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Abstract

The replacement of incandescent lighting mandated by the largest countries around the world is powering a paradigm shift to solid-state lighting. LED lighting offers significant advantages over alternative lighting technologies, especially as the lumens per watt increases and the cost per lumen decreases. One of the main benefits with these replacement technologies is the actual life time of the bulb and its cost/watt-hour comparison to traditional incandescent bulbs. While a traditional incandescent bulb has a life expectancy of 1000 hours(1), LED bulbs offer the promise of up to 50,000(2) hours of operating time, while consuming only approximately 20% of the power for equivalent light output. But without the right precautions the lofty promise of nearly 25 years without changing a light bulb may fall short.



Optimizing Operating Life for LED-based Light Bulbs

With the acceptance of LED technology as a cost-effective replacement for incandescent lighting, the design process presents challenges that could potentially lead to reduced lifetime for the LED-based bulb. The complexity and reliability of the driver circuit and the LEDs themselves are areas of concern that need to be addressed in order to maximize operating life.

The robustness of solid state lighting technology compared to relatively fragile incandescent and halogen bulbs is one of the key features that attracts consumers. However, LEDs require DC current for proper operation and need to be driven by a circuit which converts the standard AC line voltage down to a usable level.

In order to make LED-based bulbs compatible with standard light sockets the driver circuit needs to be integrated into the bulb, which increases potential failure mechanisms unless dealt with properly. The integration of the driver circuit inside the bulb now makes the bulb susceptible to reliability issues, such as infant mortality or degraded MTTF (mean time to failure) rates. MTTF, the measure of the amount of time until first failure, is normally calculated based on the number of components and the type of components, using the FIT rates (failures in time, measured relative to 1,000,000,000 hours) of each component in the circuit. Since the driver circuit transforms a high AC-voltage (110VAC/220VAC) down to a DC voltage that can be used to power the LEDs, electrical isolation is necessary for safety reasons. In an electrically isolated AC-DC converter, feedback is provided from the secondary side to the controller on the primary side via an opto-isolator (or optocoupler), a discrete component that converts an electrical signal to light, sends that signal across an isolation barrier and then converts it back to an electrical signal.

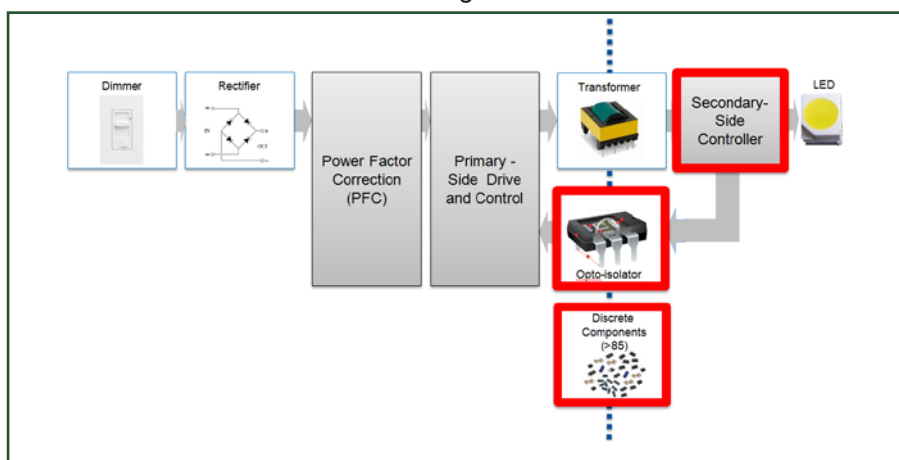


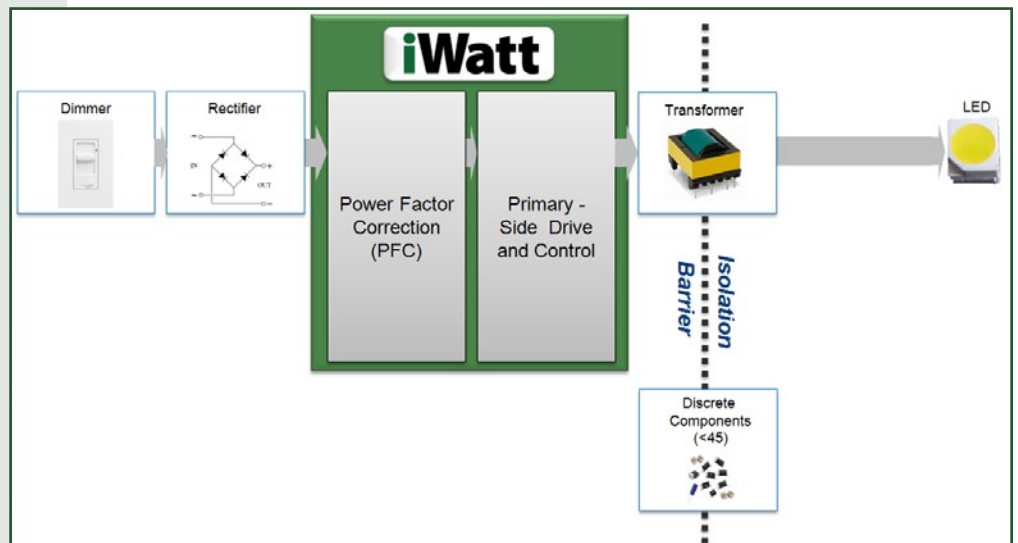
Figure 1. Typical Off-Line LED Driver Circuit

Since opto-isolators have higher FIT rate compared to semiconductor components, they reduce the MTTF rating for the overall circuit. In addition the opto-coupler's current transfer ratio can change over time and temperature due to ageing effect and can affect the loop stability of the power supply thus reducing the life of the LED driver circuit. Whilst many LED lamps and luminaires may operate at elevated PCB temperature, the weak links must be eliminated in order to achieve the desired long lifetime.

Primary-Side LED Current Sensing

Figure 2 shows iWatt's proprietary primary-side digital control technology, PrimAccurate™, which allows for sensing of the LED current via the primary side of the isolation transformer using real-time waveform analysis, removing the need for direct feedback from the output while maintaining very tight constant current regulation for the LED string. An important additional benefit of the PrimAccurate technology is internal feedback loop compensation, simplifying the design and removing external components. By reducing the external components count and eliminating the opto-isolator (the component with the highest FIT rate), the reliability of the LED driver circuit goes up, improving the overall reliability of the entire bulb.

Figure 2. iWatt's
PrimAccurate™ Digital
Control Architecture



Extending the Operating Life of LEDs

An equally important concern with the operating life of LED-based bulbs is the expected lifetime of the LEDs. Like any other semiconductor component, the higher the operating junction temperature of the LED, the lower the expected life of the device. One method to ensure long operating life is to de-rate the current driving the LED and simply use more LEDs to generate a specific light output, resulting in less heat generation per LED and therefore a lower junction temperature. This approach serves to extend operating life but at the cost of more LEDs and it does not accommodate external factors, such as the physical properties of the light fixture, which may contribute to higher than expected heating.

A second method is to optimize the maximum LED current, then establish a desired maximum junction temperature at which the LED's current needs to be reduced in order to prevent degradation. iWatt's digital controllers for LED driving, implement a two-stage protection scheme that allows the designer to program the maximum LED temperature by using a single external device.

An NTC (negative temperature coefficient) resistor can be placed physically near the LED cluster and acts as a temperature monitor. The NTC resistor is connected to the iWatt LED driver IC which then uses that temperature feedback device to protect the LEDs. In the event that the maximum programmed temperature threshold is reached, the controller reduces the LED current by 10% increments until the temperature stabilizes. If the temperature

**Figure 2. Two-Stage Digital
Control Architecture in
iWatt's FlickerLess™ SSL
LED Drivers**

drops, the LED current steps back up to its maximum programmed value in equal and opposite 10% increments, with an appropriate amount of hysteresis to prevent oscillations. There is also a fail safe mode where the current through the LEDs reduces to 1% of programmed output current in the event of a major failure event. Temperature protection offers flexibility in the design of the LED bulb and peace of mind that the bulb will be fully protected under extreme operating conditions.

Conclusion

LEDs have evolved to the point where cost and light output have equaled the competitive solutions and are now gaining momentum as a realistic replacement for incandescent bulbs in the home. The key to the success of this new technology is in the implementation of the driver. Besides the obvious parameters that each designer strives to optimize, efficiency, cost and dimming control, two additional factors, temperature and reliability are the true keys to guaranteeing the long operating life promised by LEDs. iWatt's proprietary digital control architecture makes high quality and long life LED lighting of the future a viable reality.

References

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