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REFERENCE DESIGN 4367 INCLUDES: ✓Tested Circuit ✓Schematic ✓Description ✓Test Data ✓Layout

Adding Three Power MOSFETs Lets a Single Step-Down Converter Drive RGB LEDs in Projectors

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Abstract: This application note is an RGB LED driver reference design for a low-power projector. The design features a single MAX16821 HB LED driver to drive the RGB LEDs one at a time. This approach reduces the components needed, resulting in an efficient, small, and economical design. Board layout and test results are shown.

Introduction

This application note presents an RGB LED driver reference design for a low-power projector. This high-current LED driver is based on a single MAX16821 device that drives 10A to a set of RGB LEDs in step-down mode with less than 1 μ s turn-on/turn-off times. Only one color LED is driven at a time, with RGB colors sharing the PWM period in required proportions.

LED Driver Specifications

- Input supply voltage: 10V to 15V
- LED drive current: 10A
- LED forward voltage: 4.5V to 6V
- LED current rise/fall times: < 1 μ s
- LED current ripple: 10% peak to peak, max

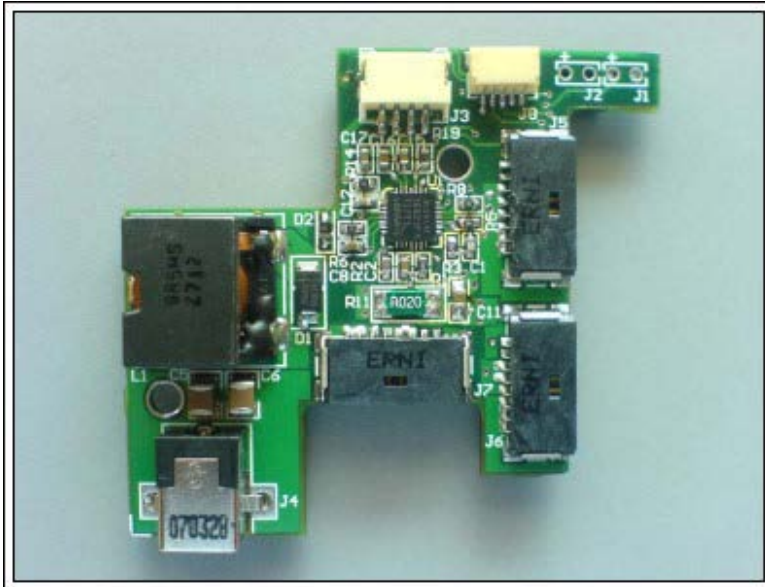
Inputs

- V_{IN} (J4): supply voltage input
- PWMR, PWMB, PWMG (J8 pins 1, 3, and 4): RGB PWM input signals. Amplitude should be 3.3V to 5V. As output can rise/fall within 1 μ s, any PWM period higher than 2 μ s can be used. Only one of the above three signals should be high at a time.
- PWMN (J8 pin 4): digital NOR of PWMR, PWMG, and PWMB. PWMN will be high only when all three PWM signals are low.
- ON/OFF (J1): leave open or drive +5V to enable the driver. Connect to GND for disabling the board.

Outputs

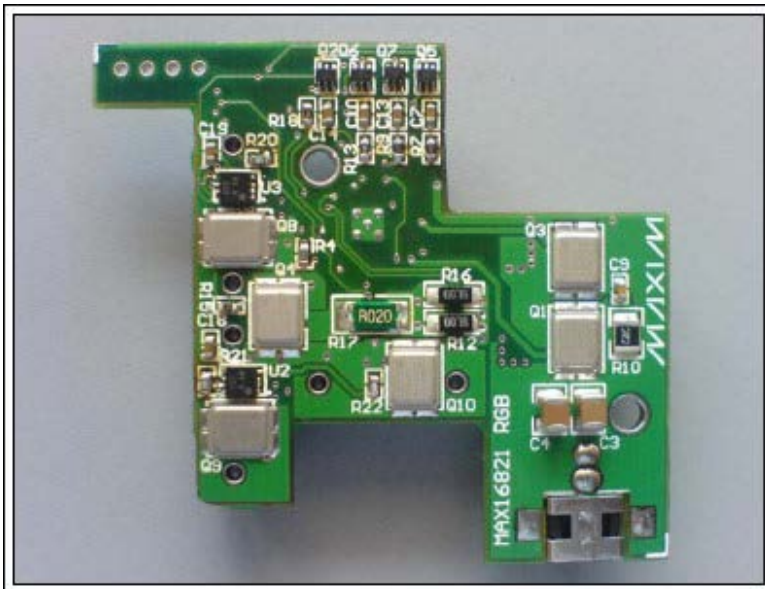
- LEDR, LEDG, LEDB (J5, J6, and J7): 10A RGB LED outputs. Connect LED+ to pins 3, 4, and 5; connect LED- to pins 6, 7, and 8.

- OUTV (J2): provides a signal proportional to the LED current. The voltage at OUTV will be 135 times the voltage across R12||R16.
- VIN_OUT (J3): input supply-voltage output for connecting to other boards. Pins 1 and 2 are VIN+; pins 3 and 4 are GND.



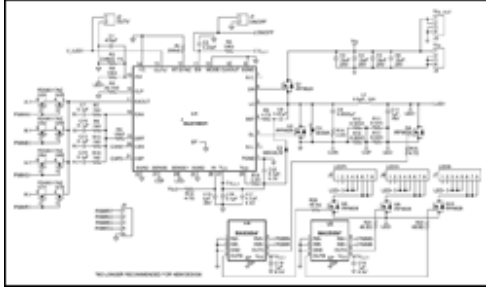
[More detailed image \(PDF, 1.25MB\)](#)

Figure 1. The LED driver board (top view).



[More detailed image \(PDF, 1.35MB\)](#)

Figure 2. The LED driver board (bottom view).



[More detailed image](#) (PDF, 112kB)

Figure 3. Schematic of the LED driver which features the MAX16821.

Circuit Description

Low-power projectors use a single DLP chip to process RGB colors. Only one color illuminates the DLP at any given time. This approach enables the use of a single high-current driver with additional switches to switch between the LEDs. The result is a compact and cost-sensitive projector design.

This LED driver reference design uses a single step-down converter to drive a 10A current to RGB LEDs one after the other. MOSFETS Q8, Q9, and Q10 select and route the regulated inductor current to one of the RGB LEDs, based on the PWM signals.

The core buck-converter stage that steps down the 10V to 15V input supply to the 4.5V to 6V LED forward voltage is based on an average current-mode controller, the MAX16821B. The buck converter is wired in synchronous mode with the output referenced to ground. The Mode pin is connected to GND to select the IC operation in ground-referenced buck driver mode. The converter works at a 300kHz switching frequency, optimally selected so the design can use a small size inductor and be highly efficient.

This design requires the LED current rise/fall times to be less than 1 μ s. To accomplish this, the value of output filter capacitor must be very small, thus increasing the load ripple current. Instead, a larger than usual inductor is chosen, so that the inductor ripple current is kept below the limit on the load ripple current. A 1 μ F capacitor is used at the output (C11) to limit the output-current slew rate close to 10A/ μ s and to prevent any overshoots caused by parasitic components.

This LED driver controls and maintains a 10A current through the inductor. Depending on the LED to be driven at any instant, Q8, Q9, or Q10 is turned on and the inductor current is routed through the corresponding LED. When all three LEDs are off, the inductor current is circulated locally through Q4.

The MAX16821 device has two control loops; an internal loop controls the inductor current and the external loop determines the inductor current needed to drive the LED current. In a step-down converter the inductor current is the same as the LED current. Therefore, the control is effectively reduced to a single loop that monitors the inductor current. To prevent subharmonic oscillations in the inductor current in this design, R5 limits the current error-amplifier gain to 11.5V/V. The current loop compensation does not have a pole-zero pair to increase the gain at low frequencies that makes the inductor current settle accurately to the value programmed by the voltage loop. The voltage-error amplifier compares the LED current-sense voltage across R11||R17 to an internal 100mV reference, and amplifies the error with a 70dB gain. This amplified output drives the internal current loop. Even if the internal current loop gain is less because of the high gain of the voltage-error amplifier, the LED current settles to 10A.

When the inductor current is switched between RGB LEDs and the local loop made by Q4, the voltage-error amplifier output needs to be at four different levels. These four levels are needed because the output voltage in each of these four conditions differs. Four different compensation capacitors (C7, C10, C13, and C14) store the voltage-error amplifier outputs, corresponding to four different load conditions. Compensation

capacitors are connected to the circuit, one at a time using analog switches (Q2, Q5, Q6, and Q7). As soon as an LED is turned on, the corresponding compensation capacitor immediately adjusts the error amplifier output to the voltage stored in the previous cycle, thus enabling the LED current to rise to 10A quickly.

The internal current loop absorbs the inductor pole. The output pole, formed by the LED dynamic impedance and the output capacitor C11, occurs much higher than the switching frequency. The voltage loop will have only a single pole that is the voltage-error amplifier pole. Compensation capacitors (C7, C10, C13, and C14) produce a pole at the origin and make the voltage loop cross 0dB at one-tenth the current-loop crossover frequency.

The [MAX5054](#) dual MOSFET driver (U2, U3) drive (Q2, Q5, Q6, and Q7) to enable fast switching between the LED loads and the high-current slew rates of 10A/1 μ s. A dissipative snubber, formed by C9 and R10, slows the switching edges at the LX node and also damps any overshoot/undershoot and ringing. Overvoltage protection feedback provided by R3 and R4 shuts down U1 if the output voltage exceeds 6.4V. U1 resumes switching once the output voltage reduces below 5.4V. Filter capacitor C1 prevents false triggering due to any noise. The RC network provides a 3ms delay from the supply turn-on edge, so that U1 can start after the input supply settles.

Circuit Waveforms

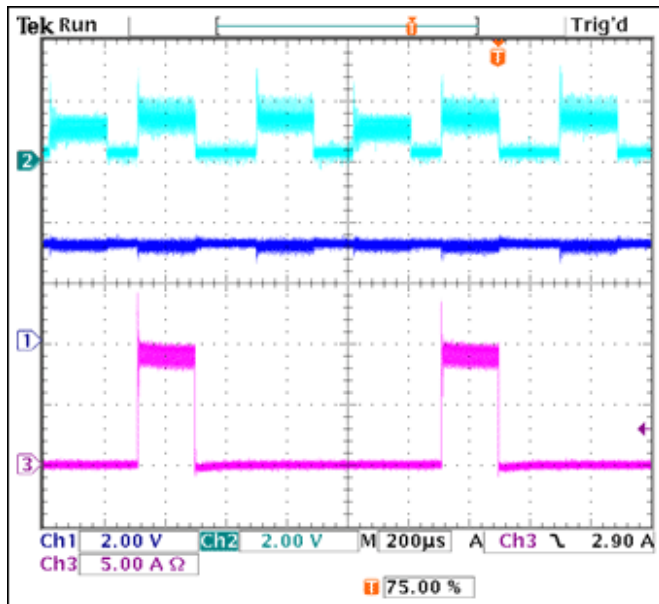


Figure 4. The scope shot shows the current through one of the LEDs (CH3); the voltage at the OUTV pin (CH1) that represents the inductor current; and the voltage at the CLP pin (CH2) that represents the PWM duty cycle. Inductor current is the same throughout the cycle. The PWM duty cycle is almost the same for blue and green LEDs, but less for the red LED. The LED current rises and settles to the final value in 1 μ s.

Temperature Measurements

- V_{IN} : 12V
- I_{OUT} : 10A to RGB LEDs with 20% PWM to each color
- Cooling: board is cooled by forced air
- Board temperature: +53°C
- Q1, Q3 case: +60°C
- Q4, Q8, Q9, and Q10: +58°C
- U1 top: +53°C

- L1 winding temperature: +70°C

Power-Up Procedure

- Connect 10A RGB LEDs to J5, J6, and J7.
- Keep PWMR, PWMG, PWMB, and PWMN signals low.
- Increase the supply voltage gradually to 10V, observing the current which should be less than 0.3A.
- Apply the PWM signals, PWMR, PWMG, and PWMB with 15% to 20% PWM duty cycle. (Each of the PWM on pulses should be positioned so that only one PWM signal is high at a time.) The PWMN signal should be the digital NOR of PWMR, PWMG, and PWMB. All three LEDs will be alternately driven with 10A for the set duty cycles.

Related Parts

[MAX16821](#)

High-Power Synchronous HB LED Drivers with Rapid Current Pulsing

[Free Samples](#)

More Information

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REFERENCE DESIGN 4367, AN4367, AN 4367, APP4367, Appnote4367, Appnote 4367

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