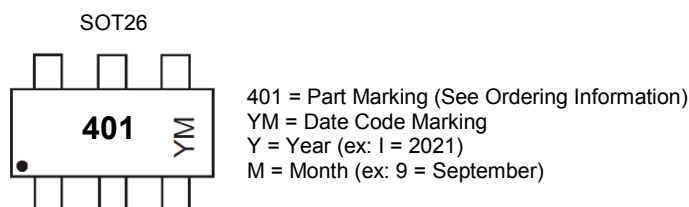


## Marking Information



### Date Code Key

Year	2017	...	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Code	E	...	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<sub>A</sub> = +25°C, unless otherwise specified.)

Characteristic	Symbol	Value	Unit
Supply Voltage	V <sub>S</sub>	40	V
Output Current	I <sub>OUT</sub>	100	mA
Output Voltage	V <sub>OUT</sub>	40	V
Reverse Voltage Between All Terminals	V <sub>R</sub>	0.5	V

## Thermal Characteristics

Characteristic	Symbol	Value	Unit
Power Dissipation	P <sub>D</sub>	1,190	mW
(Note 5)		912	
Thermal Resistance, Junction to Ambient	R <sub>θJA</sub>	105	°C/W
(Note 6)		137	
Thermal Resistance, Junction to Lead	R <sub>θJL</sub>	50	
Recommended Operating Junction Temperature Range	T <sub>J</sub>	-55 to +150	°C
Maximum Operating Junction and Storage Temperature Range	T <sub>J</sub> , T <sub>STG</sub>	-65 to +150	

## ESD Ratings (Note 8)

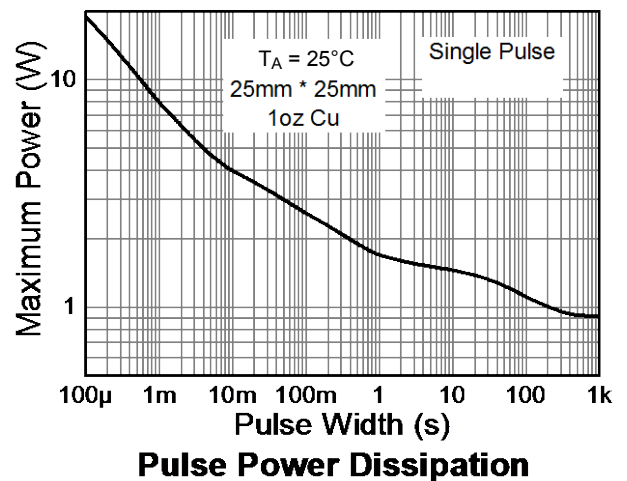
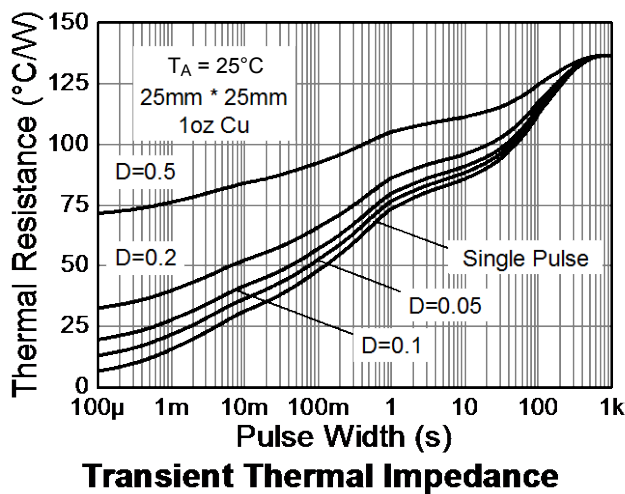
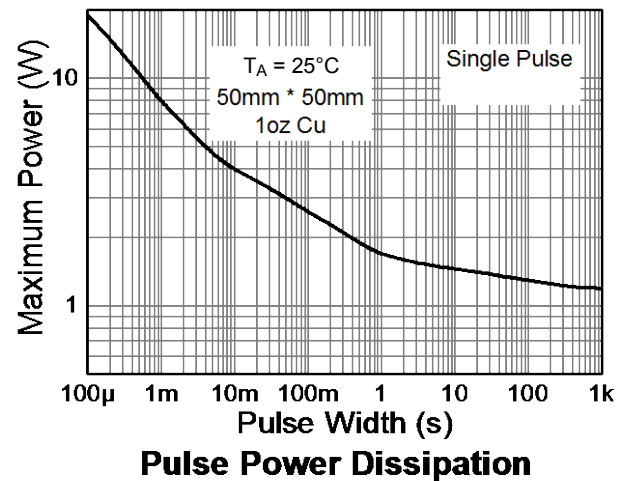
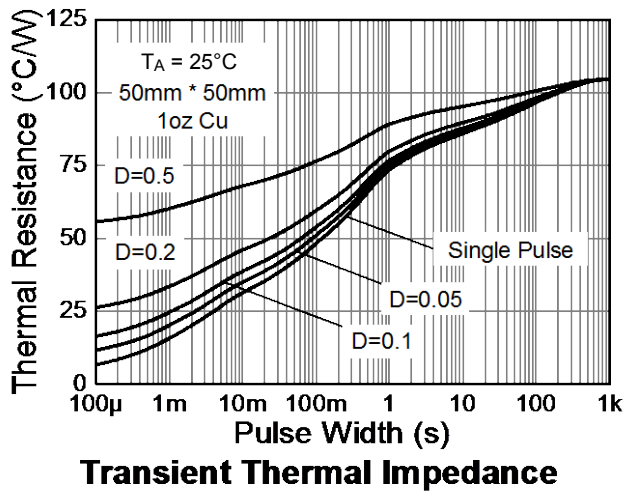
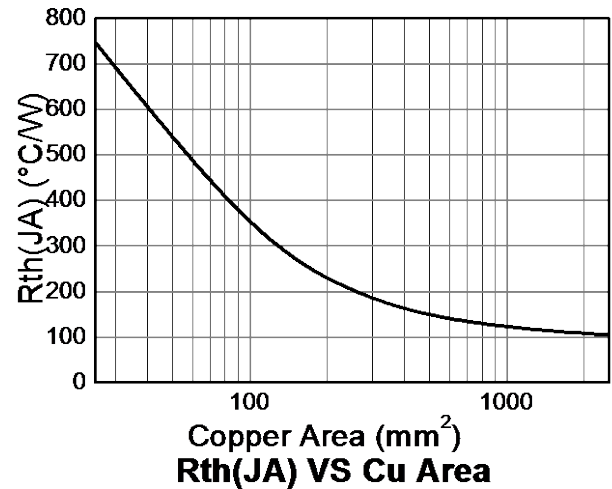
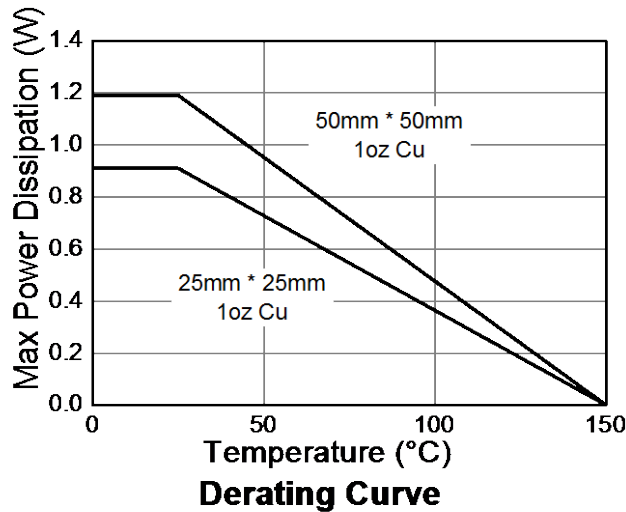
Characteristics	Symbols	Value	Unit	JEDEC Class
Electrostatic Discharge – Human Body Model	ESD HBM	800	V	1B
Electrostatic Discharge – Machine Model	ESD MM	300	V	B

- Notes:
- 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.
  - Same as Note 5, except mounted on 25mm x 25mm 1oz copper.
  - R<sub>θJL</sub> = Thermal resistance from junction to solder-point (at the end of the OUT leads).
  - Refer to JEDEC specification JESD22-A114 and JESD22-A115.

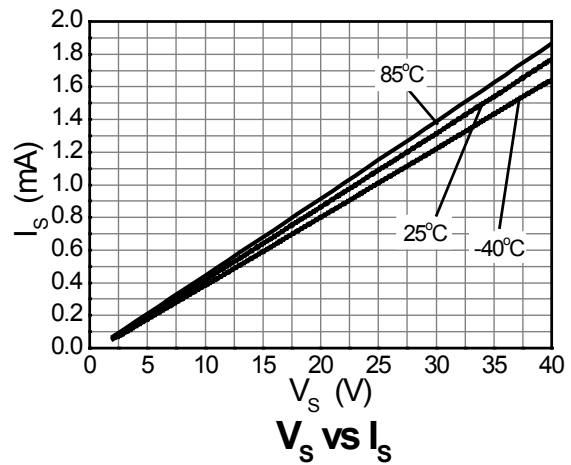
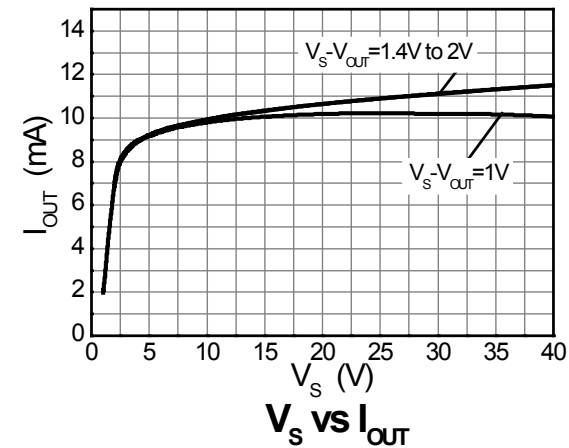
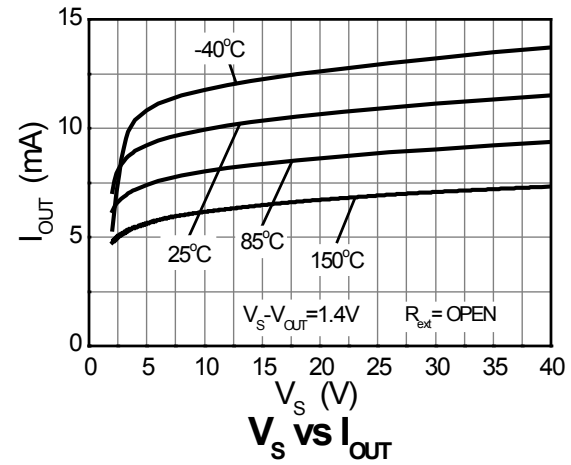
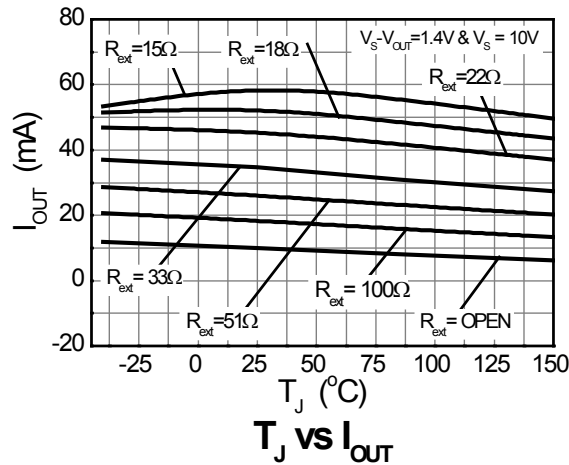
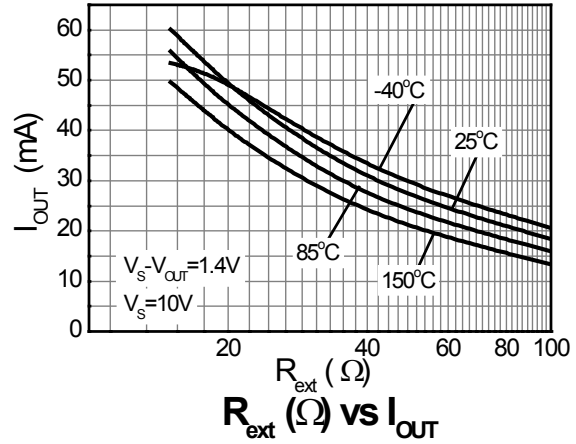
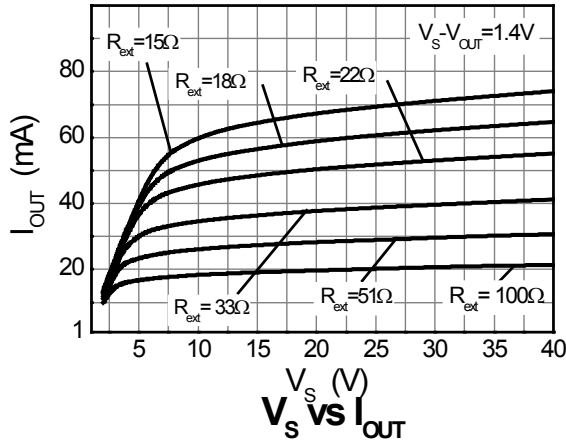
**Electrical Characteristics** (@  $T_A = +25^{\circ}\text{C}$ , unless otherwise specified.)

Characteristic	Symbol	Min	Typ	Max	Unit	Test Condition
Collector-Emitter Breakdown Voltage	$BV_{CEO}$	40	—	—	V	$I_C = 1\text{mA}$
GND (Enable) Current	$I_{GND}$	340	420	500	$\mu\text{A}$	$V_S = 10\text{V}; V_{OUT} = \text{open}$
GND (Enable) Current	$I_{GND}$	—	380	—	$\mu\text{A}$	$V_S = 10\text{V}; V_{OUT} = 8.6\text{V}$
DC Current Gain	$h_{FE}$	100	220	470	—	$I_C = 50\text{mA}; V_{CE} = 1\text{V}$
Internal Resistor	$R_{INT}$	78	91	104	$\Omega$	$I_{Rint} = 10\text{mA}$
Output Current (Nominal)	$I_{OUT}$	9	10	11	mA	$V_{OUT} = 8.6\text{V}; V_S = 10\text{V}$
Voltage Drop ( $V_{Rext}$ )	$V_{DROP}$	—	0.91	—	V	$I_{OUT} = 10\text{mA}$
Lowest Sufficient Supply Voltage ( $V_S - V_{OUT}$ )	$V_{Smin}$	—	1.4	—	V	$I_{OUT} > 8\text{mA}$
Output Current Change versus Temperature	$\Delta I_{OUT}/I_{OUT}$	—	-0.25	—	$\%/^{\circ}\text{C}$	$V_S = 10\text{V}$
Output Current Change versus Supply Voltage	$\Delta I_{OUT}/I_{OUT}$	—	1	—	$\%/V$	$V_S = 10\text{V}$

**Typical Thermal Characteristics** (@ $T_A = +25^\circ\text{C}$ , unless otherwise specified.)



**Typical Electrical Characteristics** (@  $T_A = +25^\circ\text{C}$ , unless otherwise specified.)



## Application Information

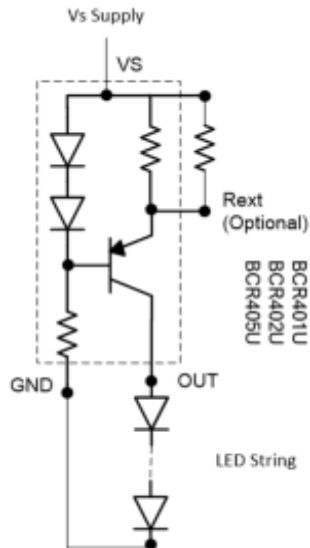


Figure 1. Typical Application Circuit for BCR40X LED Driver

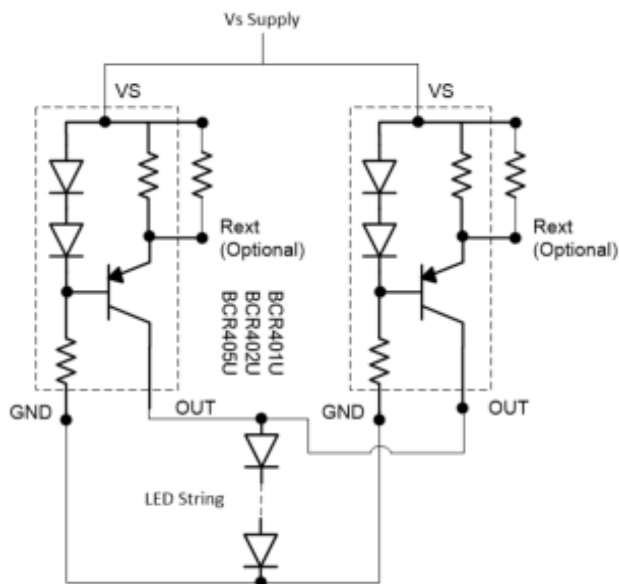


Figure 2. Application Circuit for Increasing LED Current

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 91 $\Omega$ , 44 $\Omega$ , 16.5 $\Omega$  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  $R_{EXT}$ .

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.

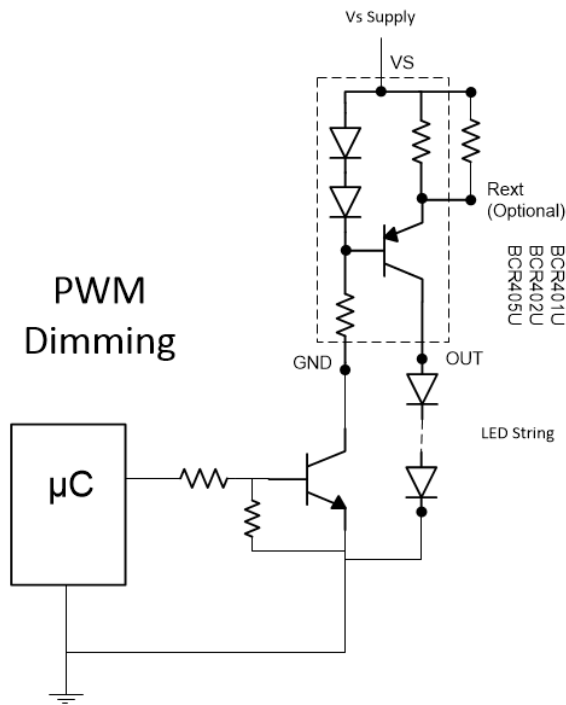


Figure 3a

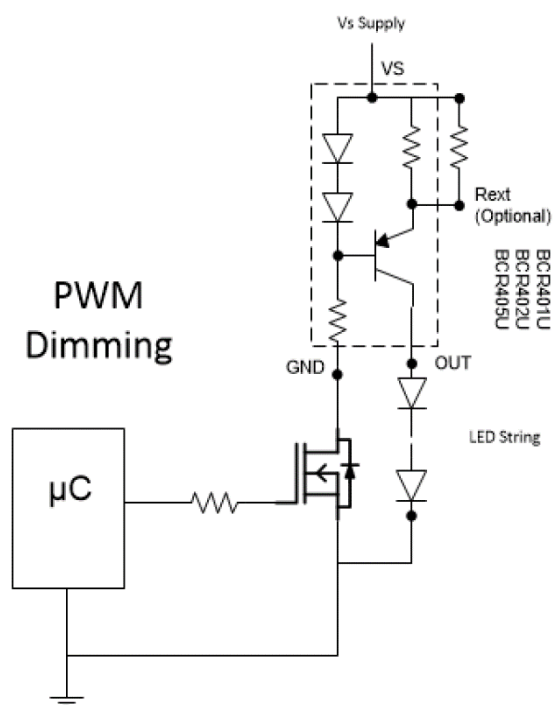


Figure 3b

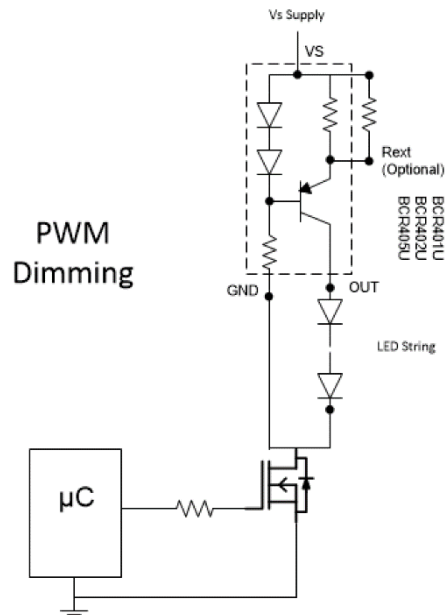


Figure 3c

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

**Application Information** (continued)

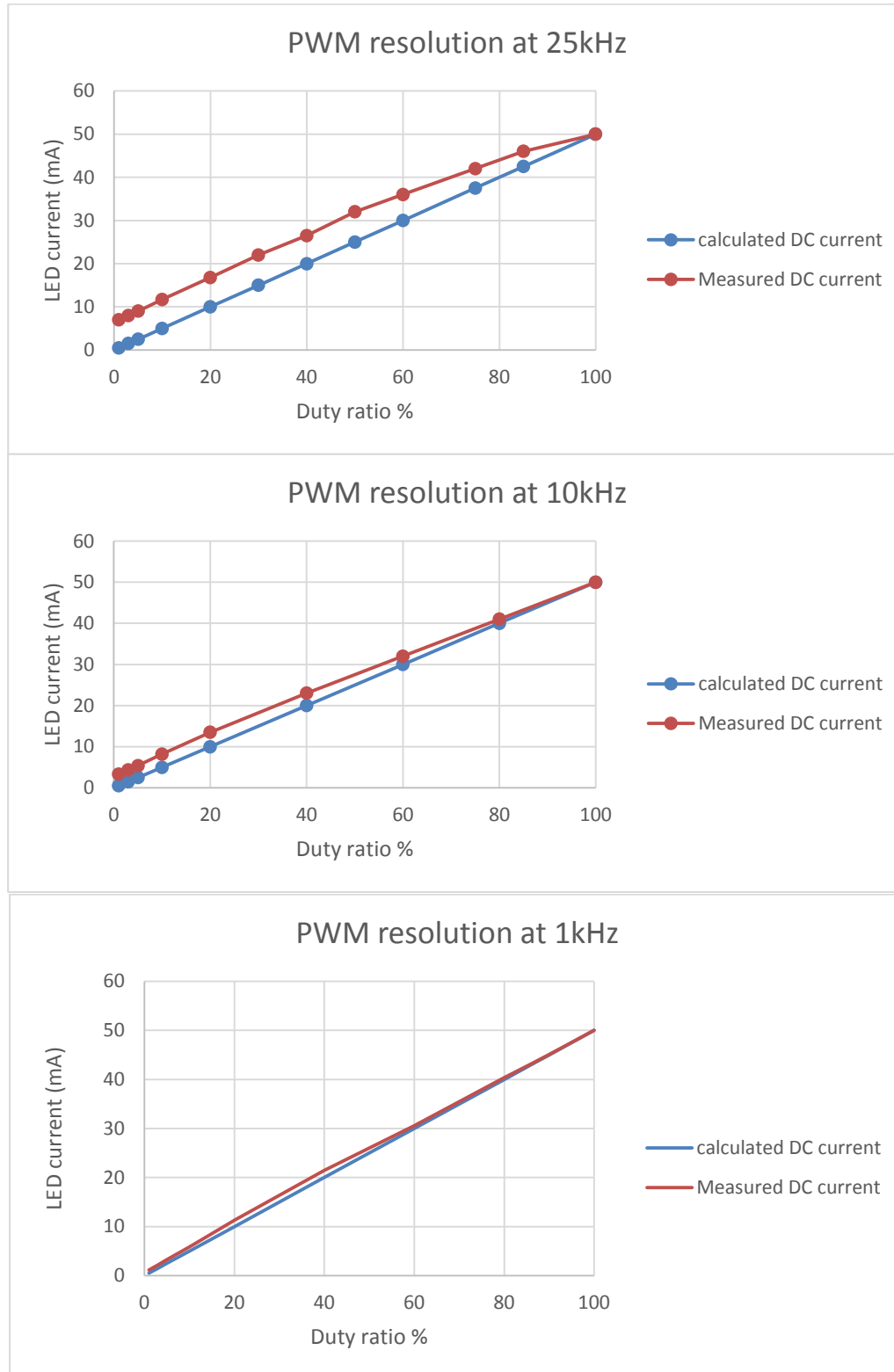


Figure 4. Typical LED Current Response vs. PWM Duty Cycle for 25kHz, 10kHz and 1kHz PWM Frequency (Refer to Circuit 3b)

## Application Information (continued)

The error between the calculated theoretical value and the measured value is due to the turn on and turn off time 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 time 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 time of the BCR401/2/5 for the configuration shown in Figure 3b is;

Turn on time = 200ns

Turn off time = 10 $\mu$ s

Please refer to the Figure 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.

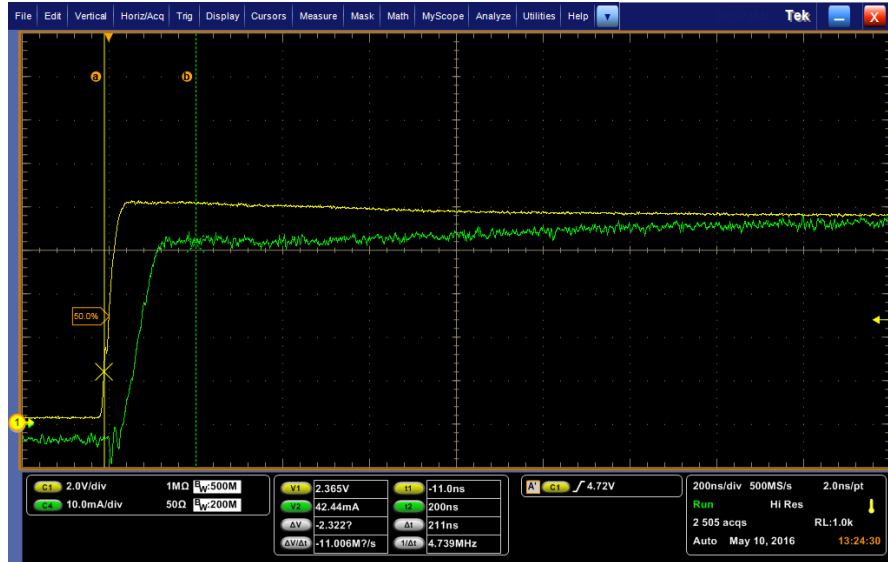


Figure 5. Turn On Time of BCR401/2/5 (PWM Method Shown in Figure 3b)

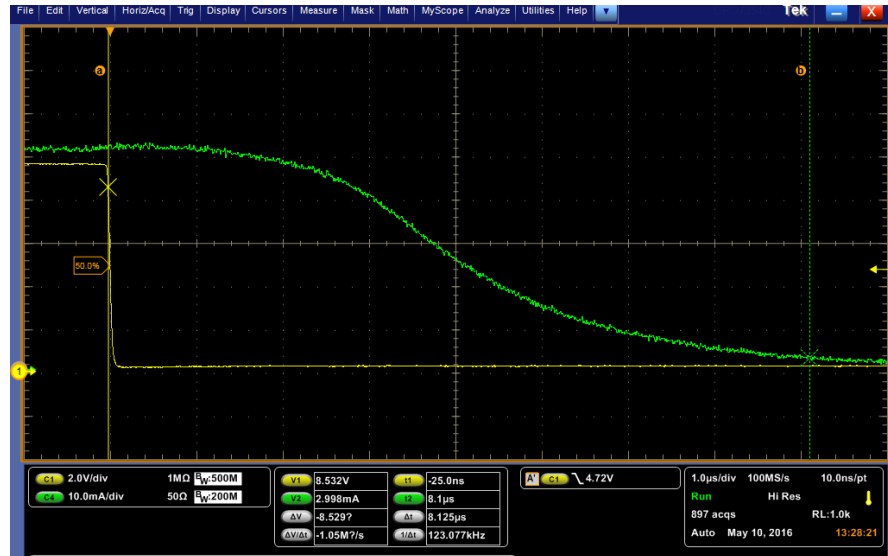


Figure 6. Turn On Time of BCR401/2/5 (PWM Method Shown in Figure 3c)

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)

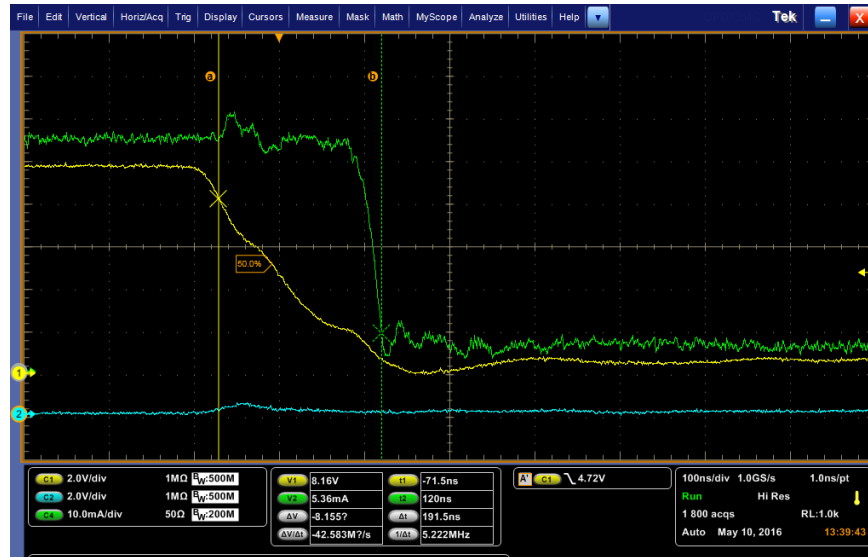


Figure 7. Turn Off Time of BCR401/2/5 While Switching the Power Path as Shown in Figure 3c

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)

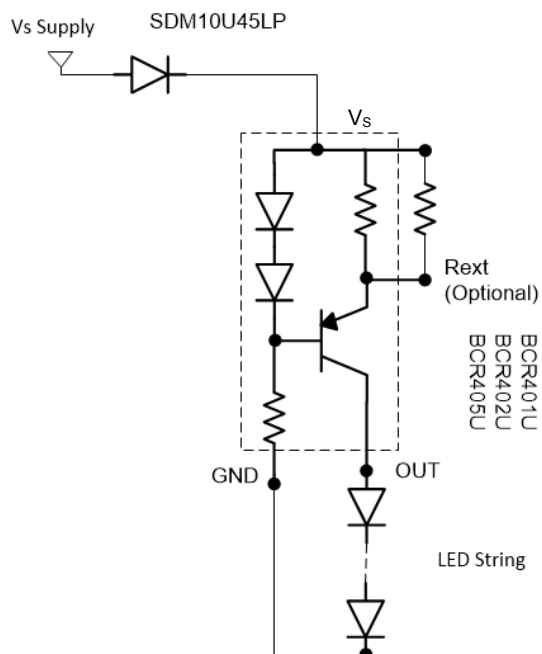


Figure 9. Application Circuit for LED Driver with Reverse Polarity Protection

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 × 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.

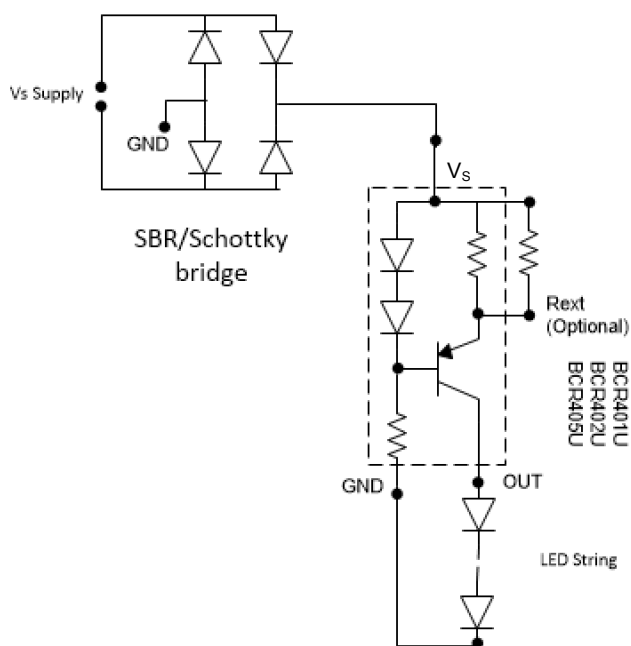
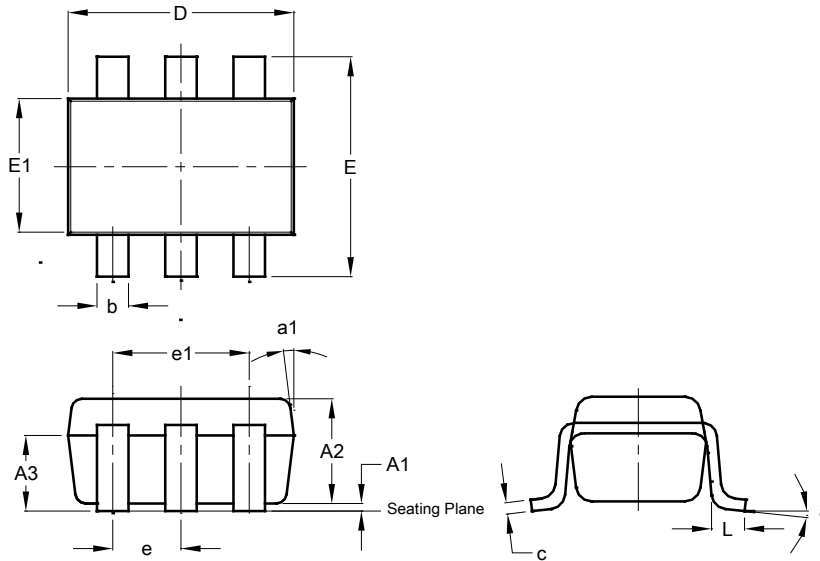


Figure 10. Application Circuit for LED Driver with Assured Operation Regardless of Polarity

## Package Outline Dimensions

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

SOT26

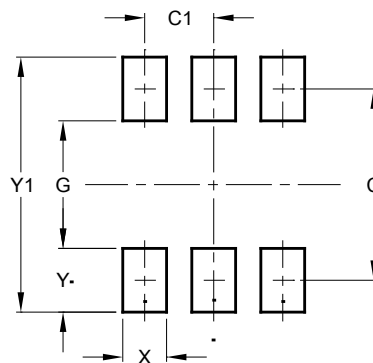


SOT26			
Dim	Min	Max	Typ
A1	0.013	0.10	0.05
A2	1.00	1.30	1.10
A3	0.70	0.80	0.75
b	0.35	0.50	0.38
c	0.10	0.20	0.15
D	2.90	3.10	3.00
e	-	-	0.95
e1	-	-	1.90
E	2.70	3.00	2.80
E1	1.50	1.70	1.60
L	0.35	0.55	0.40
a	-	-	8°
a1	-	-	7°
All Dimensions in mm			

## 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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