Out with the Old

LED driver powers halogen replacement

High brightness LEDs are an inexpensive, robust, and green replacement to halogen light bulbs. The tungsten filament base to the halogen bulb has a short lifetime compared to the robust LED. The safety hazards of the inert gas, the expense of the UV filter encasement, and the handling sensitivity of halogens are all downsides that an LED light bulb does not have.

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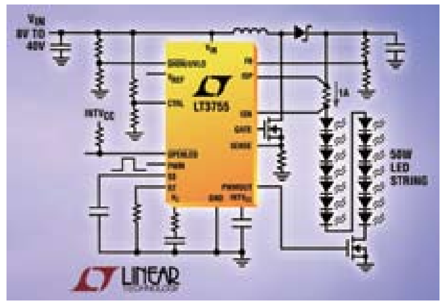
Since halogen bulbs are typically driven with 12V or 24V due to their excellent efficacy at that voltage, buildings have been hardwired with 12VAC and 24VAC transformers for powering the halogen lighting. Replacing existing halogen lighting without starting over from scratch requires an LED that can be powered from a 12VAC or 24VAC source.

Replacing AC-driven halogen lighting with LEDs can be done with a switch mode regulator LED driver designed for AC lighting with high power factor. Although switch mode LED drivers are oftentimes used to regulate a constant LED



current through a string of LEDs from a DC voltage source such as a computer battery, a car battery, or a regulated system voltage, halogen replacements run off of 12VACrms and require high power factor.[1]

[1]Power factor of an AC system is defined as the ratio of real power delivered (P) and apparent power |S| as shown in the equation below.

$$\hat{S} = P + jQ \qquad |S| = \sqrt{P^2 + Q^2} \qquad PF = P/|S|$$

The ideal load with 100% power factor (PF) is a pure resistor. When used with a 12VACrms source and a rectifier bridge (to create 120Hz from 60Hz), the power factor is slightly under 100% using a resistive load such as a halogen or incandescent bulb.

An LED driver with constant (DC) LED current has very poor power factor when used with an AC source in contrast to the resistive load. A constant DC load requires DC power from the input. With an AC source, DC power creates the highest input current when the input voltage is lowest and vice versa. This creates voltage and current input waveforms with a large phase shift and very low power factor. The goal is to create an LED driver with input current in phase with the input voltage. In order to do this, a 120Hz LED current waveform is created to demand the highest input current when the input voltage is the highest and vice versa.

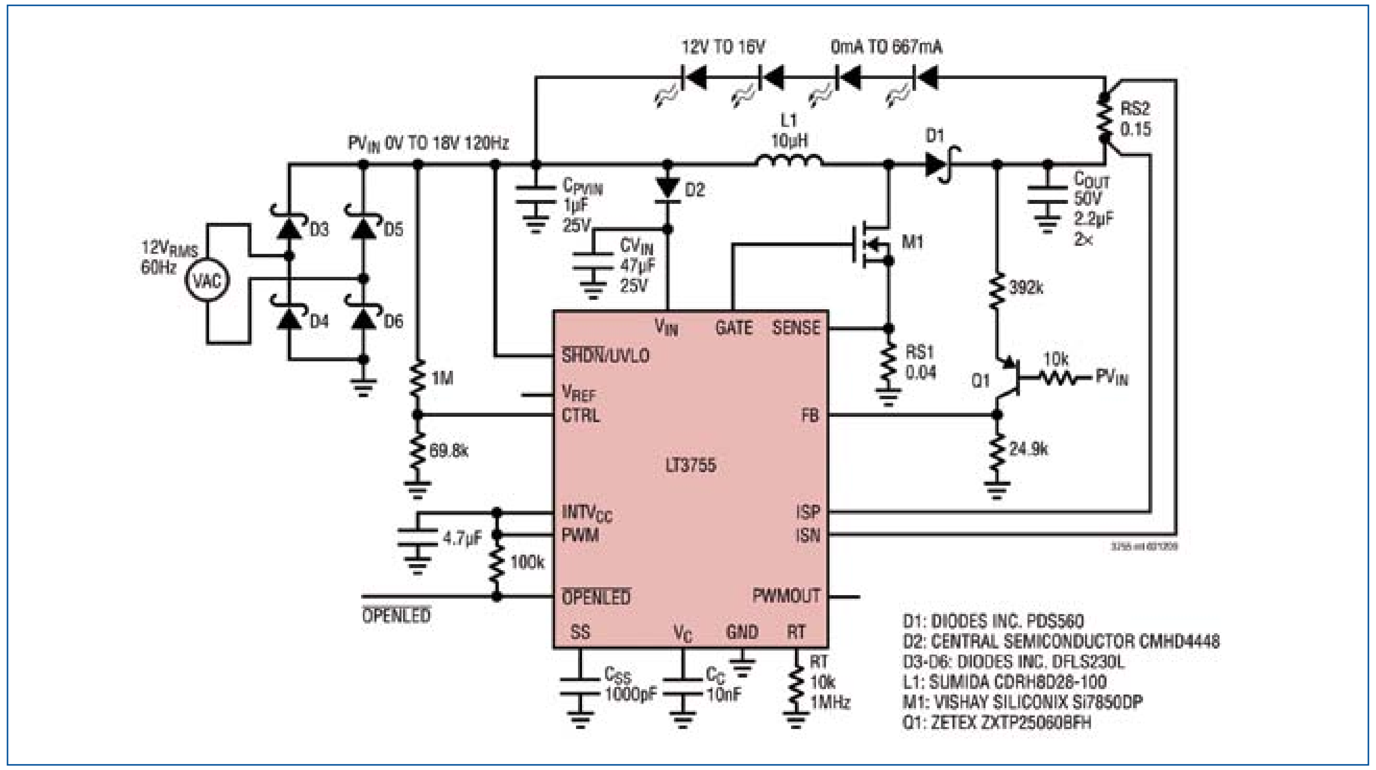


Figure 1: LT3755 AC Buck-Boost Mode LED Driver with 98.1% Power Factor Schematic.

Figure 2: 120Hz AC LED current and voltage waveforms delivering ~4W of LED power.

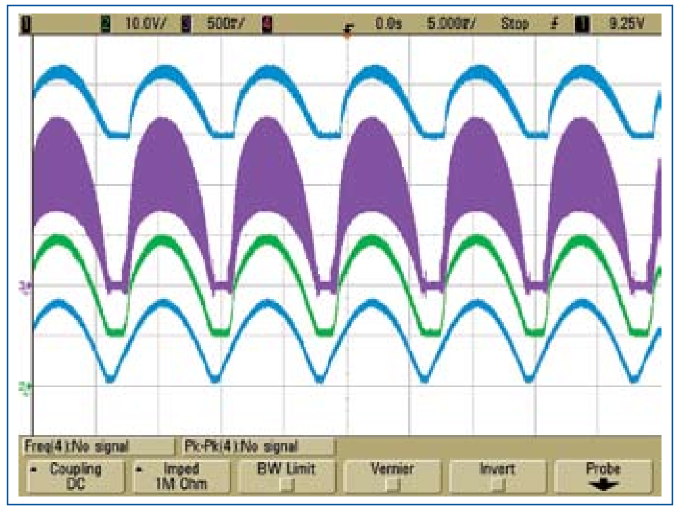


Figure 3: 120Hz AC LED driver waveforms derived from the rectified 12VACrms PVIN.

The circuit in Figure 1 is an LT3755 AC LED driver with 98.1% power factor. The topology is buck-boost mode since the wide-ranging input of 0V to 18V (12Vrms) and the wide ranging 4-LED string voltage of 9V to 14V crossover each other. The 12VACrms input is first rectified by D3-D6 to create a 120Hz 0V to 18V PVIN supply. The PVIN and VIN nodes are separated by a diode since the LT3755 works best when the VIN pin is held above 7V, maintaining 7V on INTVcc and driving the power MOSFET M1 with proper gate voltage. The diode allows peak charging of the VIN cap CVIN which is big enough to maintain charge when PVIN drops down to 0V.

LED current foldback with the CTRL pin voltage is used to create a high power factor LED driver. The maximum LED current is set by RS2 at 680mA, but the CTRL pin monitors the PVIN voltage and shapes the LED current waveform to match PVIN. When PVIN drops below the shutdown pin threshold, the IC goes into shutdown, switching stops and the soft-start feature is reset. The LED current trails off as the output capacitors are discharged and soon-enough, PVIN rises above the shutdown pin threshold voltage and the LT3755 starts back up. A light soft-start capacitor allows the LT3755 to get started up quickly and keep the power factor high. With the CTRL pin folding back the LED current at low PVIN, startup is not harsh and inrush currents do not affect the high power factor.

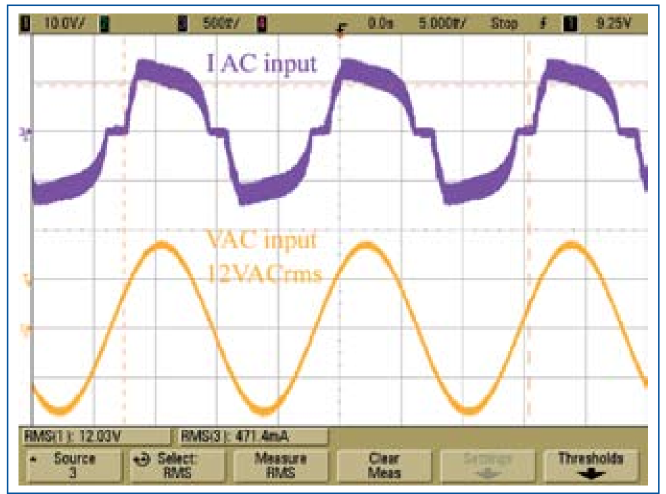


Figure 4: 12VACrms pre-rectifier line voltage and current waveforms with 98.1% power factor.

Figure 2 shows the LED string current and voltage waveforms at 120Hz. The scope was used to measure the average LED current and the average LED voltage. Multiplying the two is an approximate method for calculating the LED power. 356mA * 11.175V gives about 4W of LED power, enough for an efficient light bulb replacement.

Figure 3 shows the 120Hz waveforms generated by the LT3755 buck-boost mode AC LED driver in Figure 1. PVIN, VLED, IL1 and ILED are shown – all at 120Hz. 120Hz is a high-enough frequency to not be perceived by the human eye.

The power factor in this circuit is measured using an Agilent 6811B AC power source / analyzer. The 60Hz AC line voltage and current measurements are shown in Figure 4 below.

The LT3755 buck-boost mode AC LED driver delivers 4W of high efficiency LED power at 120Hz with 98.1% power factor. This circuit can be used to replace 12VAC halogen lighting with more robust LEDs. The high power factor of this AC LED driver rivals the high power factor of an incandescent filament-based bulb with purely resistive load properties.

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