

# Driving Avago RGB LED light source module and white LED light source module

## Application Note 5307

### Introduction

The RGB light source module consist of the following parts:

- a) ADJD-MJ50,
- b) ADJD-MJ51,
- c) ADJD-MJ60 and
- d) ADJD-MJ61.

The RGB LED light source module consist of four LED strings. Each LED string consists of series connected LEDs. The LED strings are

- Red color - Connect with R+ and R- terminals.
- Green color - Connect with G1+ and G1- terminals
- Green color - Connect with G2+ and G2- terminals
- Blue color - Connect with B+ and B- terminals.

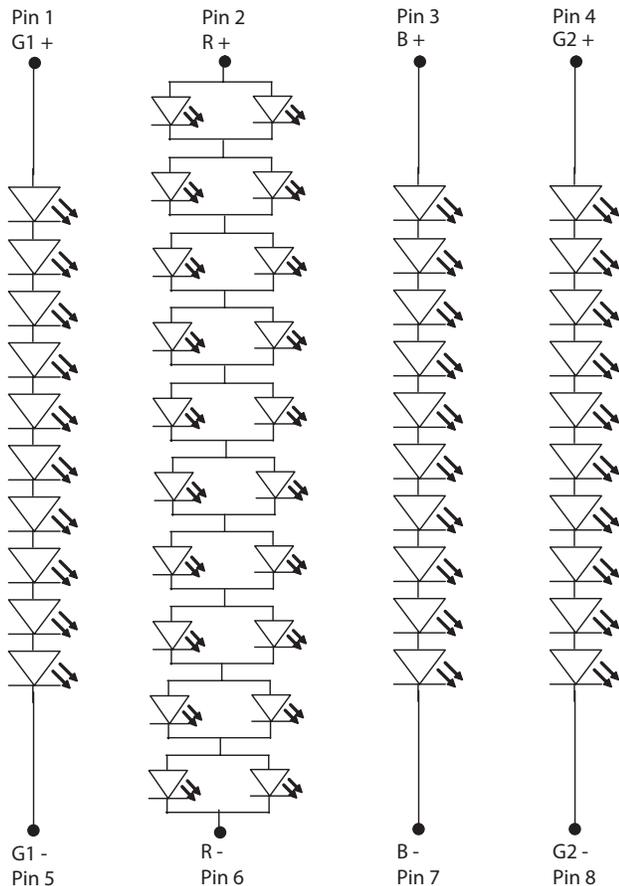


Figure 1a. RGB light source module electrical configuration

The electrical configuration is shown in figure 1. The three colors in the LED light source will mix to form a resultant color. Depending on the mix ratio, any color within the color gamut of the LED can be obtained. The color gamut of the LED light source is the triangle formed by the three colors points on the CIE chromaticity chart. The three color points are from Red, Green and Blue LED color.

Each of the LED string can be driven independently.

The 3.5W white LED light source module consists of ADJD-xD00 and ADJD-xD01. The 10.5W white LED light source module consists of ADJD-xD20 and ADJD-xD21.

The white LED light source can be configured as

- a) one LED strings of 20 LEDs in series, or
- b) two LED strings of 10 LEDs in series, or
- c) four LED strings of 5 LEDs in series.

Figure 1(b) shows the electrical configuration for the white LED light source module.

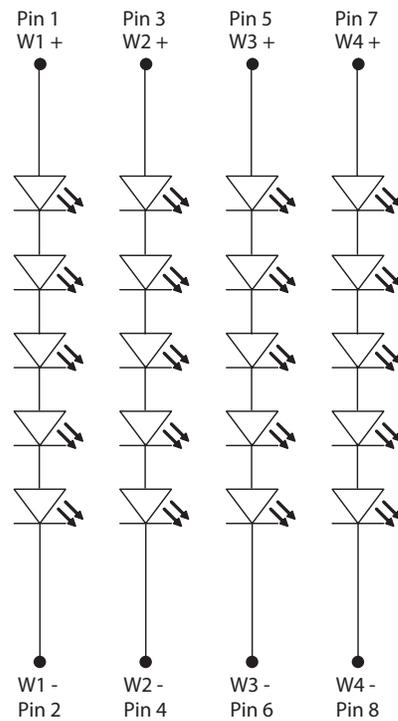


Figure 1b. White LED light source module electrical configuration

## Resistive Current Limiting

A fixed voltage is applied to the positive terminal of each LED string through a resistor. The negative terminal is connected to GND. The value of the resistor is determined by the current needed and the input voltage, according to the equation

$$R = \frac{V_{IN} - VF}{IF}$$

The current required for red, green and blue color LEDs are determined from the required luminous intensity needed to obtain the color. The forward voltage drop, VF of the LED strings is obtained from the datasheet. The resistor required can thus, be calculated from the equation above. Figure 2 shows the circuit of the simple resistive current driver.

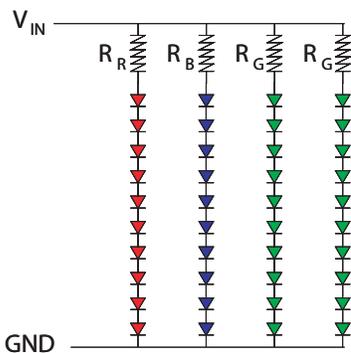


Figure 2. Resistive current limiting driver

This simple circuit works but the color and brightness will shift if the VF drifts. If the color or brightness is to be changed, the resistor has to be changed and replaced. A potentiometer can be added to the fixed resistor. The fixed resistor is set to the maximum operating current for each LED color string. The potentiometer adjusts the maximum allowable current to a lower desired current. This is shown in Figure 3.

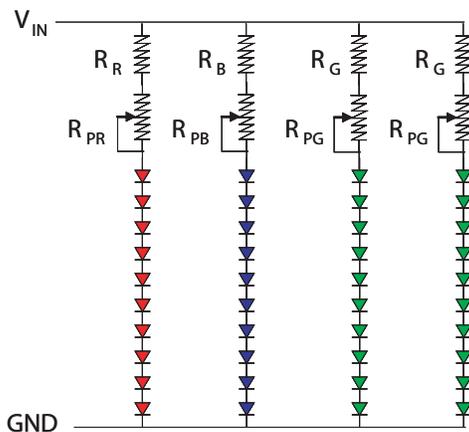


Figure 3. Modified for manual color adjustment

Resistor  $R_R$ ,  $R_B$ ,  $R_G$  is determined by the maximum allowable LED current.

This method is simple but suffers from lower efficiency due to the higher power dissipation. It is also sensitive to input voltage variation and VF drift, causing color and brightness shift.

## PWM Dimming

Figure 2 can be modified to allow PWM dimming instead of using a potentiometer.

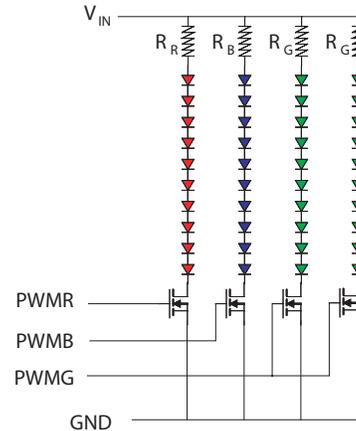


Figure 4. Simple resistive driver with FETs for pulse width dimming

PWMR, PWMB and PWMG signals provide the pulse width modulation to dim the LED strings. Resistor  $R_R$ ,  $R_B$ ,  $R_G$  is to limit the maximum current in each LED string. It is important to choose the FET transistor with the lowest possible on-state resistance and with a suitable voltage and current rating. The voltage rating of the FET transistor must be greater than  $V_{IN}$ , the input voltage supply.

This circuit is simple but also suffers from current variation, causing brightness shifts and color change. The circuit is not recommended for use in Avago's color controller products, HDJD-J822 and ADJD-J823.

### Constant Current Methods

The constant current methods as the name implies mean that the LED current through the red, green and blue LED strings are constant. The constant current method is best in providing a constant light intensity and therefore a consistent mix ratio to produce a resultant color. There are two constant current methods:

- a) linear current driver
- b) switch mode current driver.

### Linear IC constant current LED driver

Example of such ICs is the Maxim 16800, Infineon TLE4242G and Austriamicrosystems AS3691 and the AS3692 LED driver.

For details, refer to the manufacturers' web site,  
<http://www.maxim-ic.com>,  
<http://www.infineon.com>  
 or  
<http://www.austriamicrosystems.com>

Linear integrated IC LED driver typically used a single resistor to set the LED current.

### TLE4242G

The TLE4242G regulate 177mV between REF and GND pins. The maximum input voltage rating is 42V with a dropout voltage of 0.7V.

The LED current is equal to  $\frac{0.177}{R1}$

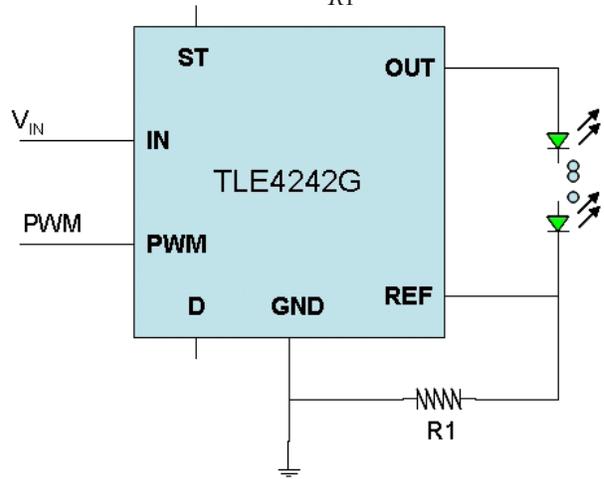


Figure 5. Infineon TLE4242G LED driver

Table 1 shows the R1 values and its associated LED current to drive the LED string.

Table 1. Resistor selection for circuit in Figure 5.

LED string	LED current	R1	Comment
Red	300 mA	0.59	Parallel resistors of 1.1 and 1.3 ohm
Green / Blue	150 mA	1.18	Parallel resistors of 2.4 and 2.4 ohm

The PWM is an input to regulate LED brightness. If not needed, the PWM is connected to VIN.

## MAX16800

For each LED string, one MAX16800 will be used. A minimum of four MAX16800 is required to drive one unit of RGB light source module.

The  $V_{OUT}$  pin is connected to the anode of the LED string. The cathode of the LED string is connected to the CS+ pin. The input voltage supply must be higher than  $V_{OUT}$  to provide the voltage  $V_Q$ . I.e.  $V_{IN} = V_F + V_Q$ , where

$V_F$  = total  $V_F$  of the LED string

$V_Q$  = Incremental LED driver voltage = 1.2V for  $V_{IN} > 12V$ .

As the maximum operating  $V_{IN}$  is 40V, the LED driver can only be used if the  $V_F$  is less than 38.6V. This is usually the case for typical  $V_F$  of the green or blue LED strings. However, the driver will not be suitable if the green or blue LED string  $V_F$  are more than 38.6V or is at the maximum  $V_F$  specification.

The value of  $R_S$  is calculated from the equation,

$$R_S = \frac{V_{sense}}{I_{LED}}$$

Note:

$V_{sense}$  is the voltage across CS+ and CS- pin. Typical value is 0.204V

$I_{LED} = 300mA$  for red LED string, 150mA for green or blue LED string.

The EN input is tied to  $V_{IN}$  if unused. Alternatively, the pulse width modulation high voltage supply can be connected to both EN and  $V_{IN}$  inputs to provide PWM dimming.

For LED color management application with the ADJD-J823 and the HDJD-J822, the PWM output of each channel is not sufficient to drive both the EN input and  $V_{IN}$  input together. Instead, the PWM output from the ADJD-J823/HDJD-J822 is connected to the EN input of the MAX16800. A constant voltage supply is connected to  $V_{IN}$ . Figure 6 illustrate the simplified circuit for the red pulse width modulation (PWMR) to drive red LED string.

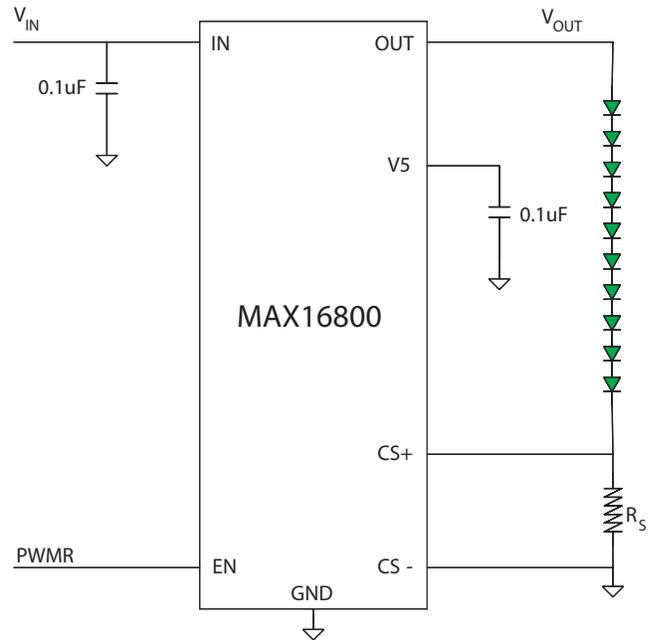


Figure 6. Simplified LED driver circuit with PWMR dimming control

## Switch Mode LED Driver

The switch mode regulator can be used for step up (boost) or step down (buck) or step up / step down (buck – boost), depending on circuit and the input voltage supply. The voltage at the output is controlled by pulse width modulation at a switching frequency of a few kHz to a few hundred kHz. Its chief advantage is that its efficiency is generally higher than linear mode. Its main disadvantage is the complexities in design. Most switching regulators can be designed in any of these configurations. Designers should obtain information on the datasheets and application notes from the manufacturer.

Some examples of switch mode LED drivers are provided.

## HV9911

The HV9911 switch mode LED driver provides control input for dimming.

- Dimming by linear voltage input which modifies the LED current level. This is done by designing the proper combination of voltage at IREF pin and the current sense resistor at FDBK pin.
- Dimming by pulse width modulation input. This is done through the PWM pin.

The typical circuit is shown in figure 7 for continuous conduction mode boost LED driver.

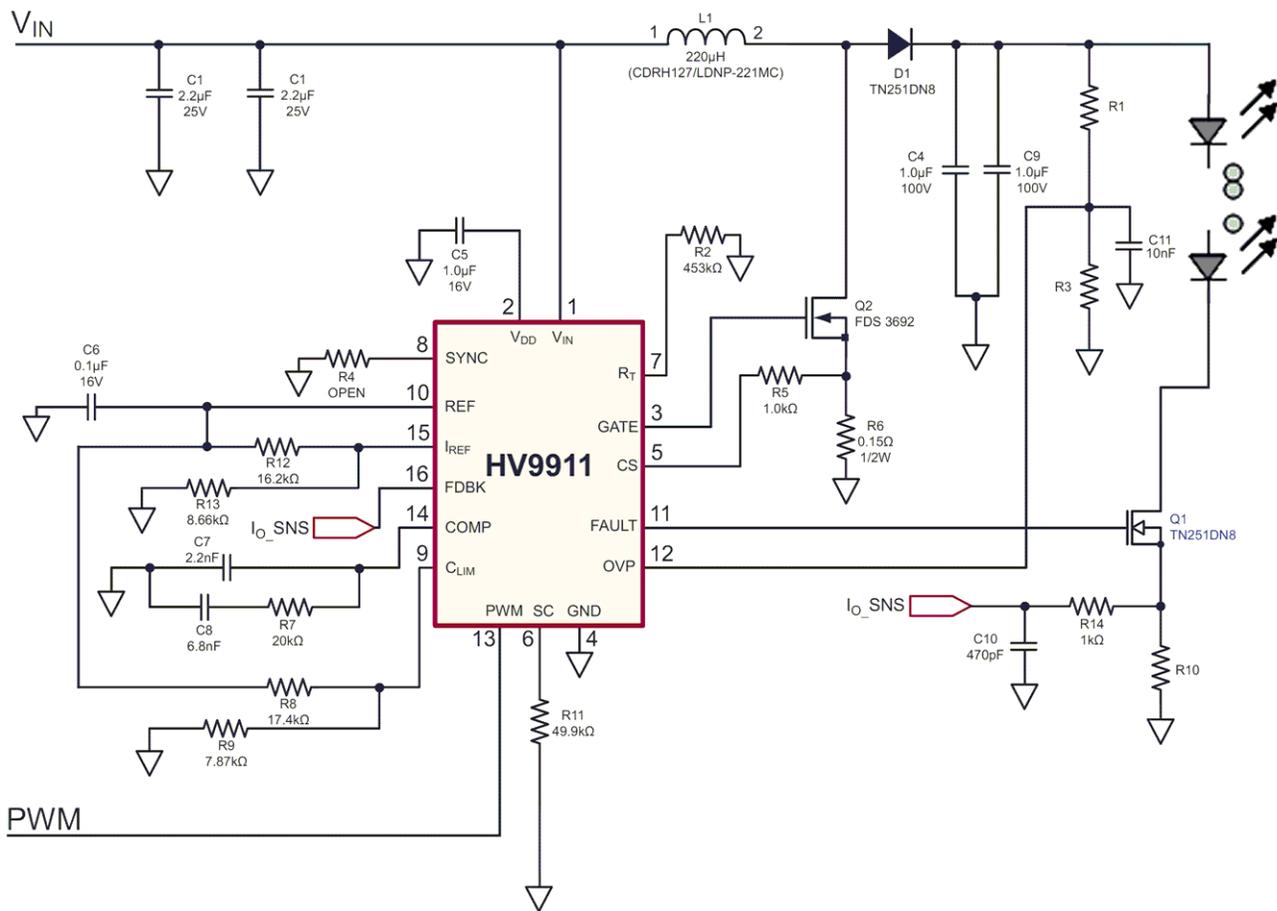


Figure 7. HV9911 LED driver circuit

Table 2 shows the R1, R3 and R10 values for Figure 7 circuit.

**Table 2. Resistor selection for circuit in Figure 7.**

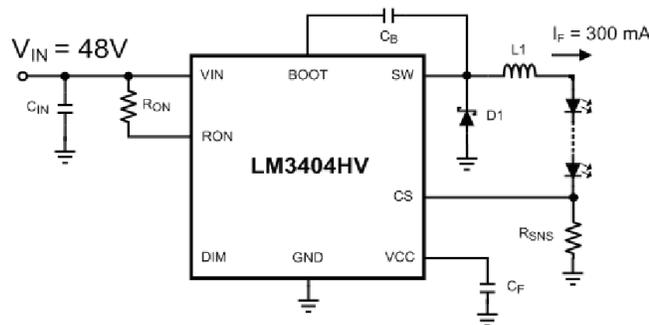
LED string	VIN	R10	R1	R3	OVP	LED current	No of LED strings in series
Red	12V	1.45	20k	560	46V	300mA	1
Green/Blue	12V	2.9	20k	560	46V	150mA	1
Green/Blue	24V	2.9	82.5k	1.13k	92V	150mA	2

If PWM is not needed, PWM is connected to VDD pin.

### LM3402HV /LM3404HV

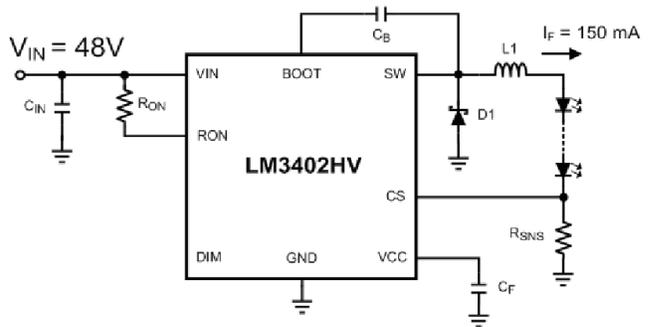
The LM3402HV/ LM3404HV are step down buck LED drivers.

Figure 8 shows the circuit to drive the red LED string at 300mA. The components required are listed are shown in Table 3



**Figure 8. L3404HV circuit for red LED string.**

Figure 9 show a circuit to drive green or blue LED string 150mA. Table 4 lists the parts for this circuit.



**Figure 9. LM3402HV circuit for green or blue LED string.**

**Table 3. Component list for red LED string.**

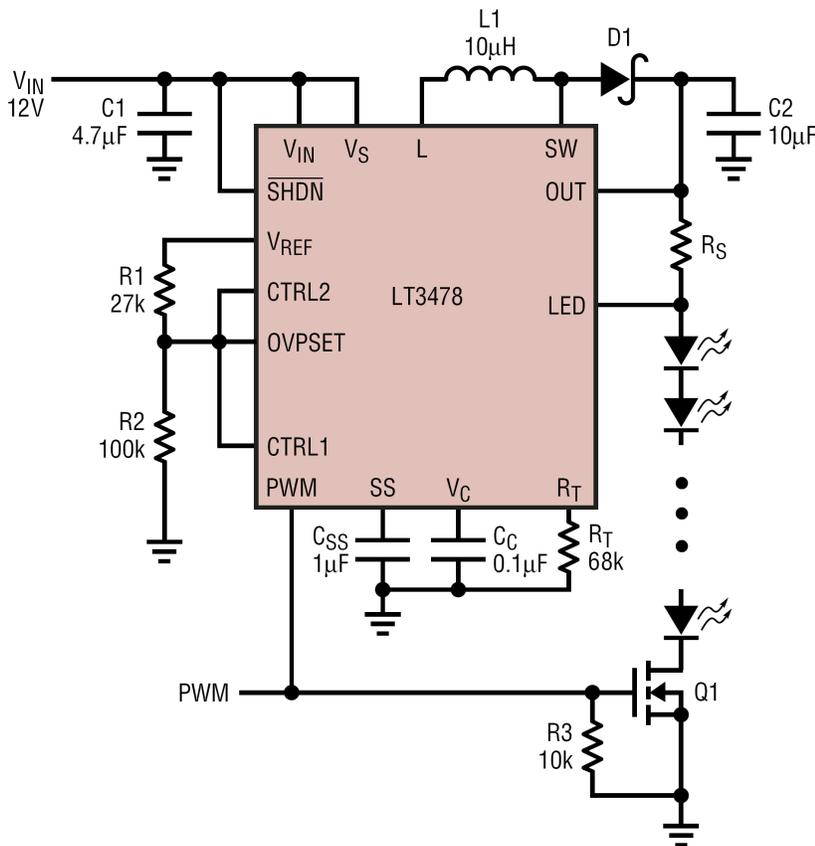
ID	Part Number	Type	Size	Parameters	Qty	Vendor
U1	LM3404HV	LED Driver	S0-8	75V 1.0A	1	NSC
L1	SLF10145T-331MR54	Inductor	10.1 x 10.1 x 4.5mm	330µH 0.54A, 0.68Ω	1	TDK
D1	CMSH1-60M	Schottky Diode	SMA	60V 1A	1	Central Semi
Cf	VJ0805Y104KXXAT	Capacitor	0805	100nF 10%	1	Vishay
Cb	VJ0805Y103KXXAT	Capacitor	0805	10nF 10%	1	Vishay
Cin	C3216X7R2A105M	Capacitor	1206	1µF 100V	1	TDK
Rsns	ERJ6BQFR68V	Resistor	0805	0.68Ω 1%	1	Panasonic
Ron	CRCW08053403F	Resistor	0805	340kΩ 1%	1	Vishay

**Table 4. Component list for green or blue LED string.**

ID	Part Number	Type	Size	Parameters	Qty	Vendor
U1	LM3402HV	LED Driver	MSOP-8	75V 0.5A	1	NSC
L1	SLF7045T-331MR25	Inductor	7.0 x 7.0 x 4.5mm	330μH 0.25A, 0.74Ω	1	TDK
D1	CMMSH1-60	Schottky Diode	SOD-123F	60V 1A	1	Central Semi
Cf	VJ0805Y104KXXAT	Capacitor	0805	100nF 10%	1	Vishay
Cb	VJ0805Y103KXXAT	Capacitor	0805	10nF 10%	1	Vishay
Cin	C3216X7R2A105M	Capacitor	1206	1uF 100V	1	TDK
Rsns	CRCW08051R33F	Resistor	0805	1.33Ω 1%	1	Vishay
Ron	CRCW08054993F	Resistor	0805	499kΩ 1%	1	Vishay

**LT3478**

Figure 10 shows the LT3478 application circuit to drive the LED strings.



**Figure 10. LT3478 LED driver circuit.**

If PWM is not used, it must be tied to logic high to enable the LED driver.

Table 5 lists the possible  $R_S$  value to drive red, green or blue LED strings.

**Table 5.  $R_S$  selection for the circuit in Figure 10.**

LED string	LED current	$R_S$
Red	300mA	0.33 ohm
Green / Blue	150mA	0.68 ohm

## Boostpuck

The 04015-D-I-350 Boostpuck from Luxdrive has external CTRL, REF pin and an on board trimmer. The onboard trimmer is first set to maximum 350mA current.

Figure 11 show the circuit to reduce the LED current from 350mA to the rated current required. This circuit can drive 4 to 12 LEDs in series, so the RGB LED light source module LED strings can be driven with the circuit. The white light source module can be driven by configuring to 2 strings of 10 LEDs in series.

A 12V DC supply is connected across  $V_{in+}$  and  $V_{in-}$  terminal.

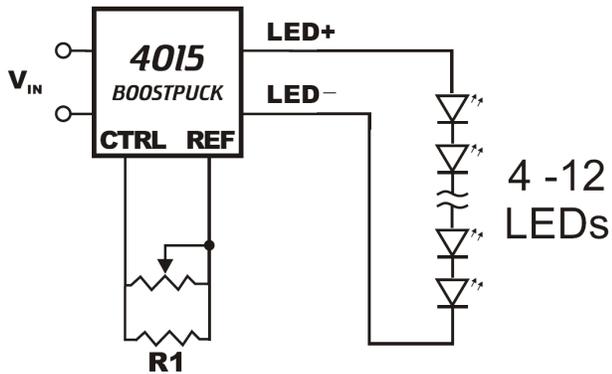


Figure 11. LED driver circuit to reduce from 350mA to rated current

Set the potentiometer to maximum resistance. Next, select R1 so that the LED driver current is limited to the maximum LED current rating. The values are 150mA for RGB LED light source module green and blue LED string, 300mA for RGB LED light source module red LED string, 50mA for 3.5W white LED light source module and 150mA for 10.5W white LED light source module.

Use the potentiometer to adjust the LED current from 0mA to the maximum LED current rating. If you do not need the current adjustment, the potentiometer can be removed.

The following circuit is used if one potentiometer is used to control brightness of two Green LED strings.

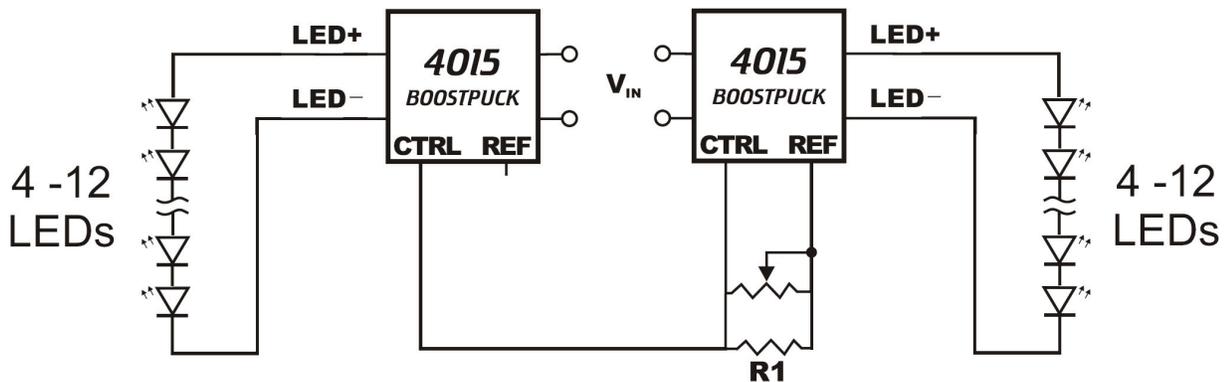


Figure 12. One potentiometer to adjust brightness of two green strings

## APPENDIX 1. LED Driver Manufacturer Web Sites

The list is not an endorsement from Avago Technologies.

Its main purpose is to help engineers who are choosing appropriate LED driver for Avago Technologies LED products.

Advanced Analogic Technologies Inc.	<a href="http://www.analogictech.com">www.analogictech.com</a>
Allegro Microsystems Inc.	<a href="http://www.allegromicro.com">www.allegromicro.com</a>
Austriamicrosystem	<a href="http://www.austriamicrosystems.com">www.austriamicrosystems.com</a>
Intersil Corporation	<a href="http://www.intersil.com">www.intersil.com</a>
Fairchild Semiconductor Corporation	<a href="http://www.fairchildsemi.com">www.fairchildsemi.com</a>
Infineon Technologies AG	<a href="http://www.infineon.com">www.infineon.com</a>
IXYS Corporation	<a href="http://www.ixys.com">www.ixys.com</a>
LEDdynamics	<a href="http://www.ledynamics.com">www.ledynamics.com</a>
Linear Technology Corporation	<a href="http://www.linear.com">www.linear.com</a>
Lumidrives Ltd.	<a href="http://www.lumidrives.com">www.lumidrives.com</a>
Maxim Integrated Products	<a href="http://www.maxim-ic.com">www.maxim-ic.com</a>
Melexis Microelectronic Systems	<a href="http://www.melexis.com">www.melexis.com</a>
Microsemi Corporation	<a href="http://www.microsemi.com">www.microsemi.com</a>
National Semiconductor Corporation	<a href="http://www.national.com">www.national.com</a>
On Semiconductor	<a href="http://www.onsemi.com">www.onsemi.com</a>
Power Integrations Incorporated	<a href="http://www.powerint.com">www.powerint.com</a>
ST Microelectronics	<a href="http://www.st.com">www.st.com</a>
Supertex Incorporated	<a href="http://www.supertex.com">www.supertex.com</a>
Sipex Corporation	<a href="http://www.sipex.com">www.sipex.com</a>
Texas Instruments Incorporated	<a href="http://www.ti.com">www.ti.com</a>
Toko Incorporated	<a href="http://www.toko.com">www.toko.com</a>
Zetex Semiconductors	<a href="http://www.zetex.com">www.zetex.com</a>

## References

1. Datasheet: MAX16800, TLE4242G, LT3478, HV9911, LM3402, LM3404
2. Supertex AN H55 Boost Converter LED Drivers using Supertex's HV9911

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