Marvell. Moving Forward Faster

Marvell Response
(LED Driver PFC section)
Energy Star Luminaries v1.0 specification Draft 1

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Summary & Recommendations

- Lower power factor means:
  - Need to reserve up to 2X more idle capacity in power plants
  - Up to 4X Increase in transmission losses
- With new LED driver ICs from multiple vendors, the LED Driver cost is same with or without power factor correction
  - There is no additional cost whether PFC is 0.5, 0.7 or 0.9x
- Active PFC (in ICs) significantly improve LED driver lifetime by
  - Eliminating need for higher voltage e-Capacitor &
  - Reducing inrush current
  - So even for lower PF values, active PFC is a must to improve driver lifetime and match high LED lifetimes
- Active PFC reduces third harmonic distortion as compared to passive PFC or no PFC solutions
- We recommend >0.9 PF with active PFC for all LED bulbs whether for commercial, industrial or residential applications

Why We Need Power Factor Correction for LED Lights

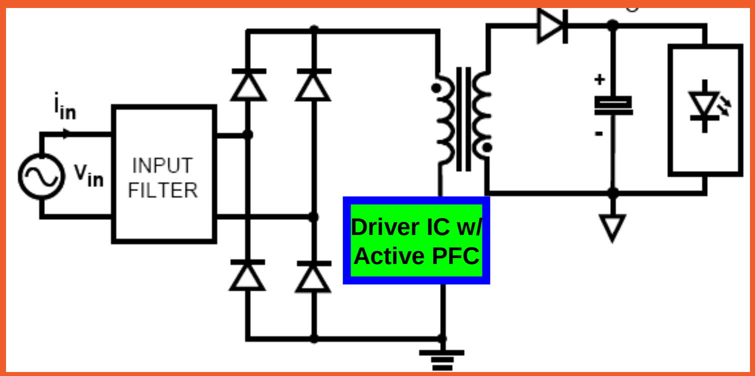
- Assume by 2015
  - 1 Billion LED bulbs installed with average power of 10W per bulb
- By using LED bulbs with low power factor, more energy is required to deliver same amount of real power
  - Which means more installed capacity at the power plant
- Plant Capacity required to light these is inversely proportional to power factor (PF) value of these 1 Billion LED bulb
  - PF=0.999 → 10,000 MW
  - PF=0.9 → 11,100 MW
  - PF=0.7 →14,300 MW
  - PF=0.5 → 20,000 MW
- Higher transmission losses as electrical loss is proportional to current squared
  - Assume transmission loss = L at PF value of 1.0
  - Transmission losses at PF 0.7 = 2L ← $Pi = I^2R$
  - Transmission losses at PF 0.5 = 4L

New LED Driver ICs with integrated PFC from multiple IC vendors Reduce total Driver Cost (On Semi, ST Micro, Marvell, NXP)

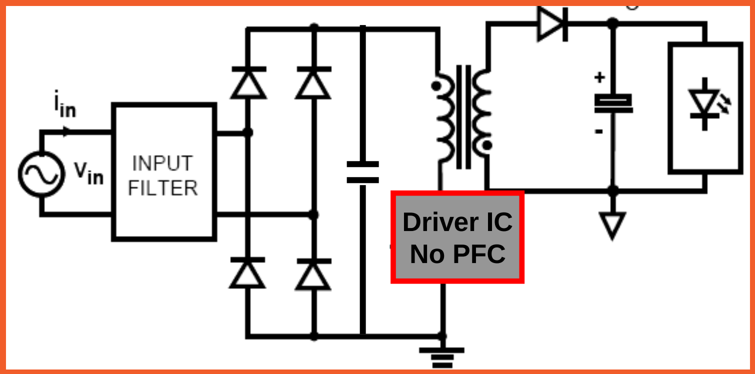
- Traditional PFC Implementations required few additional components
  - **Passive PFC → with discrete components and High Voltage e-Caps**
    - It is Simple, but still required High Voltage e-Cap (400Vdc)
    - High Voltage e-Cap is Required → Shorten Life span of LED driver
    - Higher 3rd Harmonic is common side effect
    - The Class-C of IEC 1000-3-2 limits the 3rd Harmonic of (PF x 30)%
  - **Two stage PFC → Two-Stage (PFC + LED Driver chipset)**
    - Two separate chips – one for driver and other for PFC
    - 25 cent incremental cost to LED driver over non PFC version
- New Single-stage Active PFC Implementations do not require any additional components or extra cost
  - The driver BOM cost is similar as Non-PFC LED Driver
  - LED Driver and PFC circuitry are integrated in one chip
  - Significant Improvement in driver life time as Low Voltage capacitors are used
  - Harmonic distortion is much less compared to no PFC or passive PFC
- The PF > 0.9 is already required in other countries
  - Korea Standard (KS) and EU recommends PF > 0.9 for Po>5W

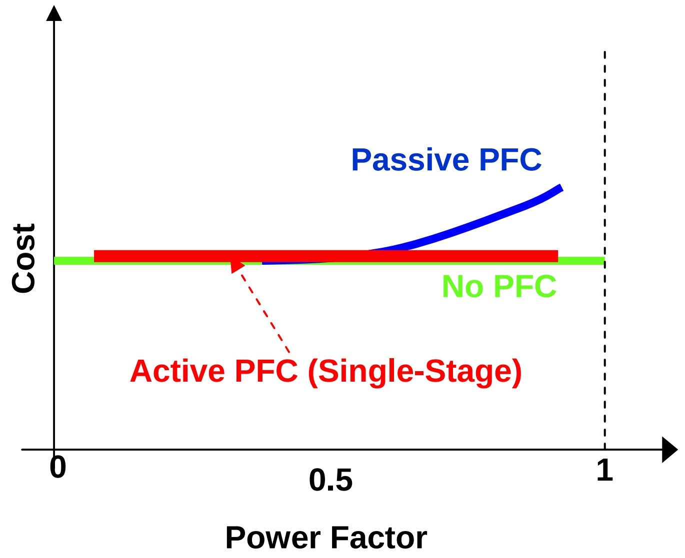
No Cost Penalty for Active PFC Implementations

Integrated PFC LED Driver



No PFC LED Driver





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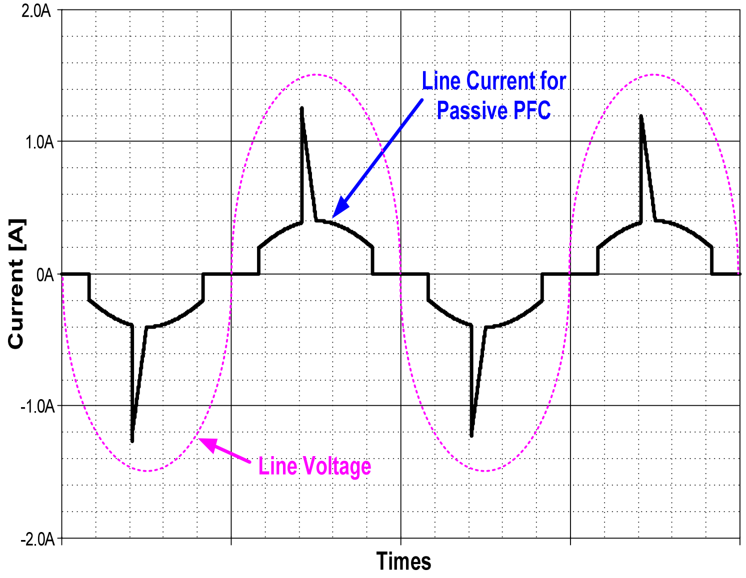
Overview of Passive PFC

- IEC 1000-3-2 (EN 61000-3-2) → Lighting Application belongs to Class-C
  - PF=0.99 → 3rd Harmonic should be less than 30%, (27% for PF=0.9)
- Passive PFC have 3rd harmonic higher than 30% & lower lifespan
  - Large e-Cap for Higher PF → Higher 3rd Harmonic
  - **High Voltage e-Cap** is Required → Shorten Life time

Harmonic Order (n)	Maximum Permissible Harmonic Current Expressed as a Percent of the Input Current at the Fundamental Frequency (%)
2	2
3	30 • λ*
7	10
9	7
13	5
$11 \leq n \leq 39$ (odd harmonics only)	3
*λ is the circuit power factor	



IEC 1000-3-2, Class-C

Electrolytic Cap Life Time Factors

- Electrolytic capacitor: Aluminum plat, Aluminum oxide (dielectric layer), Electrolyte (liquid)
- Two factors that impact E-cap performance
  - Overvoltage: creating hotspots where additional break-down occurs

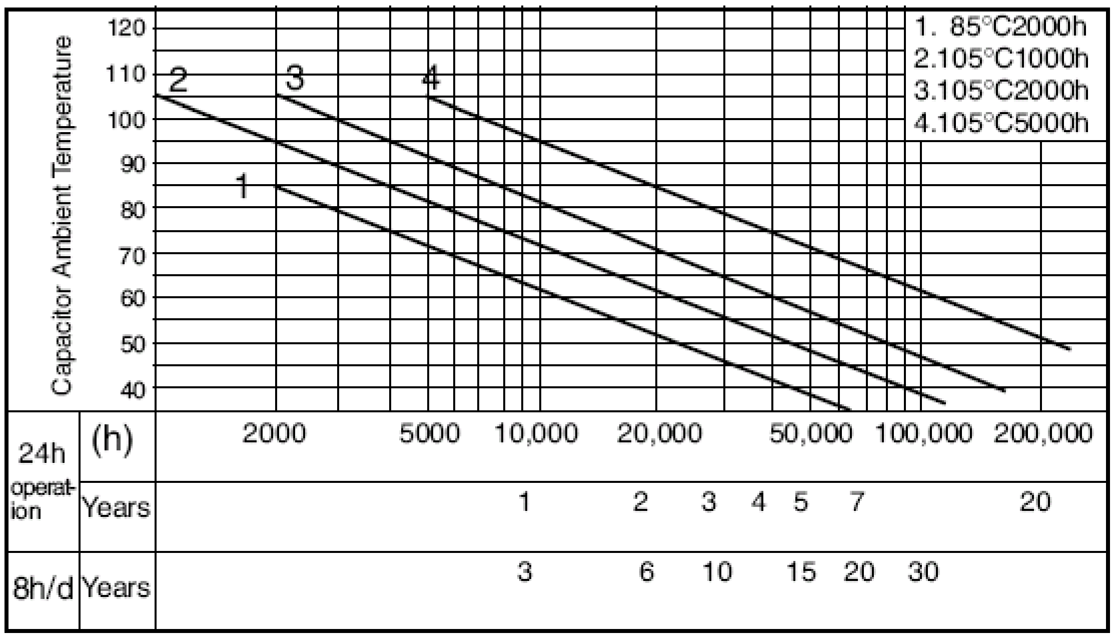
    Solution: Derating, enough voltage margin
  - Heat: evaporate the liquid, building up pressure, result in a violent leak, every 10deg C over 85 will cut the life expectancy in half

    Solution: Derating, enough temperature margin
- Failure rate of E-cap is related its energy storage, which is proportional to the square of the rated voltage multiplying with capacitance
- Standard inexpensive consumer-grade electrolytic capacitors are rated for 85°C maximum working temperature

Electrolytic Cap Life Time Estimation – from Panasonic

Rule of thumb: every 10 deg C increasing will cut the life time expectancy in half

■ Expected Life Estimate Quick Reference Guide



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Active PFC Significantly Increases Driver Life Time as compared to Drivers with No PFC or Passive PFC (4X better in Example…)

Items	LED Driver with No PFC or Passive PFC	LED Driver with Active PFC (Single Stage)
1. Electrolytic Cap	10-33uF X 2 (AC Input side) (valley fill passive PFC as example)	330uF X 2 (DC LED side)
2. Voltage on E-Cap, V	390	25
3. Voltage rating, V	450	35
4. Voltage derating	76% (=190/250)	71% (=25/35), **better**
5. Relative failure rate estimation	$V^2C=450^2$ x 10=2025000 1 (normalize)	$V^2C=35^2$ x 330=404250 0.20 (normalize), **better**
6. Heatsink temperature,°C	85	85
8. E-cap temperature,°C	105 (assume 20 °C higher than heat sink)	105 (85+20)
9. E-cap temperature rating, **Note 1**	105 (5000hours)	125 (5000hours)
10. Temperature derating	100% (105/105)	84% (105/125), **better**
11. Life time ratio based on tem. derating	1	4, **longer**
12. Power factor	0.8	0.99, **better**
13. THD	N.A. **(third harmonics highly possible can not meet IEC-1000-3-2)**	<10% (meet IEC-1000-3), **better**

Note 1: Based on Digi-key availability: there is no 10uF/125 °C available on digi-key. There are 2 options for 10uF/250V/105 °C E-cap on digi-key. There are 3 options for 330uF/35V/125 °C E-cap on Digi-key, referring to next page.

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Summary of the Life Time of Electrolytic Capacitors

- If the capacitance is the same, the higher the voltage rating, the higher the failure rate
- If the voltage is the same, the high the capacitance, the higher the failure rate
- Failure rate of E-cap is proportional to the square of the rated voltage multiplying with capacitance
- If two E-cap is used serialized in order to meet the voltage rating, the failure rate of one of them is dramatically increased due to the voltage is not evenly dropped on both of them. One of them will take more voltage than another one and fail much earlier due to the characteristics variation.
- Item 9 in the table on previous page is based on the high voltage E-cap availability on Digi-key. Of cause there is 125°C even higher temperature E-cap. But it is much more expensive and there is very fewer vendors comparing the low voltage E-cap.

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