# μModule LED Driver Integrates All Circuitry, Including the Inductor, in a Surface Mount Package

by David Ng

## Introduction

Once relegated to the hinterlands of low cost indicator lights, the LED is again in the spotlight of the lighting world. LED lighting is now ubiquitous, from car headlights to USB-powered lava lamps. Car headlights exemplify applications that capitalize on the LED's clear advantages—unwavering high quality light output, tough-as-steel robustness, inherent high efficiency—while a USB lava lamp exemplifies applications where *only* LEDs work. Despite these clear advantages, their requirement for regulated voltage *and* current make LED driver circuits more complex than the venerable light bulb, but some new devices are closing the gap. For instance, the LTM®8040 μModule LED driver integrates all the driver circuitry into a single package, allowing designers to refocus their time and effort on the details of lighting design critical to a product's success.

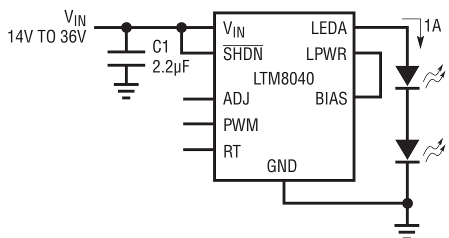


**Figure 1. Driving an LED string with the LTM8040 is simple—just add the input capacitor and connect the LED string**

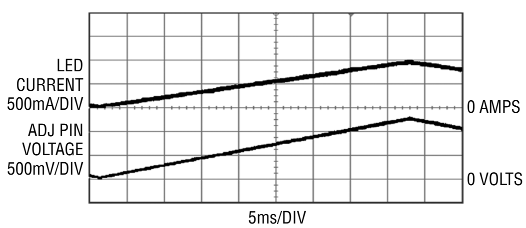


**Figure 2. Drive a 0V to 1.25V voltage into the ADJ pin to control the LED current amplitude**

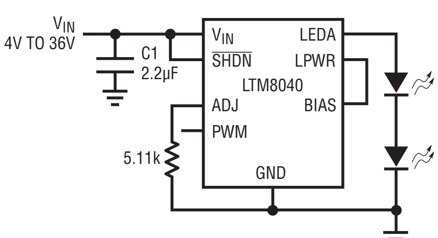


**Figure 3. Control the LED current with a single resistor from ADJ to ground**

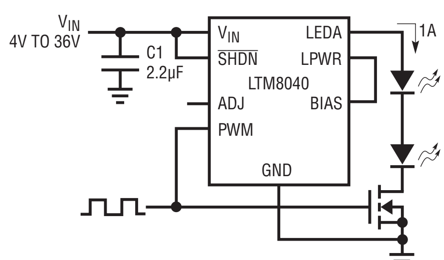


**Figure 4. The LTM8040 can PWM its LED string with an external MOSFET.**

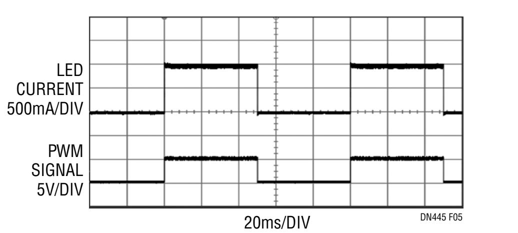


**Figure 5. The LTM8040 can PWM LED current with minimal distortion, even at frequencies as low as 10Hz.**

## A Superior LED Driver

The LTM8040 is a complete step-down DC/DC switching converter system that can drive up to 1A through a string of LEDs. Its 4V to 36V input voltage range makes it suitable for a wide range of power sources, including 2-cell lithium-ion battery packs, rectified 12VAC and industrial 24V. The LTM8040 features both analog and PWM dimming, allowing a 250:1 dimming range. The built-in 14V output voltage clamp prevents damage in the case of an accidental open LED string. The default switching frequency of the LTM8040 is 500kHz, but switching frequencies to 2MHz can be set with a resistor from the RT pin to GND.

## Easy to Use

The high level of integration in the LTM8040 minimizes external components and simplifies board layout. As shown in Figure 1, all that is necessary to drive an LED string up to 1A is the LTM8040 and an input decoupling capacitor. Even with all this built-in functionality, the LTM8040 itself is small, measuring only 15mm × 9mm × 4.32mm.

## Rich Feature Set

The LTM8040 features an ADJ pin for precise LED current amplitude control. The ADJ pin accepts a full-scale input voltage range of 0V to 1.25V, linearly adjusting the output LED current from 0A to 1A. Figure 2 shows the ratiometric response of the output LED current versus the ADJ voltage. The ADJ pin is internally pulled up through a 5.11k precision resistor to an internal 1.25V reference, so the output LED current can also be adjusted by applying a single resistor from ADJ to ground, as shown in Figure 3.

The PWM control pin allows high dimming ratios. With an external MOSFET in series with the LED string as shown in Figure 4, the LTM8040 can achieve dimming ratios in excess of 250:1. As seen in Figure 5, there is little distortion of the PWM LED current, even at frequencies as low as 10Hz. The 10Hz performance is shown to illustrate the capabilities of the LTM8040—this frequency is too low for practical pulse width modulation, being well within the discrimination range of the human eye.

The LTM8040 also features a low power shutdown state. When the $\overline{SHDN}$ pin is active low, the input quiescent current is less than 1µA.

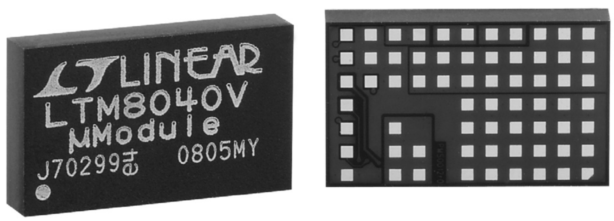


**Figure 6. Only 9mm × 15mm × 4.32mm, the LTM8040 LED Driver is a complete system in an LGA package**

## Conclusion

The LTM8040 µModule LED driver makes it easy to drive LEDs. Its high level of integration and rich feature set, including open LED protection, analog and PWM dimming, save significant design time and board space.

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*LTC6412, continued from page 21*

because the control target is often more complicated than a simple peak or RMS amplitude, and the amplitude noise introduced by the analog control loop may be unacceptable. A common solution for these systems is an analog VGA driven by a DAC as depicted in Figure 9.

The contradiction of a DAC controlling an analog-controlled VGA may appear at first as unusual and unecessary, but the arrangement provides key benefits. The gain step resolution is not determined by the VGA, and 8–12 bit DAC's are relatively inexpensive. More importantly, the signal gain can be adjusted with arbitrary smoothness, so the baseband processor can continue its demodulation/decoding operation without interruption. Most digital VGAs produce unacceptable signal discontinuities. The DAC does have a glitch of its own, but it is a baseband glitch that can be smoothed with filters. The glitch in many digital VGAs has no such remedy.

### Gain and Temperature Compensation

Many communication receivers require frequent gain optimization, but others are designed with over-performing ADCs that can tolerate moderate signal amplitude variation and avoid much of the AGC hardware problem. However, even these "fixed gain" system blocks often require a gain

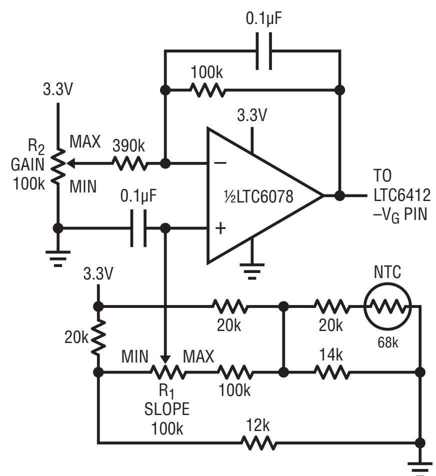


**Figure 12. Thermistor-based application circuit for static gain adjust and temperature gain slope compensation. Adjust R1 and R2 as needed and route output to $-V_G$ control terminal of the LTC6412.**

adjustment to compensate gain drift overtemperature and any cumulative gain tolerance of the other components. Several system components are cascaded to form a chain that usually includes a VGA to perform a one-time adjustment of gain and temperature slope to compensate the tolerances and slopes of the other components. In this scenario, the required temperature and compensation information is not known to the baseband processor or it is impractical to send this data to a suitably located VGA.

An analog-controlled VGA is a natural solution for this application because it can easily interpret the output of most temperature transducers without digitization. Figure 10 shows

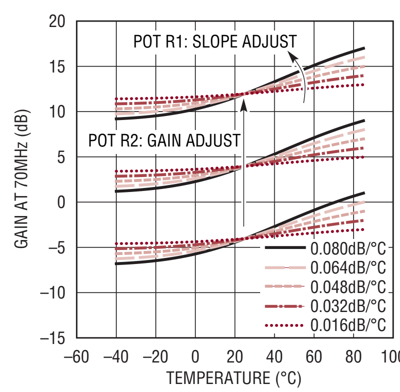


**Figure 13. Gain vs temperature performance characteristics of the thermistor-based circuit shown in Figure 12**

a simple application circuit using a common PTAT temperature sensor and an op amp to create the required $-V_G$ signal to adjust room temperature gain and temperature slope as shown in Figure 11. If temperature slope accuracy is only important for T > 0°C, then the same function can be performed with an inexpensive NTC thermistor as shown in Figures 12 and 13. Trying doing that with a digitally controlled VGA!

## Conclusion

By combining the advanced SiGe process with an innovative design, the LTC6412 offers unparalleled analog VGA performance at 3.3V. The tiny 16mm² leadless package and minimal external components produce a cost effective, fully differential VGA solution in less than 1cm² of PCB area.