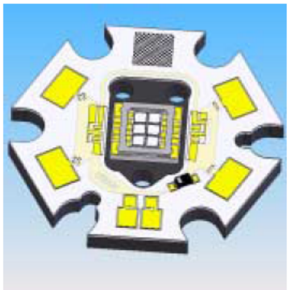
MIC2196 OSRAM LED LIGHTING

Osram OSTAR®: Micrel LED Driver Advancements

Introduction

Today's high current LEDs are finding applications that replace conventional lamps including filament and fluorescent and metal-halide lamps as well as conventional LEDs. These new LEDs bring the advantages of high reliability, color control and extended lifetime as well as usually better luminous efficiency. They are finding applications in the home, industrial, portable devices and in vehicles. The latest high current LEDs include multiple series connected LED strings on a single thermal/ mechanical substrate. They are driven with current control to give matched light output on each LED. Typical mechanical configurations include star, string and ring. Driving these series of connected arrays of LEDs requires accurate control of the LED current to control illumination and power consumption as well as giving a long operational life.

This article summarizes the key requirements for driving Osram OSTAR® high current LED arrays and shows how these requirements can be met with an elegant and easy to implement driver based on the Micrel MIC2196.



LEW E3A

Figure 1. The OSTAR® 6 LED Array

Figure 1 consists of an array of six outstanding brightness and luminance (up to 18cd/m2) white LED emitters in ThinGaN® LED technology. These are mounted onto an ultra-low thermal resistance substrate. The entire assembly is only 20mm in diameter and capable of dissipating 27W. This power handling is even more impressive when one considers that the six LEDs occupy an area of only 2.1mm x 3.2mm. The nominal operating current of this series connected array is 700mA with a peak current rating of 1A. The total voltage variation of the device is between 17V and 26V at full load current.

General Description

Typically, these arrays of LEDs are required to work from a nominal 12 volt DC supply which can have a significant output voltage variation. Dimming can be used to reduce light levels or to match mixed color RGB LEDs light output. Dimming requirements are complicated by the variations present in the chromaticity of high power LEDs with LED current. Two common methods of dimming are presently used; a continuous (analog) dimming where the current in the LED is reduced in a linear manner and PWM dimming where the LED current is turned ON and OFF by a switch to achieve an average current. Compensation and optical feedback may be required in the case of mixed color RGB LEDs where the variations in chromaticity with load current exceed the perception level of the human eye. In terms of chromaticity, this is known as exceeding the four-step Macadam ellipse.

This level of optical compensation and feedback is beyond the scope of the present article. PWM dimming frequency must be well above the persistence of vision threshold.

An ability to turn the LED array completely off can also be considered part of a dimming scheme.

The LED driver must have a small footprint and have high efficiency since it usually packaged with or very close to the lamp. Electrical noise on the input side must be minimized in order to reduce the amount of additional filtering required to meet conducted emissions specific-ations. Moreover, the driver should provide over-voltage safety protection in the event of an open circuit LED. Finally, the driver electronics must also be easy to implement and flexible in application.

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Driver Key Points Specifications
V_{IN}: 12V nominal; 10V to 16V overall.
V_{OUT}:17V to 30V
Nominal I_{OUT}: up to 0.7A.
Maximum I_{OUT} up to 1.0A.
Current setting accuracy +/- 10%
Easy to implement dimming:-
Continuous analog dimming from 100% to 10%.
PWM Dimming from 100% to 3% PWM frequency 100-300Hz
OSTAR® 'OFF' capability.
700mA Efficiency. >90% under all variations of input voltage and OSTAR® voltage.
Overvoltage protection
Low parts count
All SMD single-sided PCB.

Driver Design Description

The LED Driver uses a Micrel MIC2196 400kHz boost controller as the power stage. The MIC2196 steps up the input voltage using a boost switch-mode power cell. The power switch Q2 boosts the input voltage using L1, D1 and C1. Q2 is an N-channel MOSFET whose gate is driven by the MIC2196 controller. The high current capability of the MIC2196 FET driver reduces switching loss in the MOSFET which is a major factor in determining overall efficiency. The high operating frequency means that the main energy storage components L1 and C1 can be small-value, small-footprint.

Overvoltage protection is implemented simply as zener diode Z1. In event of an open circuit, the LED current feedback signal will be lost and the output voltage will rise because the PWM duty cycle will increase. In this event, the zener Z1 will conduct at around 33V limiting the maximum possible overvoltage by injecting current into the feedback network in such a way as to reduce the duty cycle.

The required OSTAR® current is measured by the current sense resistor R10 and used to control the duty cycle of the MIC2196. 330mohm for R10 gives 700mA nominal current with DIM pin not used (open-circuit). A value of 680mΩ for R10 will give a nominal 350mA LED current. This current measurement is scaled to the error amplifier within the MIC2196 by means of R14 and R3. A 1 percent voltage reference, Z2, gives the required current setting accuracy without the need for an external current sense amplifier.

The two different dimming methods are shown in the schematics of Figures 2 and 3 respectively.

Referring to Figure 2; continuous dimming is achieved simply by adding the resistor R15 and inputting a DC voltage to the 'Analog DIM' pin as shown in Figure 2. Alternatively, a filtered PWM signal could be applied to the same pin. The dimming range of 5V to 0V gives a linear variation of 10 percent to 100 percent output current.

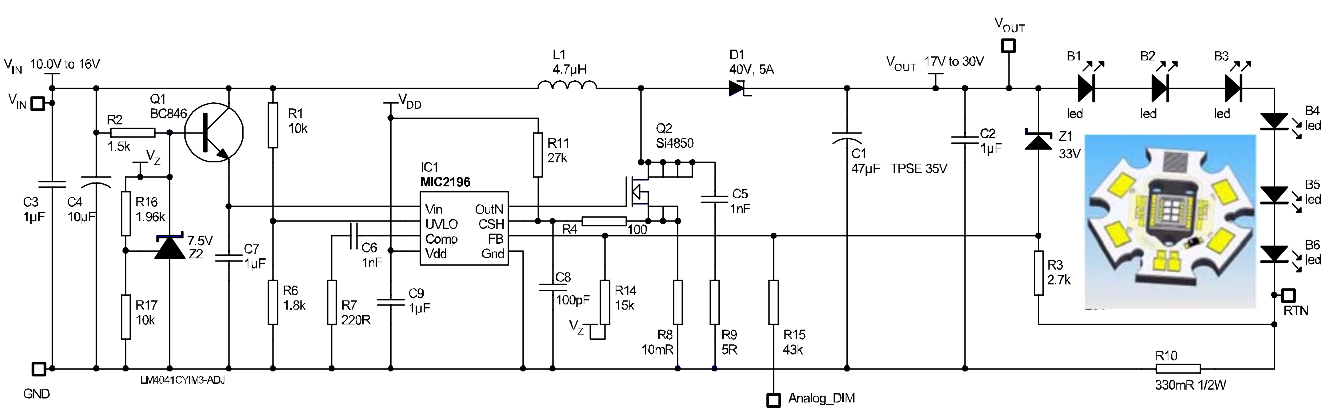

Figure 2. Continuous (Analog) Dimming

PWM dimming can be understood by referring to Figure 3. In this case, the Analog DIM resistor R15 is removed. The OSTAR® current setting components remain the same; R10, R3 and R14. To achieve PWM operation, a low RDSON MOSFET Q3 is added. This MOSFET is the switch which allows PWM-ing. Q3 ON resistance is low when compared to R10 so it does not significantly affect the current sensing network. A PWM drive signal of 100-300Hz and amplitude of 5V (for a logic level MOSFET) is applied to the gate of Q3. A pull-down resistor, R15, holds the MOSFET 'OFF' when no gate drive signal is present. Therefore, this circuit can be simply adapted to give an OSTAR® OFF capability.

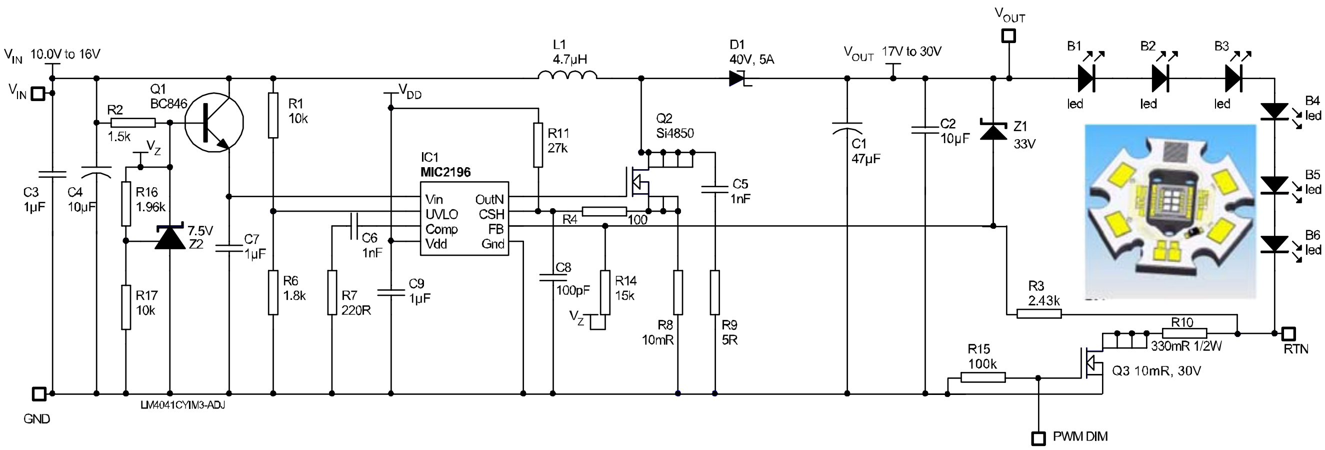

Figure 3. PWM Dimming

PCB Implementation

The entire circuit capable of power levels up to 30W can be implemented on a single sided 25mm x 30mm PCB using SMD multi-source components, see Figure 4.

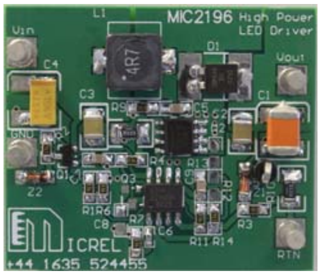

Figure 4. OSTAR® Driver PCB

Test Results

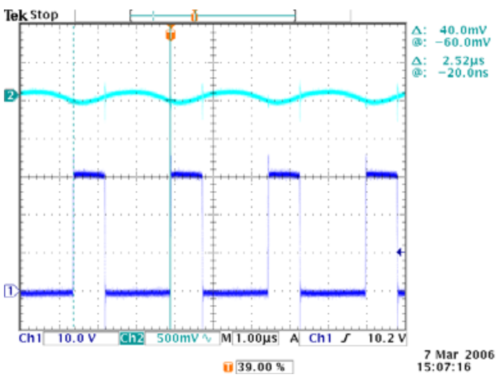

Figure 5. Test Results @700mA OP Current (Unless Otherwise Stated)

Input EMI

The upper test waveform, Figure 5, shows the input EMI with V_{IN} = 10V and I_{OUT} = 700mA. The lower waveform the Drain-Source voltage of Q2. The EMI is ~200mV pp quasi-sinusoid with minimal high frequency content. This means very little, if any, additional filtering is needed.

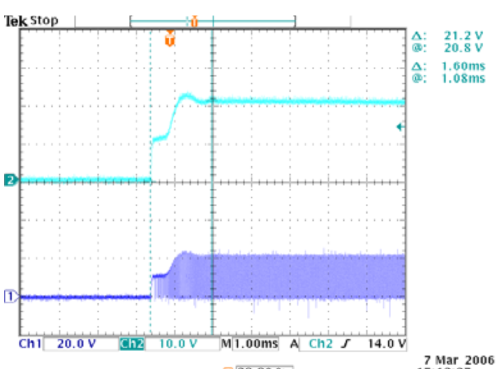

Figure 6. Start-Up

Figure 6 is start up with V_{IN} = 10V in and V_{out} = 20V and 700mA OSTAR® current. The upper waveform is the voltage across the OSTAR® and the lower voltage the Drain-Source voltage of Q2. Start up takes <2ms and is well controlled.

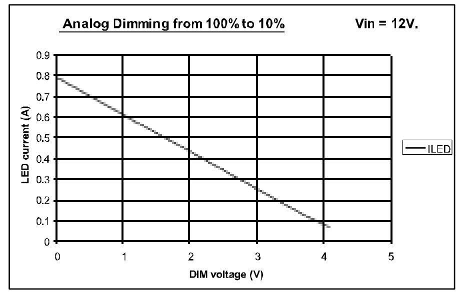

Figure 7. Continuous (Analog) Dimming, Using Schematic from Figure 2

In Figure 7 the variation in OSTAR® current, with dimming voltage applied to the Analog DIM pin is shown. OSTAR® current is proportional to dimming voltage and controllable down to 10 percent of full load current.

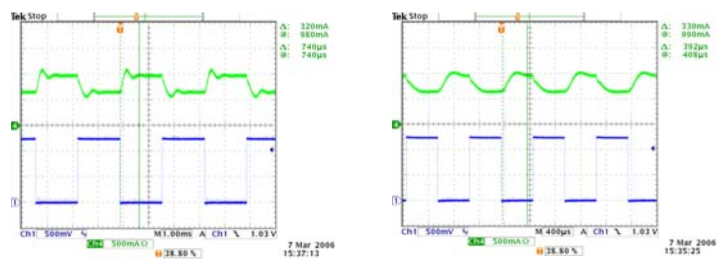

Figure 8. Output Step Load Response

In Figure 8, the Analog DIM pin is stepped between 0V and 5V. In this configuration, R3 and R15, from Figure 2, have been set to give a step from 700mA to 1A. The traces are for V_{IN} = 10V t (left) and V_{IN} = 16V (right). These waveforms illustrate the driver's ability to work at 1A OSTAR® current. In addition it can be seen that PWM-ing of the Analog DIM pin is possible. The response is dominated by the LC constant of the output filter.

PWM Dimming Linearity

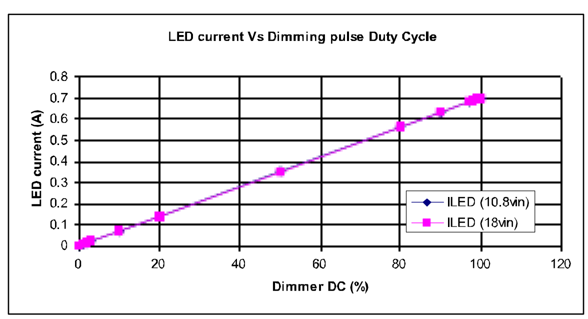

Figure 9. PWM Dimming, Refer to Schematic in Figure 2

PWM Dimming in Figure 9 is substantially linear from 1 percent to 100 percent OSTAR® current over the input voltage range.

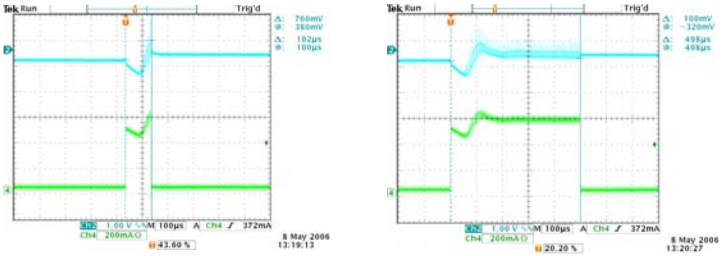

Figure 10. PWM Dimming Duty Cycle Control

The waveforms in Figure 10 show the OSTAR® current below and the Driver output voltage above. The left hand waveform is at 1 percent duty and the right hand one at 5 percent duty. The ripple in both cases is due to the dynamic response of the driver. In the case of PWM, dimming the driver dynamic response has been optimized to achieve 1 percent dimming.

Current Setting Accuracy

A MathCAD program was developed to calculate the current setting resistors; R3, R14 and R15, see Figure 11.

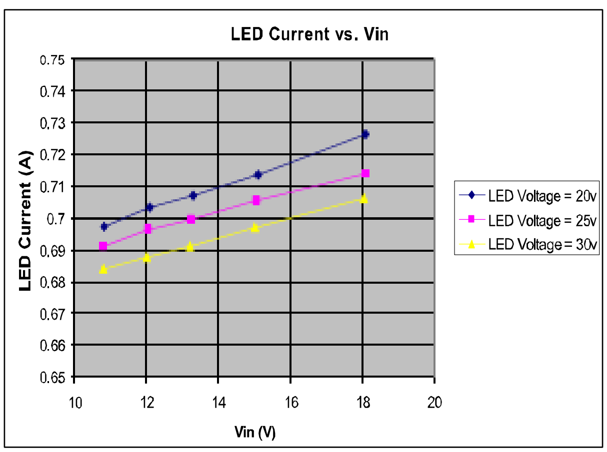

Figure 11. LED Current vs. V_{IN}

Over the range of input voltage and OSTAR® voltage variation, the OSTAR® current varies from 680mA to 720mA. This corresponds to a tolerance of ±3 percent from these causes. Taking into account all component temperature variations, as well as Z1, voltage reference tolerance indicates that the design goal of ±10 percent will be easily achieved.

Efficiency

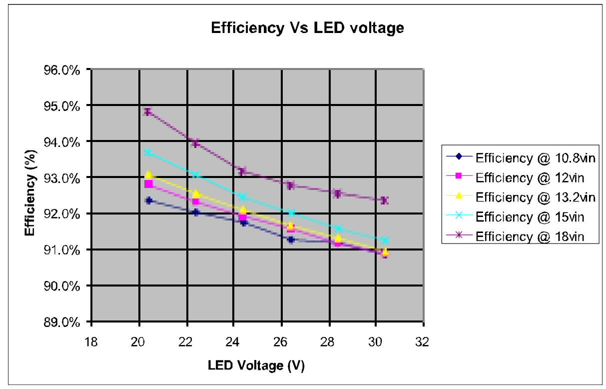

Figure 12. Efficiency vs. LED Voltage

Efficiency under all variations of input voltage and possible OSTAR® voltage meets the design goal of better than 90 percent, see Figure 12.

A Bill of Materials, to illustrate the lowered cost of this solution, is given at the end of this document.

Summary

We have seen in this article how to implement a highly efficient flexible driver for the Osram OSTAR® series of LED Arrays. This driver exhibits better than

90% efficiency, is able to operate with continuous or PWM dimming to 1% load current. Current is controlled very accurately and the OSTAR® can be switched

OFF if required. The total driver solution fits onto a compact 25*30mm PCB which can easily be interfaced to the OSTAR®.

References

1. OSTAR®-Lighting Application Note; March 2006 Authors: Andreas Stich, Monika Rose

2. Osram Data Sheet OSTAR® - Lighting with / without Optics; LEW E3B, LEW E3A- 2006-03-20

3. Micrel MIC2196 Data Sheet: - http://www.micrel.com/_PDF/mic2196.pdf

Bill of Materials for Micrel MIC2196 OSTAR® LED Driver

Value	Pattern	Qty.	Components	Notes
OSTAR®		1		Shown as B1 – B6 on schematic
LM4041CYIM3-ADJ	SOT-23	1	Z2	
MIC2196	SO-8	1	IC1	SO8 Boost controller
Si4850	SO-8_PP_sg1	1	Q2	N-Channel MOSFET
1.5k	0805	1	R2	Resistor
1.8k	0603	1	R6	Resistor
1.96k	0603	1	R16	Resistor
100	0603	1	R4	Resistor
100k	0603	1	R15	Resistor
100pF	0603	1	C8	Ceramic Capacitor
10k	0603	2	R1, R17	Resistor
10mR, 30V	TSOP6	1	Q3	N-Channel MOSFET
10mR	1210	1	R8	Resistor
10µF	1210	1	C2	Ceramic Capacitor
10µF	7257	1	C4	
15k	0603	1	R14	Resistor
1nF	0603	1	C6	Ceramic Capacitor
1nF	0805	1	C5	Ceramic Capacitor
1µF	0805	2	C7, C9	Ceramic Capacitor
1µF	1210	1	C3	Ceramic Capacitor
2.4k	0603	1	R3	Resistor
220R	0603	1	R7	Resistor
27k	0805	1	R11	Resistor
330mR 1/2W	1210	1	R10	Resistor
33v	MLL34	1	Z1	
4.7µH	CDRH104R	1	L1	Inductor
40V, 5A	SMC	1	D1	Schottky Diode
47µF	7257	1	C1	
5R	0805	1	R9	Resistor
BC846	SOT-23	1	Q1	65V NPN Bipolar

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