20 TO 100mA LED CONSTANT CURRENT REGULATOR IN SOT26

Description

This Linear LED driver is designed to meet the stringent requirements of automotive applications.

The BCR402UW6Q monolithically integrates a transistor, diodes, and resistors to function as a Constant Current Regulator (CCR) for LED driving. The device regulates with a preset 20mA nominal that can be adjusted with an external resistor up to 100mA. It is designed for driving LEDs in strings and will reduce current at increasing temperatures to self-protect. Operating as a series linear CCR for LED string current control, it can be used in applications with supply voltages up to 40V.

With no need for additional external components, this CCR is fully integrated into the SOT26, minimizing PCB area and component count.

Features

- LED Constant Current Regulator Using PNP Emitter-Follower with Emitter Resistor to Current Limit
- I_{OUT} = 20mA ± 10% Constant Current (Preset)
- I_{OUT} up to 100mA Adjustable with an External Resistor
- V_S – 40V Supply Voltage
- P_D up to 1W in SOT26
- LED Dimming Using PWM up to 25kHz
- Negative Temperature Coefficient (NTC) Reduces I_{OUT} with Increasing Temperature
- Parallel Devices to Increase Regulated Current
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **The BCR402UW6Q is suitable for automotive applications requiring specific change control; this part is AEC-Q101 qualified, PPAP capable, and manufactured in IATF 16949 certified facilities.**
  https://www.diodes.com/quality/product-definitions/

Applications

Constant Current Regulation (CCR) in automotive LED lighting:

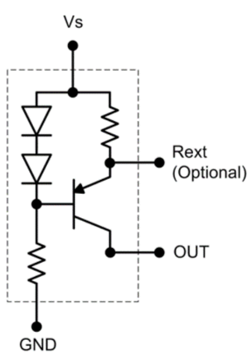
- Interior and Exterior Automotive LED Lighting
- Dome and Mood Lighting
- Puddle Lighting
- Side Marker Lights

Mechanical Data

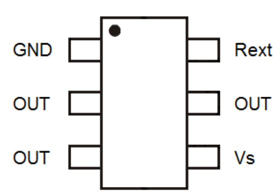
- Case: SOT26
- Case Material: Molded Plastic. "Green" Molding Compound. UL Flammability Rating 94V-0
- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: Finish - Matte Tin Plated Leads, Solderable per MIL-STD-202, Method 208 (e3)
- Weight: 0.018 grams (Approximate)

SOT26

Top View



Internal Device Schematic



Top View
Pin-Out

Pin Name	Pin Function
V_S	Supply Voltage
OUT	Regulated Output Current
Rext	External Resistor for Adjusting Output Current
GND	Power Ground

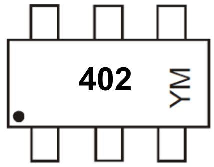
Ordering Information (Note 4)

Part Number	Compliance	Marking	Reel Size (inches)	Tape Width (mm)	Quantity per Reel
BCR402UW6Q-7	Automotive	402	7	8	3,000

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.
4. For packaging details, go to our website at https://www.diodes.com/design/support/packaging/diodes-packaging/.

Marking Information

SOT26



402 = Part Marking (See Ordering Information)
YM = Date Code Marking
Y = Year (ex: I = 2021)
M = Month (ex: 9 = September)

Date Code Key

Year	2016	…	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Code	D	…	I	J	K	L	M	N	O	P	R	S

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Code	1	2	3	4	5	6	7	8	9	O	N	D

Absolute Maximum Ratings (Voltage relative to GND, @ T_A = +25°C, unless otherwise specified.)

Characteristic	Symbol	Value	Unit
Supply Voltage	V_S	40	V
Output Current	I_{OUT}	100	mA
Output Voltage	V_{OUT}	40	V
Reverse Voltage Between All Terminals	V_R	0.5	V

Thermal Characteristics

Characteristic		Symbol	Value	Unit
Power Dissipation	(Note 5)	P_D	1,190	mW
	(Note 6)		912	
Thermal Resistance, Junction to Ambient	(Note 5)	$R_{\theta JA}$	105	°C/W
	(Note 6)		137	
Thermal Resistance, Junction to Lead	(Note 7)	$R_{\theta JL}$	50	
Recommended Operating Junction Temperature Range		T_J	-55 to +150	°C
Maximum Operating Junction and Storage Temperature Range		T_J, T_{STG}	-65 to +150	

ESD Ratings (Note 8)

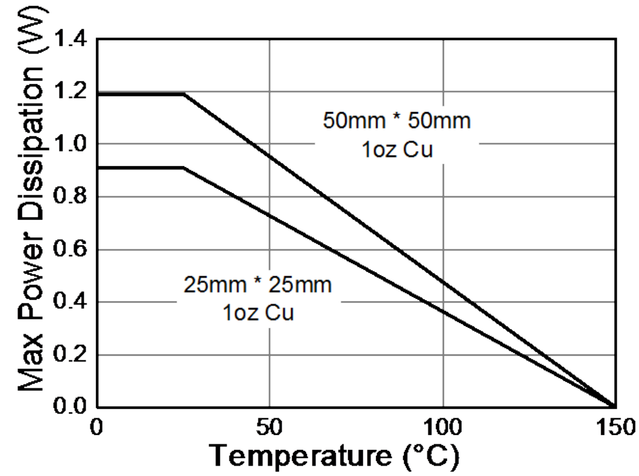
Characteristics	Symbol	Value	Unit	JEDEC Class
Electrostatic Discharge – Human Body Model	ESD HBM	800	V	1B
Electrostatic Discharge – Machine Model	ESD MM	300	V	B

Notes:
5. For a device mounted with the OUT leads on 50mm x 50mm 1oz copper that is on a single-sided 1.6mm FR4 PCB; device is measured under still air conditions while operating in steady-state.
6. Same as Note 5, except mounted on 25mm x 25mm 1oz copper.
7. $R_{\theta JL}$ = Thermal resistance from junction to solder-point (at the end of the OUT leads).
8. Refer to JEDEC specification JESD22-A114 and JESD22-A115.

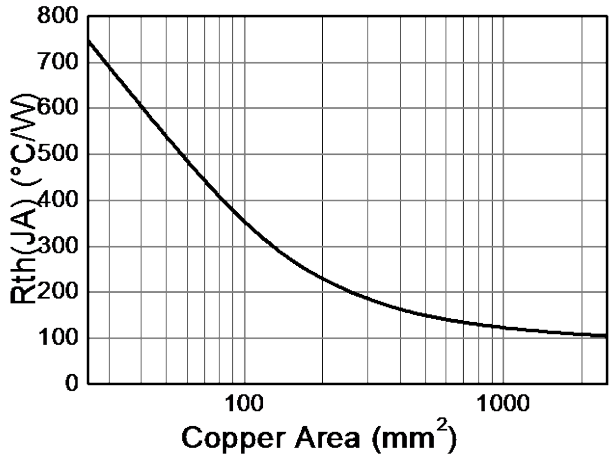
Electrical Characteristics (@ T_A = +25°C, unless otherwise specified.)

Characteristic	Symbol	Min	Typ	Max	Unit	Test Condition
Collector-Emitter Breakdown Voltage	BV_{CEO}	40	—	—	V	I_C = 1mA
GND (Enable) Current	I_{GND}	340	420	500	µA	V_S = 10V; V_{OUT}= Open
GND (Enable) Current	I_{GND}	—	380	—	µA	V_S = 10V; V_{OUT}= 8.6V
DC Current Gain	h_{FE}	100	220	470	—	I_C = 50mA; V_{CE} = 1V
Internal Resistor	R_{INT}	38	44	52	Ω	I_{RINT} = 20mA
Output Current (Nominal)	I_{OUT}	18	20	22	mA	V_{OUT}= 8.6V; V_S = 10V
Output Current	I_{OUT}	25	28	31	mA	V_S = 12V; R_{ext} = 95Ω
		31	35	39	mA	V_S = 12V; R_{ext} = 53Ω
		57	63	69	mA	V_S = 10V; R_{ext} = 17Ω
Voltage Drop (V_{REXT})	V_{DROP}	—	0.88	—	V	I_{OUT}= 20mA
Lowest Sufficient Supply Voltage (V_S-V_{OUT})	V_{SMIN}	—	1.4	—	V	I_{OUT}> 18mA
Output Current Change vs. Temperature	$\Delta I_{OUT}/I_{OUT}$	—	-0.25	—	%/°C	V_S = 10V
Output Current Change vs. Supply Voltage	$\Delta I_{OUT}/I_{OUT}$	—	1	—	%/V	V_S = 10V

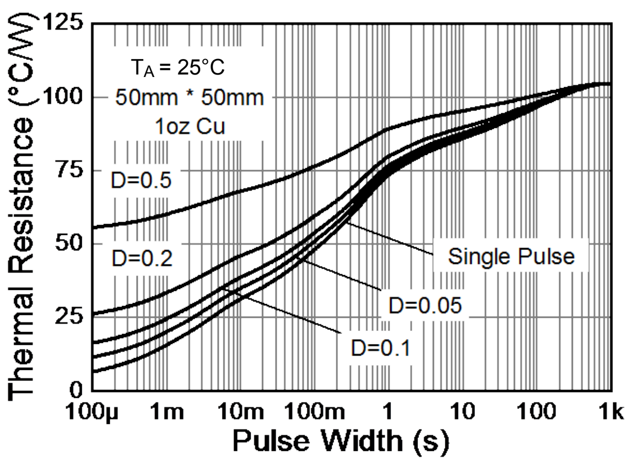
Typical Thermal Characteristics (@ T_A = +25°C, unless otherwise specified.)



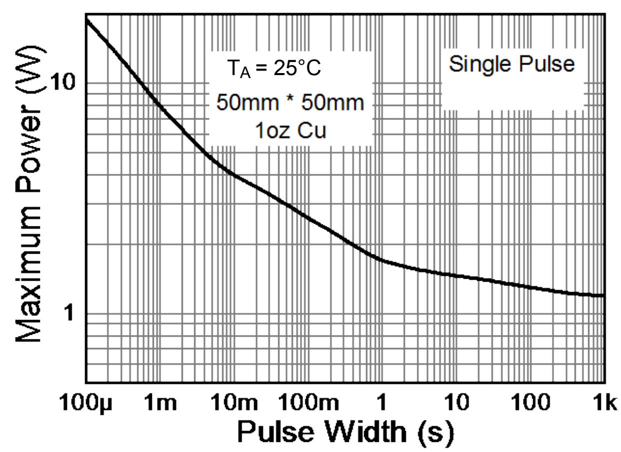
Derating Curve



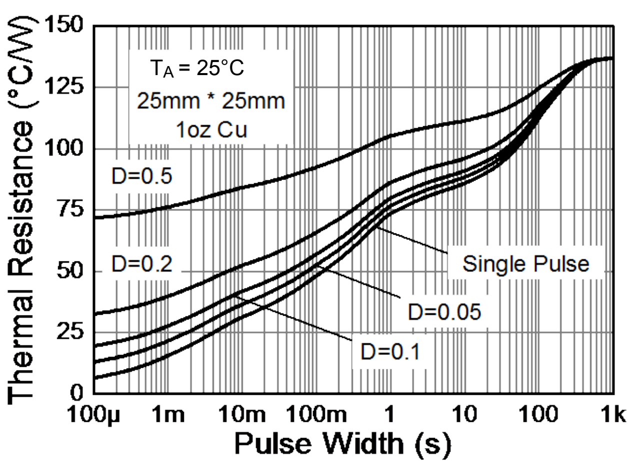
Rth(JA) VS Cu Area



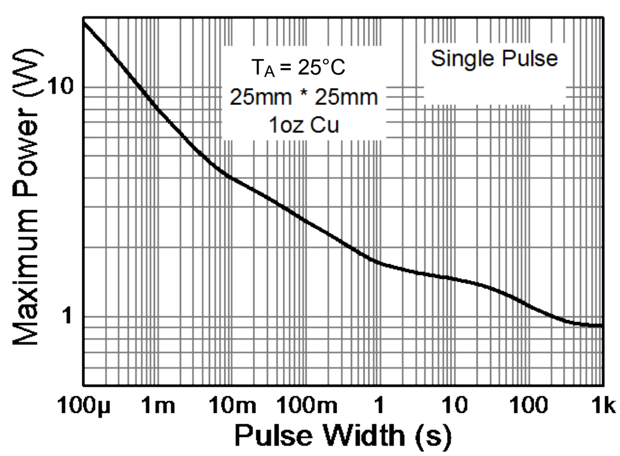
Transient Thermal Impedance



Pulse Power Dissipation

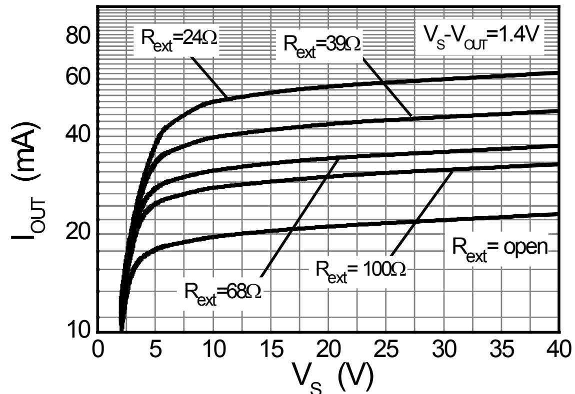


Transient Thermal Impedance

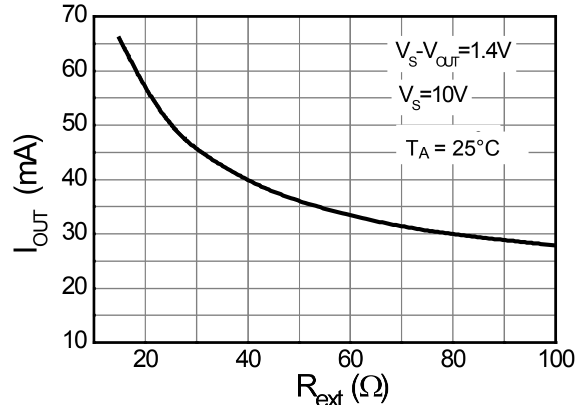


Pulse Power Dissipation

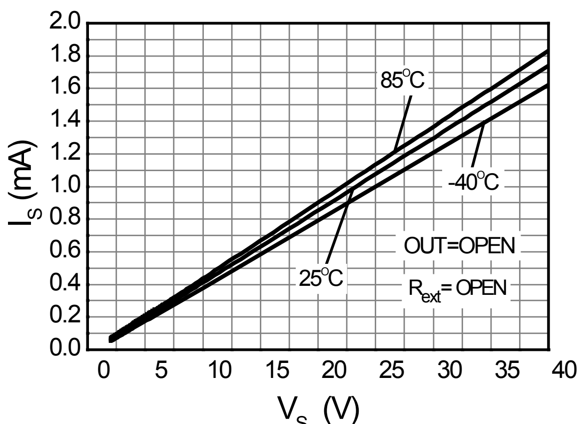
Typical Electrical Characteristics (@ T_A = +25°C, unless otherwise specified.)



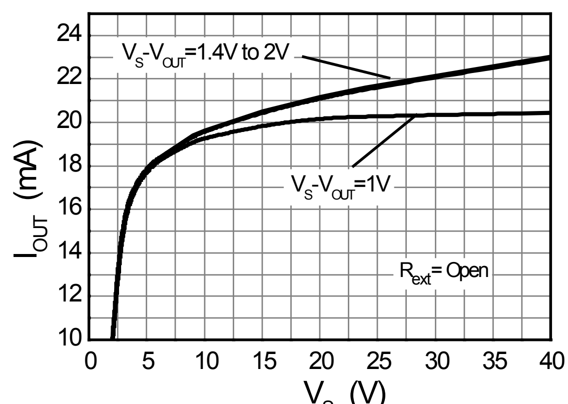
V_S vs I_{OUT}



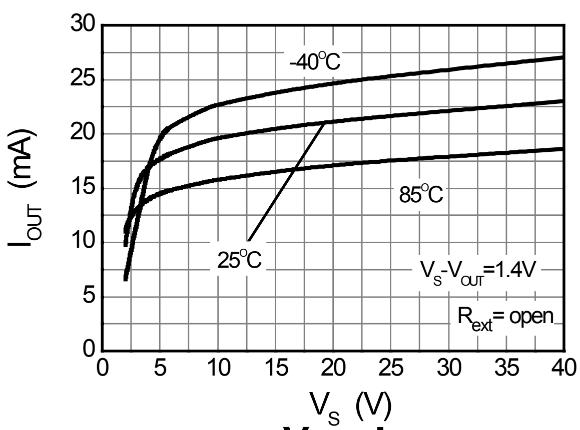
R_{ext} vs I_{OUT}



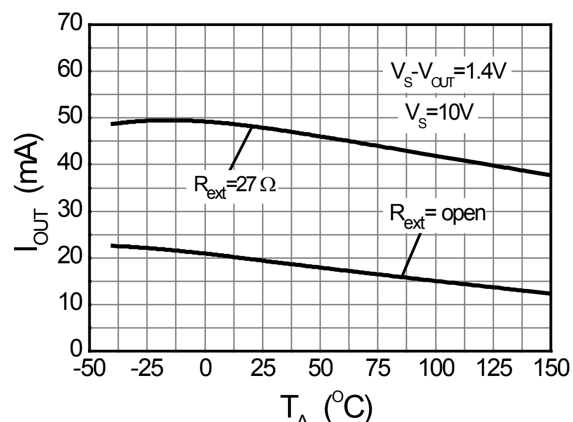
V_S vs I_S



V_S vs I_{OUT}



V_S vs I_{OUT}



T_A vs I_{OUT}

Application Information

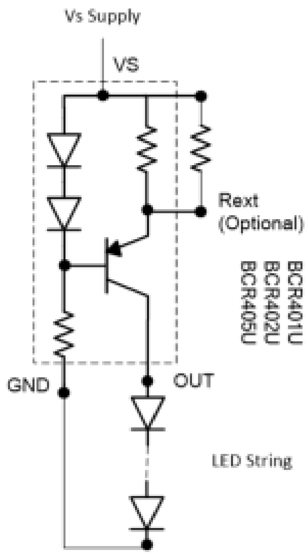


Figure 1. Typical Application Circuit for BCR40X LED Driver

The BCR401/2/5 are designed for driving low-current LEDs with typical LED currents of 10mA to 100mA. They provide a cost-effective way for driving low-current LEDs compared to more complex switching regulator solutions. Furthermore, they reduce the PCB board area of the solution as there is no need for external components like inductors, capacitors, and switching diodes.

Figure 1 shows a typical application circuit diagram for driving an LED or string of LEDs. The devices come with an internal resistor (R_{INT}) of typically 91Ω, 44Ω,16.5Ω which is in the absence of an external resistor, sets an LED current of 10mA, 20mA, 50mA respectively. LED current can be increased to a desired value by choosing an appropriate external resistor, $R_{ext.}$

The R_{ext} vs. I_{OUT} graphs should be used to select the appropriate resistor. Choosing a low tolerance R_{ext} will improve the overall accuracy of the current sense formed by the parallel connection of R_{INT} and $R_{ext.}$

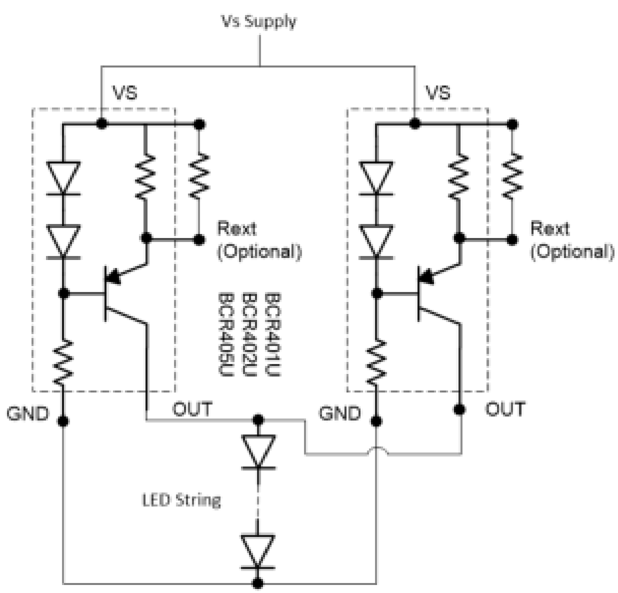


Figure 2. Application Circuit for Increasing LED Current

The negative temperature coefficient of the BCR series allows easy paralleling of BCR410/2/5s. In applications where current sharing is required either due to high current requirements of LED strings or for power sharing, two or more BCR401/2/5s can be connected in parallel, as shown in Figure 2. Power dissipation capability must be factored into the design, with respect to the BCR401/2/5's thermal resistance. The maximum voltage across the device can be calculated by taking the maximum supply voltage and subtracting the voltage across the LED string.

$V_{DEVICE} = V_S – V_{OUT}$

$P_D = (V_{DEVICE} \times I_{LED}) + (V_S \times I_{GND})$

As the output current of BCR401/2/5 increases, it is necessary to connect an appropriate heat sink to the OUT pins of the device. The power dissipation supported by the device is dependent upon the PCB board material, the copper area, and the ambient temperature. The maximum dissipation the device can handle is given by:

$P_D = (T_{J(MAX)} - T_A) / R_{\theta JA}$

Refer to the thermal characteristic graphs in datasheet for selecting the appropriate PCB copper area.

Application Information (continued)

PWM is the most pursued method for LED dimming. In the PWM method, dimming is achieved by turning the LEDs ON and OFF for a portion of a single cycle. PWM dimming can be achieved by enabling/disabling the LED driver itself (refer to Figure 3a ,3b) or by the switching the power path on and off (refer to Figure 3c). The PWM signal can be provided by a micro-controller or analog circuitry; typical circuits are shown in Figure 3. Figure 4 is a typical response of LED current vs. PWM duty cycle, PWM method showed in Figure 3b is used for generating the graphs.

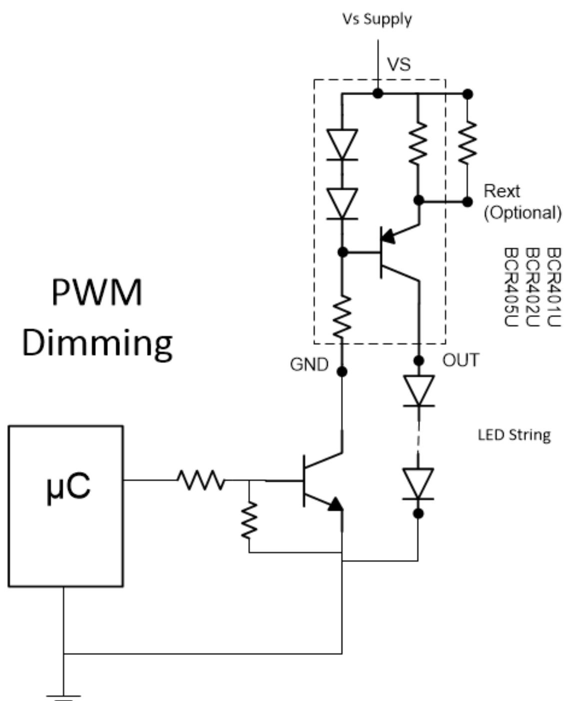


Figure 3a

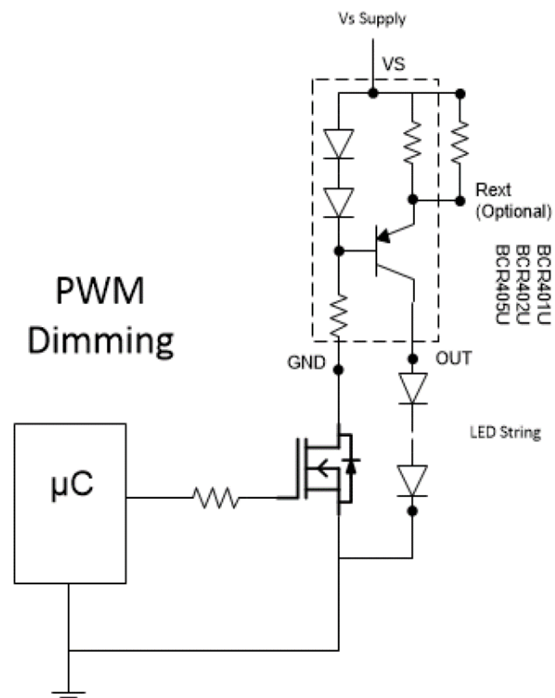


Figure 3b

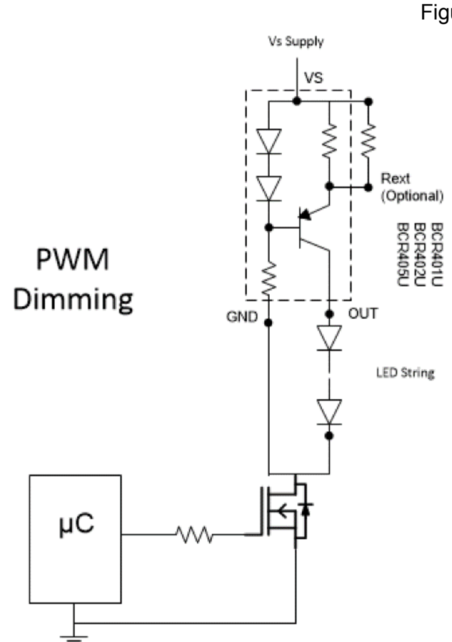
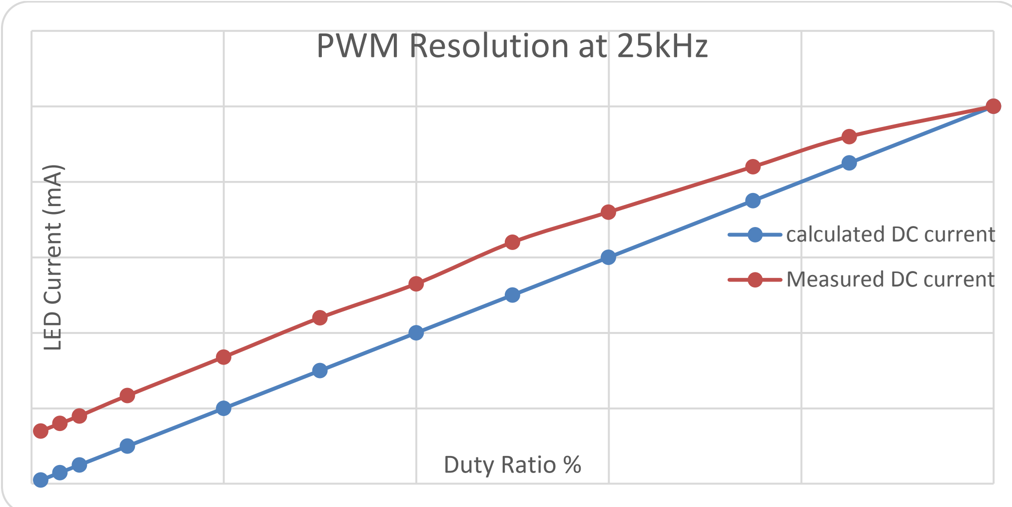
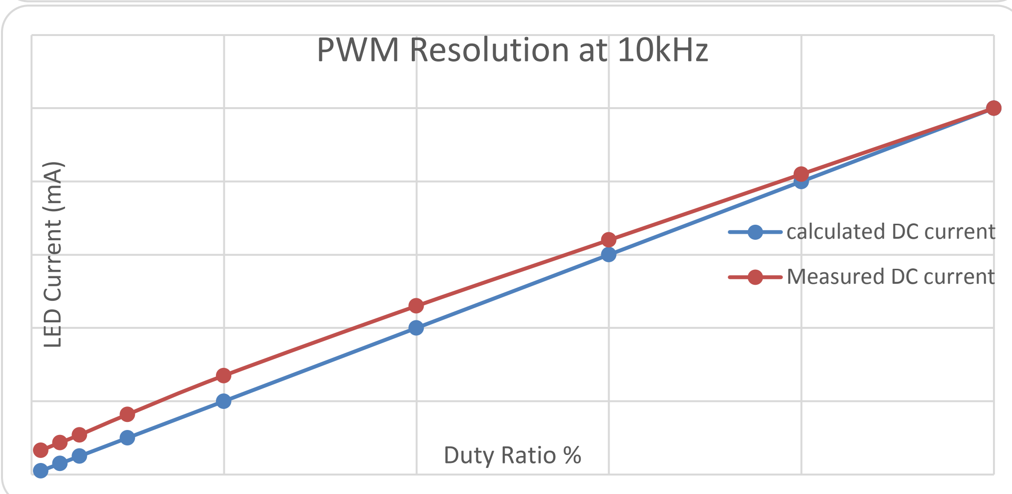


Figure 3c

Figure 3a, 3b & 3c Application Circuits for LED Driver with PWM Dimming Functionality

Application Information (continued)





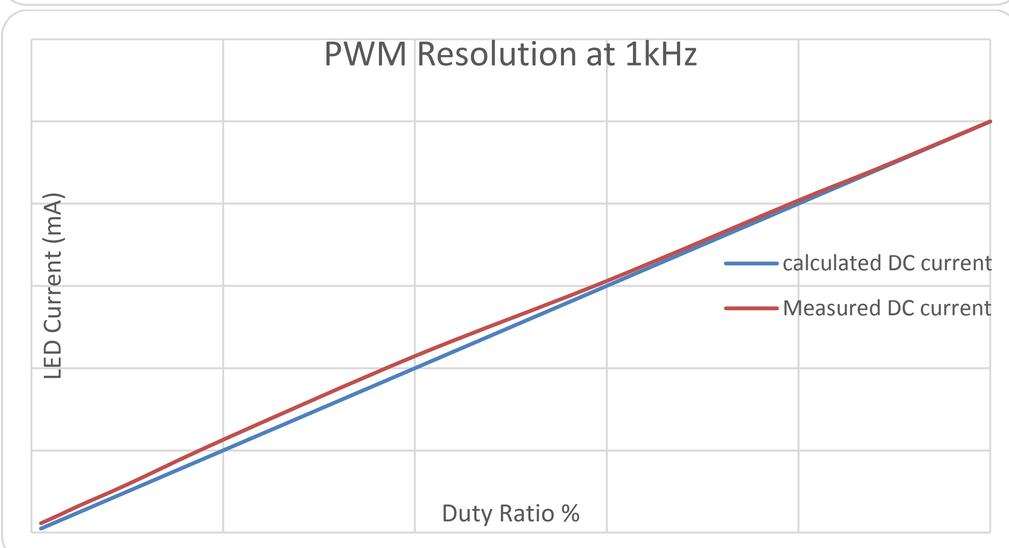


Figure 4. Typical LED Current Response vs. PWM Duty Cycle for 25kHz, 10kHz and 1kHz PWM Frequency (Refer to Circuit 3b)

Application Information (continued)

The error between the calculated theoretical value and the measured value is due to the turn on and turn off times of the BCR401/2/5. There will be a small contribution from the switches (a pre-biased transistor or a MOSFET) shown in Figure 3a and 3b towards the total turn on and turn off times of the BCR401/2/5. It is recommended to keep the external switching delays to the lowest possible value to improve PWM accuracy. The typical switching times of the BCR401/2/5 for the configuration shown in Figure 3b are;

Turn-On time = 200ns
Turn-Off time = 10µs

Please refer to the Figures 5 and 6 for the switching time performance. The percentage contribution of these switching delays increases with increasing frequency and decreasing duty ratio as can be seen in Figure 4.

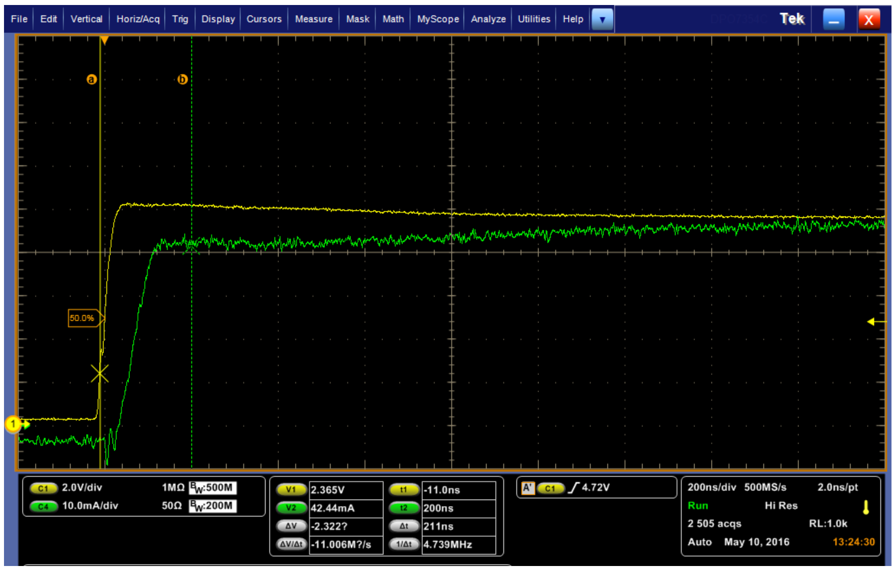


Figure 5. Turn-On Time of BCR401/2/5 (PWM Method Shown in Figure 3b)

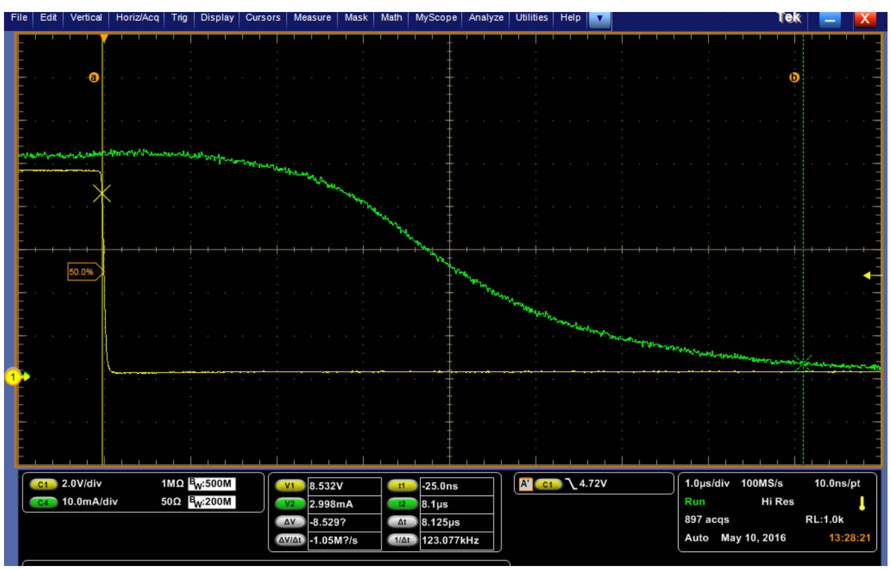


Figure 6. Turn-On Time of BCR401/2/5 (PWM Method Shown in Figure 3c)

However, where possible, the switching performance of the BCR401/2/5 can be significantly improved by switching the power path as shown in Figure 3c. The resulting turn-off time is shown in Figure 7. This resulted in an improved PWM resolution at 25kHz as shown in Figure 8.
Turn-off time = ~200ns

Application Information (continued)

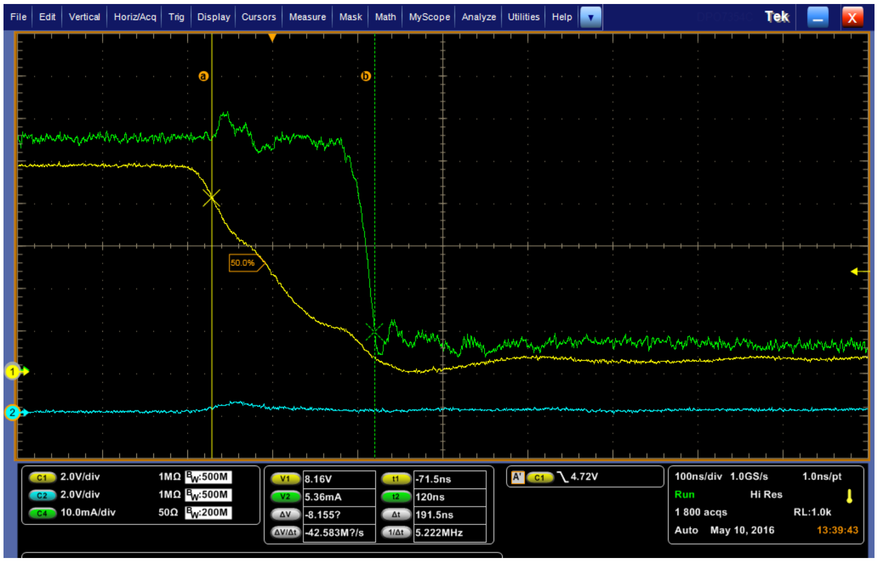


Figure 7. Turn-Off Time of BCR401/2/5 while Switching the Power Path as Shown in Figure 3c

Yellow → PWM signal.
Green → LED current.
Blue → No connection made to this probe channel.

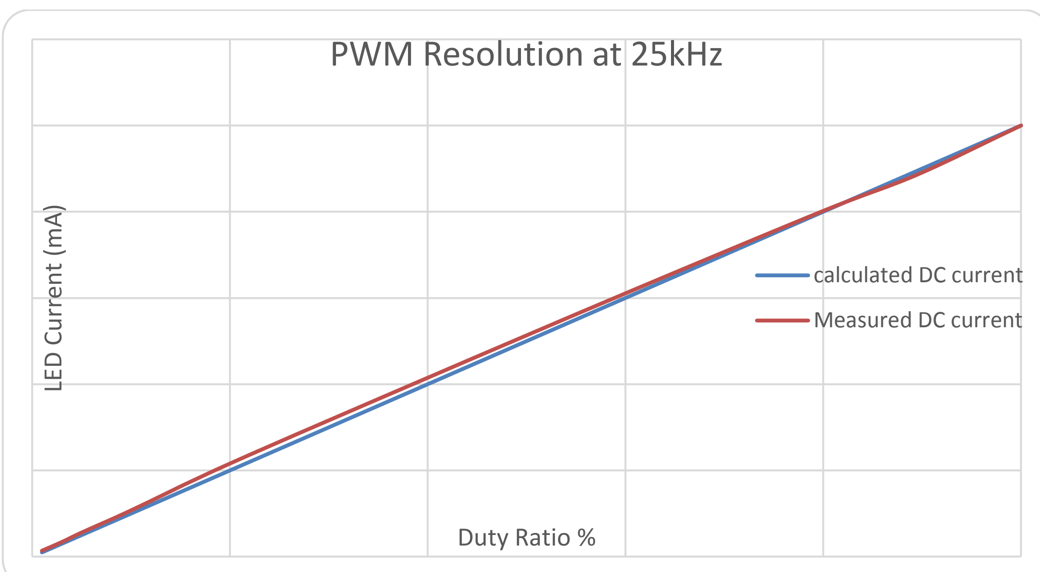


Figure 8. PWM Resolution with Power Path Switching (Refer to Figure 3c)

Application Information (continued)

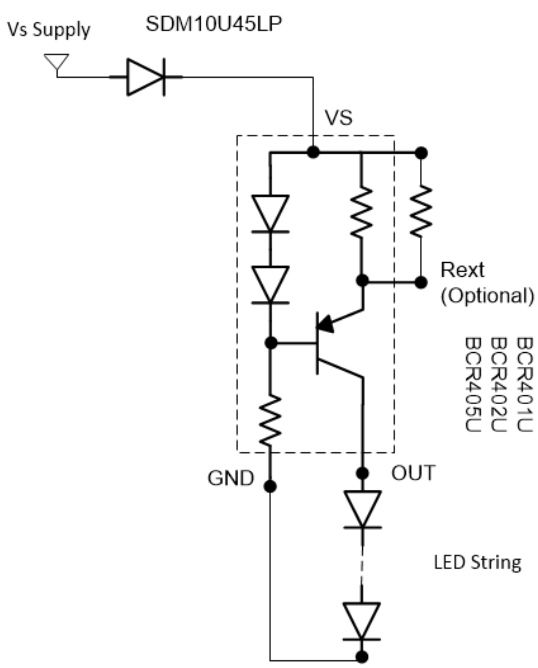


Figure 9. Application Circuit for LED Driver with Reverse Polarity Protection

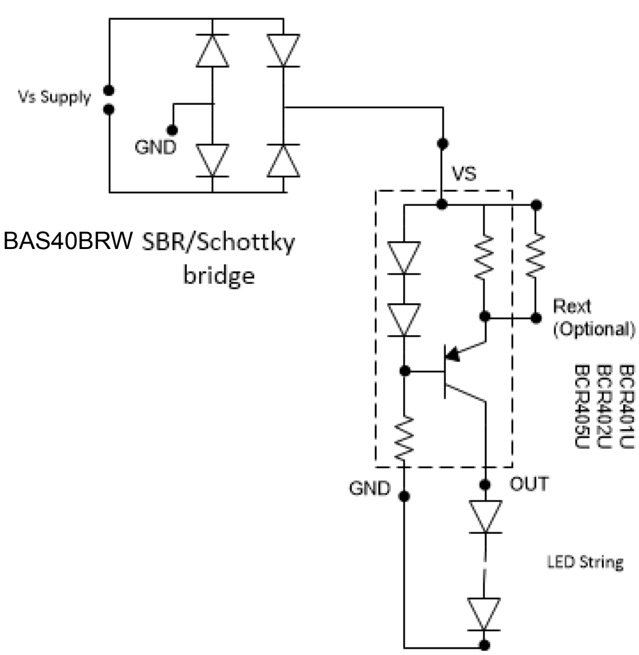


Figure 10. Application Circuit for LED Driver with Assured Operation Regardless of Polarity

To remove the potential of incorrect connection of the power supply damaging the lamp's LEDs, many systems use some form of reverse polarity protection.

One solution for reverse input polarity protection is to simply use a diode with a low V_F in line with the driver/LED combination. The low V_F increases the available voltage to the LED stack and dissipates less power. A circuit example is presented in Figure 9 which protects the light engine although it will not function until the problem is diagnosed and corrected. An SDM10U45LP (0.1A/45V) is shown, providing exceptionally low V_F for its package size of 1mm x 0.6mm. Other reverse voltage ratings are available from Diodes Incorporated's website such as the SBR02U100LP (0.2A/100V) or SBR0220LP (0.2A/20V).

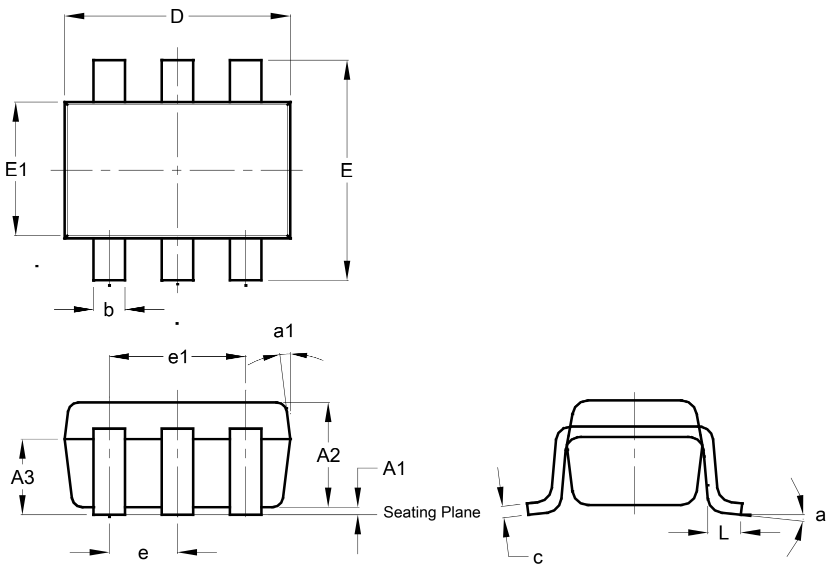
While automotive applications commonly use this method for reverse battery protection, an alternative approach shown in Figure 10, provides reverse polarity protection and corrects the reversed polarity, allowing the light engine to function.

The BAS40BRW incorporates four low V_F Schottky diodes in a single package, reducing the power dissipated and maximizes the voltage across the LED stack.

Package Outline Dimensions

Please see http://www.diodes.com/package-outlines.html for the latest version.

SOT26

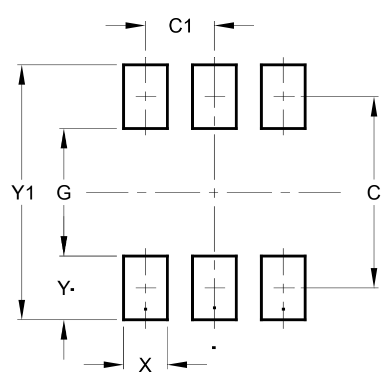


SOT26			
Dim	**Min**	**Max**	**Typ**
A1	0.013	0.10	0.05
A2	1.00	1.30	1.10
A3	0.70	0.80	0.75
b	0.35	0.50	0.38
c	0.10	0.20	0.15
D	2.90	3.10	3.00
e	-	-	0.95
e1	-	-	1.90
E	2.70	3.00	2.80
E1	1.50	1.70	1.60
L	0.35	0.55	0.40
a	-	-	8°
a1	-	-	7°
All Dimensions in mm			

Suggested Pad Layout

Please see http://www.diodes.com/package-outlines.html for the latest version.

SOT26



Dimensions	Value (in mm)
C	2.40
C1	0.95
G	1.60
X	0.55
Y	0.80
Y1	3.20

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