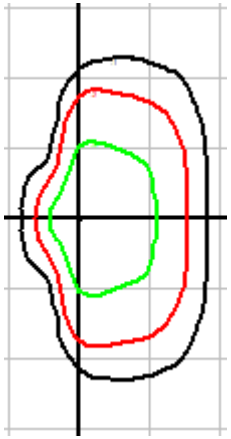
T2U



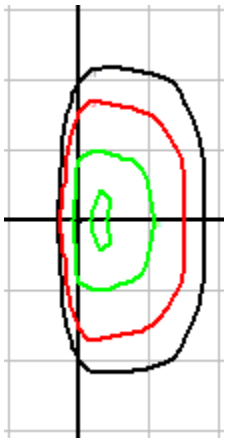
T2R



T2R-HSS



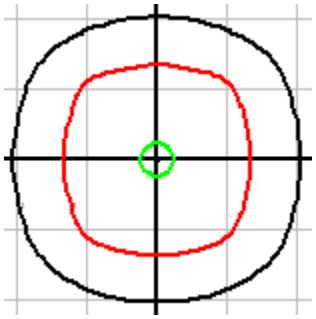
T3



T3-HSS

T4W

T4W-HSS



5WQ

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External Shields

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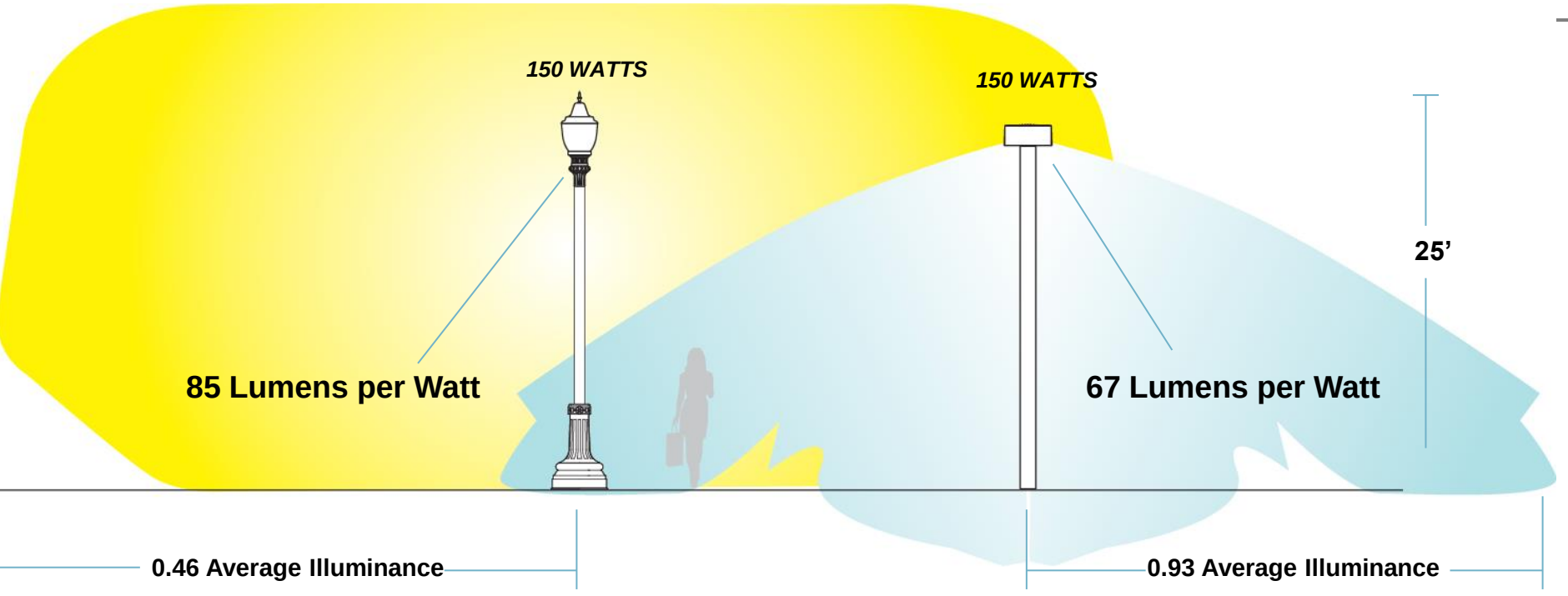
Why you should not specify by lumens per watt

Same source, same ballast, different performance



Why the “lumens per watt method” of calculating lighting fixture performance alone does not equate to energy efficiency.

Although the luminaire on the left is 27% higher in fixture LPW, it produces less than half the average illumination on the ground
To give the same illumination as the lower LPW fixtures, over twice as many of the higher LPW fixtures would be needed, resulting in a net energy increase of 102%

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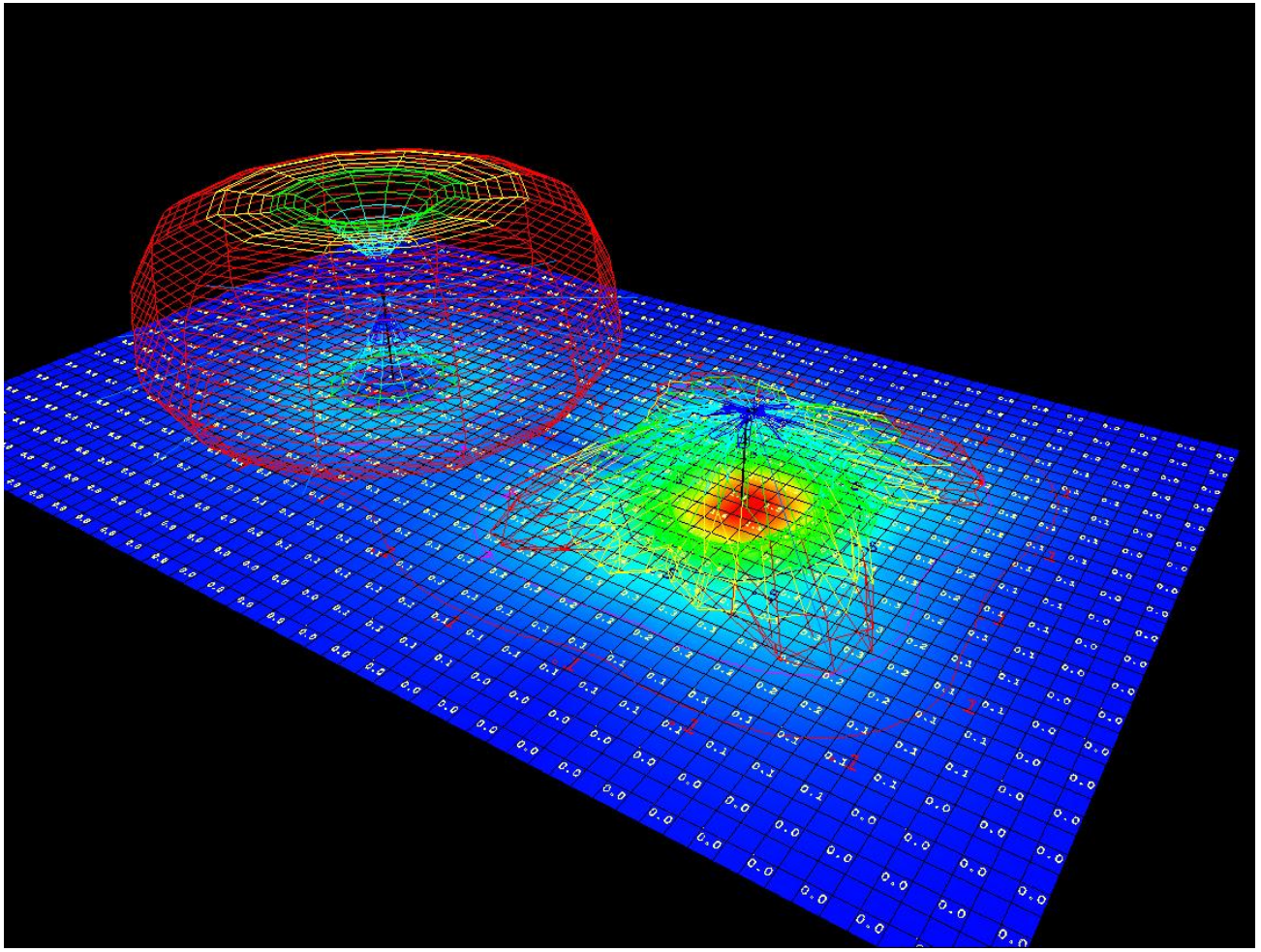
Where is the light going?



Three dimension rendering of light distributions and relative foot-candles on ground
High LWP post top on left, lower LPW shoebox on right

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Luminaire Dirt Depreciation

Dirt, dust, dead bugs and water collect inside this HID luminaire lens in

Boston, MA

How much light is really passing through the lens?

luminaire dirt depreciation factor, LDD the multiplier to be used in lighting calculations to reduce the initial light level provided by clean, new luminaires to the light level that they will provide due to dirt collection on the luminaires at the time at which it is anticipated that cleaning procedures will be instituted.

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HID | LED Equivalency

HID **vs.** **LED**

OVX Type 3 distribution

250W HPS Lamp **28,000 lumens**
(300 ballast watts)

70% Total Downward Luminaire Efficiency

19,600 lumens

Street Side Lumens **(52.7%)**

10,329 lumens

0.81 LLF **8,366 lumens**

XNV2 Type 3 distribution (new LED)

110W LED @ 1A **10,567 lumens**

100% Total Downward Luminaire Efficiency

10,566 lumens

Street Side Lumens **(82%)**

8,660 lumens

0.91 LLF **7,880 lumens**

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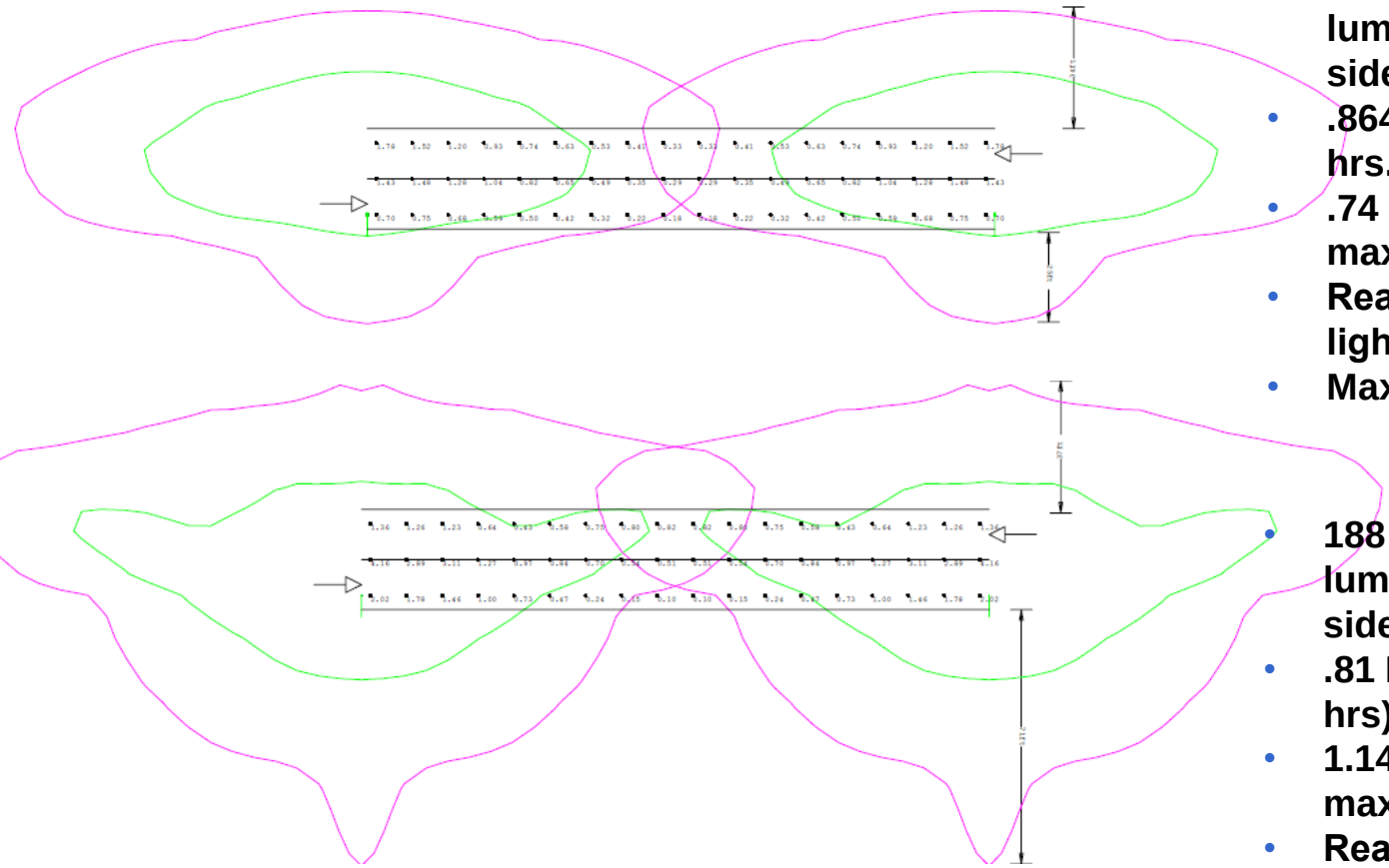
XNV2 type 2 700mA drive current vs OVH 150 watt HPS Type 3

28’ roadway, 1’ setback, 30’ mounting height, 6’ sweep arm, 175’ spacing



Purple iso = .1 FC Green Iso = .5 FC

XNV2-AC-02-2-700

- 76 watts, 7,588 initial delivered lumens, 6,458 downward street side lumens
- .864 Light Loss Factor (60,000 hrs.)
- .74 average, .17 minimum, 1.77 maximum, 4.35 to 1 ave/min.
- Rear spill light 25’, forward spill light 34’
- Max Lv Ratio .29 on R3 pavement

OVH15S2D

- 188 watts, 11,706 initial delivered lumens, 8,272 downward street side lumens
- .81 Light Loss Factor (12,000 hrs)
- 1.14 average, .10 minimum, 4.16 maximum, 11.40 to 1 ave/min.
- Rear spill light 41’, forward spill light 31’
- Max Lv Ratio .40 on R3 pavement

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Twin and Triple 1000 watt MH (1085 x 3= 3255 watts)

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Twin 213 watt Navions (618 watts)

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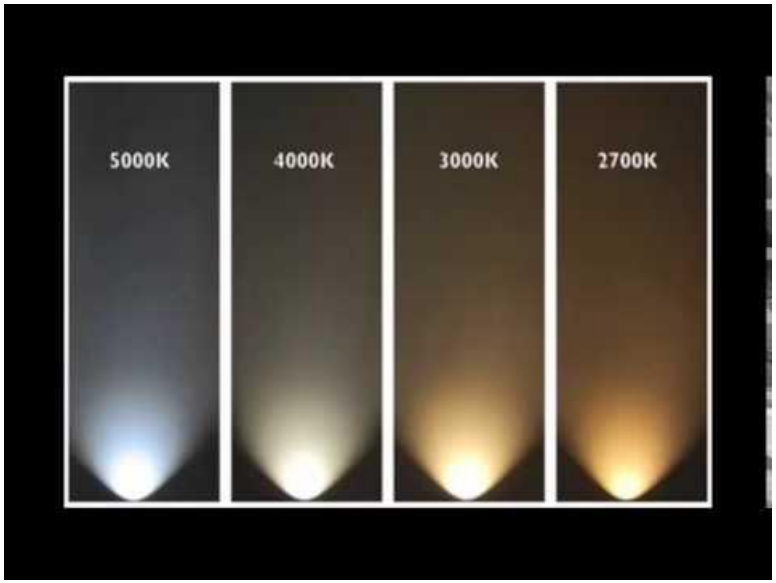
3000K vs 4000K Correlated Color Temperature Color Preference and Visibility



Existing 2200 Kelvin HPS 3000 Kelvin 4000 Kelvin

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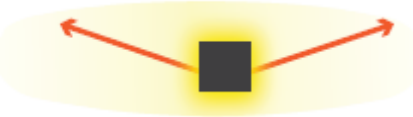
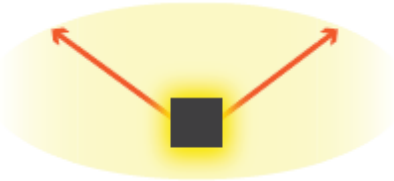
IESNA Distribution types

Same distributions for traditional technologies and LED

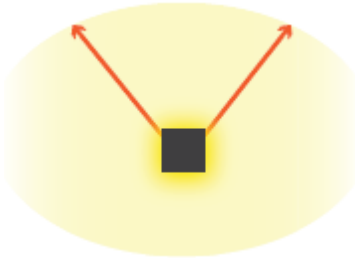
Type 1



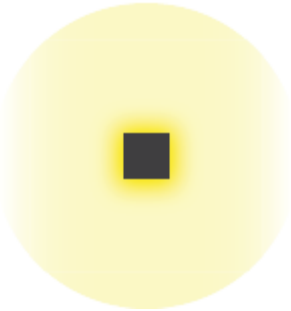
Type 2



Type 3

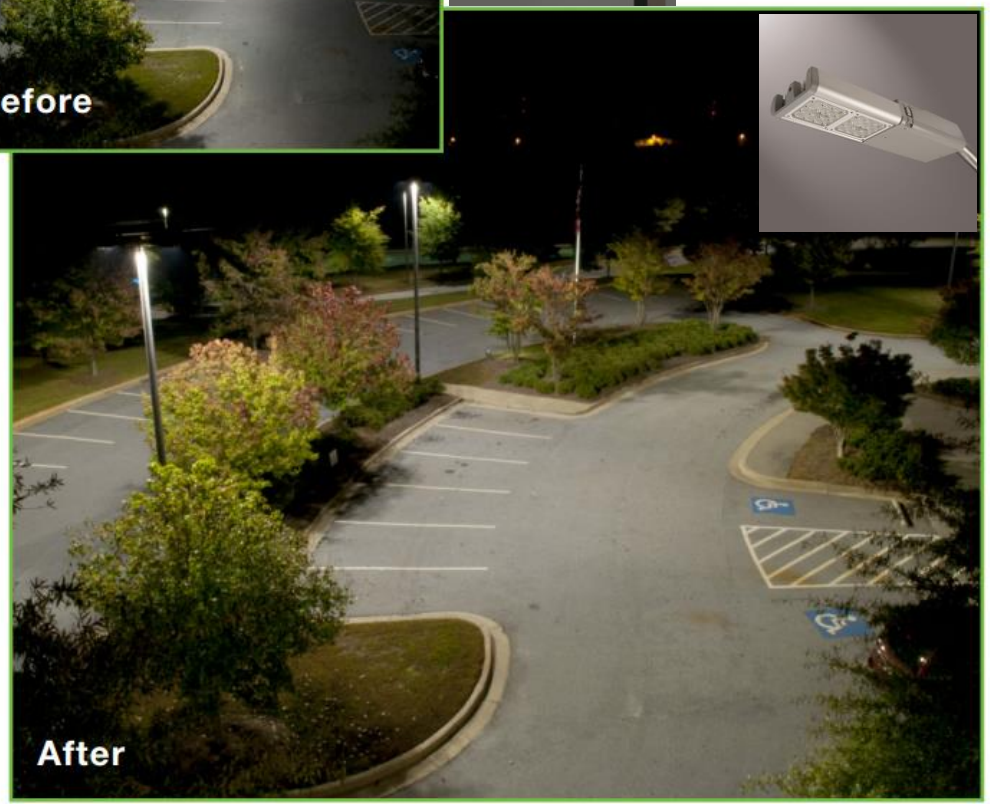


Type 4



Type 5 round

Type 5 square



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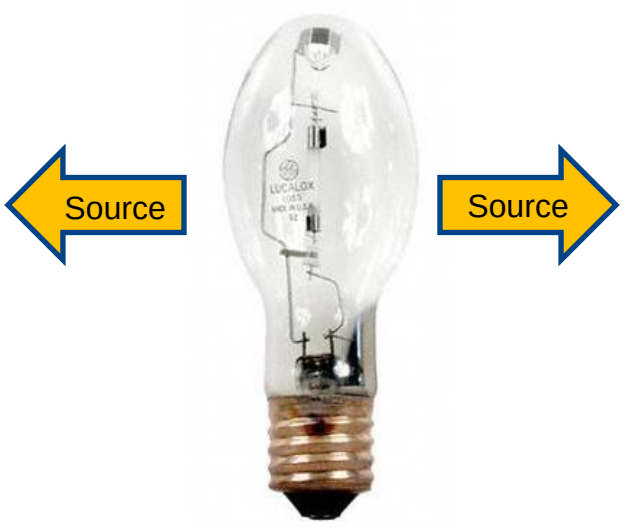
Source (Lamp) Versus Delivered Lumens

- Source= Lamp Lumens from the source.
- Example 100W HPS Lamp emits 9500 Source Lumens



- Delivered= Lumens that are controlled and distributed from the luminaire. LED Fixtures publish Delivered Lumens

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LED Replacement Product Methodology

HID		vs.	LED	
				
Typical Type 3 Distribution			LED Type 3 Distribution	
250W HPS Lamp (300 ballast watts)	28,000 lumens		155 watt LED	19,000 lumens
70% Total Downward Luminaire Efficiency	19,600 lumens		100% Total Downward Luminaire Efficiency	19,000 lumens
Street Side Lumens (52.7%)	10,329 lumens		Street Side Lumens (77.5%)	14,725 lumens
10,329 X 0.81 LLF =	8,366 lumens		14,725 X 0.81 LLF =	11,927 lumens

48% Less Energy and 30% More Maintained Street Side Lumens

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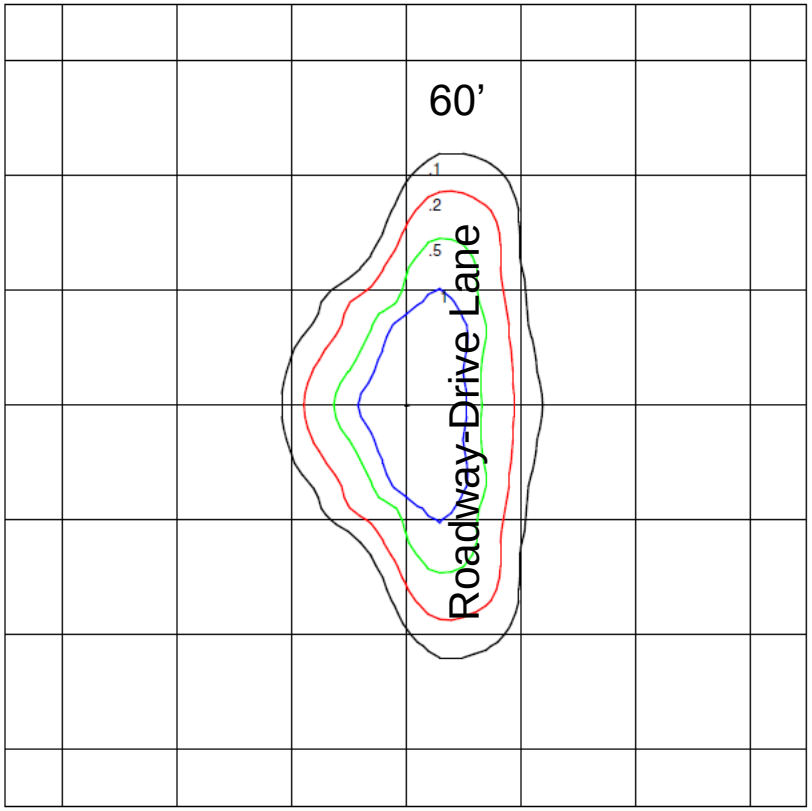
250W HPS vs.140W LED
VERD 19000 Lumens

COOPER Lighting

Photometric Toolbox

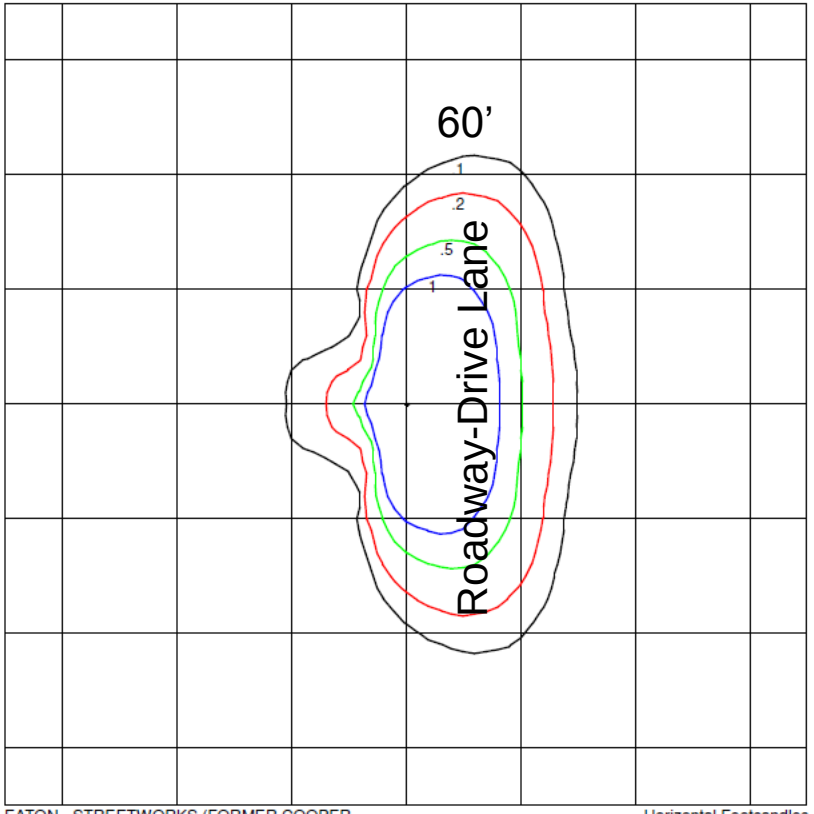


GE LIGHTING SOLUTIONS
www.gelightingsolutions.com
M2RR25S___GMS3
M-250R2
1; 250W HPS, CLEAR ED18, HORZ

Horizontal Footcandles
Scale: 1 Inch = 60 Ft.
Light Loss Factor = 1.00
Lumens Per Lamp = 27500
Total Lamp Lumens = 27500
Mounting Height = 30.00 Ft
Maximum Calculated Value = 5.64 Fc
Arrangement: Single

COOPER Lighting

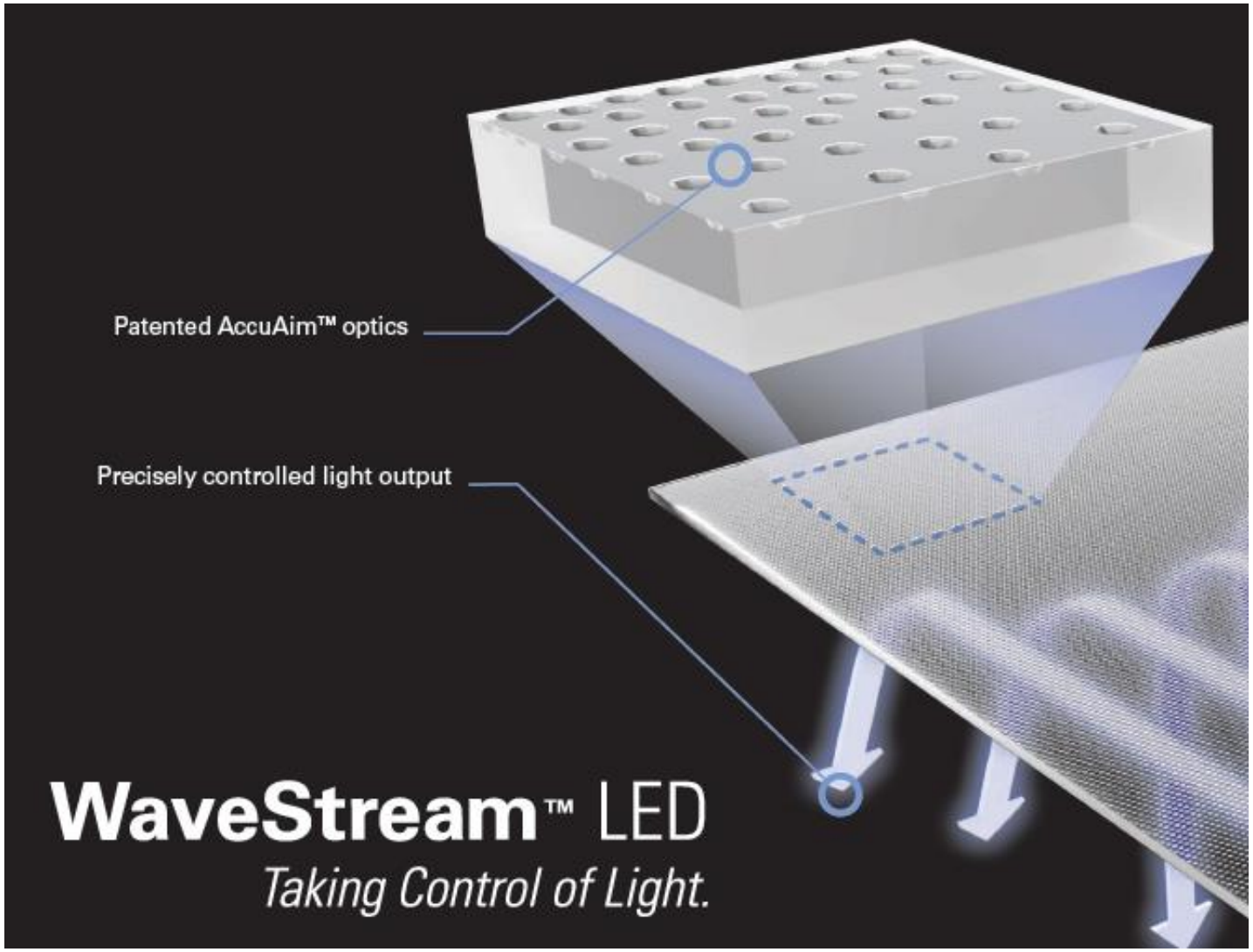
Photometric Toolbox



EATON - STREETWORKS (FORMER COOPER LIGHTING)
VERD-G-C02H-D-U-T3
VERDEON-G ROADWAY AND AREA LUMINAIRE
(2) 70 CRI, 4000K, 1370mA LEDS AND TYPE III OPTICS

Horizontal Footcandles
Scale: 1 Inch = 50 Ft.
Light Loss Factor = 1.00
Lumens Per Lamp = N.A. (absolute photometry)
Luminaire Lumens = 19080
Mounting Height = 25.00 Ft
Maximum Calculated Value = 5.31 Fc
Arrangement: Single

WaveStream™ optical technology blocks the line of sight of the LED light source from the observer while extracting the maximum amount of light on task.



Optical technology with unparalleled combination of visual comfort and performance.

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How do we achieve our vision…

We create unique experiences

"To improve the quality of life and the environment through the use of power management technologies and services…"

Eaton is enhancing urban living with design and stunning illumination

We Conserve Energy

We Improve Safety

We Create Experiences

We Connect Communities

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Class 2 LED Driver

PHILIPS

UL Class 2

PHILIPS ADVANCE

- UL Class 2 rating represents compliance with standard UL1310
- UL Class 2 rating means output is considered safe to contact and no major safety protection is required at LED/luminaire level
- UL Class 2 has the following electrical restrictions:
  - Maximum output current: 5Adc
  - Maximum output voltage: 60Vdc (dry); 30Vdc (damp/wet)
  - Maximum output power: 100W
- Any LED Driver used for Signage applications must be listed in the UL Sign Components Manual
- As component of an LED system, an LED Driver is not listed but recognized by UL (c UL us)

Solid State Lighting North America, June 2009

XITANIUM LED DRIVERS

LED luminaires with Class 2 drivers can use an acrylic lens.

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Class 1 LED Driver

PHILIPS

UL Class 1

PHILIPS ADVANCE

- LED Drivers with output outside the range required by UL1310 (Class 2) need to comply with standard UL1012
- Under this standard, LED Drivers are considered UL Class I devices
- An LED Driver with UL Class I rating means its output is considered "high voltage" and safety protection is required within the fixture
- Fluorescent and HID ballast fall under this category
- Also as a component of an LED system, an Class I LED Driver is not listed but recognized by UL (c UL us)

Solid State Lighting North America, June 2009

XITANIUM LED DRIVERS

1

Class 1 LED luminaires will have a glass or polycarbonate lens

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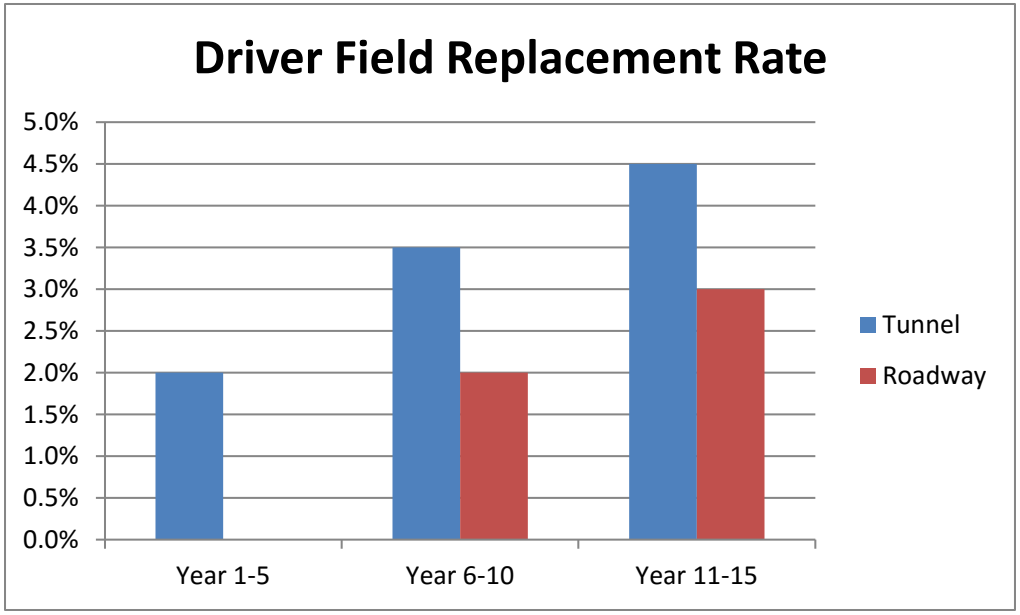
Driver Replacement Rate



- **Driver wearout data based on Detroit environmental conditions**
  - **Tunnel - 24 hr/day; roadway - 12 hr/day**
- **Years 1-5 only - expect <0.5% additional random failures**

PHILIPS

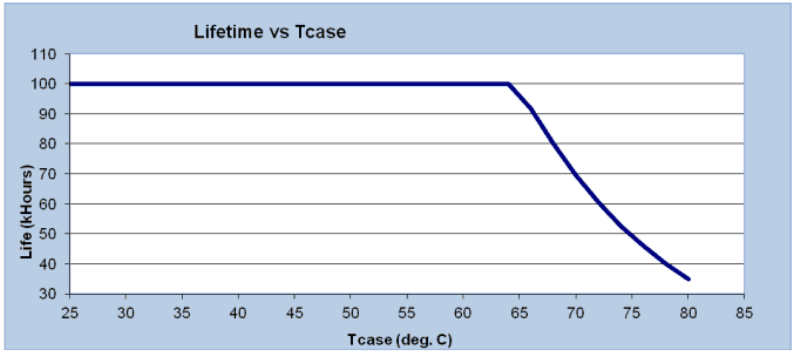
LEDINTA1050C140DOM	
Brand Name	XITANIUM
Description	XITANIUM 150W 1.05A 0-10V INT
Input Voltage	120~277
Input Frequency	50/60Hz
RoHS	Yes
Status	Active

Electrical Specifications

Failure Rate Info:

1. **<0.01% per 1 kHr @<= Tcase 80 C**

Lifetime vs. Tcase of Driver:



Revised 02/27/2012

PHILIPS LIGHTING ELECTRONICS N.A.
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Tel: 800-322-2086 · Fax: 888-423-1882 · www.philips.com/advance
Customer Support/Technical Service: 800-372-3331 · OEM Support: 866-915-5886

Eaton has extensive test data to support field performance expectations

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Cool running drivers last longer.

PHILIPS
ADVANCE

LED-INTA-0024V-41-F-O	
Brand Name	XITANIUM
Description	100W 24V 4.1A
Input Voltage	120~277
Input Frequency	50/60Hz
RoHS	Yes
Status	Active

Driver T case temperature will affect longevity.

Installation & Application Notes:

Section I – Physical Characteristics

1.1 LED Driver shall be installed inside an electrical enclosure
1.2 Wiring inside electrical enclosure shall comply with 600V/105°C rating or higher.

Section II – Performance

2.1 LED Driver is UL Class 2 power unit as per UL1310. It is also listed in the UL Sign Accessory Manual (UL SAM).
2.2 LED Driver has Class A sound rating.
2.3 LED Driver has a minimum operating ambient temperature of -40°C.
2.4 LED Driver has a life expectancy of 50,000 hours at Tcase of ≤ 80°C.
2.5 LED Driver has a life expectancy of 100,000 hours at Tcase of ≤ 70°C.
2.6 LED Driver has a typical self rise of 30°C at maximum load in open air without heat sink.
2.7 LED Driver is certified by UL for use in a dry or damp location (Outdoor Type I).
2.8 LED Driver tolerates sustained open circuit and short circuit output conditions without damage.
2.9 LED Driver maximum allowable case temperature is 90°C – see product label for measurement location.
2.10 LED Driver reduces output power to LEDs if maximum allowable case temperature is exceeded.
2.11 LED Driver has a failure rate of ≤ 0.01% per 1,000 hours.
2.12 LED Driver complies with FCC rules and regulations, as per Title 47 CFR Part 15 Non-Consumer (Class A).
2.13 LED Driver conforms to EN61558-1, EN 61558-2-17 and EN 60065.

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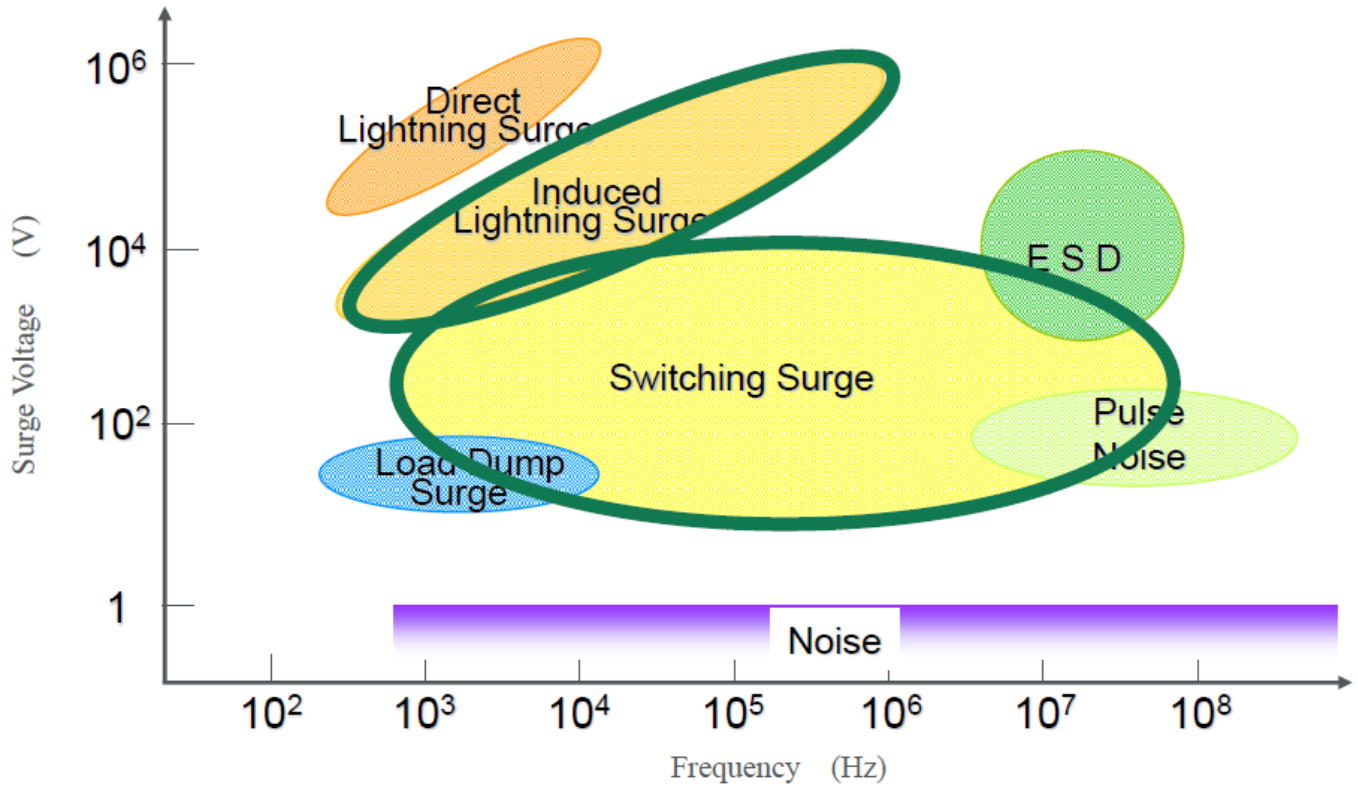
Surge Sources



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Protection Levels

Updates to C136.2-2015: Tables 1 and 7-2

TABLE 7-2
1.2/50µS – 8/20 µS COMBINATION WAVE TEST SPECIFICATION

Parameter	Test Level / Configuration		
1.2/50 µS Open Circuit Voltage Peak	Typical: 6 kV	Enhanced: 10kV	Extreme: 20kV
8/20 µS Short Circuit Current Peak	Typical: 3 kA	Enhanced: 5kA	Extreme: 10kA
Coupling Modes	L1 to PE, L2 to PE, L1 to L2, L1+L2 to PE		
Polarity and Phase Angle	Positive at 90° and Negative at 270°		
Consecutive Test Strikes	5 for each Coupling Mode and Polarity/Phase Angle combination		
Time Between Strikes	1 minute between consecutive strikes		
Total Number of Strikes	= 5 strikes x 4 coupling modes x 2 polarity/phase angles = 40 total strikes		

Note: L1 is typically "HOT", L2 is typically "NEUTRAL" and PE = Protective Earth.

Table 1
Recommended electrical transient immunity levels for common outdoor lighting applications

Lighting application	Electrical transient immunity level		
	Typical	Enhanced	Extreme
Building entrance, building exterior	X		
Parking garage, parking lot, tunnel	X	X	
Street, roadway, stadium, airport	X	X	X

Table 1 provides guidance on the level to choose from Table 7-2 for various applications

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Standard Cross Reference

Combination Wave Testing				
ANSI C82.77-5-2015 (L1 to PE, L2 to PE, L1 to L2, L1 & L2 to PE)	Category Name	C Low	C Medium	C High
	Surge Level - 8x20µs	6kV / 3kA	10kV / 5kA	20kV / 10kA
	# of Hits	40	40	40
ANSI C136.2 – 2015 (L1 to PE, L2 to PE, L1 to L2, L1 & L2 to PE)	Category Name	Typical	Enhanced	Extreme
	Surge Level - 8x20µs	6kV / 3kA	10kV / 5kA	20kV / 10kA
	# of Hits	40	40	40
IEEE C62.41.2* (* - Does not define # of strikes)	Category Name	C Low	-	C High
	Surge Level - 8x20µs	6kV / 3kA	-	20kV / 10kA
	# of Hits	*	-	*

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Surge Protection is Essential for Driver Life

UL1449 3rd Edition Safety Enhancements

- Safety standard
  - UL 1449 – "UL Standard for Safety for Surge Protective Devices"
- UL 1449 3rd Edition is now an ANSI standard
  - Reviewed, voted on, and approved by a balanced group of technical advisors including individuals from manufacturers, end-users and other interested parties
  - Changes must be voted on by this technical advisory group
- Duty Cycle Testing
  - 15 impulses of the manufacturer selected nominal discharge current
  - To pass:
    - SPD can not create a shock or fire hazard
    - Nothing in the surge path can open at any time during or after the test
  - This test includes all internal or external supplementary protective devices or overcurrent devices such as fuses or circuit breakers
- Intermediate Current Test ("Slow Cook Test")
  - L-L voltage place on the L-N mode
  - Current is limited to 1000A, 500A, 100A, and published SCCR
  - Test run for 7 hours on each or until the until safely disconnects
  - Added in addition to the Low Current Test from 2nd Edition
    - 10 amps, 5 amps, 2.5 amps, 0.5 amps
    - Test run for 7 hours on each or until the until safely disconnects

Make sure the SPD meets UL1449

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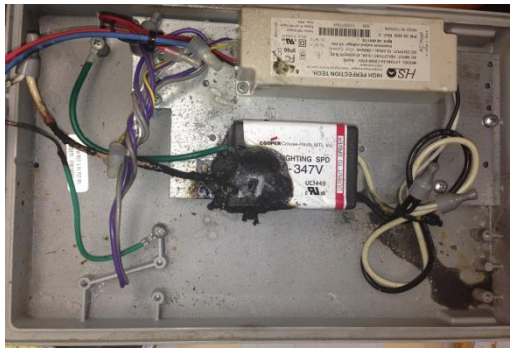
Surge Protection Device (SPD)Options

Street Light Electrical System Protection

- LED drivers offer only 6kV/3kA surge protection. Due to this low level of protection roadway lighting product require a separate surge protection device for luminaire longevity.
- Series wired SPDs will cut the power shutting off the luminaire to protect all electrical components, parallel wired SPDs will allow the luminaire to continue to operate.
- Both SPD options are wired off the terminal block to protect all upstream components including the photo control and wireless control modules.
- 20kV options available with LED indicator light to show failure of the SPD Metal Oxide Varistors (MOVs) saving time to troubleshoot.



Example of Catastrophic Event

SPD Options

- 10kV/5kA Parallel – 10MSP
- 20kV/10kA Parallel – 20MSP
- 10kV/5kA Series – 10K
- 20kV/10kA Series w/ or w/o LED indicator - 20K

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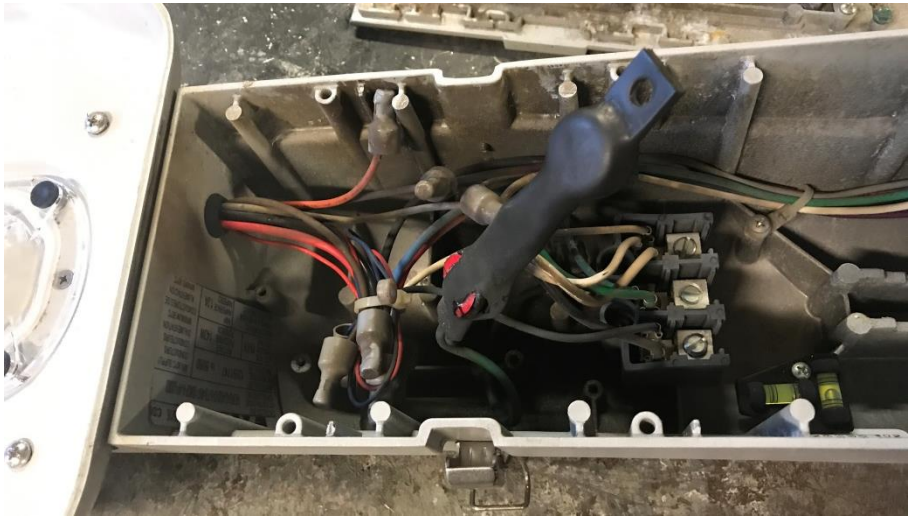
10K or 20K (Series) vs. 10MSP or 20MSP MSP (Parallel)



What's Your Strategy?

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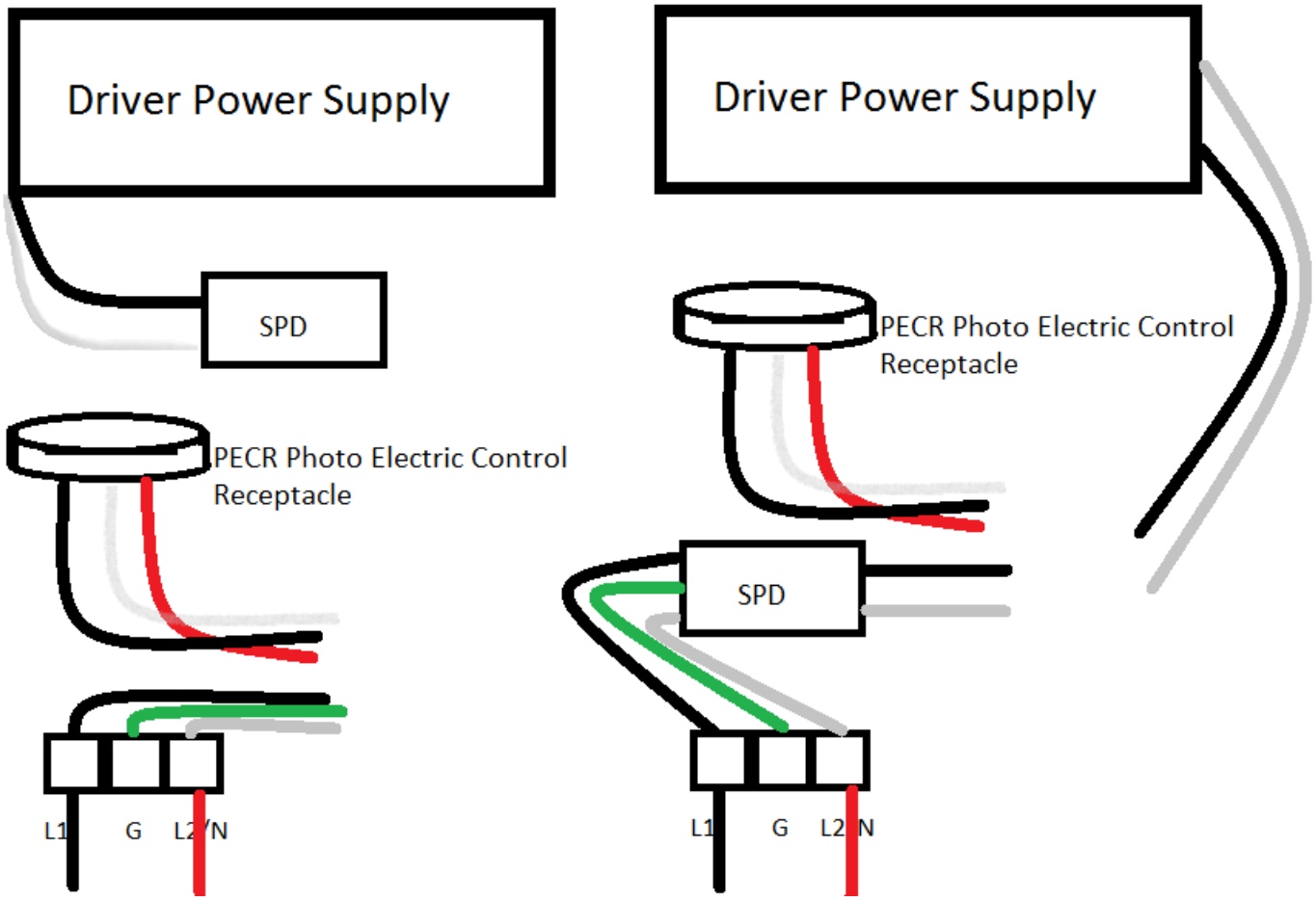
Surge Protection before Downstream Electronics (Controls and Drivers)



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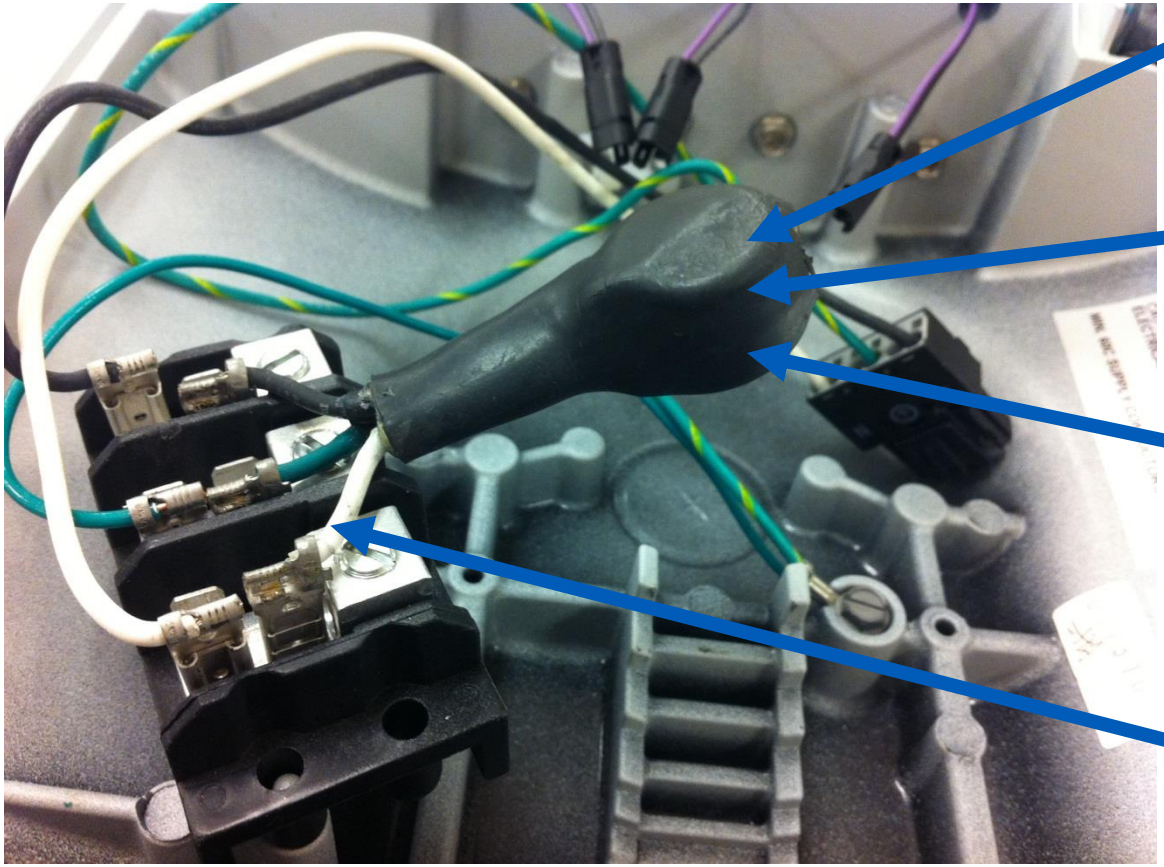
Surge Protector – What to Look For



Does not display a UL or CSA marking; non-compliance with Article 285.5

Does not describe short circuit current rating; non-compliance with Article 285.6

Does not incorporate fusing such that SPD becomes disconnected after MOV failure; non-compliance with Article 285.27

May not be 14AWG Wires; possible non-compliance with Article 285.26

Insufficient protection will reduce fixture life.

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LED Fixtures on 480 Volt Power

- As LED continues to penetrate the outdoor market space more old magnetic HID fixtures will be replaced by LED.
- Many of these HID fixtures are on older Electrical Service configurations that need special SPD consideration.

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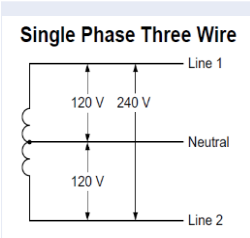
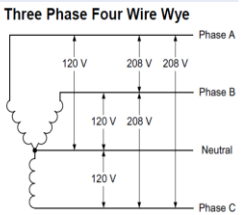
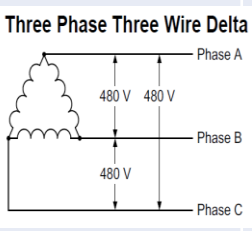
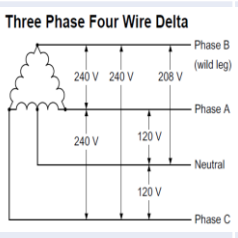
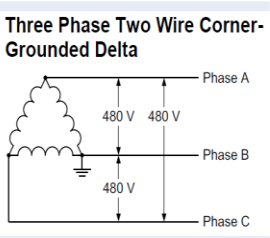
Know Your Circuit Type

Common Electrical Services and Loads					
Typical Terms, Applications and Usages	Also known as an Edison system, split-phase or center tapped neutral, this is the most common residential service in North America	The most common building electric service in North America, in smaller buildings known as the 120/208 volt Wye and in larger buildings as the 277/480 volt Wye	Used Primarily in industrial facilities to power three phase motor loads and in utility power distribution. May also be used for Magnetic HID Lighting.	Also known as high-leg or wild-leg delta. Was used in older facilities for both three phase motor loads and some single phase magnetic or incandescent lighting loads	Used to reduce wiring costs by using a service cable with only two insulated conductors rather than three insulated conductors. Prevalent in older factory and some DOT installations.
Grounded System	Yes	Yes	No	Yes	Yes
Compatible with Magnetic HID	Yes	Yes	Yes	Yes	Yes
Use with Electronic Ballast or Driver	Yes	Yes	Maybe	Maybe	Maybe
Use with Surge Module (SPD)	Yes	Yes	Special	Special	Special

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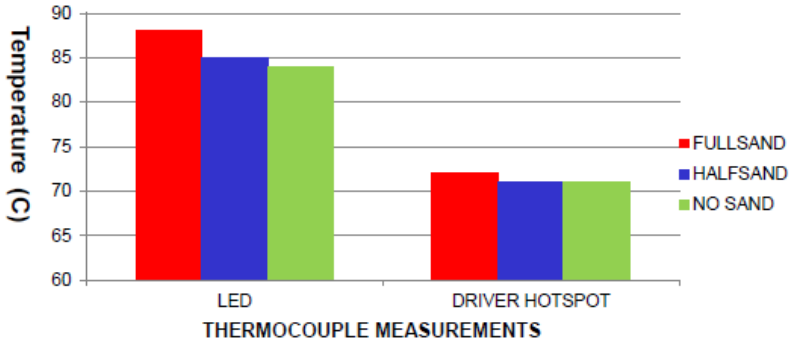
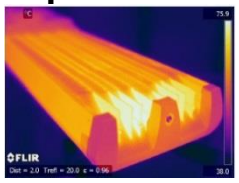
LED Luminaire and Component Testing

- **Reliability System Testing**
  - **Humidity**
  - **Salt Spray**
  - **Water IPX6**
  - **Dust IP6X**
  - **Vibration testing**
  - **UV testing**
  - **Thermal testing on luminaires at -30°C (-30°F) degree to 40°C(104°F) standard, -40°C to 50°C for certain models.**
  - **Thermal testing on components from -40°C to 90°C**
  - **Require UL accredited test laboratory**
  - **DOE approved Lighting Facts Test Laboratory partner**





NO SAND
(RAN TEST FOR 10 HRS)

HALF SAND
(RAN TEST FOR 6 HRS)

FULL SAND
(RAN TEST FOR 9 HRS)

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Ingress Protection (IP) Ratings

1st Digit of IP Rating	1st Digit Detailed Description	2nd Digit of IP Rating	2nd Digit Detailed Description
0	No Protection	0	No Protection
1	Protection against solid objects larger than 50mm	1	Protection against dripping water
2	Protection against solid objects larger than 12mm	2	Protection against dripping water if tilted up to 15°
3	Protection against solid objects larger than 2.5mm	3	Protection against spraying water
4	Protection against solid objects larger than 1.0mm	4	Protection against splashing water
5	Protection against ingress of most dust particles	5	Protection against jet(s) of water
6	Protection against ingress of all dust particles	6	Protection against heavy seas
		7	Protection against immersion for specific time under specific pressure
		8	Protection against continu-ous submersion in water

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ANSI C136 Exterior Label

- C136.15 - American National Standard for Roadway and Area Lighting Equipment – Luminaire Field Identification

  - Marker shall have black letters on a white background
  - Arithmetically rounded to the nearest multiple of 10
  - Standard either 1” square or 3” square
  - Example

    54 Watt Luminaire becomes “50”

    55 Watt Luminaire becomes “60”

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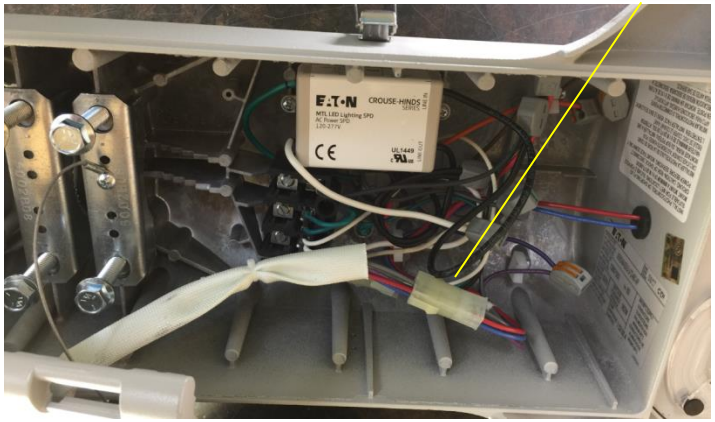
Lineman friendly features for quick and easy installation and maintenance

Tool-less Access
Stainless steel latches provide easy, tool-less access to the electrical compartment, even with lineman's gloves.

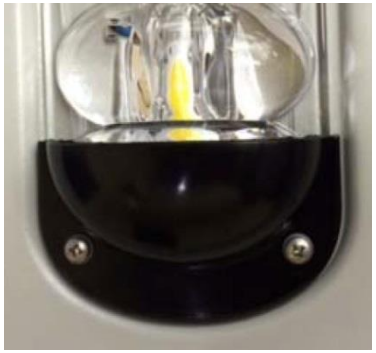
Hinged, Removable Power Door
Driver is mounted to door. Integral hinge allows door to hang securely while making wire connections and can be easily removed without the use of tools.

Driver tray quick disconnect



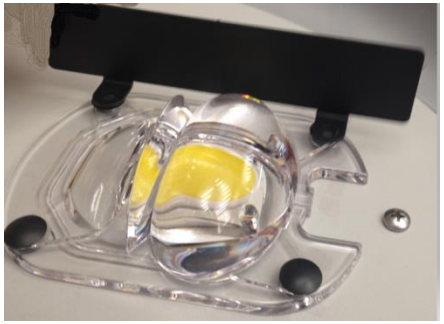
VERD-M electrical chamber with Crouse Hinds 20kV SPD with LED indicator light

Now with WAGO connectors for quick component replacement



Field installed house side light shield

HS-VERD



Field installed side or front vertical light shield.

VGS-F/B – Front or Back

VGS-SIDE – Side only

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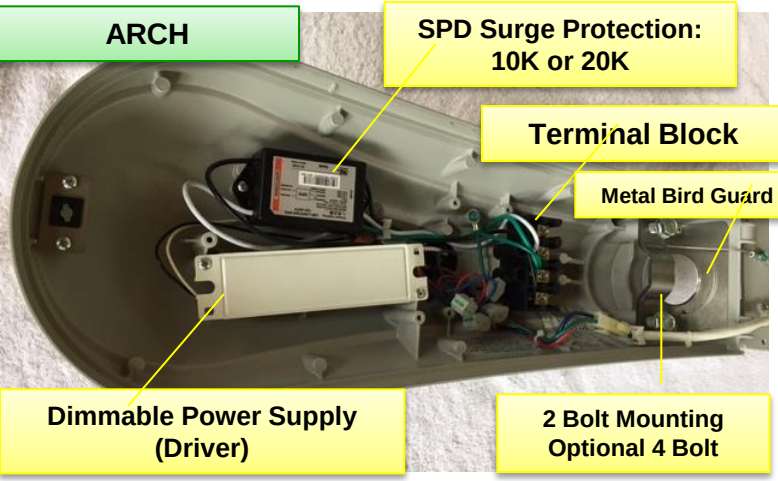
Mechanical Features and Component Replacement

ARCH

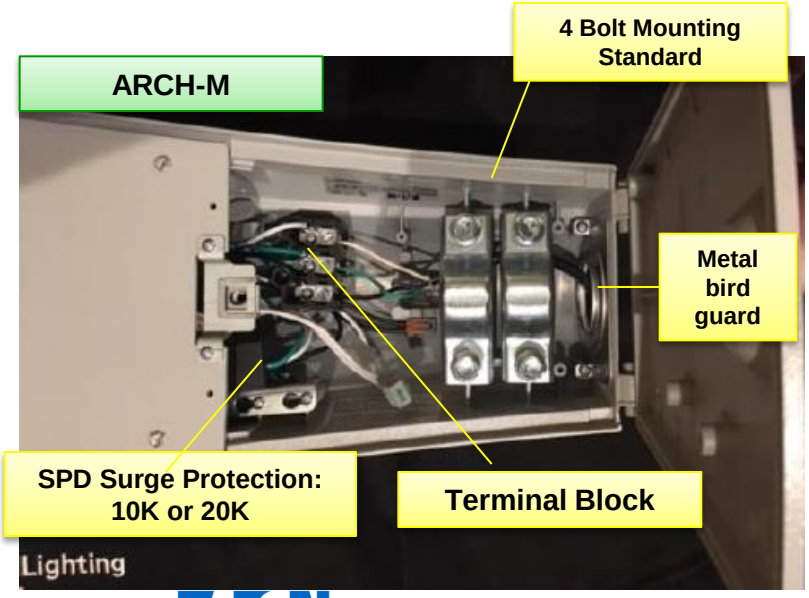


ARCH small

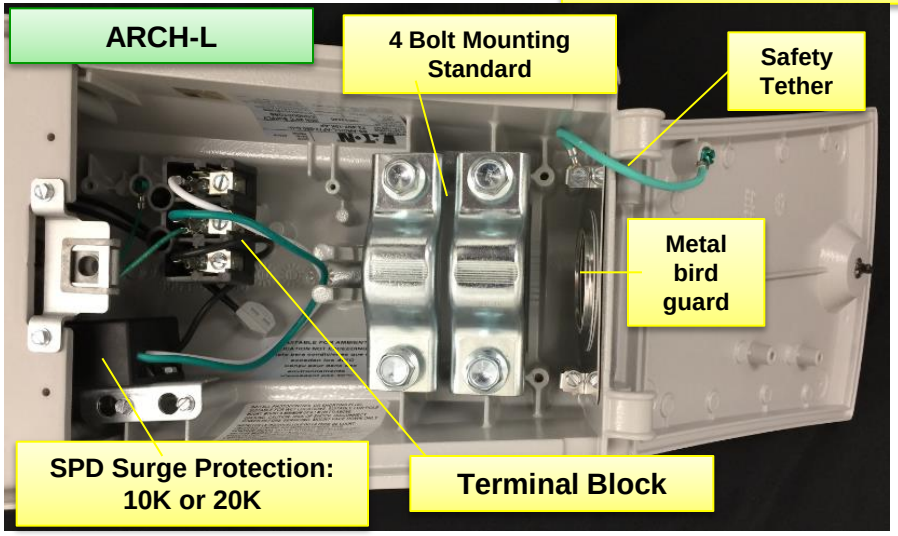
WAGO electrical connectors to driver and surge module for easy component replacement

- **HS-ARCH-16 –** House side shield for 16 LED optic
- **HS-ARCH-24 –** House side shield for 24 LED optic

ARCH-M



ARCH-L



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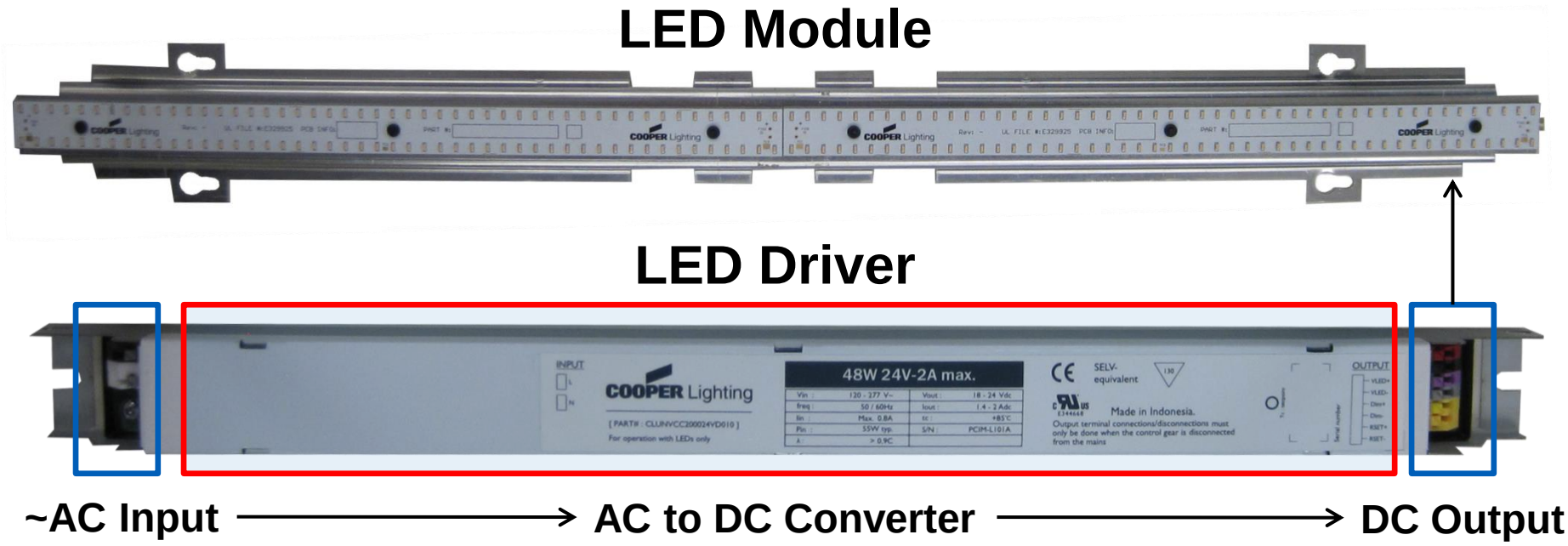
What is an LED Driver?

An LED driver consists of one or more electronic components to limit voltage/current applied to the LED. Generally, alternating current (AC) voltage is converted into direct current (DC) which *drives* the LEDs based on design.



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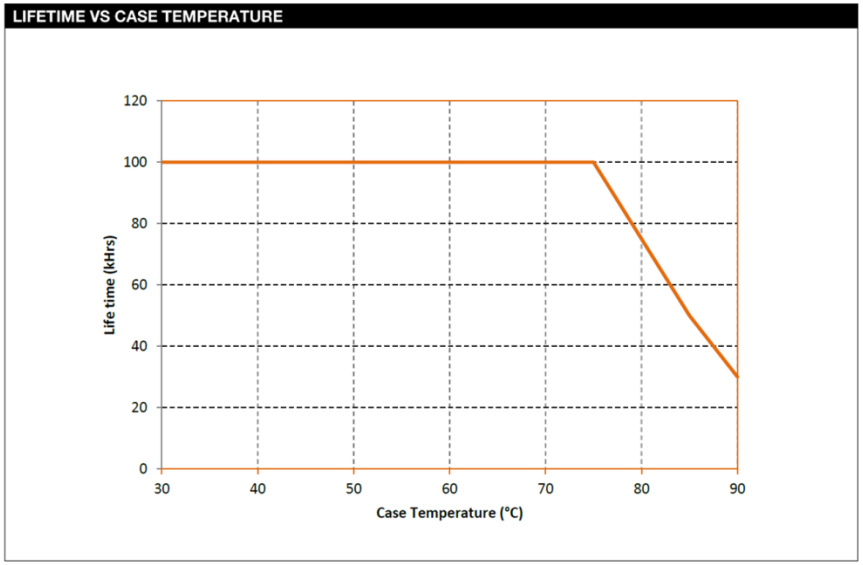
LED Driver or Power Supply

- Driver specification sheet shows 100,000 Lifetime when operating < 75 °C
  - Driver Max Temp 90°C
  - Driver Warranty 85°C
- Driver is standard with 6kV Transient Protection ANSI C62.41 Category B



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Class 2 LED Driver

PHILIPS

UL Class 2

PHILIPS ADVANCE

- UL Class 2 rating represents compliance with standard UL1310
- UL Class 2 rating means output is considered safe to contact and no major safety protection is required at LED/luminaire level
- UL Class 2 has the following electrical restrictions:
  - Maximum output current: 5Adc
  - Maximum output voltage: 60Vdc (dry); 30Vdc (damp/wet)
  - Maximum output power: 100W
- Any LED Driver used for Signage applications must be listed in the UL Sign Components Manual
- As component of an LED system, an LED Driver is not listed but recognized by UL (c UL us)

Solid State Lighting North America, June 2009

XITANIUM LED DRIVERS

LED luminaires with Class 2 drivers can use an acrylic lens.

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Class 1 LED Driver

PHILIPS

UL Class 1

PHILIPS ADVANCE

- LED Drivers with output outside the range required by UL1310 (Class 2) need to comply with standard UL1012
- Under this standard, LED Drivers are considered UL Class I devices
- An LED Driver with UL Class I rating means its output is considered "high voltage" and safety protection is required within the fixture
- Fluorescent and HID ballast fall under this category
- Also as a component of an LED system, an Class I LED Driver is not listed but recognized by UL (c UL us)

Solid State Lighting North America, June 2009

XITANIUM LED DRIVERS

1

Class 1 LED luminaires will have a glass or polycarbonate lens

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Example of Test Results of In Situation Tc

Eaton Archeon Series Cobrahead

Driver Tc Measurement of 75 C

RESULTS

LED LUMINAIRE:

The input current and voltage was measured and recorded in the table below both at the beginning and end of the temperature test:

Beginning Input Voltage (V):	119.90
Beginning Input Current (A):	0.71
Beginning Input Wattage (W):	85.50
Ending Input Voltage (V):	120.20
Ending Input Current (A):	0.69
Ending Input Wattage (W):	82.60
Test Start Date:	2017-03-07
Test Start Time:	8:13:24 AM
Test Stop Date:	2017-03-07
Test Stop time:	3:43:27 PM

The ending current measurement [was] ~~[was not]~~ within 10 percent of the beginning current measurement.

LAB TECH: Contact engineer if there is a 10% or greater difference in the current measurements.

	Housing Cat. No:	ARCHEON	Trim	Limit
	Housing manufacturer:	EATON		
			Temp. °C	
	Thermocouple Location			
1	DRIVER Tc		75	90
2	DRIVER .5 IN FROM LINE IN		78	90
3	DRIVER .5 IN FROM LINE OUT		83	90
4	LM80 LED TC point CENTER DIODE NEAR DRIVER		94	105
5	LM80 LED TC point END DIODE NEAR DRIVER		91	105
6	PRINTED WIRING BOARD NEAR DRIVER		92	105
7	VID CASE		75	85
8	FIXTURE AMBIENT NEAR SPD		68	85
9	connector in driver compartment		74	90
10				
11				
12				
13				
14				
15				
16				
17				

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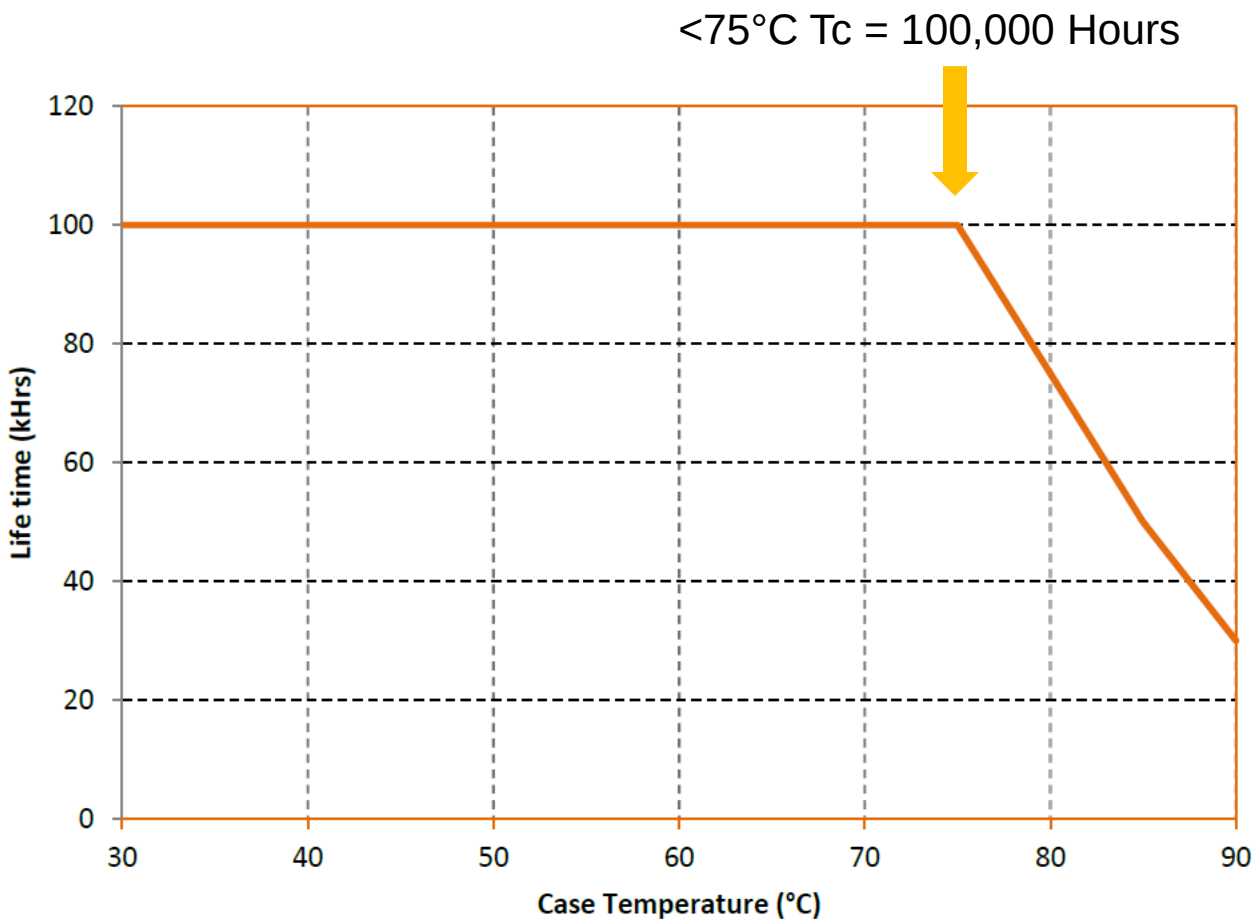
Lifetime vs Case Temperature

LIFETIME VS CASE TEMPERATURE



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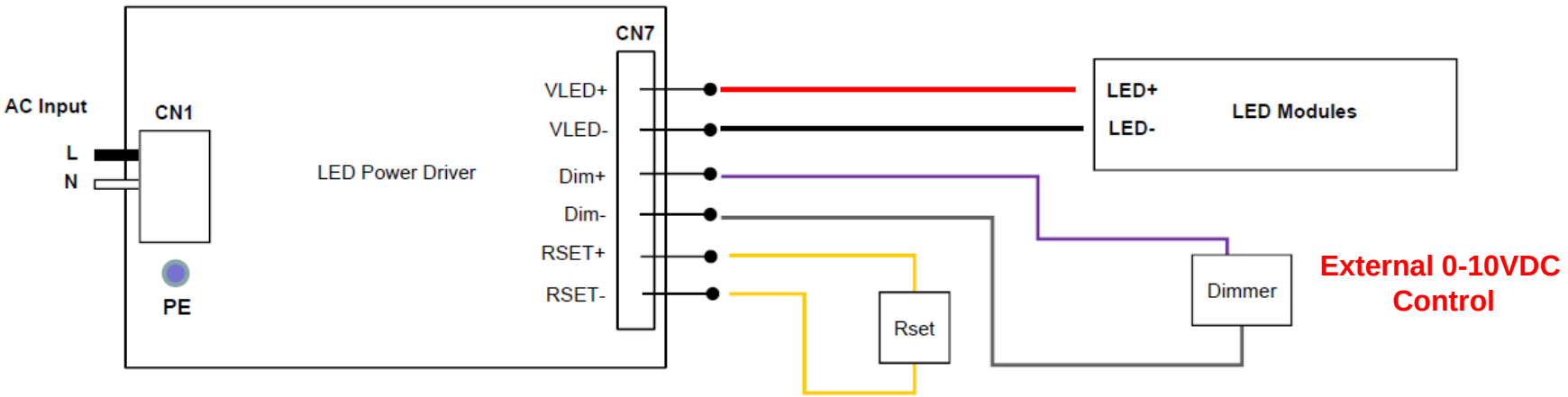
Dimming

Similar to other light sources, LEDs are dimmed by reducing the current. The two most common methods of dimming are *line voltage* and *0-10VDC*. The wallbox dimmers are the same for LED as it is for incandescent or fluorescent.

Typical Wiring for 0-10V Dimming Driver



LEDs are capable to be dimmed to very low levels, <1%

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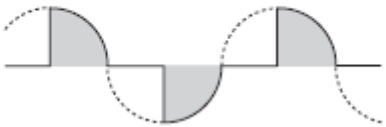
Dimming

Line Voltage

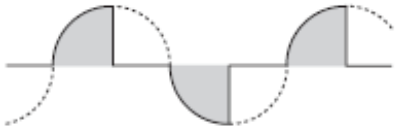
Line voltage dimming involves modifying the AC voltage waveform at the input to the LED driver. Leading edge type is the most common type of dimmer available in the world.

Standard phase control or "leading edge."



Advantages:
Low cost, availability
Disadvantages:
Inconsistent dimming
Main Application:
Residential

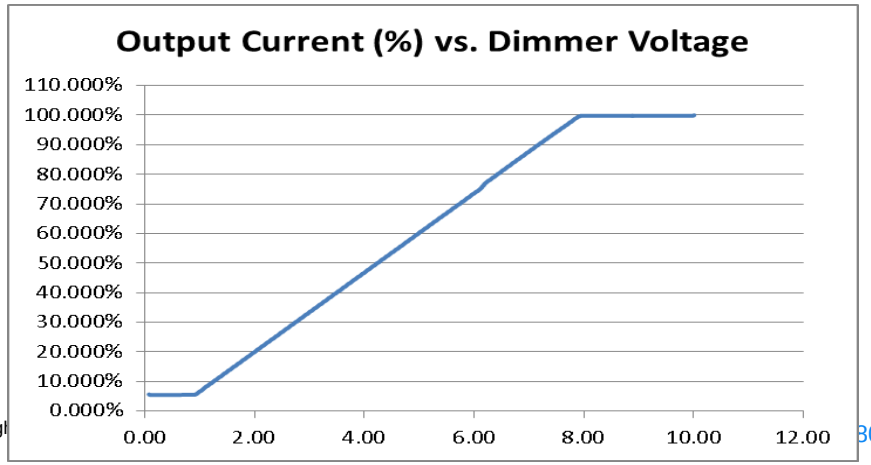
Reverse phase control or "trailing edge."



0-10VDC

Requires a reference voltage for operation, hence the name 0-10VDC. A special dimmer which can either source or sink current interfaces with the driver. Purple (+) and Gray (-) wires.

Advantages:
Consistent dimming, lower levels
Disadvantages:
Higher cost, limited mounting distance
Main Application:
Commercial



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Driver Features - DALI

Digital Addressable Lighting Interface (**DALI**) is a trademark for network-based systems that control lighting in building automation. The underlying technology was established by a consortium of lighting equipment manufacturers as a successor for 0-10 V lighting control systems, and as an open standard alternative to Digital Signal Interface (DSI), on which it is based.

Offers:

- Dimming
- Data storage – used in some NLC systems for self commissioning
- Data bus communications

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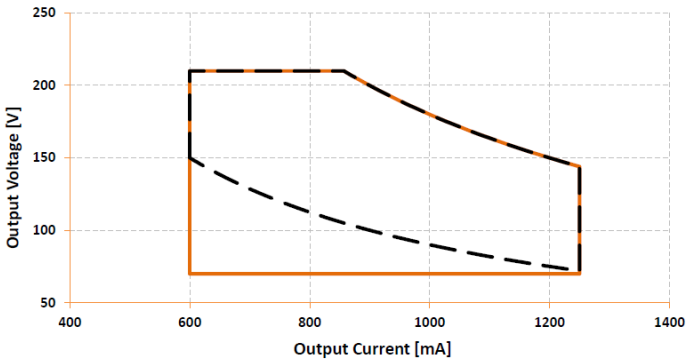
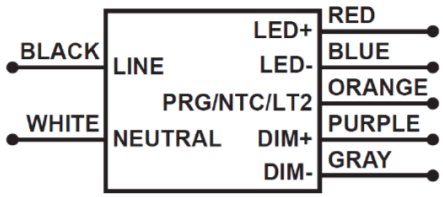
Driver Features - Programming

Output	
Output Current (mA)	600-1250mA 1mA resolution (programmable)
Output Voltage (VDC)	70-210VDC
Output Ripple Current	<30% @ 1250mA
Max. Output power (W)	180W (model dependent)
LED Power-up time	< 0.5sec
Load Regulation	<5%
Line Regulation	<5%
Over voltage protection	Yes, non- latching
Over load protection	Power fold back @185W
Output short-circuit protection	Yes, non- latching
Dimming	
Dimming Control	0 – 10V (Isolated)* AstroDIM
Dimming Range	10-100% (50mA min)
Dimming Type	Analog
Source/Sink Current	1mA

OPERATING RANGE



WIRING DIAGRAM



Note 1: Maximum suggested remote mounting distance is 32 feet. For additional information on further distances and EMI compliance reference application note LED126.

Note 2: The Dimming input is isolated and will allow Class 2 or non-Class 2 wiring across Purple and Gray wires

With programming tool this driver can be programmed from 600mA to 1250mA

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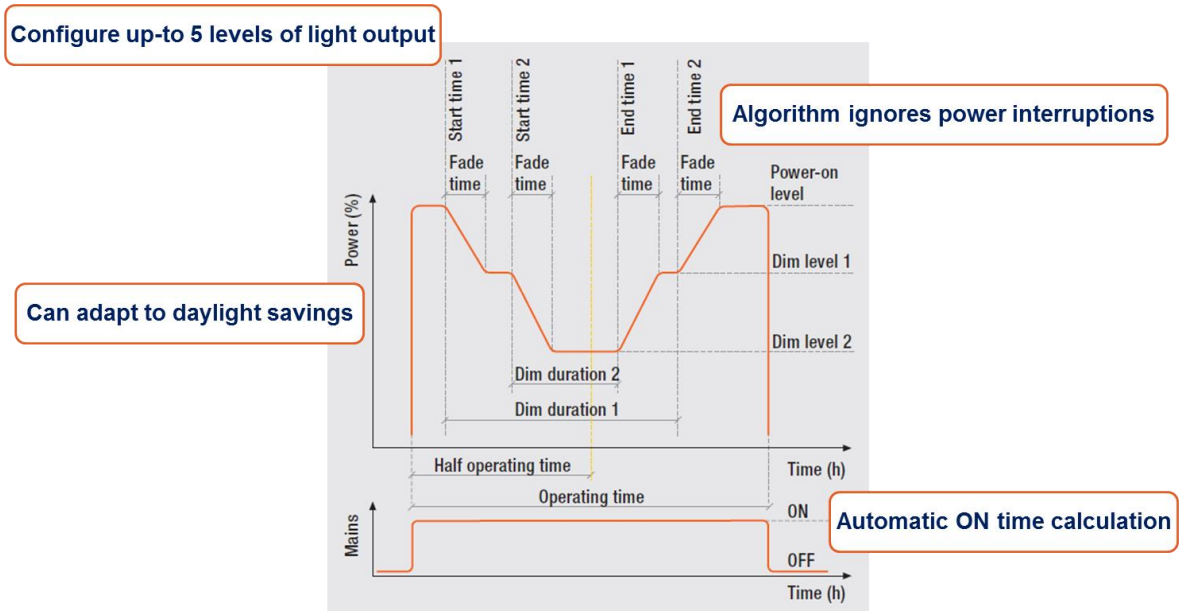
Driver Features – CLO and AHD

Constant Lumen Output (CLO) – driver can be programmed to increase current over time to compensate for lumen depreciation

After Hours Dimming:



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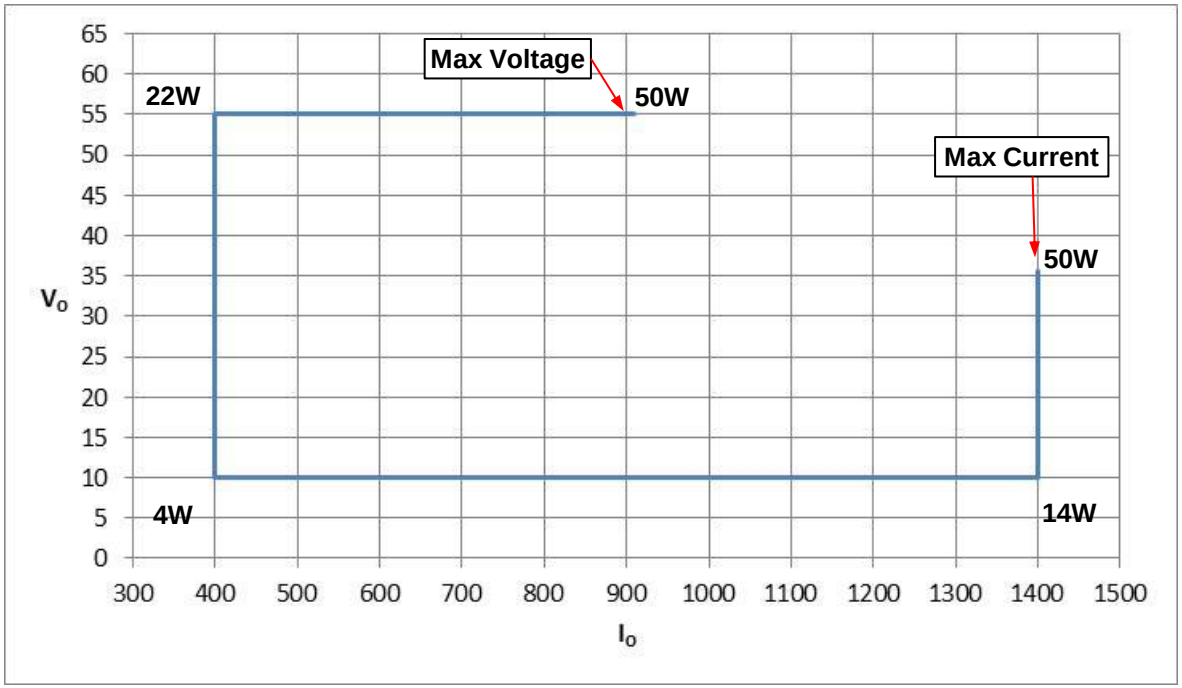
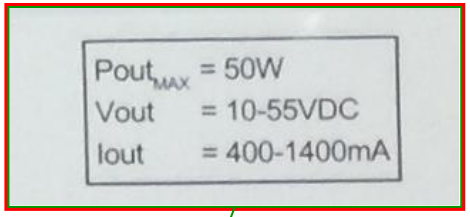
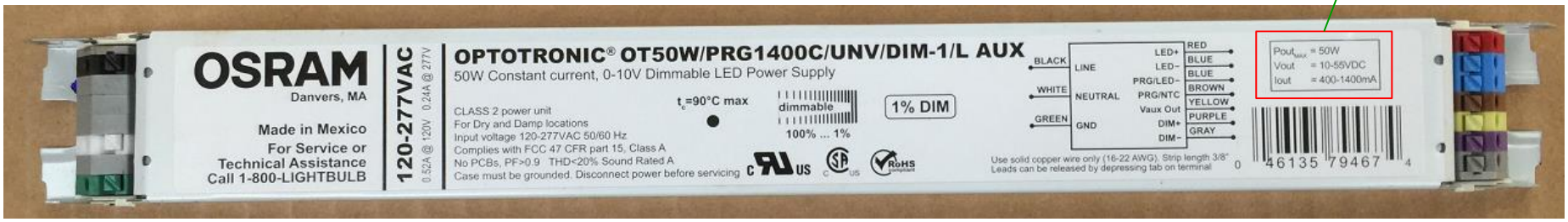
Interpreting the Driver Spec – Power Envelop







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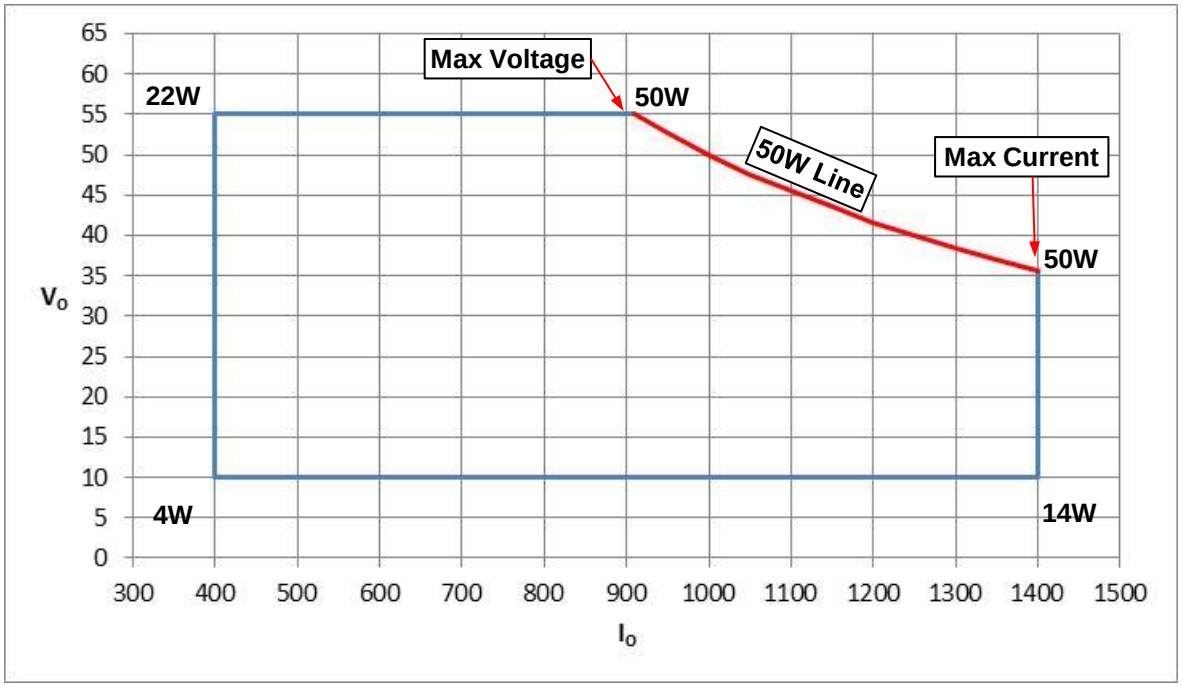
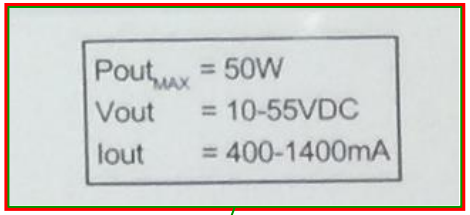
Interpreting the Driver Spec – Power Envelop





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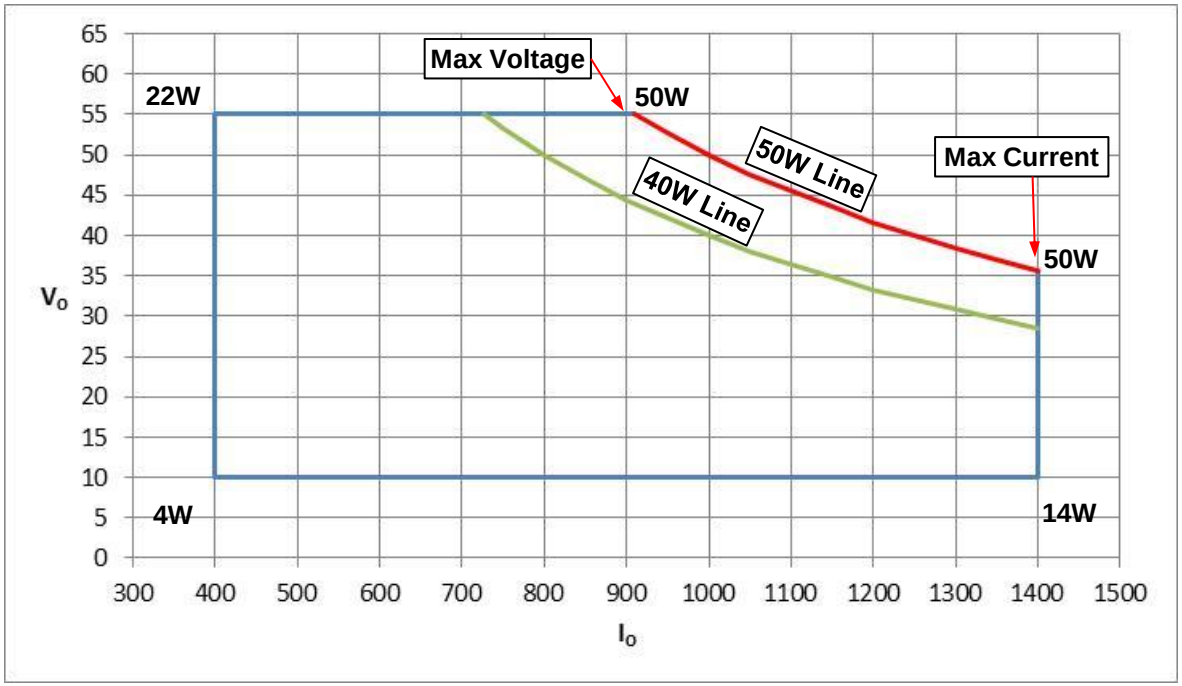
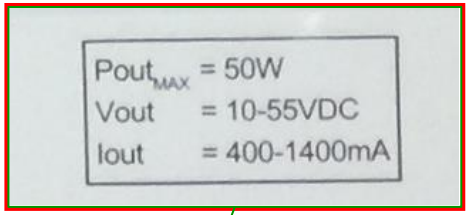
Interpreting the Driver Spec – Power Envelop





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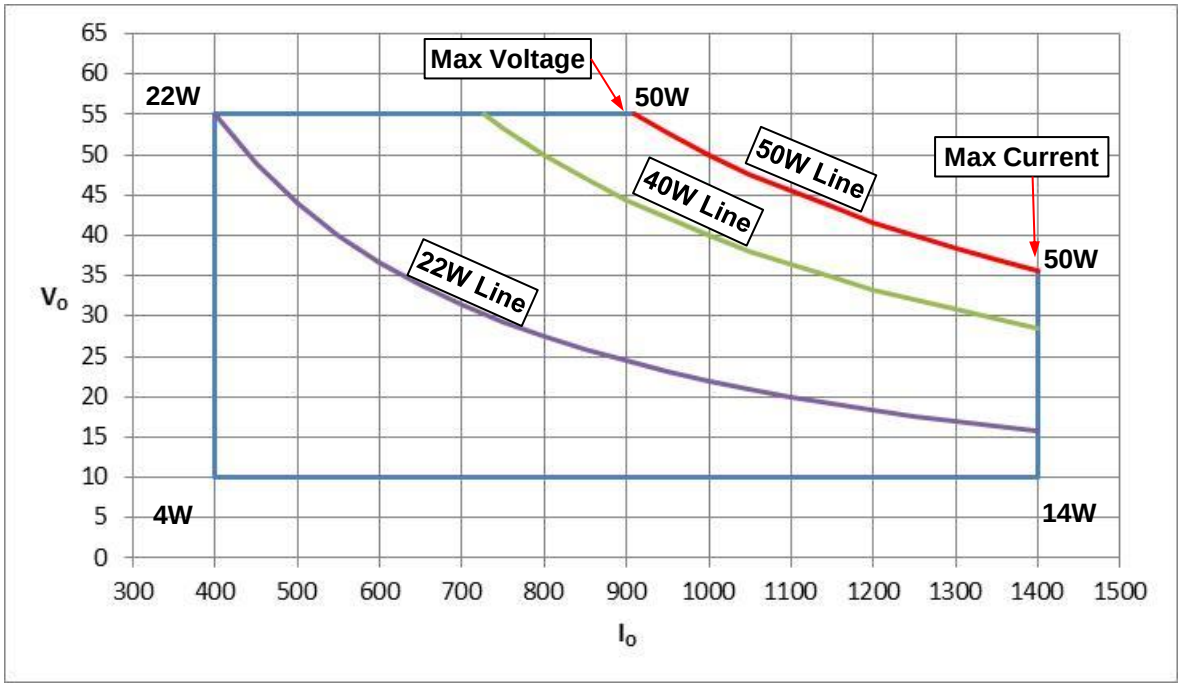
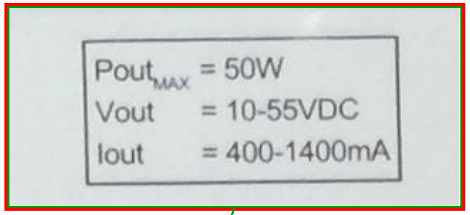
Interpreting the Driver Spec – Power Envelop





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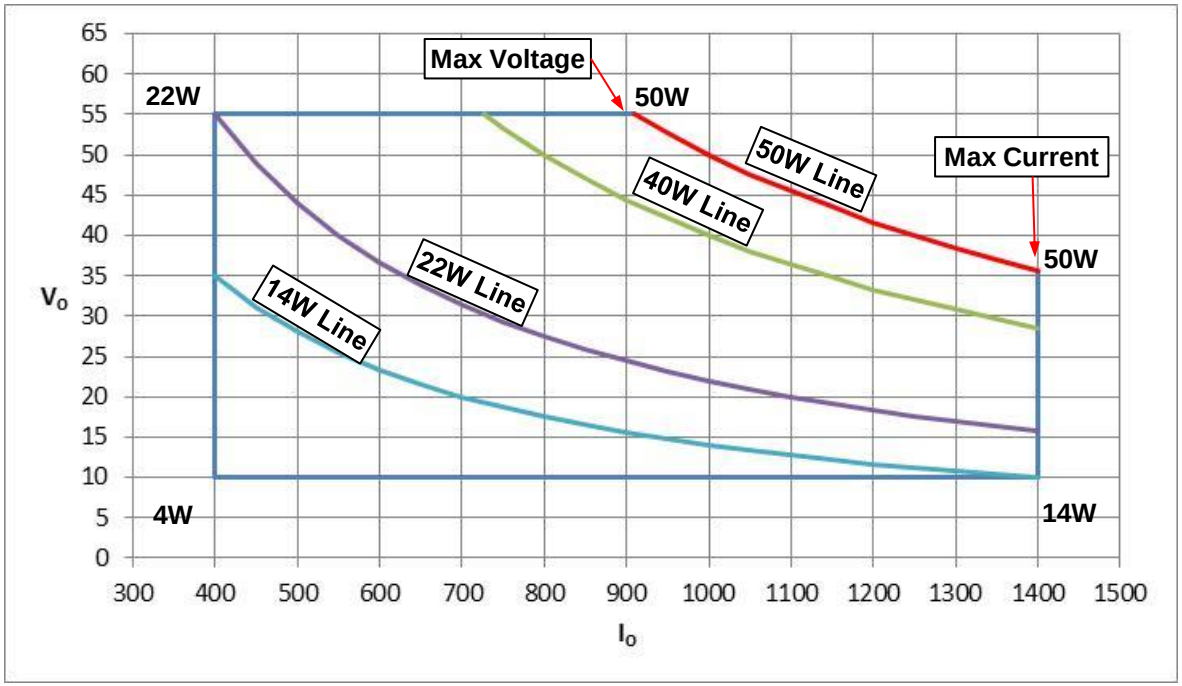
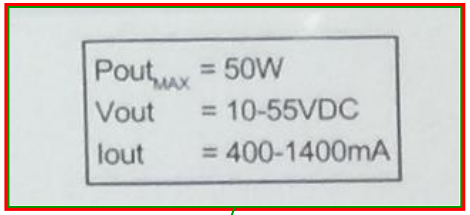
Interpreting the Driver Spec – Power Envelop





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LED Driver – Power Factor, Basic Definition

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LED Driver – Power Factor, Basic Definition

$$PF = \frac{P_W}{P_{VA}} = \frac{Real\ Power\ (W)}{I_{RMS}\ .V_{RMS}\ (VA)}$$

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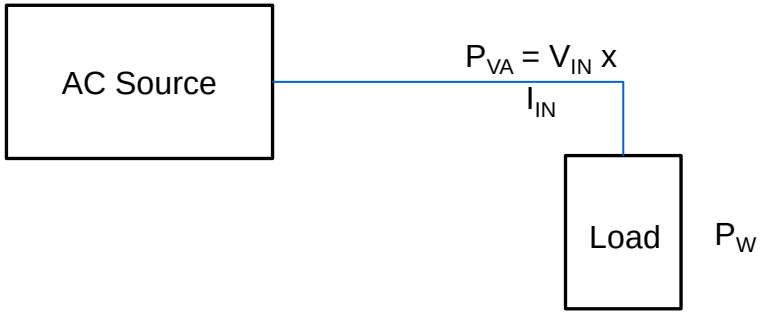
LED Driver – Power Factor, Basic Definition

$$PF = \frac{P_W}{P_{VA}} = \frac{Real\ Power\ (W)}{I_{RMS}\ .V_{RMS}\ (VA)}$$

P_W is the actual power in watts that is dissipated by load

P_{VA} is the product of the measured input AC voltage and current to the load



Minimum Power Factor requirement

Residential: 0.7

Commercial: 0.9

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LED Driver – Input Current Distortion, THDi

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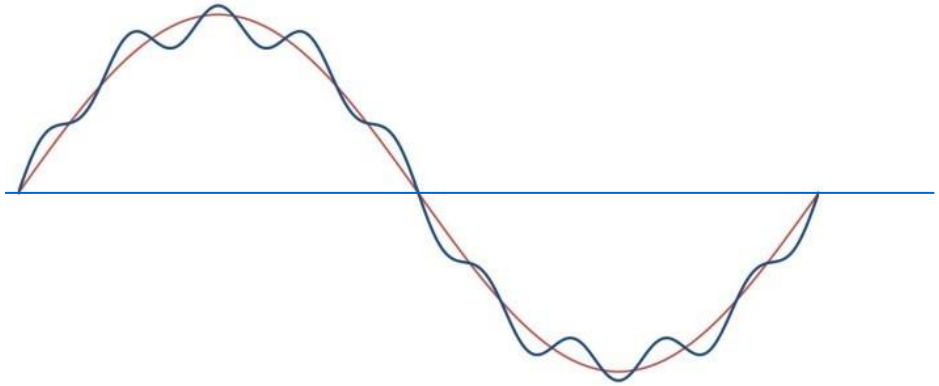
LED Driver – Input Current Distortion, THDi

Definition: Distortion is a measure of the deviation from a pure sine wave.

Deviation from a pure sine wave happens when Harmonics are introduced

Harmonics are higher frequency sine wave components of the fundamental 60 Hz



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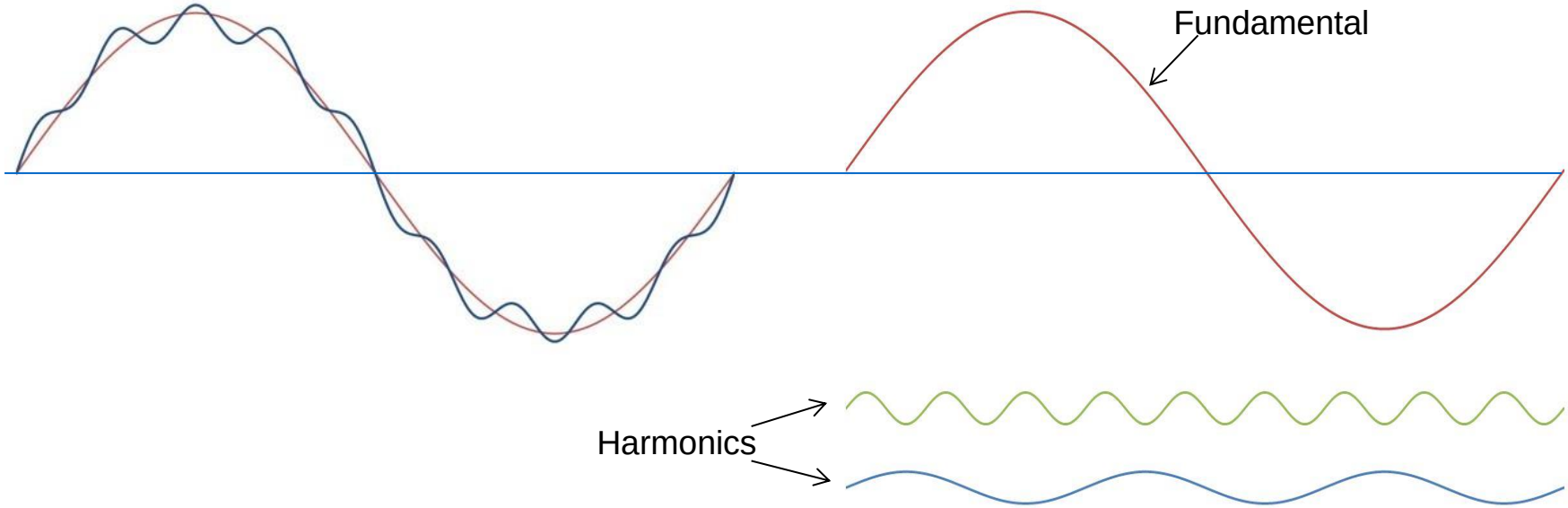

$$THD(\%) = \frac{\sqrt{sum\ of\ all\ squared\ harmonics}}{fundamental} \times 100 = \frac{\sqrt{\sum {I_i}^2}}{I} \times 100$$

Maximum input current distortion allowed by DLC is 20%

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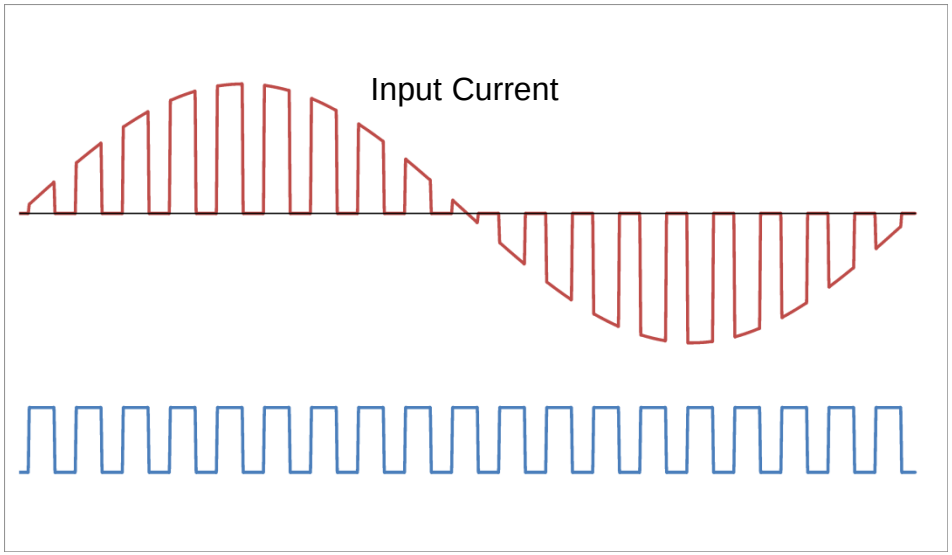
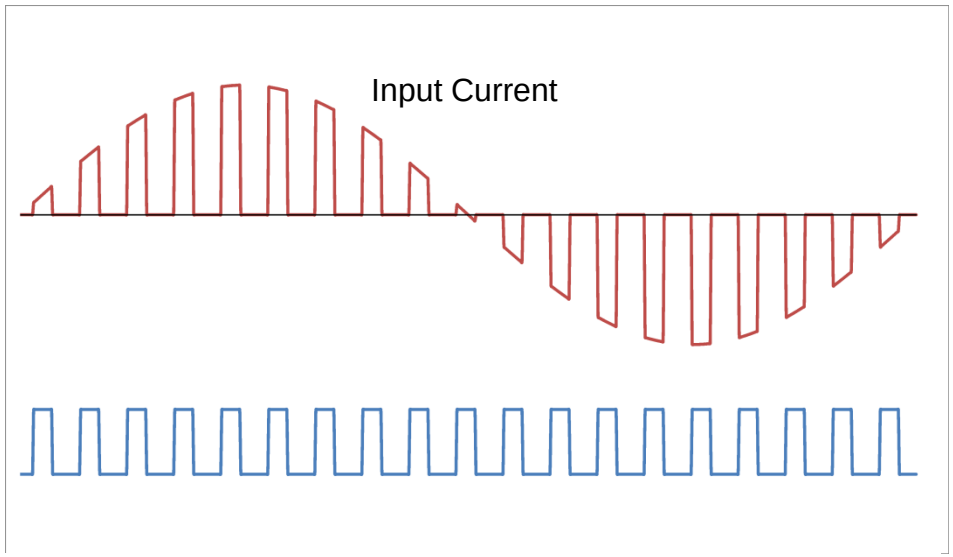
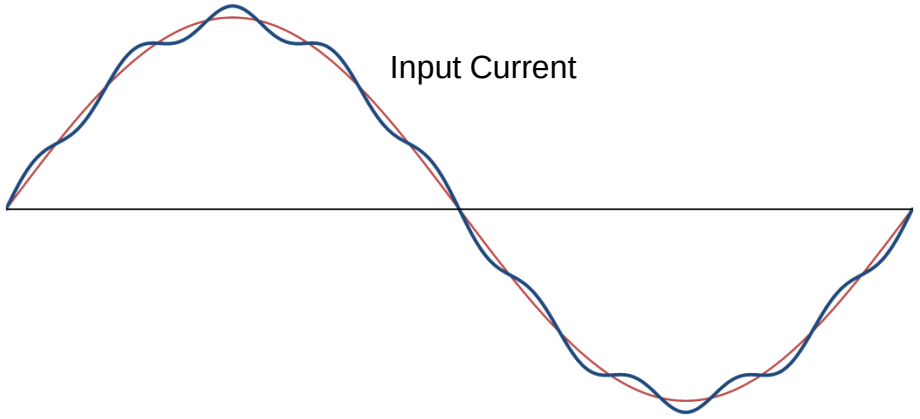
LED Driver – Input Current Distortion, THDi



108V Input



132V Input



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LED Driver – Efficiency

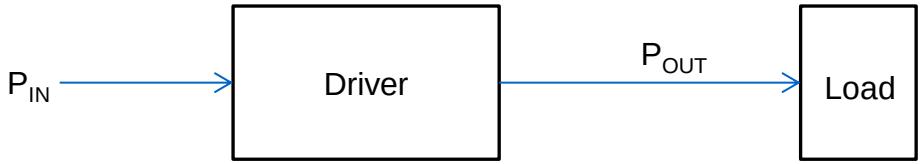
The ratio of output Power to Input power at full load.

$$Efficiency\ (\%) = \frac{Output\ Power}{Input\ Power} \times 100$$

An isolated (class 2) Flyback Converter can be as high as 90% efficient

A driver that is less than 80% efficient is considered inferior

Efficiency is a trade off between cost, performance, availability, thermal limit and reliability



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LED Driver – Regulation

Regulation is a measure of how well a driver output stays on target as conditions change

$$Regulation\ (\%) = \frac{Change\ in\ Output}{Target\ Output} \times 100 = \frac{I_{Max} - I_{Min}}{I} \times 100$$

The output may change due to Line voltage, load, temperature or frequency

Regulation less than 5% is considered good

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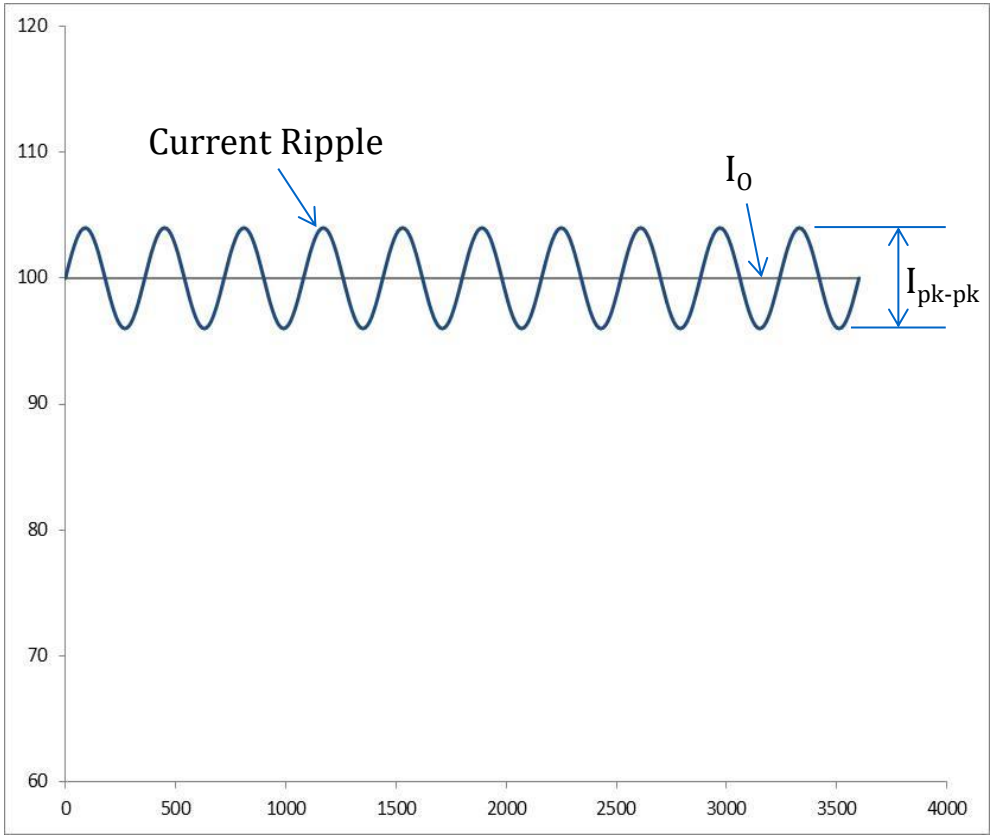
LED Driver – Output Ripple Current

Ripple is a measure of the quality of the output



$$Ripple(\%) = \frac{Maximum\ swing\ of\ output}{Target\ Output} \times 100 = \frac{I_{pk-pk}}{I_O} \times 100$$

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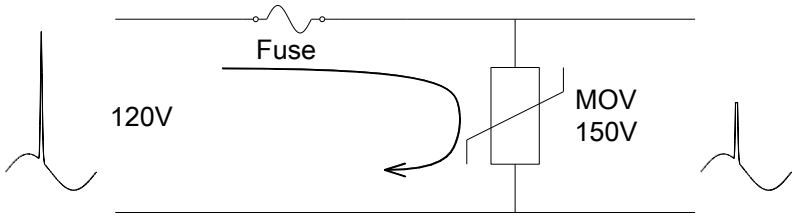
LED Driver – Surge

- Voltage Surge is a brief increase in voltage.
- Lightning Strikes are the main cause of voltage surge
- Surge voltage can reach several thousand volts



- May result in a high inrush current from hundreds to several thousand Amps
- Surge Suppressors (MOV) are used to clamp the surge voltage to a safe level

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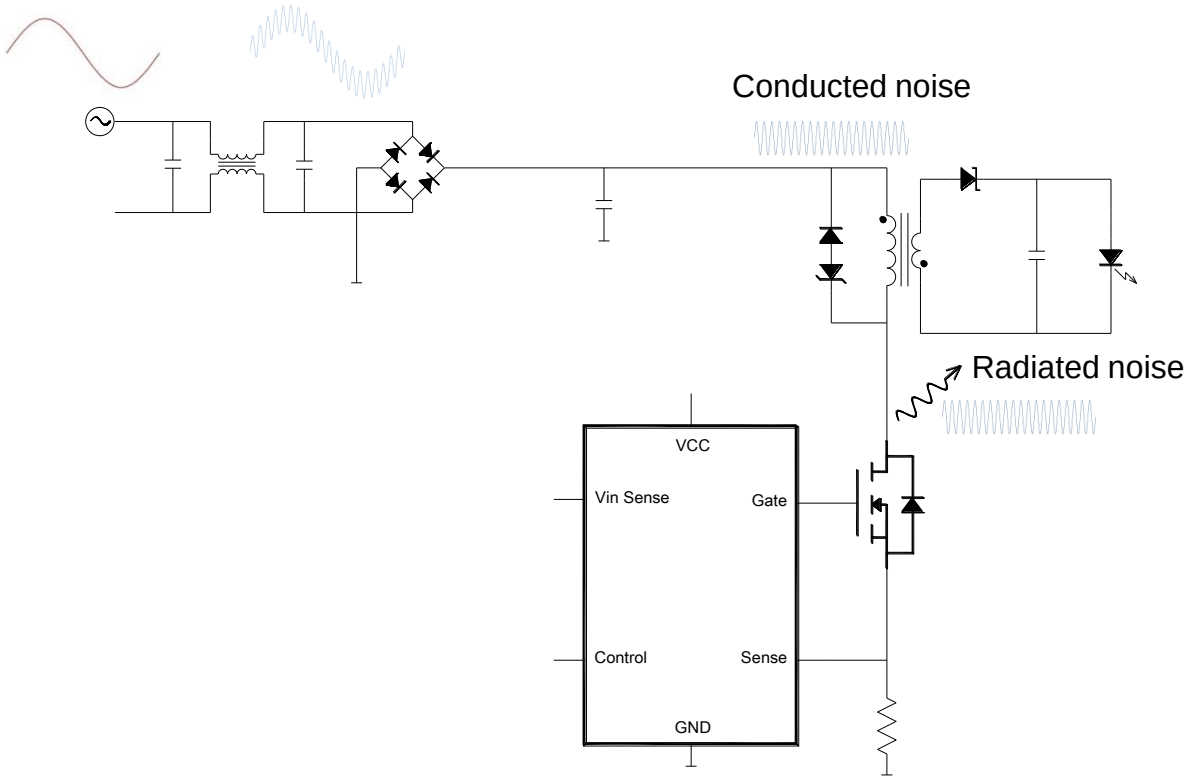
LED Driver – EMI

High Frequency Switching Current is radiated and conducted to the outside world causing radio interference.



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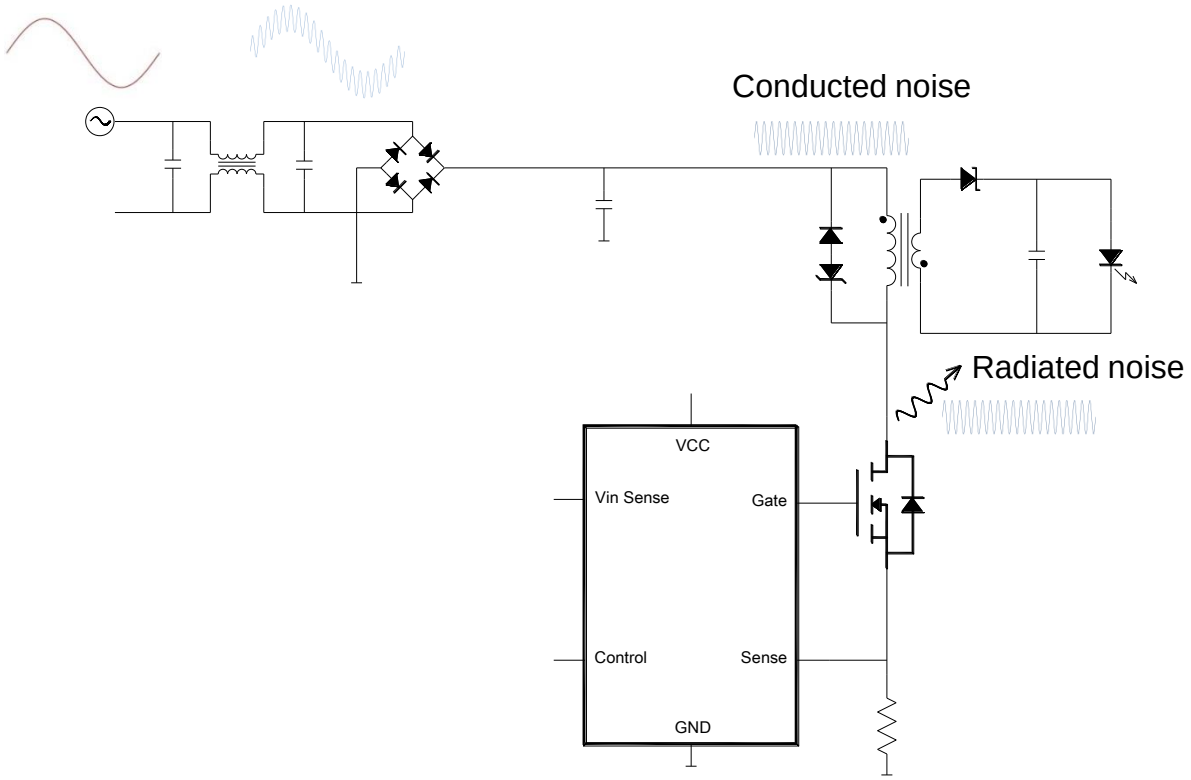
LED Driver – EMI

High Frequency Switching Current is radiated and conducted to the outside world causing radio interference.

An EMI filter is used to decouple the high frequency switching current from line

FCC Regulates Radio Interference



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Inrush Current of LED Driver

- What is it? Current need to charge front end of driver (capacitors)
- It's a known quantity:

ELECTRICAL SPECIFICATIONS		
Input		
Input Voltage (VAC)	120V-277V (+/- 10%)	
Frequency Range (Hz)	50 – 60 Hz (+/- 10%)	
	120V	**277V**
Input Current (A)	1.7	0.75
THD @ Full load	<15%	<20%
Power Factor @ Full load	>0.95	>0.95
Efficiency @ Full load	≥88%	≥90%
Inrush Current (A_{pk})	44A, 190 µs	131A,190µs

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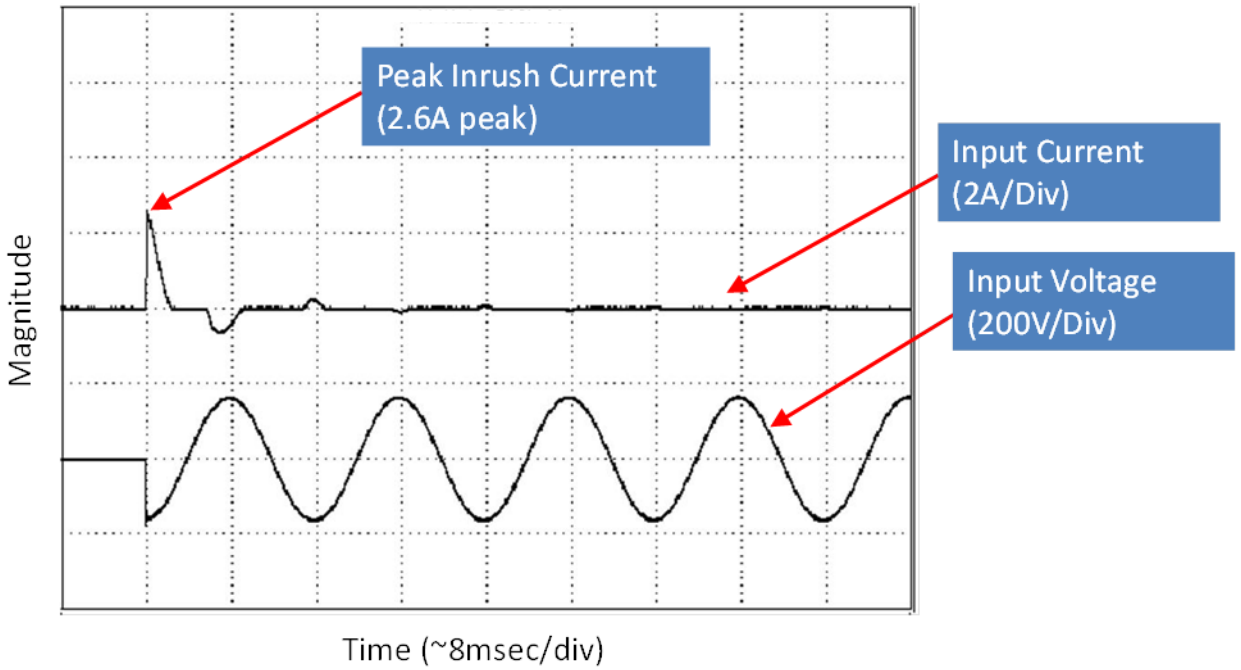
What does Inrush Current look like?



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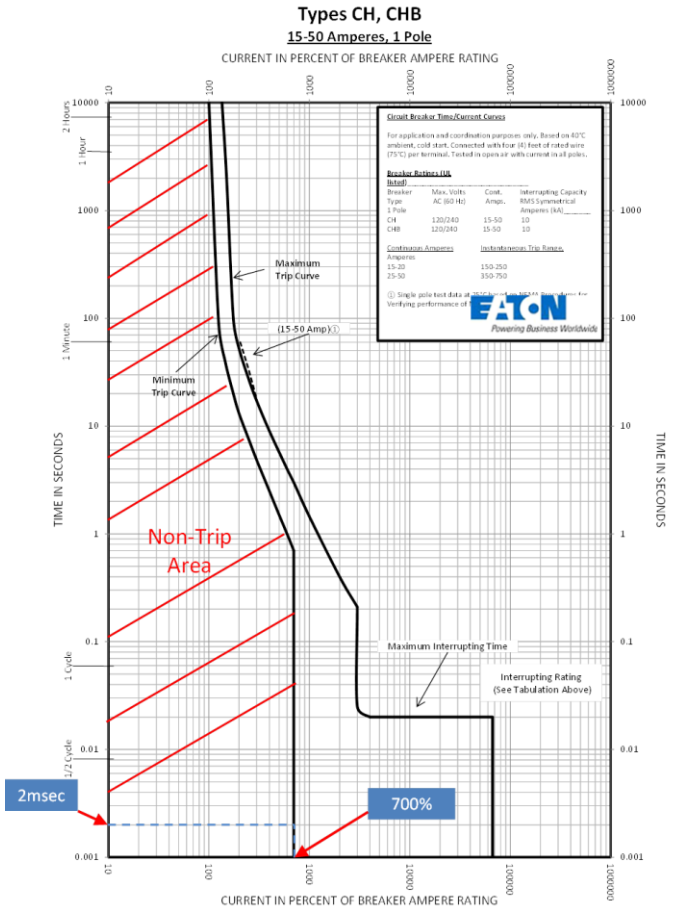
Inrush Current of LED Driver

- What to do? Add up the inrush currents on the circuit and make sure your circuit breaker can handle it



Max Input Power Rating: 60W (or 0.5A average steady-state per luminaire at 120V input)

Inrush Current: 2.6A peak for 2msec (per Figure 1)

The designer wants to know how many luminaires can be placed on the 15A breaker and not exceed 12A while at the same time, preventing false tripping due to inrush current. Knowing that each luminaire draws 0.5A you can calculate 24 luminaires will draw 12A steady-state current. But, will there be an issue with inrush current? To investigate let's use the same Eaton CH breaker shown in Figure 3. The duration of the inrush current is 2msec. The minimum breaker trip curve is at 700% of rated breaker current or 105A (15A x 700%). 24 luminaire each with 2.6A peak of inrush current is 62.4A. Therefore the design will work as expected without any nuisance tripping due to inrush!

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Archeon ARCH S Series Roadway

Streetworks

Catalog #		**Type**	
Project			
Comments		**Date**	
Prepared by			

DESCRIPTION

The Archeon™ Small LED roadway luminaire delivers all the performance benefits of the latest Eaton LED platforms and technologies with a modern, yet familiar cobrahead form factor. This discrete LED solution with the patented, high-efficiency AccuLED Optics™ system, provides uniform and energy conscious illumination for municipal streets and highways. Our customer focused features include single latch tool-less entry, industry leading surge protection options and superior lumen maintenance and performance, all in an economical design. Available in 14 standard lumen packages per optic making it the ideal LED replacement for any application of 50W to 150W HPS cobraheads.

SPECIFICATION FEATURES

Construction
Heavy-duty die-cast aluminum housing and door. Tool-less entry, hinged removable door for easy maintenance. 3G vibration rated.

Optics
Choice of four patented, high-efficiency AccuLED Optics . Available in Type IIR, III, IV wide and V square wide the optics are precisely designed to shape the distribution maximizing efficiency and application spacing. Offered standard in 4000K (+/- 275K) CCT and minimum 70 CRI. Optional 3000K, 5000K CCT. For the ultimate level of spill light control, an optional house side shield accessory is available and can be field or factory installed. The house side shield is designed to seamlessly integrate with the T2R, T3, and T4W optics. Optics are IP66 enclosure rated.

Electrical
120-277V 50/60Hz, 347V 60Hz or 480V 60Hz operation. Standard 0-10V dimming and 10kV/10kA common- and differential- mode surge protection available. Thermal management transfers heat away from the LED source for optimal efficiency, light output and lumen maintenance. Ambient operating temperature from -40°C to 40°C; 50°C HA, high ambient, capability available. Standard with three-position tunnel type compression terminal block. Greater than 90% lumen maintenance expected at 60,000 hours.

Mounting
Two-bolt/one-bracket slipfitter with cast-in pipe stop and 2.5° leveling steps. Fixed-in-place bird guard seals around 1-1/4" to 2" (1-5/8" to 2-3/8" O.D.) mounting arms. Optional 15° pole mount arm available with round pole adapter and mounting hardware included.

Finish
Housing and cast parts finished in five-stage super TGIC polyester powder coat paint, 2.5 mil nominal thickness for superior protection against fade and wear. Consult your lighting representative at Eaton for a complete selection of standard colors.

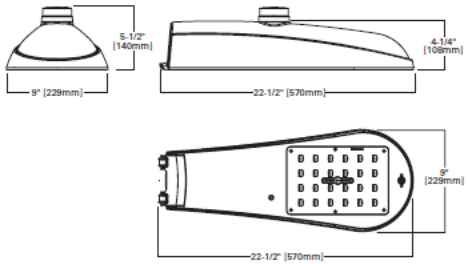
Warranty
Five-year warranty, ten-year optional.

ARCH ARCHEON SMALL

LED

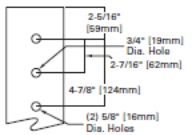
ROADWAY LUMINAIRE

DIMENSIONS

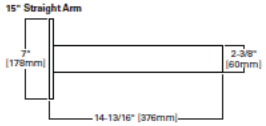


OPTIONAL ARM

TYPE "M" - Drilling Pattern



15° Straight Arm



POWER AND LUMENS (AF16 LIGHT ENGINE)

Light Engine - AF16		AF16-20	AF16-30	AF16-40	AF16-50	AF16-60
Power (Watts)		24	32	42	53	63
Wattage Label		20	30	40	50	60
Input Current @ 120V (A)		0.202	0.266	0.346	0.446	0.529
Input Current @ 277V (A)		0.098	0.124	0.158	0.210	0.241
Input Current @ 347V(A)		-	0.101	0.128	0.159	0.187
Input Current @ 480V (A)		-	0.074	0.094	0.126	0.145
Optics						
T2R	4000K/5000K Lumens	2,996	3,803	4,784	6,010	6,745
	Bug Rating	B1-U0-G1	B1-U0-G1	B1-U0-G1	B1-U0-G1	B1-U0-G2
	3000K Lumens	2,652	3,366	4,235	5,320	5,971
	Bug Rating	B1-U0-G1	B1-U0-G1	B1-U0-G1	B1-U0-G1	B1-U0-G1
T3	4000K/5000K Lumens	2,982	3,785	4,762	5,982	6,713
	Bug Rating	B1-U0-G1	B1-U0-G1	B1-U0-G1	B1-U0-G2	B1-U0-G2
	3000K Lumens	2,640	3,350	4,215	5,295	5,942
	Bug Rating	B1-U0-G1	B1-U0-G1	B1-U0-G1	B1-U0-G2	B1-U0-G2
T4W	4000K/5000K Lumens	2,972	3,773	4,746	5,962	6,691
	Bug Rating	B1-U0-G1	B1-U0-G1	B1-U0-G2	B1-U0-G2	B1-U0-G2
	3000K Lumens	2,631	3,340	4,201	5,278	5,923
	Bug Rating	B1-U0-G1	B1-U0-G2	B1-U0-G2	B1-U0-G2	B1-U0-G2
SWQ	4000K/5000K Lumens	3,037	3,855	4,850	6,092	6,837
	Bug Rating	B2-U0-G1	B3-U0-G1	B3-U0-G1	B3-U0-G2	B3-U0-G2
	3000K Lumens	2,688	3,412	4,293	5,393	6,052
	Bug Rating	B2-U0-G1	B2-U0-G1	B3-U0-G1	B3-U0-G1	B3-U0-G2

LUMEN MAINTENANCE

Model	Ambient Temperature	TM-21 Lumen Maintenance (60,000 hours)	Theoretical L70 (Hours)
AF16 (20-50W) AF24 (20-70W)	Up to 50°C	>95%	416,000
AF16 (60W) AF24 (80W)	Up to 50°C	>90%	205,000
AF24 (90-100W)	Up to 40°C	>90%	205,000

LUMEN MULTIPLIER

Ambient Temperature	Lumen Multiplier
0°C	1.02
10°C	1.01
25°C	1.00
40°C	0.99
50°C	0.97

POWER AND LUMENS (AF24 LIGHT ENGINE)

Light Engine - AF24		AF24-20	AF24-30	AF24-40	AF24-50	AF24-60	AF24-70	AF24-80	AF24-90	AF24-100
Power (Watts)		21	31	40	54	64	74	83	94	96
Wattage Label		20	30	40	50	60	70	80	90	100
Input Current @ 120V (A)		0.179	0.257	0.338	0.450	0.534	0.619	0.695	0.783	0.798
Input Current @ 277V (A)		-	0.122	0.155	0.212	0.244	0.279	0.312	0.347	0.354
Input Current @ 347V(A)		-	0.100	0.125	0.161	0.187	0.217	0.244	0.275	0.280
Input Current @ 480V (A)		-	0.073	0.094	0.127	0.145	0.165	0.184	0.205	0.209
Optics										
T2R	4000K/5000K Lumens	2,859	4,002	5,164	6,658	7,644	8,522	9,209	9,870	9,972
	Bug Rating	B1-U0-G1	B1-U0-G1	B1-U0-G1	B1-U0-G2	B1-U0-G2	B1-U0-G2	B1-U0-G2	B1-U0-G2	B1-U0-G2
	3000K Lumens	2,531	3,543	4,571	5,894	6,766	7,544	8,152	8,737	8,827
	Bug Rating	B1-U0-G1	B1-U0-G1	B1-U0-G1	B1-U0-G1	B1-U0-G2	B1-U0-G2	B1-U0-G2	B1-U0-G2	B1-U0-G2
T3	4000K/5000K Lumens	2,843	3,980	5,135	6,621	7,602	8,475	9,158	9,816	9,917
	Bug Rating	B1-U0-G1	B1-U0-G1	B1-U0-G2	B1-U0-G2	B1-U0-G2	B2-U0-G2	B2-U0-G2	B2-U0-G2	B2-U0-G2
	3000K Lumens	2,517	3,523	4,546	5,861	6,729	7,502	8,107	8,689	8,779
	Bug Rating	B1-U0-G1	B1-U0-G1	B1-U0-G1	B1-U0-G2	B1-U0-G2	B1-U0-G2	B2-U0-G2	B2-U0-G2	B2-U0-G2
T4W	4000K/5000K Lumens	2,825	3,955	5,102	6,580	7,554	8,421	9,100	9,754	9,855
	Bug Rating	B1-U0-G1	B1-U0-G2	B1-U0-G2	B1-U0-G2	B2-U0-G2	B2-U0-G3	B2-U0-G3	B2-U0-G3	B2-U0-G3
	3000K Lumens	2,501	3,501	4,516	5,825	6,687	7,454	8,055	8,634	8,724
	Bug Rating	B1-U0-G1	B1-U0-G1	B1-U0-G2	B1-U0-G2	B1-U0-G2	B2-U0-G2	B2-U0-G2	B2-U0-G3	B2-U0-G3
SWQ	4000K/5000K Lumens	2,905	4,067	5,247	6,766	7,768	8,660	9,358	10,030	10,134
	Bug Rating	B2-U0-G1	B3-U0-G1	B3-U0-G1	B3-U0-G2	B3-U0-G2	B3-U0-G2	B3-U0-G2	B4-U0-G2	B4-U0-G2
	3000K Lumens	2,572	3,600	4,645	5,989	6,876	7,666	8,284	8,879	8,971
	Bug Rating	B2-U0-G1	B3-U0-G1	B3-U0-G1	B3-U0-G2	B3-U0-G2	B4-U0-G2	B4-U0-G2	B4-U0-G2	B4-U0-G2

CERTIFICATION DATA

UL and cUL Wet Location Listed
IP66-Rated Optics
3G Vibration Rated
ISO 9001

ENERGY DATA

Electronic LED Driver
0.9 Power Factor
<20% Total Harmonic Distortion
120-277V 50/60Hz
-40°C Minimum Temperature Rating
+40°C Ambient Temperature Rating

EPA

Effective Projected Area (Sq. Ft.): 0.5

SHIPPING DATA

Approximate Net Weight:
12 lbs. (5.4 kgs.)

Eaton
1121 Highway 74 South
Peachtree City, GA 30269
P: 770-486-4800
www.eaton.com/lighting

Specifications and dimensions subject to change without notice.

TD521019EN
2017-05-19 16:32:23

HID is still available!
Eaton Streetworks 2018 HID Portfolio Summary

RMA

HPS (50,70,100,150,200)
PSMH (70,100W)

Vanguard

HPS (70,100,150,200,250)
PSMH (70,100,150,250,320,350,400W)
Probe Start (175,250,400W)

OVX

HPS(50,70,100,150,200,250,400)
PSMH (70,100,150,175,200,250,400W)
Probe Start 175,250,400)

OVZ

HPS (50,70,100,150,200,250)
PSMH (70,100,150,175,250W)
Probe Start (175,250W)

OVH

HPS(50,70,100,150,200,250W)
PSMH (70,100,150,175,250W)
Probe Start (175,250W)

OVF

HPS(50,70,100,150,200,250)
PSMH (150,250,320,350,400W)
Probe Start (250,400W)

OVY

HPS (150,200,250,400)
PSMH (150,250,,320,350,400W)
Probe Start (250,400W)

Galleria Square

HPS (100,150,250,400,1000W)
PSMH (150,175,250,320,350,400,750,1000W)
Probe Start (175,250,400,1000W)

Tribute Site

HPS(100,150,200,250,400W)
PSMH (100,150,175,250,320,350,400W)
Probe Start (175,250,400W)

Traditionaire Series

HPS(50,70,100,150,175,200,250W)
PSMH (70,100,150,175,250W)
Probe Start (175,250W)

Lexington Series (LXT LXF LXD)

HPS (50,70,100,150W)
PSMH (70,100,150,175W)
Probe Start: (175W)

Generation Series

HPS (50,70,100,150,250,320W)
All PSMH (70,100,150,250,320W)
Probe Start (175,250,400W)

Acorn (ANE WST)

HPS (50,70,100,150,200,250W)
PSMH (70,100,150,175,250W)
Probe Start (175,250W)

Eagle

HPS (1000W) PSMH (1000W)
Probe Start (1000,1500W)

GPF

HPS (150,200,250,400,1000W)
PSMH (150,250,320,350,400, 750, 1000W)
Probe Start (250,400,1000W)

CFB

HPS (100,150,200,250,400W)
PSMH (100,150,175,250,320,350,400W)
Probe Start (175,250,400W)

HMX

HPS (400,750,1000W)
PSMH (400,750,1000W)
Probe Start MH (400,750,1000W)

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Technology Trends in LED

- IOT
- Controls
- Cameras/Sensors

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The Internet of Things - What

- ***The Internet of Things(IoT) is the network of***
- ***physical devices, vehicles, home appliances, and***
- ***other items embedded with electronics, software,***
- ***sensors, actuators, and connectivity which enables***
- ***These objects to connect and exchange data***
- **Source: Wikipedia**

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The Internet of Things - Outdoor Lighting

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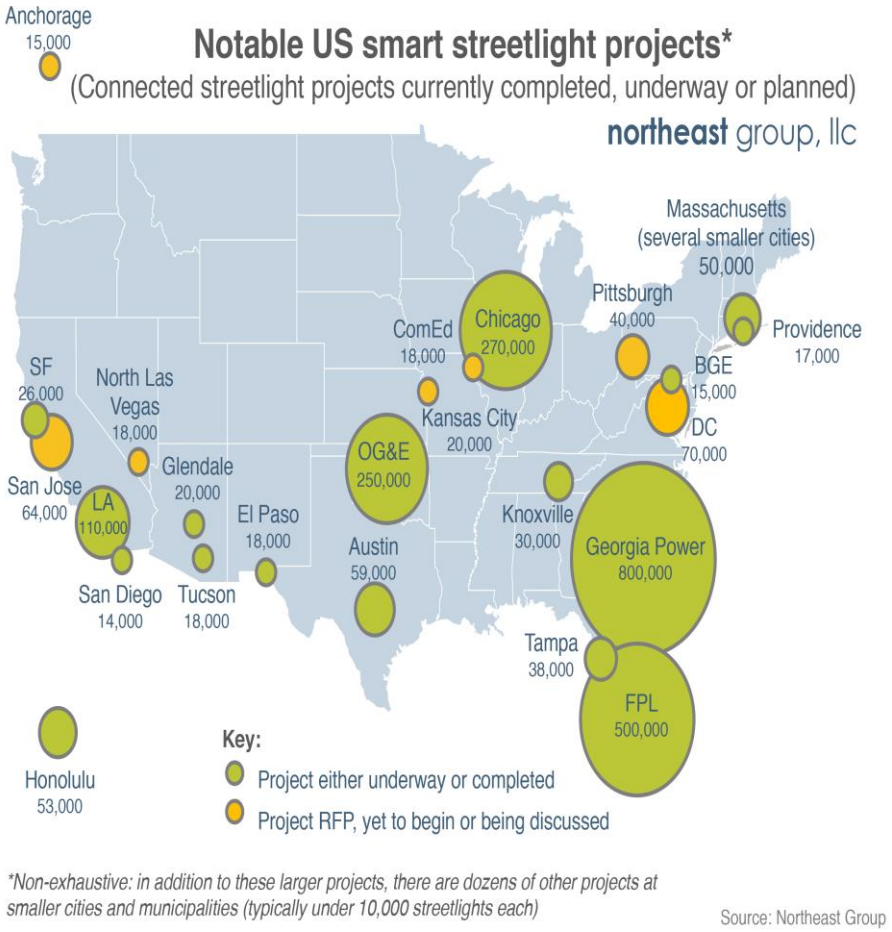
The Internet of Things - Where



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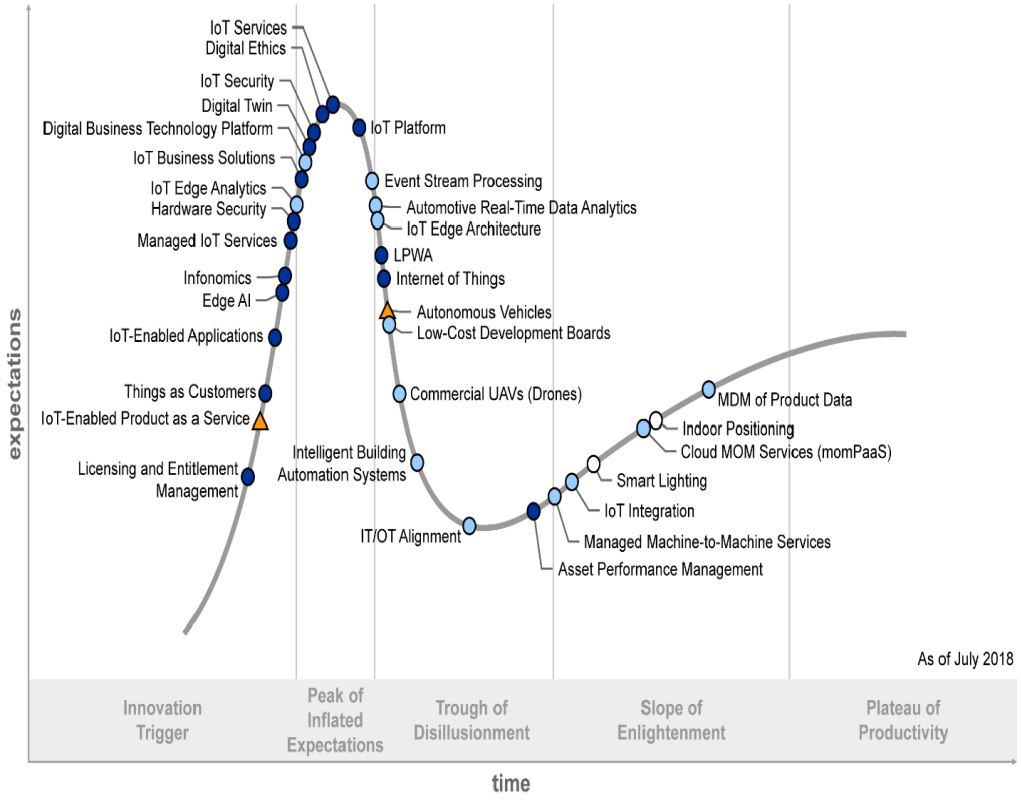
The Internet of Things - When

Hype Cycle for the Internet of Things



Source: Gartner Hype Cycle for emerging technologies, Published August 2018

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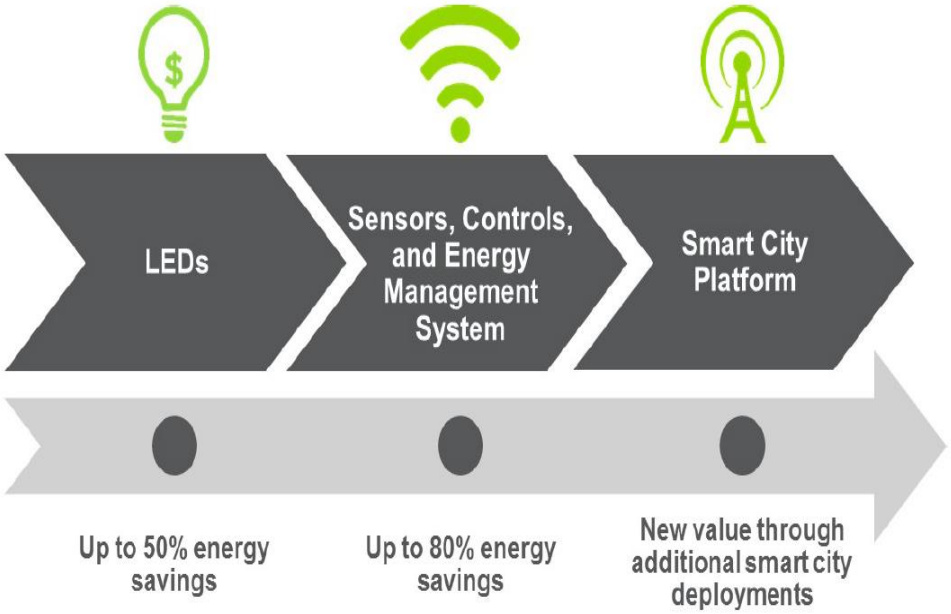
The Internet of Things - What

From LEDs to Networked Controls and Smart City Platforms



Source: Navigant Research Leaderboard : Smart Street Lighting 2018

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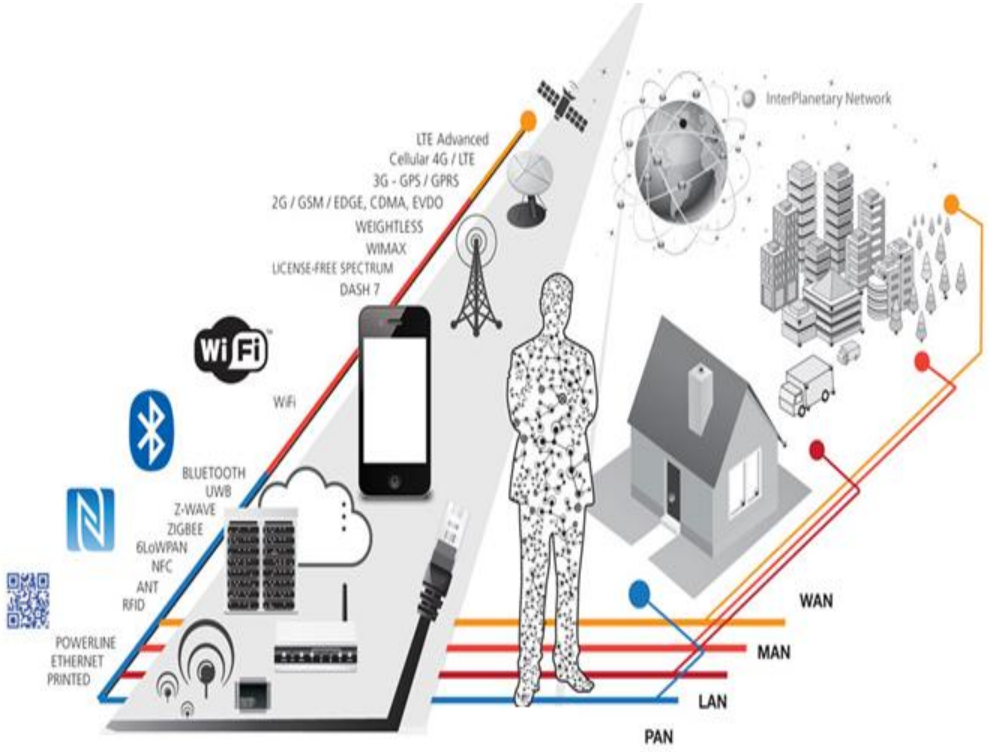
The Internet of Things - How Connectivity

Outra-luminaires Communication



Different wired and wireless network protocols can be used depending on the location, scale and distance of the luminaires and on the device types connecting to these luminaires.

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The Internet of Things - How Connectivity

Outra-luminaires Communication

Wireless Network Technology	Frequency	Range	Data Rate	Use Case / Advantage
Bluetooth LE 4.x	2.4 GHz	10 - 80 m	1 Mbps	Low cost, low power / good battery life
Bluetooth LE 5.0	2.4 GHz	50 - 200 m	125 Kbps - 2 Mbps	Low cost, wider range, wider data rate, better battery life
Wi-Fi	2.4 GHz & 5GHz	30 - 200 m	Upto 1 Gbps	High data rates, to be used in higher bandwidth applications such as video
Zigbee	2.4 GHz	50 - 150 m	250 Kbps	Low cost, used often in the Connected Home and Connected Building settings
LoRaWAN	868 MHz & 915 MHz	Upto 16 Km	< 50 Kbps	Long range, low bandwidth, very low power for extended battery life
3G	850/900/1900 MHz	14 - 18 Km	1 - 10 Mbps	Mature and commonly deployed longrange network
4G LTE - Cat 5	LTE bands	15 - 18 Km	300 Mbps	Long range - High bandwidth data application
4G LTE - Cat M	LTE bands	17 - 18 Km	1 Mbps	Long range - IoT application
NB-IoT	LTE bands	Upto 22 Km/35 Km	170/250 Kbps	Long range - IoT application
5G	3.5 GHz / 24-28 GHz	Max 100 Km	Upto 20 Gbps	New protocol with a large variety of use cases

Selecting the most relevant network protocol depends on the application used along with the luminaire, from controlling lights to providing more advanced functions. (e.g. gunshot detection, etc.)

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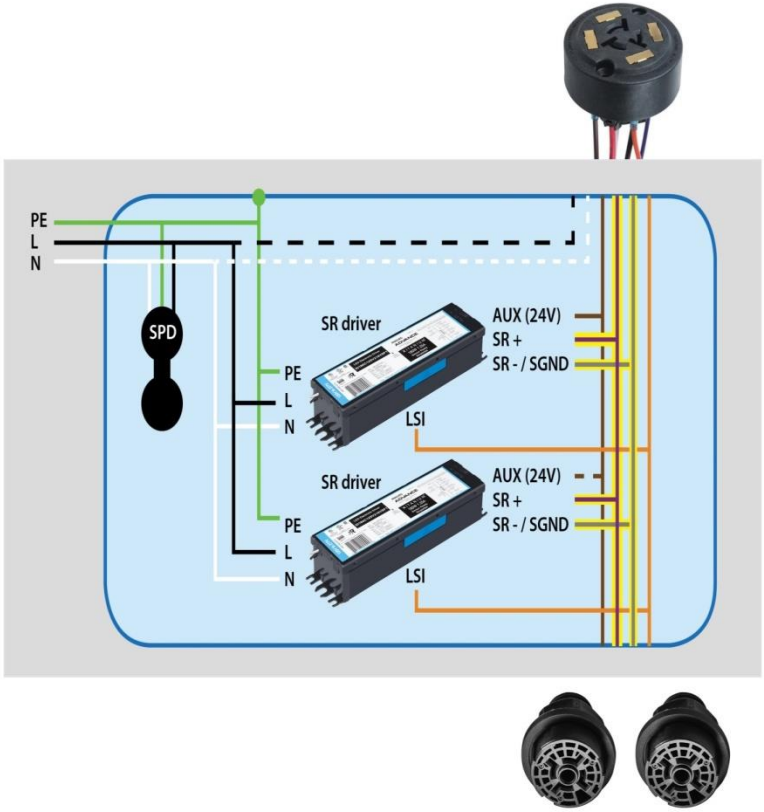
The Internet of Things - How Connectivity

Intra-luminaires Communication



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The Internet of Things - How Connectivity

Intra-luminaires Comparing SR/DALI to other standards

	0 – 10V	DALI	USB	I2C
Data & Power	Not Possible	2 Wire	4 Wire	4 Wire
Communication	Analog, Uni-directional, No Switch to Off	Digital, Bi-directional, Sufficient Speed	Digital, Bi-directional, Very High Speed	Digital, Bi-directional, High Speed
Portfolio Synergy	High	High	Low	Low
Eco System	Strong in NA, Declining in EU	Strong in EU, Emerging in NA	Stong Globally, but not yet in lighting	None
Ease of Design-in	High	High	Medium	Medium
Use Inside/Outside Fixtures	OK	OK	OK	Only Inside
Daisey Chain Multiple Units (1:N)	No	Yes	No	Yes
Cost	Low	Medium	Low-Medium	Low

DALI can be an option for intra-luminaire communications.

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The Internet of Things - How Sensors

Outdoor Sensors

	Local Sensing	Basic Network Sensing	Advanced Networked Sensing
Use cases and technology	**Energy savings with** **Presence Detection** (PIR, Microwave) **Light Detection** (Cad)	**Activity Detection** (PIR, Microwave, Time of Flight, Camera, Bluetooth) **Weather Measuring** (Temperature, pressure, humidity, windspeed, fog, ice) **Accident Reporting** (Luminaire Tilt and Vibration)	Traffic reporting People counting Plate reading City air quality mapping Parking optimization Seismic event reporting Gunshot detection
Value	$	$$	$$$$

The diversity of upcoming luminaire sensors requires inter-operability.

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The Internet of Things - How Sensors

Gunshot detection and video are examples of advanced sensor applications.

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The Internet of Things - How Data

Data needs to be refined and analyzed to become useful.

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The Internet of Things - How Standards

Assurance of **compatibility** with mutual interoperability testing with **partners** and **certification.**

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The Internet of Things - How Standards

Standardization of following for Interoperability

Communication	Agreement on protocol and data
Electrical	Assignment and V / I ratings
Mechanical	Determination of dimensions and tolerances

Sensor Ready certified

DiiA Consortium (DALI 2.0)

Zhaga Consortium (book18)

ANSI (C137.4 C136.54 C136.41)

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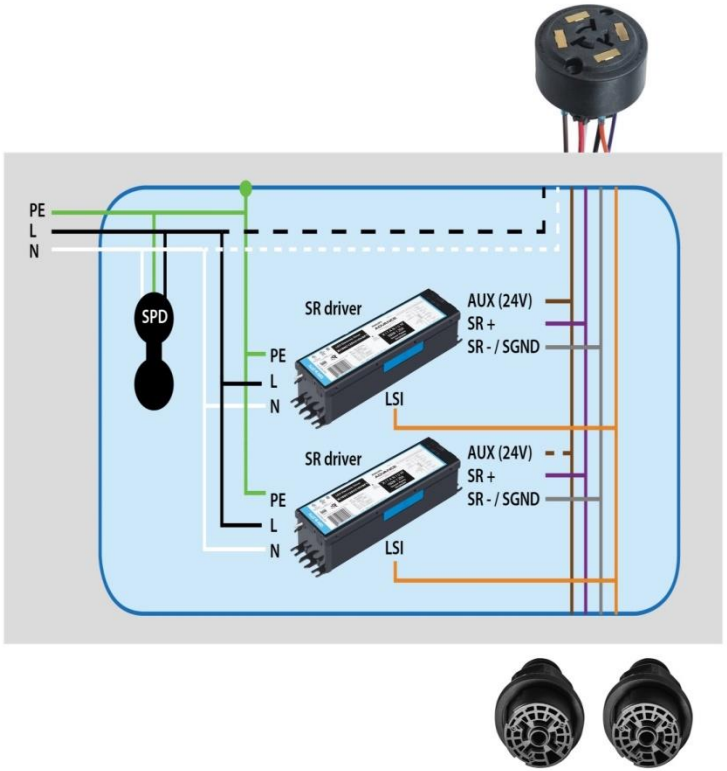
The Internet of Things - How Standards

Luminaire Sensor Ready (SR) Platform



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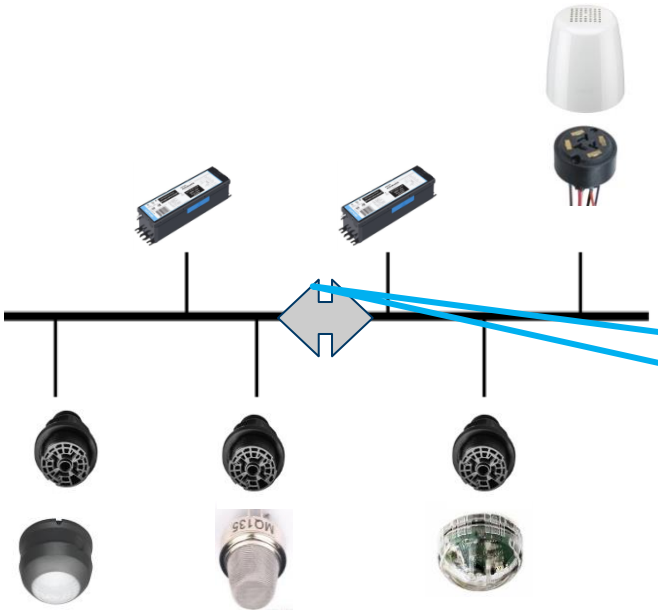
The Internet of Things - How Standards

- Improved **communication** with bi-directional anc communication between LED driver, controller and



Communication protocol, sometime referred to DALI 2.0 supported by DiiA program and ANSIC137.4.

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The Internet of Things - How Cyber Security

Cyber Security in IoT lighting

DLC NLC Technical Requirements version 3.0

- UL 2900-1
- NIST IoT Cybersecurity Framework
- ISO 27001
- ISA/IEC 62443

DESIGNLIGHTS CONSORTIUM

NIST National Institute of Standards and Technology

ISA International Society of Automation (ISA)

UL Underwriters Laboratories

ISO International Organization for Standardization

IEC INTERNATIONAL ELECTROTECHNICAL COMMISSION

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The Internet of Things - What

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“IoT will allow cities to provide better service for their citizens. ”

Photo Controls

- Fail off long life photo control – Recommended for LED luminaires to maximize driver lifetime by eliminating day burners.
- Fail on long life photo control – Similar to traditional style photo controls with superior design for longer life.
- Long life LED photocontrol manufacturers include Sun Tech, EYE and others .

Sun - Tech

EYE LIGHTING INTERNATIONAL

Why install an LED luminaire that has a 15 to 20 year design life with a photo control that has to be replaced every 5 years?

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Typical Networked Control System

Lighting Fixture
Highly efficient LED fixtures

+

Wireless Lighting Controller
Intelligent, wireless lighting controller

+

Wireless Gateway
Communicates with cloud-based system

+

Software Services
Full status and control from Google Maps

Technology - Scalable - Robust - Low Cost

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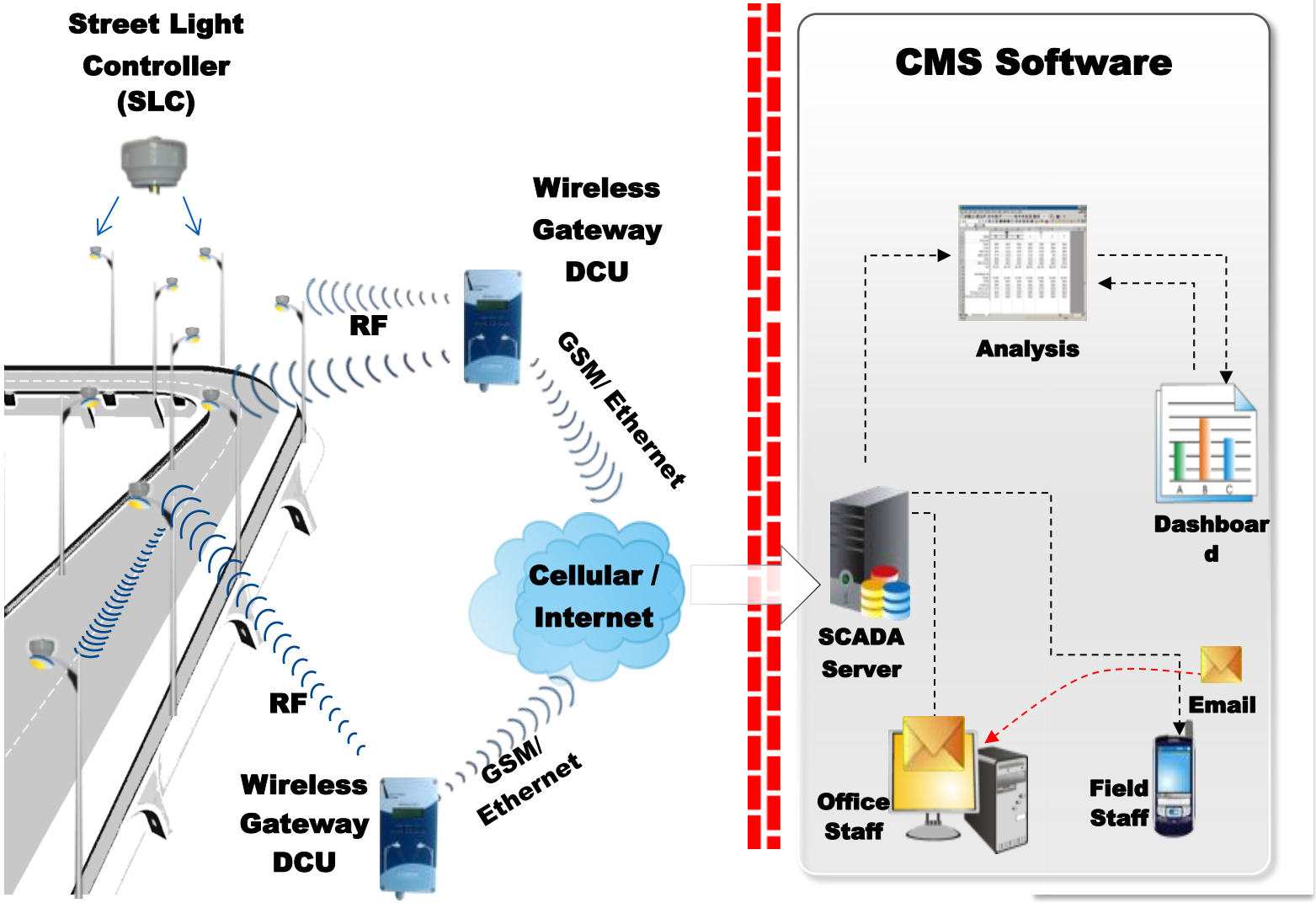
Typical System Connectivity



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LumenSafe - Energy Efficient LED Street Lighting and Smart Camera Technology

Eaton LED Roadway and Area Lighting Products

Eaton Integrated Network Security Camera Solutions

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Eaton Corporation

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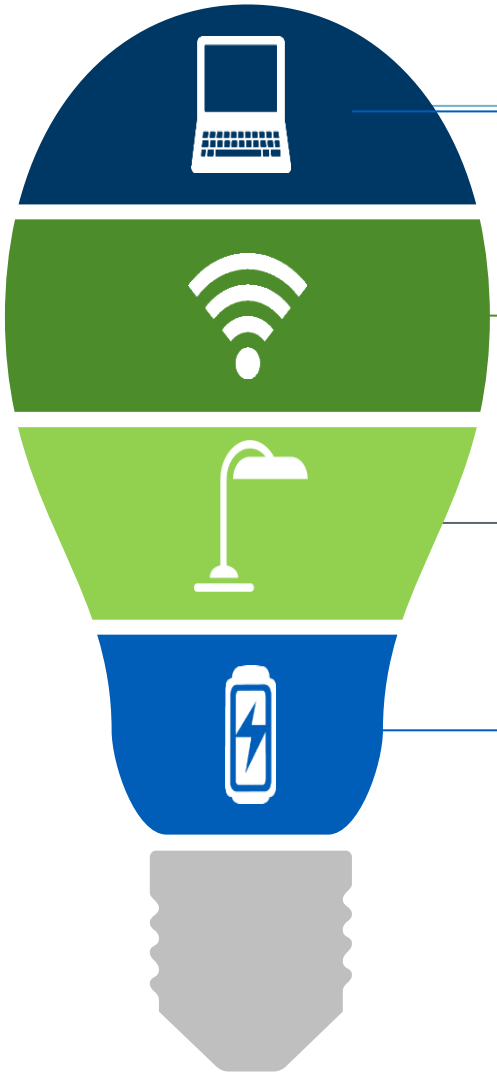
Eaton Lighting Solutions …



Software
Software Applications
Data accumulation & analysis

Connectivity
Communication & Sensing
Physical devices & Controllers

Lighting
Advanced LED fixtures

Eaton Power
Unparalleled knowledge of
electrical power management

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Leveraging the Lighting Infrastructure

Cities should leverage the lighting real estate when upgrading HID to LED

- Addition of a connected solution can help to automate and link key services currently fragmented
- From street lights with energy & maintenance…to parking meters…to traffic management… etc.
- Be smarter & work smarter, be more efficient and drive to eliminate silo management

Cities with a common, single network can continue to add features in the future

- Add new services and new sensors to add new value and features
- Utilize open API (application programming interface) to drive innovation with APPs & software
- Improving public safety helps drive growth & commerce and enhances the lives of its citizens

Must solve new, cross-department sales channel and generate value for the citizen through direct or indirect interactions

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How do we achieve our vision…

We do more to improve safety

"To improve the quality of life and the environment through the use of power management technologies and services…"

Eaton is adding value & improving security with our LED luminaires

We Conserve Energy | ***We Improve Safety*** | We Create Experiences | We Connect Communities

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Streetworks / McGraw-Edison / Lumark 2018 Product Introduction

Camera Integration

- Ideal for highly trafficked or safety conscious areas
  - Roadways, intersections, schools, public facilities, retail, hotels
- All camera and networking equipment integrated to the luminaire
  - “Plug and play” approach
  - Improved aesthetic over pole bolt-on approach
  - Multiple data backhaul options – cellular, Wi-Fi, ethernet
  - Built-in SD card slot for local storage option and reduced bandwidth
- Commercial and industrial rated solution from world-class camera partner
  - IP66, NEMA 4X and IK10 impact ratings
  - High nighttime performance
  - Digital remote zoom and focus
- Flexibility to work with customer’s preferred software vendor
  - Multiple video compression and streaming file format options
- Luminaire power and control maintained on separate circuit

2018 launch – Galleon and Navion

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Integrated Network Security Camera

Ease of installation

- Provides real-time surveillance with no wiring required beyond line power
- No complexity of multi-step installations, low-voltage power conversion, networking equipment or bulky boxes on poles

Leading camera technology

- Streamlined, outdoor-ready fixed dome camera that offers video quality up to HDTV 1080p
- Advanced compression techniques to reduce bandwidth and storage requirements
- Varifocal lens and remote zoom and focus eliminates the need for hands-on fine tuning

Flexibility in networking and software

- Variety of networking options for bringing the camera feed to a monitoring system
- Optimally designed for deployment in the video management system or security software platform of customer's choice

...

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How do we achieve our vision…

We strive to connect communities

"To improve the quality of life and the environment through the use of power management technologies and services…"

Eaton is working with the Smart Cities Council and forming new alliances

We Conserve Energy

We Improve Safety

We Create Experiences

We Connect Communities

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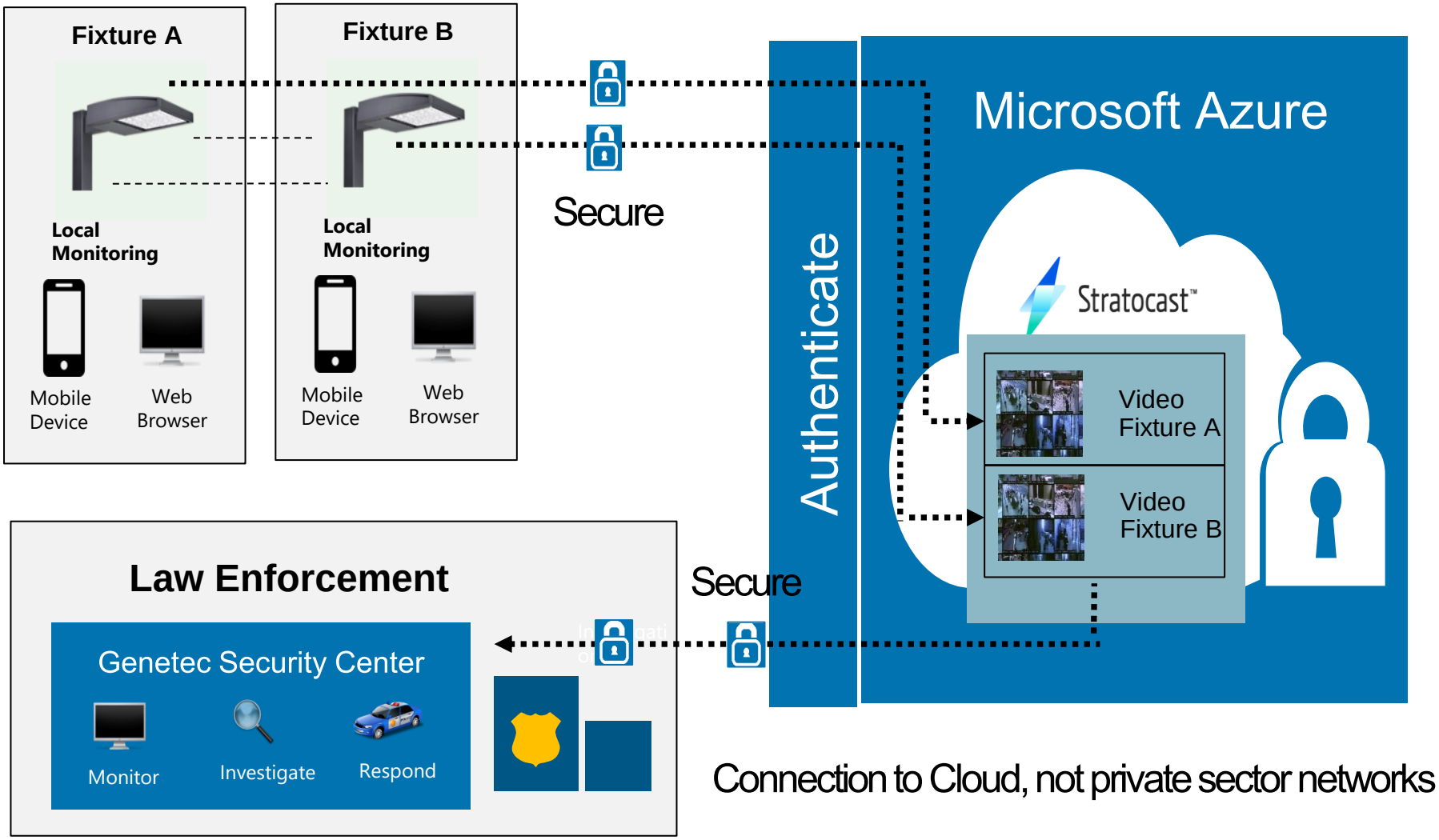
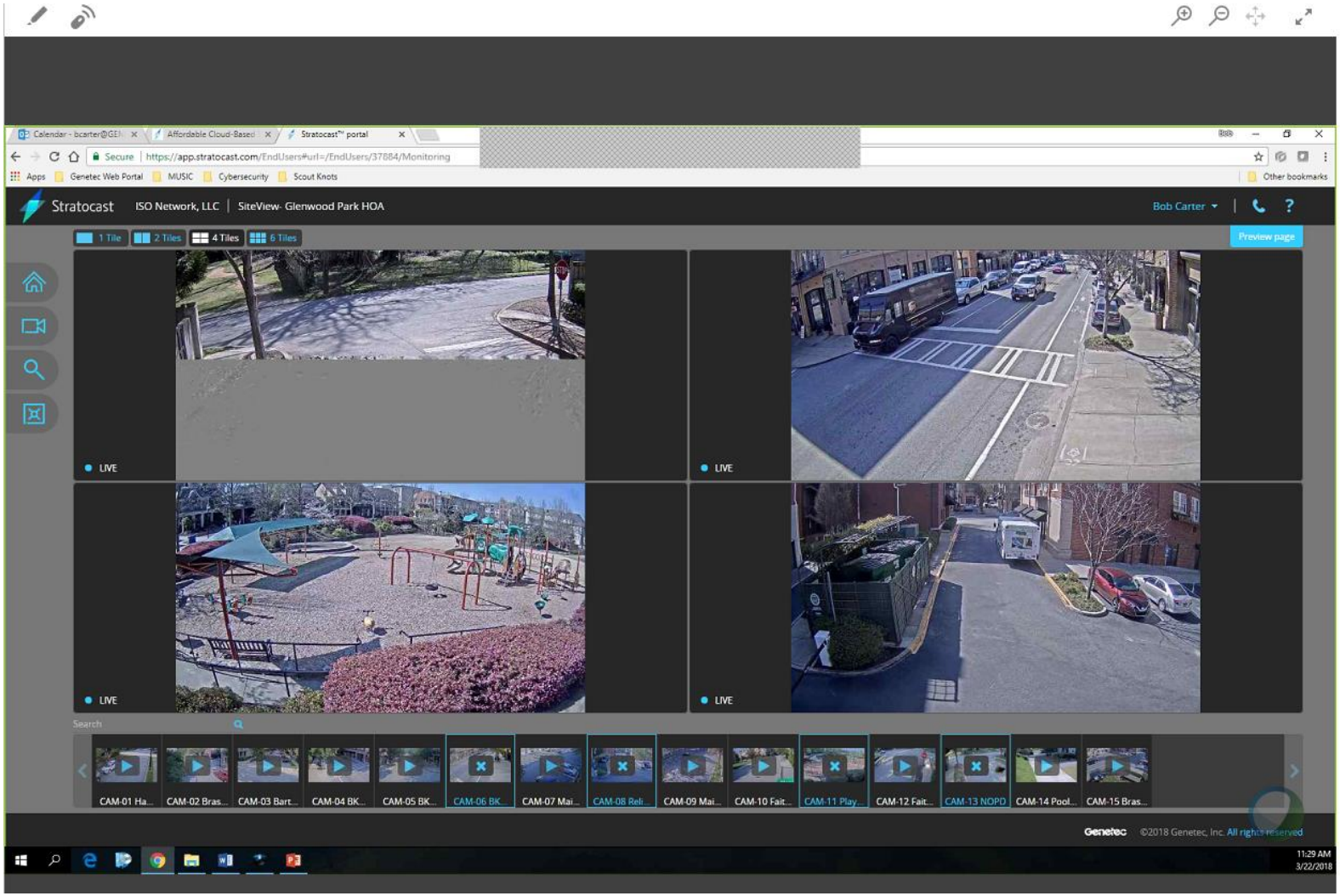
Integrated Network Security Camera



Live Video Feed From Multiple Locations



City of Durango

- Challenges of Change

Sept. 30, 2018

SALC

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Initial LPEA Project Goals

- LPEA will convert 2,100 street lamps to LED
  - Existing wattages from 100- 465W
- 50% energy reduction!! Reducing kWh
  - Coop $ savings to our members
  - Reducing Carbon Emissions
- Anticipating little or no maintenance
  - 15 year life expectancy with minimal lumen loss

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The Process to getting there

- Acceptance/Approval Process- The Easiest part
  - City/town requests for LEDs
  - Track record: EEC Success
    - 800 Commercial Lighting Rebates
    - $2 Million in LED rebates
    - 5MW of Energy Savings
    - Coop recognition with peers and members
  - Payback
    - Initial anticipated Payback 7 Years
    - Maintenance/labor savings

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Initial Projected PAYBACK

Replacement of 2,100 Street Lights		
	Annual kWh	Annual Cost of Power
HID Lamps	2,440,809	$234,042
Lumen for Lumen LED Replacement	1,153,106	$106,745
PROJECTED ANNUAL SAVINGS	1,150,665	$127,297

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Manufacturer Selection

- Technical specifications
- Competitive pricing
- Manufacturer reputation
- Product performance
- Support / Responsiveness
- Local Referrals

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Challenges to installation

- **Internal**:
  - Operations: Number of lights to inventory
  - Ownership, light counts, sizes, types and Billing.
  - Installation- Internal or sub-contractor
  - Replacement sizing of LEDs,… A new Paradigm

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Goals to Illumination

- Guidelines used, IES RP8 Standards
  - Existing HPS lights exceeded or did not meet safety guidelines
    - Overconservative about safety
- Reduce SKU's
  - Result could be replacing lower lumen HPS with higher lumen LED
- **Lessens learned:**
  - SKU's need to be well thought through
  - Accurate count of inventory

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Field Test – 100 Luminaires

GOAL:
Reducing lumens while surpassing standards for pedestrian and roadway safety

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Lessons Learned from Field Testing

PHOTEMETRICS

Large Intersections

Small Intersections

Highways

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New Photometric PAYBACK

Replacement of 2,100 Street Lights		
	Annual kWh	Annual Cost of Power
Initial Annual Savings	1,150,665	$127,297
With New Photometrics	610,076	$58,498
SAVINGS WITH NEW PHOTOMETRICS	1,768,182	$165,243

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Communication and Marketing

- **INTERNAL-** Presentation on Features and Benefits to:
  - Employees, Staff, Operations, Engineering
  - Board members
- **EXTERNAL**-
  - Meetings with City contacts
  - Presentations to Town Cou
  - Press Release
  - Article in monthly magazine,

Streetlight retrofit underway

In the continued effort to save energy and provide further service to members, LPEA is retrofitting more than 2,000 streetlights owned by the co-op in the City of Durango.

"We're changing out the old high-pressure sodium and metal halide streetlights to energy efficient LEDs," says Ray Pierotti, LPEA project specialist who oversees lighting technology. "Beyond the

FOR IMMEDIATE RELEASE, OCTOBER 11, 2017

NEWS RELEASE

City and LPEA Host Outdoor Lighting Forum for

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Challenges to Installation

- **Dark Sky Hurdles**
  - AMA, Dark Sky warnings and recommendations
    - Educate, Compromise, Concession
    - Operational and City acceptance

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LED STUMBLING BLOCK

- Initial Customer reaction
  - Too much light
  - Too Bright, too WHITE
  - Light Trespass
  - Don’t want light at all

- Initial City/Town Reaction
  - Over reactive, failure to get information
  - Handling Calls from customers
  - Forwarding information to LPEA to address.

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Customer Service FAQ Sheet

- Why is LPEA making this lighting changeout?
- Will my bill be reduced on the new LED rental lights?
- The new lights seem brighter than the old ones.
- How will this affect the light pollution?
- The light has a glare from my window
- What's the right amount of light?

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Customer Service FAQ Sheet

- **Why is LPEA making this lighting change out?**
  - There is 70-80% energy savings using efficient LEDs. The new street lights will last 15 years with little or no maintenance.
  - The reduction of energy usage reduces our operating costs and saves our members money.
  - This aligns with our mission statement of providing reliable power (street lights always on) and being environmentally responsible.

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Customer Service FAQ Sheet

- **The new lights seem brighter than the old ones.**
  - The old technology was inefficient and degraded quickly, often recycling and burnt out.
    - The new LEDs, will consistently function at peak performance, which was not the case with the old technology.
- **How will this affect the light pollution?**
  - All lights have no up light greater than 90 degrees with minimal backlight and glare, meeting recommendations of Dark Sky Consortium.
  - The color or hue of light meets Dark Sky recommendations of 3,000 kelvin (k) or less.

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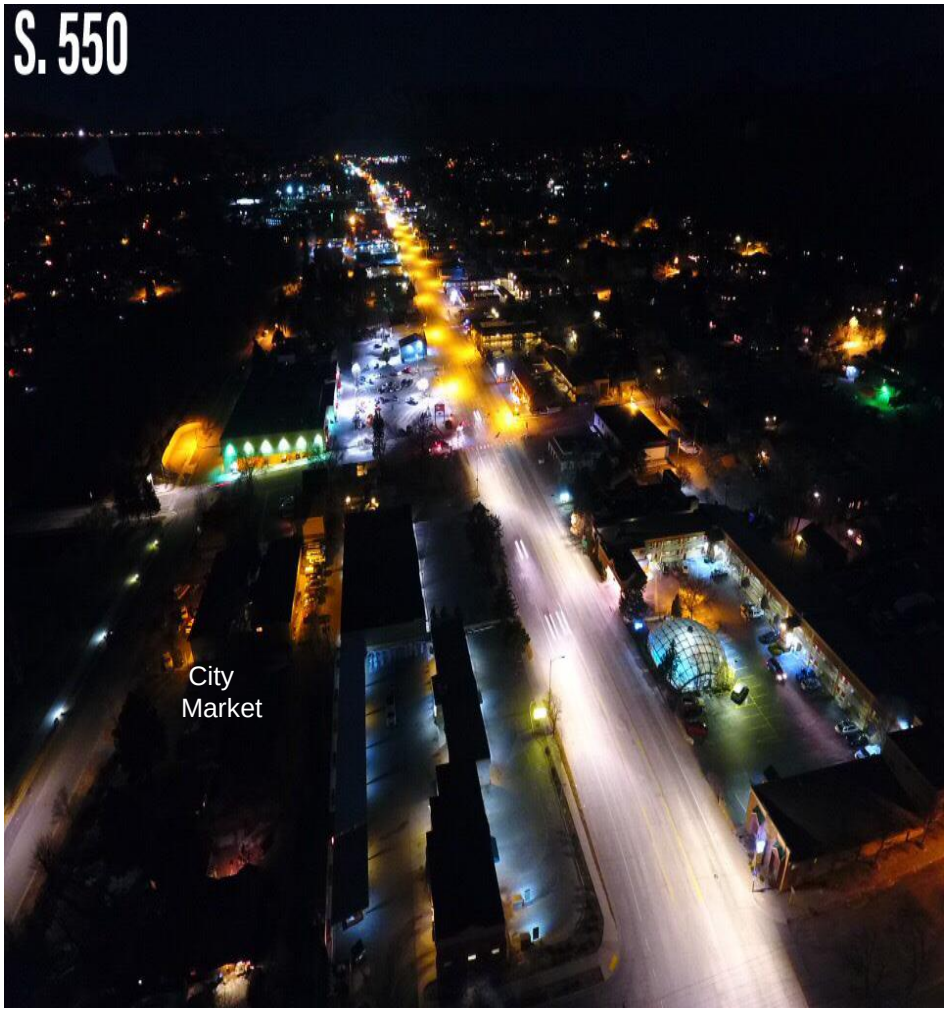
Color/Hue: 3000 Kelvin



3k

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Customer Service FAQ Sheet

- **The light has a glare from my window, what can you do?**
  - We have backside and side shields that can be installed upon customer request.
  - At 10pm when pedestrian traffic is reduced, the photo sensor will begin dimming the light to 50%, still providing the proper amount of light but reducing light pollution during bedtime hours. They will be back to 100% by 5am.

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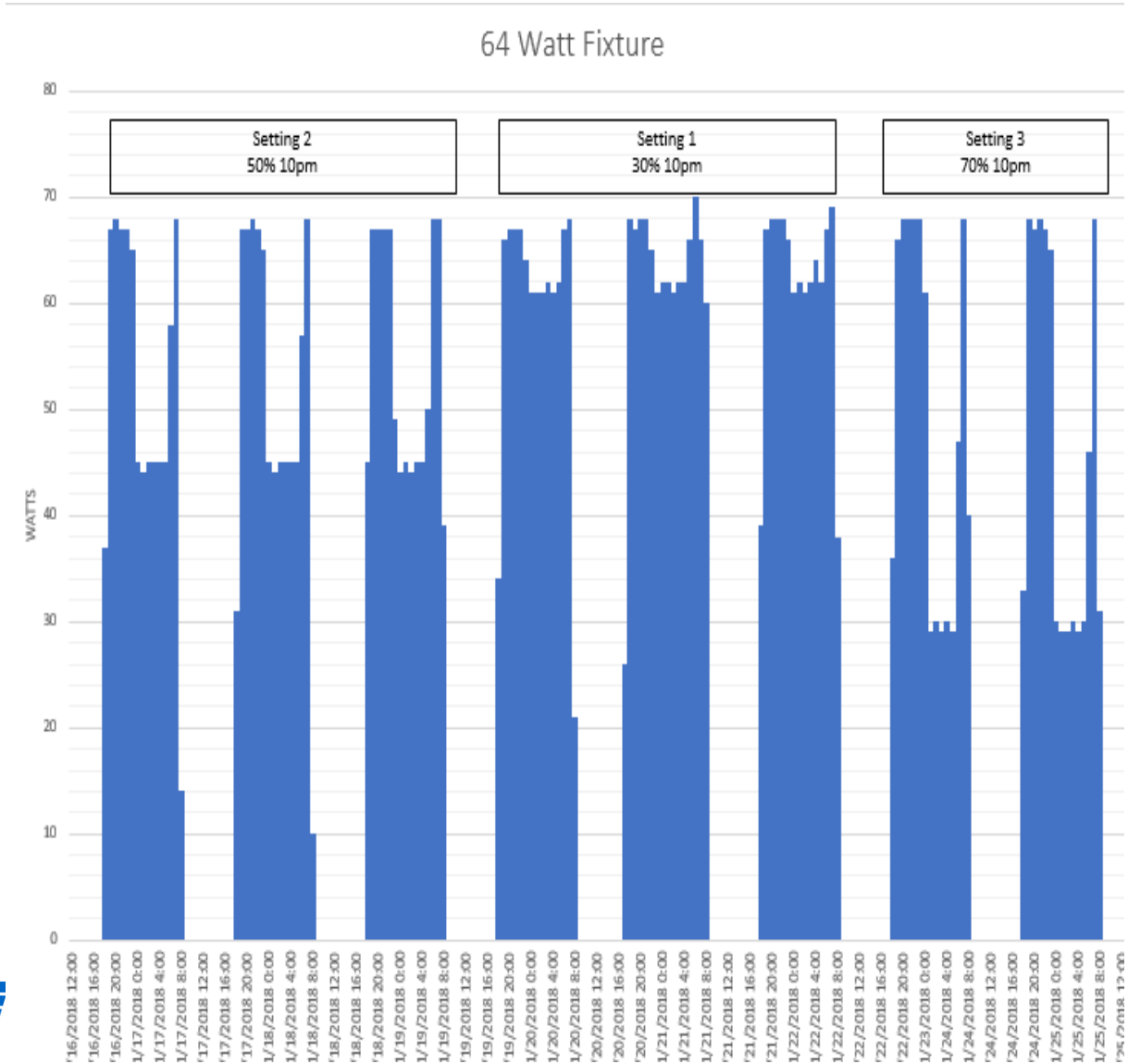
Dimming Photocell



Dark Sky Compliance

- "BUG" (TM-15-07) Rating (**B**acklight, **U**plight, **G**lare)
  - No Uplight (above 90º)
  - Minimal Backlight and Glare
  - Example: 50W (Small) B1, U0, G1

- Dimming Photo Sensors
  - Residential: 50% at 10PM
  - Business: 50% at Midnight
  - Major Roadway: 30% at Midnight

- Color/hue: 3,000 Kelvin

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City/Town/Member Savings

- Some lights downsized from “medium” to “small”
  - Savings from $24.08 rate to $16.99 rate
  - Savings accumulate as exchanges occur
- Savings from LED fixtures will create further savings
  - Reduced energy consumption and maintenance should reduce all rental light rates in 2019 by approximately 25%
- City of Durango Annual savings of $5,000 - $10,000 a year

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FINAL PAYBACK

75% reduction including downsizing, new photometric's, and dimming

Replacement of 2,100 Street Lights	
kWh Savings	**1,900,000.0**
Annual Cost of Power	**$180,000.0**
CO2 reduction	**3.0 Million lbs.**
Payback for Coop	**5.0 Years**

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LESSONS LEARNED

- It's a process; From buy in to installation
- Assume billing/inventory inaccuracies and issues
- Use IT for accountability tools, "Workforce, Survey123"
- Just because it's installed doesn't mean it's the right light
- Anticipate/Plan for potential problems ie. Kelvin, shields, photocells

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Thank you for the opportunity.

For questions, please contact Bobby

BobbyBrooks@Eaton.com 770-486-3071

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