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Power Electronics for Solid State Lighting

Efficiency Considerations

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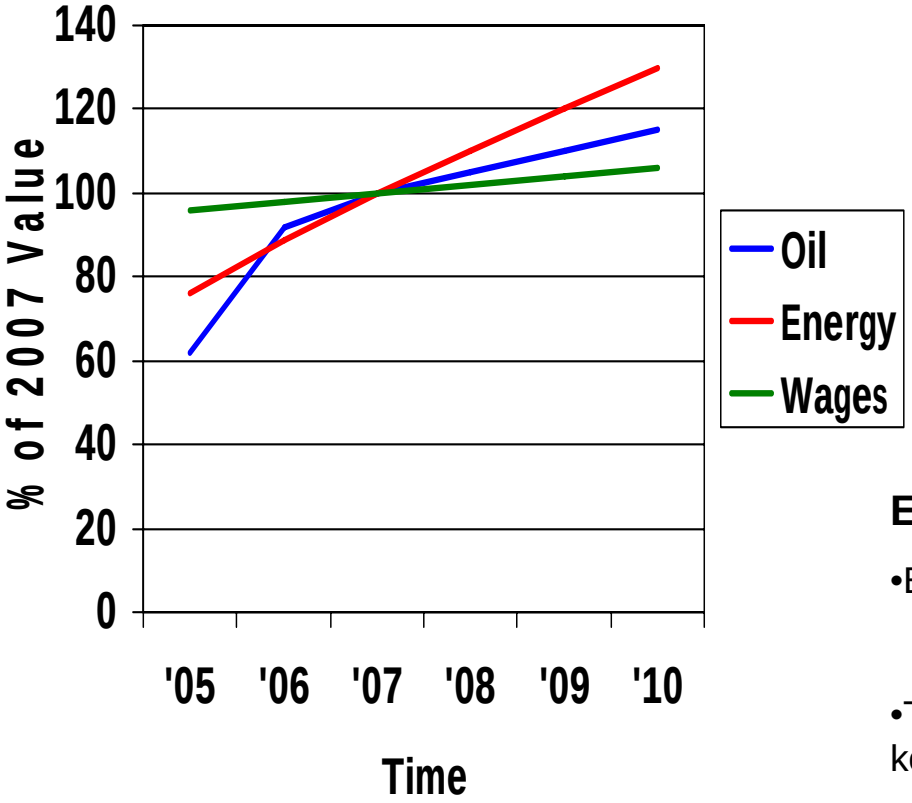
Human Challenges



Energy Conservation is a pervasive issue

•Energy Costs are rising

•The average individual's ability to earn wages cannot keep pace.

•LED Lighting, if properly implemented could contribute significant energy savings

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North America: Situation Analysis

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- LED lighting technology is moving into the general lighting marketplace fueled by the efficiency of High Brightness LEDs (HB LEDs) and the unlimited control characteristics of HB LEDs for dimming and colorization.
- Electrical Lighting consumes 22% of total electrical energy in the USA.*
- When LEDs (both AC and DC powered) reach an efficacy of 150 Lumens per watt, they could save about $17B in annual electricity costs in the USA alone.*
- The shift from traditional lighting to LED based lighting requires a higher level of technology for lighting due to LED power & control requirements.

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*Data Source: *Next Generation Lighting Industry Alliance*

The Value Proposition

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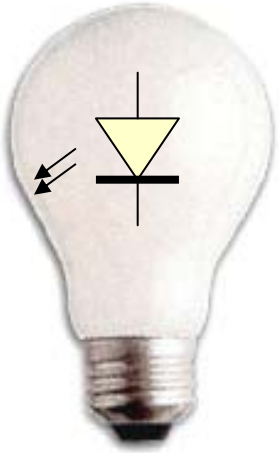

HB LED Technology Promises:

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

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U.S. Department of Energy
Energy Efficiency and Renewable Energy

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In 2006 the DOE introduced its Solid State Lighting Commercial Product Testing Program intended to:

- Guide DOE planning for SSL R&D and commercialization support activities, including ENERGY STAR® program planning
- Support DOE technology procurement activities and associated technology demonstrations
- Provide **objective product performance information to the public** in the early years, helping buyers and specifiers have confidence that new SSL products will perform as claimed
- Guide the development, refinement, and adoption of credible, standardized test procedures and measurements for SSL products

The results of the pilot testing were disappointing with:

- Poor efficacy (some fixtures were less than incandescent)
- Poor color performance
- Reliability Unknown

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Source: http://www.netl.doe.gov/ssl/comm_testing.htm

Light Source Efficacy & Reliability

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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

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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

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System Components

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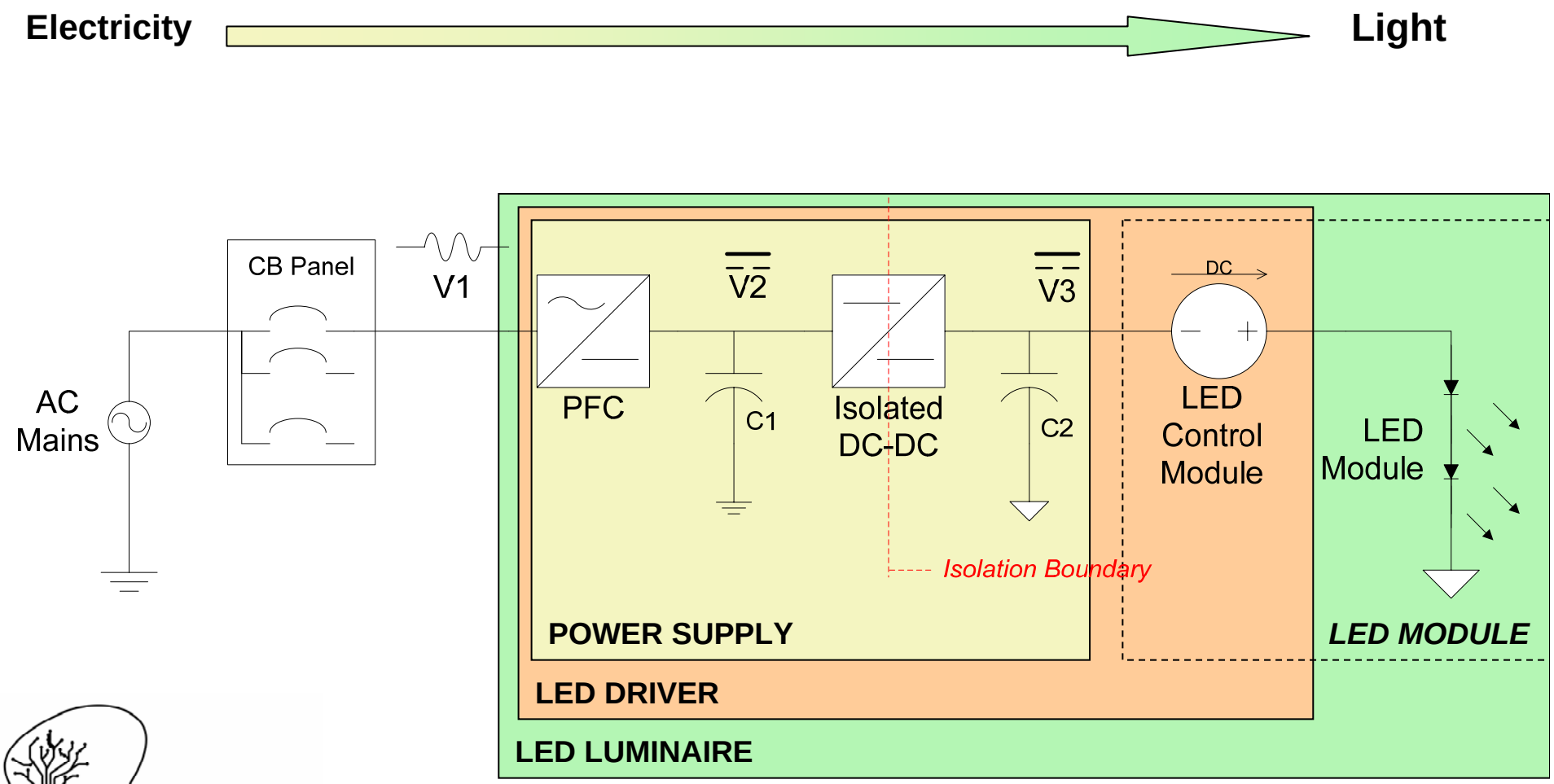

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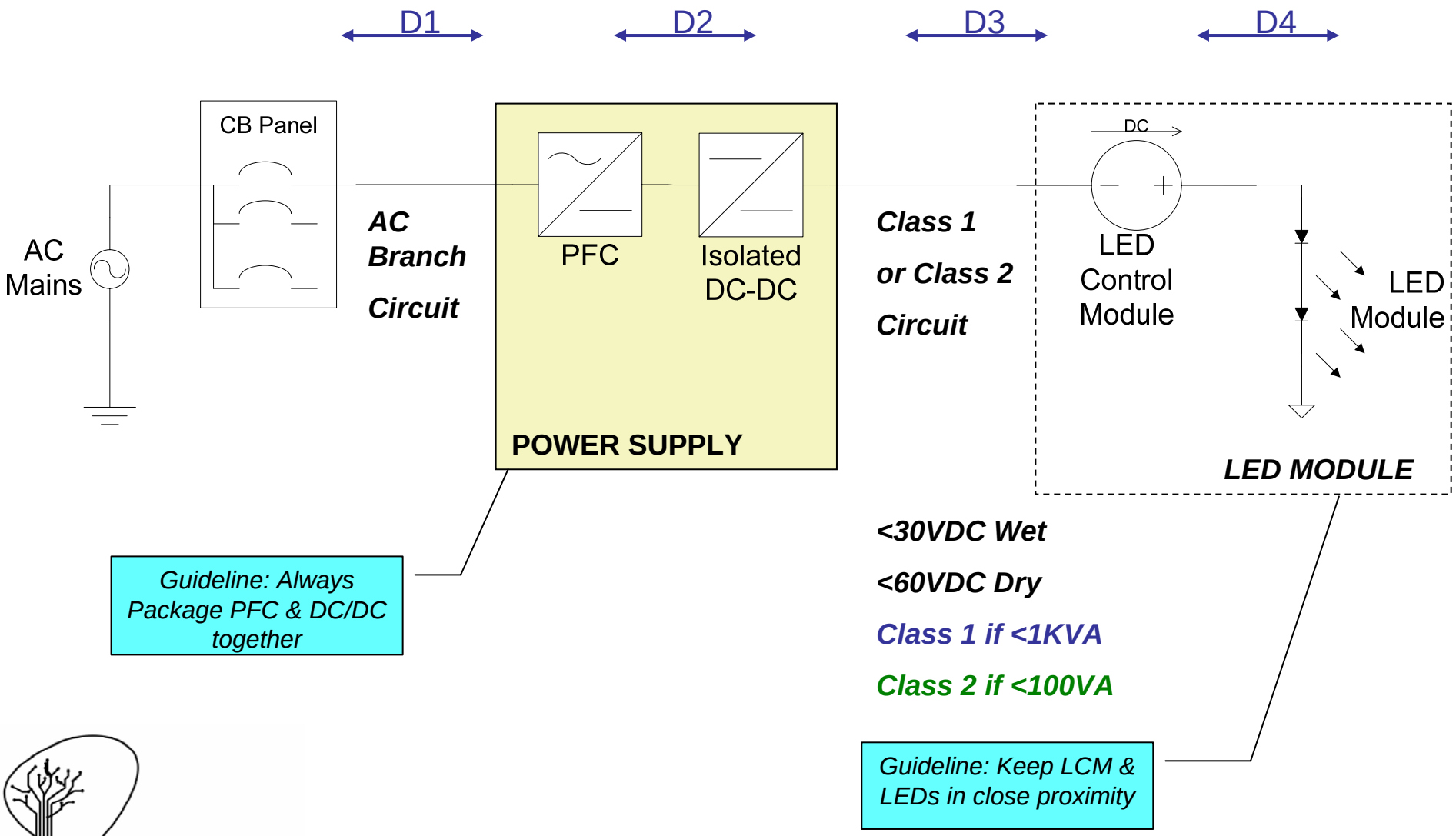
Intellectual Property Warning: Patents exist for Integrated Fixtures

System Components



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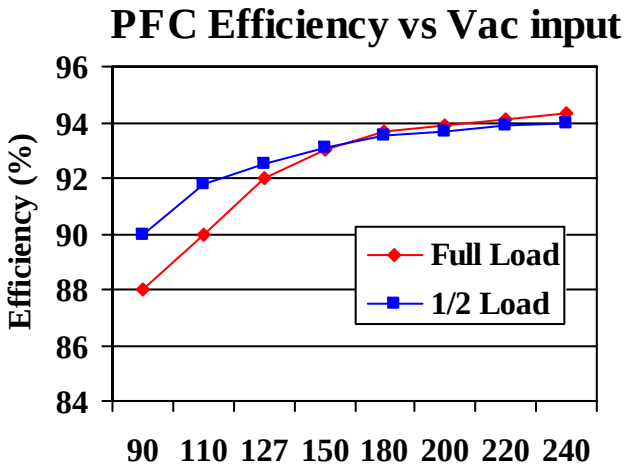
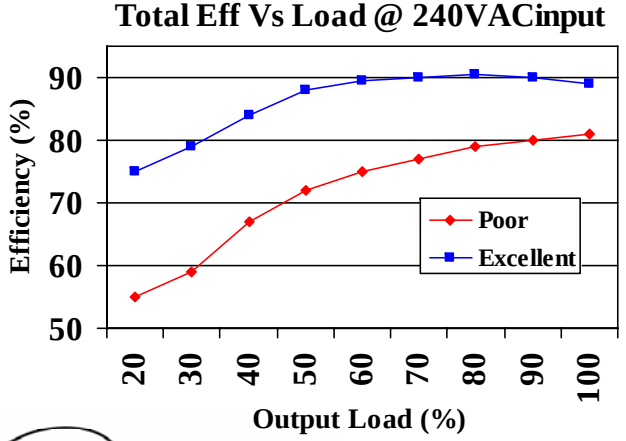
Power Supply Efficiency





Switching Power supplies prefer to operate at the high end of the input range, and maximum power to provide best (or typical) efficiency.

REPRESENTATIVE EXAMPLE OF PS EFFICIENCY

Power Supply efficiency performance requires testing and characterization at the operating points

Beware of "TYPICAL EFFICIENCY" claims

For 12 and 24V Products:

Poor	Good	Excellent
<75%	80-87%	>88%

@ the operating point (i.e. Vin, Vout, Iout)

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System Efficiency (good example)

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Design Spec

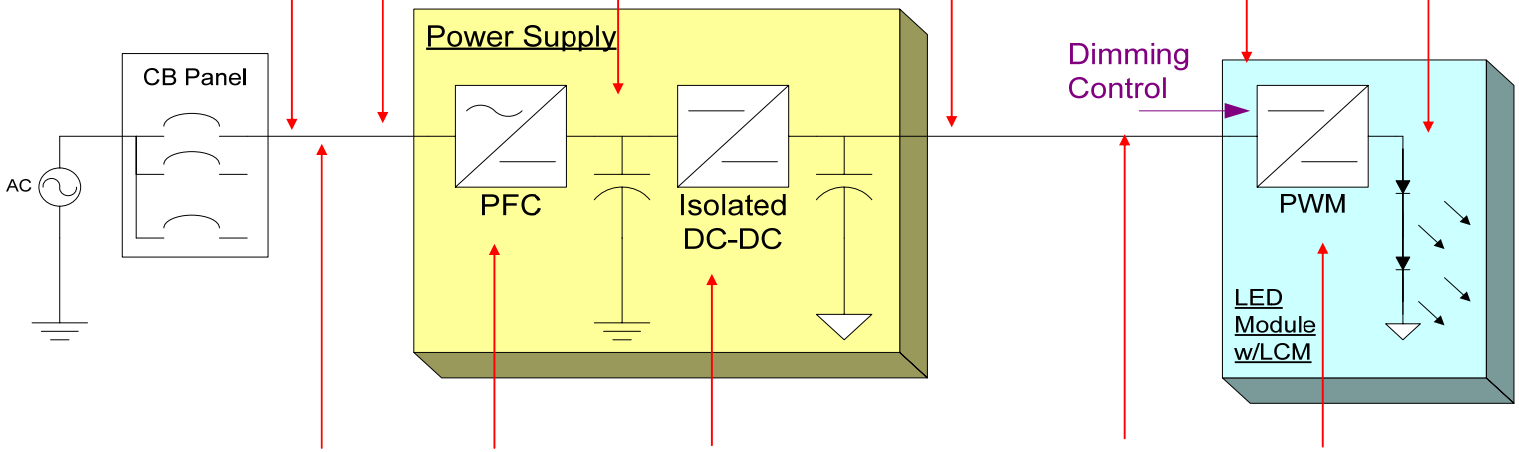
Light Output (flux)	1200	Lumens
Color Temp	Warm White	
CCT	3100K	
AC Input	240	VAC

HB LED Specification

Minimum Flux	60	Lumens
Drive Current	0.35	A
Forward Voltage	3.15	Vdc
Qty Devices Needed	20	

Actual Light Output = 1323 Lumens

Delivered Node Power 29.7 29.4 27.9 23.4 23.2 22.1 Watts



Component Efficiency	99%	95%	84%	99%	95%
Component Pout	29.4	27.9	23.4	23.2	22.1
Component Pin	29.7	29.4	27.9	23.4	23.2
Component Losses	0.30	1.47	4.47	0.23	1.16

System Losses	Watts	7.63	Power Supply Efficiency	80%
System Efficiency	%	74.30%	LED Control Module Efficiency	95%
System Efficacy	Lum/Watt	44.58		

System Efficiency (poor example)

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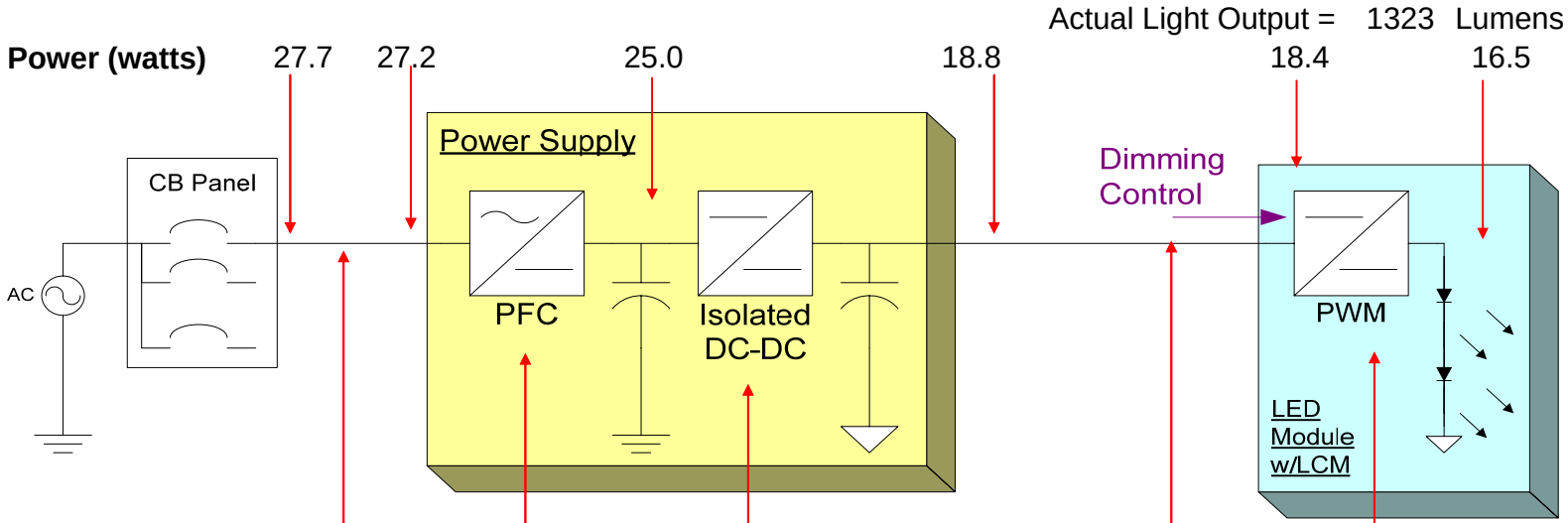
Design Spec			**HB LED Specification**		
Light Output (flux)	1200 Lumens		Minimum Flux	80 Lumens	
Color Temp	Neutral White		Drive Current	0.35 A	
CCT	4100K		Forward Voltage	3.15 Vdc	
AC Input	120 VAC	*(choose 120 or 240)*	Qty Devices Needed	15	

Actual Light Output = 1323 Lumens



Component Efficiency	98%	92%	75%	98%	90%	
Component Pout	27.2	25.0	18.8	18.4	16.5	
Component Pin	27.7	27.2	25.0	18.8	18.4	
Component Losses	0.55	2.17	6.25	0.38	1.84	

System Losses	Watts	11.19	Power Supply Efficiency	69% (Beware or TYPICAL Eff claims!)
System Efficiency	%	59.64%	LED Control Module Efficiency	90%
System Efficacy	Lum/Watt	47.71		

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Power Supply
& LED Driver Choice

Impact System Efficiency
profoundly

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