OPTIMIZING **OPERATING LIFE** FOR LED-BASED LIGHTBULBS

IMAGE: THINKSTOCK

LED BULBS PROMISE 25 YEARS OF SERVICE, PROVIDED DESIGNERS MANAGE TEMPERATURE, RELIABILITY, AND DIMMING CONTROL. THE KEY TO SUCCESS IS THE DRIVER IMPLEMENTATION.

SCOTT BROWN • iWATT INC

Government regulations around the world that mandate the phaseout of incandescent lightbulbs are powering a paradigm shift to solid-state lighting technologies. LED lighting offers significant advantages over alternatives, especially as LED bulbs' lumens-per-watt performance increases and their cost per lumen declines.

A longer operating lifetime and a lower operating cost per watt-hour are among LED technologies' main benefits over the traditional incandescent bulbs they replace. The robustness of solid-state lighting technology, compared with the relative fragility of incandescent and halogen bulbs, is a key selling point with consumers. An incandescent bulb typically has a life expectancy of 1000 hours (**Reference 1**). LED bulbs, by contrast, promise 50,000 hours of operating life or longer (**Reference 2**) while consuming only approximately 20% of the power for the equivalent light output.

If designers don't take the necessary precautions, however, LED lighting may fall short of its promise of letting the consumer go nearly 25 years without changing a bulb. The complexity and reliability of LEDs and their driver circuits, which must be compatible with legacy dimmer technology, are areas of concern that designers must address in order to maximize LED-based lighting systems' operating life.

LEDs require constant dc current at voltages well below the rectified ac line voltage for proper operation and thus need to be driven by a circuit that converts the standard ac line voltage down to a usable level. In order to make LED-based bulbs compatible with standard light sockets, the designer must integrate the driver circuit into the bulb. If not handled properly, such integration increases an LED bulb's potential failure mechanisms.

The legacy drivers previously available for LED bulbs required large numbers of external components, costly isolation components, and special design strategies to prevent them from causing long-term degradation of key components (such as electrolytic capacitors). Integration of the driver circuit now makes the bulbs 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 and type of components, using the FIT rates (failures in time, measured relative to 1 billion hours of operation) of each component in the circuit. Because the driver circuit transforms a high ac voltage (100V ac/220V ac) down to a dc voltage that can be used to power the LEDs, electrical isolation is necessary for safety reasons.

In a typical electrically isolated ac/dc converter, a discrete optoisolator, or optocoupler, provides feedback from the secondary side to the controller on the primary side by converting an electrical signal to light, sending that signal across an isolation barrier, and then converting it back to an electrical signal (**Figure 1**). Because optocouplers have higher FIT rates than semiconductor components, they reduce the MTTF rating for the overall circuit.

Additionally, the optocoupler's current-transfer ratio can change over time and temperature as a result of aging effects. Such variation can affect the loop stability of the power supply and thereby shorten the life of the LED driver circuit. Though many LED lamps and luminaires can operate at an elevated PCB temperature, designers must eliminate the weak links in order to achieve the desired long lifetime.

Figure 2 shows iWatt's primary-side digital control technology, PrimAccurate. The proprietary approach uses real-time waveform analysis to sense the LED current via the primary side of the isolation transformer, eliminating the need for direct feedback from the output while maintaining tight constant-current regulation for the LED string.

An additional benefit of the technology is internal feedback-loop compensation, which simplifies the design and reduces the external-component count. In particular, elimination of the optocoupler—the component with the highest FIT rate—increases the reliability of the LED driver circuit and thus improves the overall reliability of the bulb.

AT A GLANCE

- LEDs require circuit drivers that convert standard ac line voltage to usable dc current and voltage.
- In order to make an LED-based bulb compatible with standard light sockets without compromising operating life, the designer must integrate the driver circuit in a way that does not increase the bulb's potential failure mechanisms.
- Because the driver circuit transforms a high ac voltage down to a dc voltage, electrical isolation is necessary. One approach uses real-time waveform analysis to sense the LED current via the primary side of the isolation transformer, eliminating the need for direct feedback from the output while maintaining tight constant-current regulation for the LED string.
- A two-step approach to driving LEDs uses an initial boost converter to provide the necessary impedance to load the dimmer—reducing potentially damaging inrush current—and to bring the input current back into phase with the line current, improving the overall power factor of the circuit.

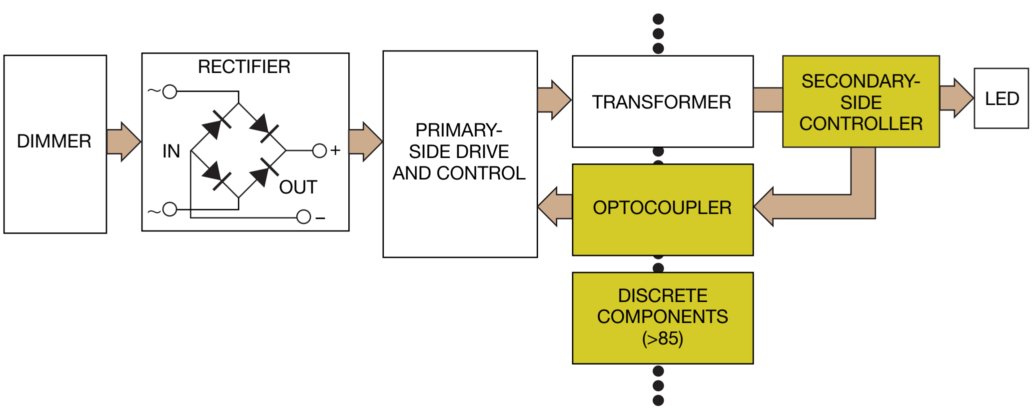

Figure 1 The feedback circuit in a typical offline LED driver circuit requires secondary-side regulation via an optocoupler and many discrete components, resulting in a large bill of materials and a lower overall lifetime for the LED driver.

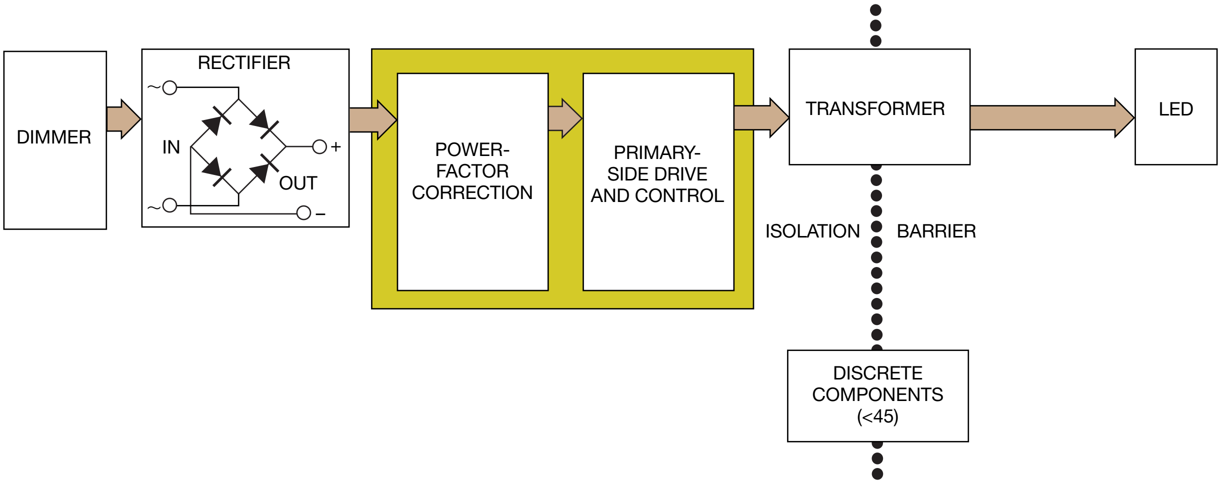

Figure 2 PrimAccurate primary-side digital control architecture reduces the LED driver circuit's external component count and eliminates the need for an optocoupler, thereby improving solid-state-lighting bulb reliability.

The LED bulbs being manufactured today must also be backward compatible with the lighting technology already in place in family homes. Dimmers provide ambience in the home, and one benefit of LED lighting as an alternative to incandescent bulbs is that LEDs can easily be dimmed to match incandescent-bulb characteristics more effectively than can compact fluorescent bulbs.

The LED driver, however, needs to manage several factors to support the dimmer function, including dimmer detection, compatibility, and light flicker. To optimize the operating life of the lighting system, a concern is the durability of the dimmer when used with an LED driver.

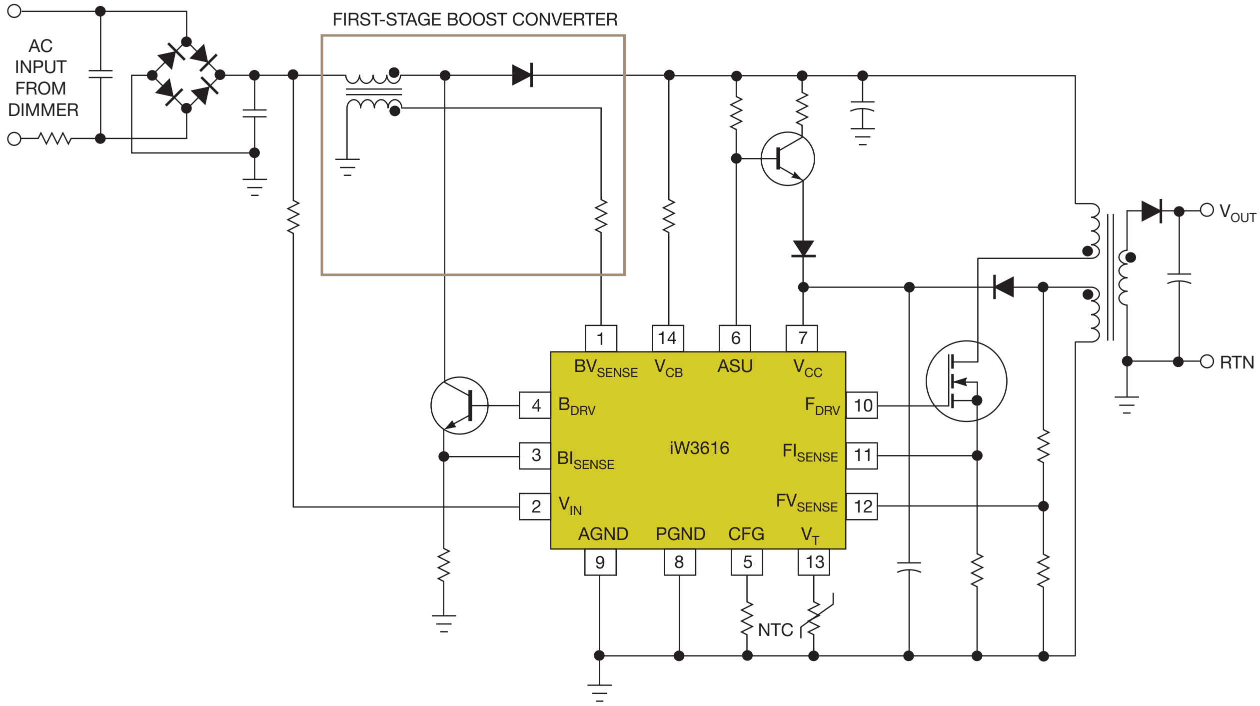

Figure 3 The circuit in this example of a two-stage, high-power-factor-correction LED driver (the iW3616) uses an NTC resistor to provide LED overtemperature protection and derating, thus extending bulb lifetime.

The typical Type A-lamp incandescent bulb is purely resistive. When a dimmer is used to control the brightness of a traditional A-lamp, the resulting load on the dimmer is also purely resistive, and the current through the dimmer is constant and controlled.

An LED driver is effectively a current source, however, and its input looks highly capacitive to the dimmer, which on startup will see a large spike of inrush current to charge up that capacitive load before stabilizing the current at a much lower level. This inrush current is potentially damaging to a standard dimmer and must be reduced to avoid compromising the dimmer-circuit lifetime.

One solution to the dimmer inrush problem is to use a two-step approach to drive the LEDs instead of using a straight flyback converter, which has highly capacitive input impedance. In the two-step approach, the initial stage increases the impedance to a manageable level and thereby reduces the inrush current, providing the safety and protection necessary for the dimmer.

The iWatt iW3616 LED driver (**Figure 3**) uses a two-stage approach with an initial boost converter whose function is twofold: first, to provide the necessary impedance to load the dimmer, reducing the inrush current, and, second, to bring the input current back into phase with the line current, improving the power factor of the overall circuit. The approach not only enables a longer-lasting dimmer but also can provide a high power factor. The digital control block that provides the primary-side control in the iW3616 contains algorithms for detecting and operating with virtually all dimmers available in the market. The same algorithms control the boost converter, optimizing the circuit's dynamic input impedance to increase the power factor and reduce the inrush current.

AN LED DRIVER IS EFFECTIVELY A CURRENT SOURCE, AND ITS INPUT LOOKS HIGHLY CAPACITIVE TO THE DIMMER.

An equally important concern when optimizing the operating life of LED-based bulbs is the expected lifetime of the LEDs themselves. As is the case for any semiconductor component, the higher an LED's operating junction temperature, the shorter its life expectancy. Electrolytic capacitors also have a life expectancy that is dependent on operating temperature.

One solution is to derate 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. The approach extends the bulb operating life, but at a trade-off of a higher solution cost due to the higher number of required LEDs. Further, it does not accommodate external factors, such as the physical properties of the light fixture, that may contribute to higher-than-expected heat.

An alternative method is to optimize the maximum LED current by establishing a maximum junction temperature that would trigger a reduction in the LED current in order to prevent degradation. Digital LED driver controllers are available that implement a two-stage protection scheme, letting the designer use a single external device to program the maximum LED temperature. An NTC (negative temperature coefficient) resistor is placed physically near the LED cluster to act as a temperature monitor. The NTC resistor connects to the LED driver IC, which uses the temperature-feedback device to protect the LEDs.

The iW3616 shown in **Figure 3** uses an NTC device to protect the LEDs in an LED bulb. If the LED cluster reaches the programmed maximum-temperature threshold set by the NTC component, the controller reduces the LED current in 10% increments until the temperature stabilizes. If the temperature 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. If a major failure event occurs, a fail-safe mode reduces the current through the LEDs to 1% of programmed output current. This overtemperature-protection topology offers flexibility in the design of the LED bulb and peace of mind that the bulb will be fully protected under extreme operating conditions.

LEDs have evolved to a point at which cost and light output have equalized across competitive solutions, and LED lighting is gaining momentum as a realistic replacement for incandescent lighting in the home. The key to the success of this new technology is in the implementation of the driver. Besides the obvious parameters of efficiency and cost that every designer strives to optimize, the additional factors of temperature, dimming control, and reliability are the true keys to guaranteeing the long operating life promised by LEDs. **EDN**

REFERENCES

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Scott Brown, senior vice president of marketing at iWatt Inc, joined the company in October 2011 with more than 20 years of experience in the analog semiconductor industry. Before joining iWatt, Brown held marketing and management positions at National Semiconductor, Micrel, On Semiconductor, Catalyst Semiconductor, and Semtech. He holds a bachelor of science degree in electrical and electronics engineering from Brunel University (London).

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