



ROAL
living energy

Power Electronics for Solid State Lighting

Reliability Considerations

6/24/2007

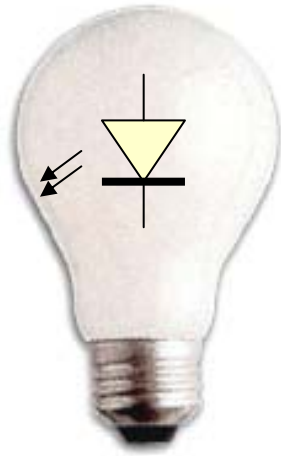
Don Mulvey
Executive Vice President



LIFE FOR YOUR LIGHT

The Value Proposition

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HB LED Technology Promises:

- ✓ *Energy Savings*
- ✓ *Long Life*
- ✓ *Sustainability*



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Light Source Efficacy & Reliability



Type	Watt	Typical Lumens	Lumen /Watt	CCT	Life (hrs)
Incandescent Bulb	100	1200	12	2700	1000
Fluorescent Linear	18	1300	72	4000	10000
Compact Fluorescent	20	1200	60	4000	10000
Halogen	150	2700	18	3000	2000
High Pressure Sodium	50	3500	70	2000	12000
Metal Halide	100	6800	68	4000	15000
HB LED	Neutral (1.1W)	80	73	4100	>50000
Best in Class	Warm (1.1W)	60	55	3100	>50000

Perspective on Light

What's a lumen?

-] We've lived with incandescent bulbs for 100+ years.
-] 100W of Incandescent light is recognizable
-] LED light output needs a familiar perspective.



Incandescent Bulb	(watts)	40	60	100	150
HB Cool White LED	(watts)	6.6	9.9	16.4	24.7
HB Warm White LED	(watts)	8.7	13.1	21.8	32.7

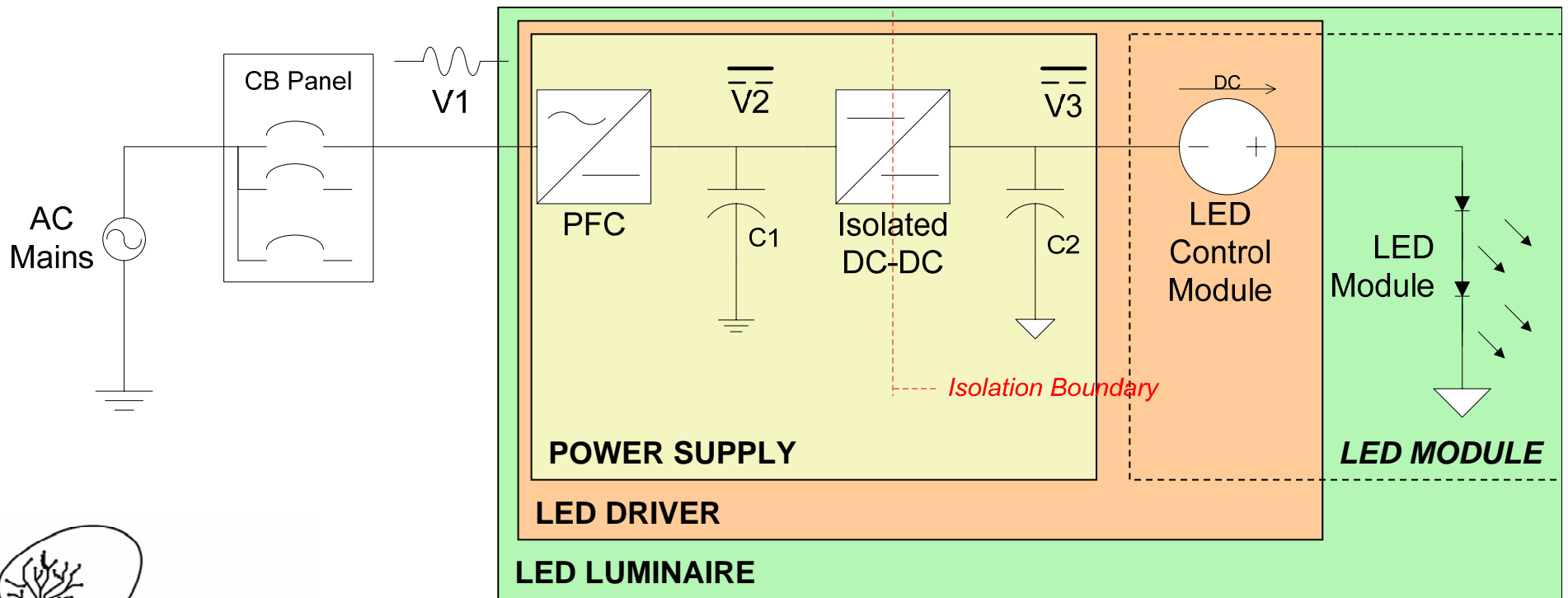
*Does not factor in electronics efficiency



System Components



Electricity Light



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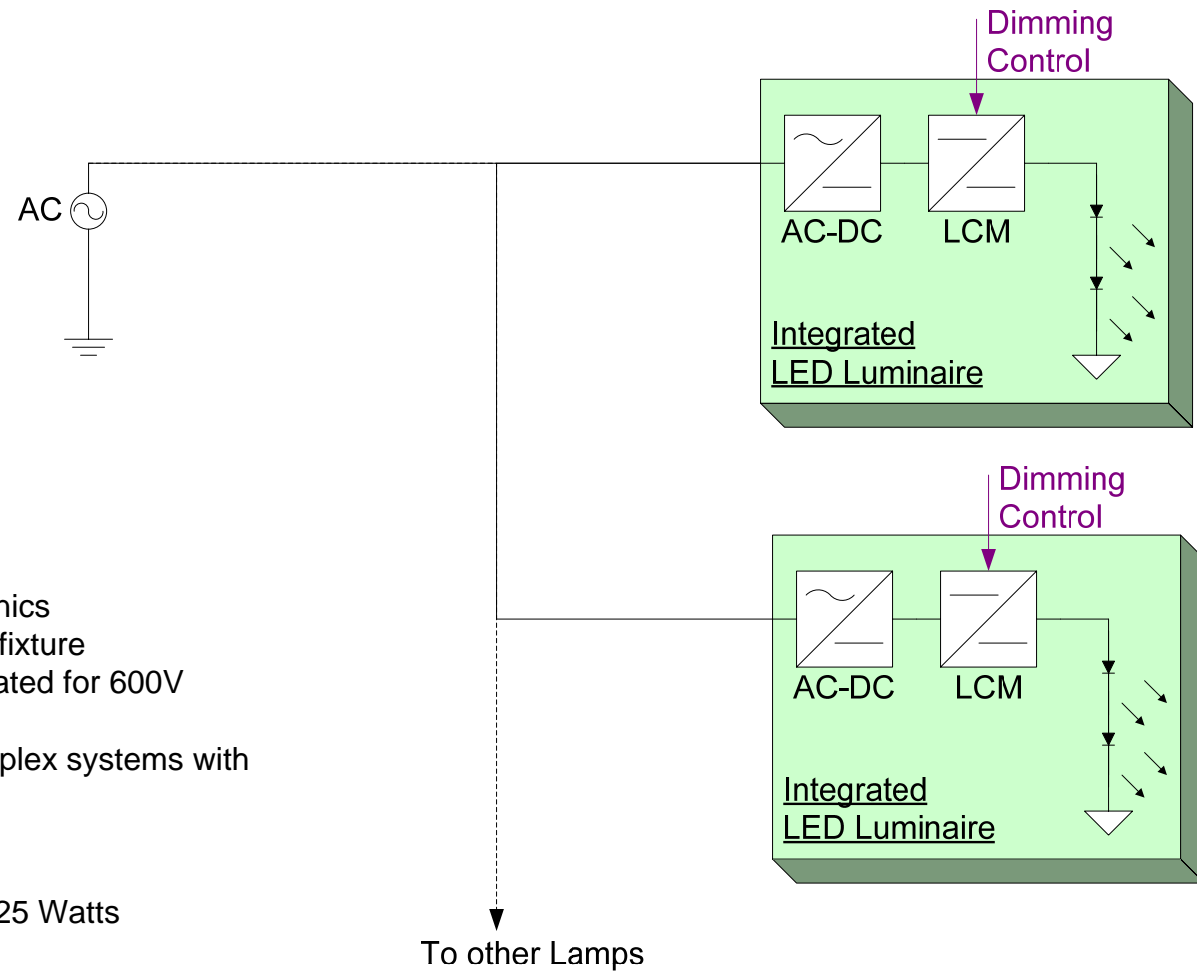
Intellectual Property Warning: Patents exist for Integrated Fixtures

System Reliability

-] Factors all System elements into the analysis
-] LEDs 50,000 hr rating is based on LUMEN Maintenance, not MTBF:
 -] ~5.7 years for 24 hour operation
 -] ~17 years for 8 hour operation daily
-] System Complexity is a major consideration.
-] The quantity of LED Control Modules depends on the number of lighting fixtures deployed
-] The quantity of power supplies depends on the total power of the system, and the electrical architecture of the system



Distributed AC Architecture



Pros:

- Uses existing AC wiring
- Standards exist for wiring

Cons:

- Light fixtures burdened by electronics
- New maintenance issues at each fixture
- All wiring to the fixtures must be rated for 600V and treated as hazardous
- Larger systems result in very complex systems with many power supplies

Probably not suitable for fixtures <25 Watts



System Reliability: AC Architecture

Design Spec

Total number fixtures	100
Light Output per fixture	1200 Lumens
Luminaire Efficacy	50 Lum/Watt
Max Power Per fixture	24 watts
Total Power Consumption	2400 watts

100W
bulb

<u>MTBF Prediction</u>		<u>Design Margin</u>		
<u>Parameter</u>	<u>Units</u>	<u>Low</u>	<u>Med</u>	<u>High</u>
Avg AC-DC Converter Size	watts	25	25	25
Total Qty AC-DC Converters	#	100	100	100
Total Qty LED Control Modules (LCM)	#	100	100	100
MTBF Rate for AC-DC @ 25C	hrs	300,000	500,000	750,000
MTBF for LCM @ 25C	hrs	4,000,000	4,000,000	4,000,000
AC-DC Failure Rate per 1M Hrs	#	3	2	1
LCM Failure Rate per 1M Hrs	#	0.25	0.25	0.25
Total AC-DC Failure Rate per 1M hrs	#	333	200	133
Total LCM Failure Rate per 1M hrs	#	25	25	25
Total Failure Rate per 1M Hrs	#	358	225	158
Predicted MTBF for System	hrs	2,791	4,444	6,316
Predicted MTBF for System	Days	116	185	263
Predicted MTBF for System	Yrs	0.3	0.5	0.7
Predicted MTBF for 8 Hr/365D operation	Yrs	0.96	1.52	2.16

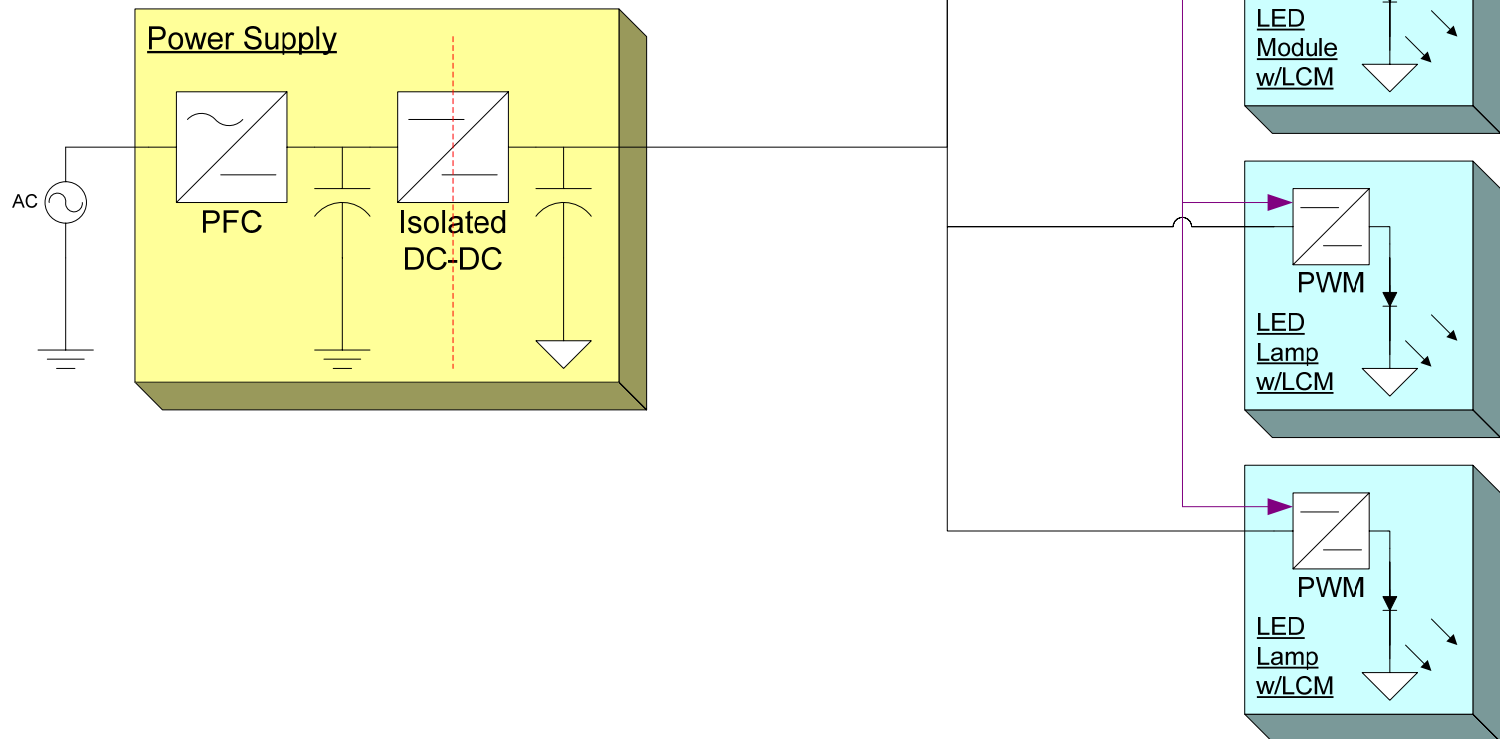
Distributed DC Architecture

Pros:

- Removes AC-DC PS from Fixtures
- Reduced Complexity over AC
- Larger, higher power AC-DC reduces system complexity & cost
- Redundancy is possible

Cons:

- DC power must be distributed (new market requirement)
- DC distribution standards for buildings is limited



System Reliability: DC Architecture



Design Spec

Total number fixtures	100
Light Output per fixture	1200 Lumens
Luminaire Efficacy	50 Lum/Watt
Max Power Per fixture	24 watts
Total Power Consumption	2400

<u>MTBF Prediction</u>		Design Margin			
Parameter	Units	Low	High	Low	High
Avg AC-DC Converter Size	watts	250	250	1,200	1,200
Total Qty AC-DC Converters w/Redundancy	#	11	11	3	3
Total Qty LED Control Modules (LCM)	#	100	100	100	100
MTBF Rate for AC-DC @ 25C	hrs	150,000	500,000	50,000	350,000
MTBF for LCM @ 25C	hrs	4,000,000	4,000,000	4,000,000	4,000,000
AC-DC Failure Rate per 1M Hrs	#	7	2	20	3
LCM Failure Rate per 1M Hrs	#	0.25	0.25	0.25	0.25
Total AC-DC Failure Rate per 1M hrs	#	71	21	60	9
Total LCM Failure Rate per 1M hrs	#	25	25	25	25
Total Failure Rate per 1M Hrs	#	96	46	85	34
Predicted MTBF for System	hrs	10,453	21,645	11,765	29,787
Predicted MTBF for System	Days	436	902	490	1,241
Predicted MTBF for System	Yrs	1.2	2.5	1.3	3.4
Predicted MTBF for 8 Hr/365D operation	Yrs	3.58	7.41	4.03	10.20

A DC Architecture could reduce the
number of Power Supplies
Deployed.

This could significantly reduce the
number of expected failures
resulting in lower maintenance
costs.

