AN1161

BCR430UW6 Application Information

This document details the application and use of the Diodes BCR430UW6 low dropout linear LED driver. It should be used in conjunction with the BCR430UW6 data sheet which details the full electrical specification of the BCR430UW6.
Sections of this document include external resistor selection, power dissipation and over temperature protection (OTP), PWM dimming, SPICE modeling and the BCR430UW6 evaluation board which allows engineers to appraise and evaluate the BCR430UW6 when designing reliable and robust LED driver solutions for LED strings.

Applications for the BCR430UW6 include:

- Architectural lighting
- Retail lighting
- Automotive lighting
- Strip lighting

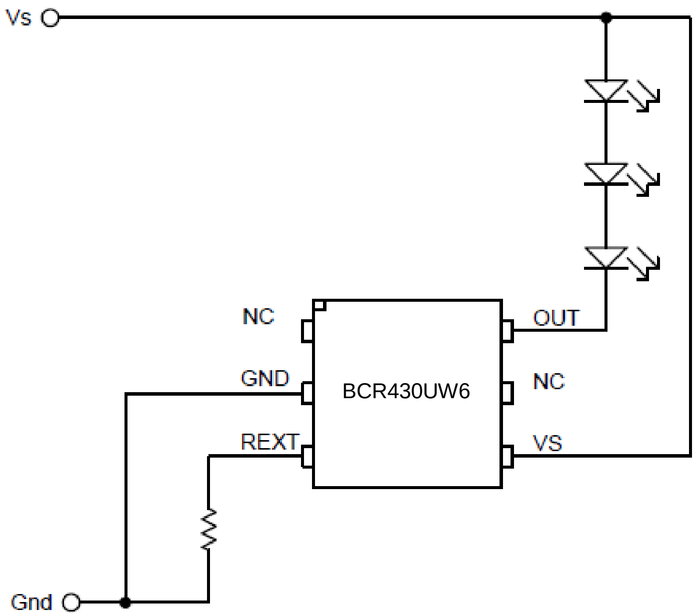

Figure 1: Typical Application

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1 Introduction

The BCR430U is a monolithically integrated linear LED controller designed to function as a Constant Current Regulator (CCR) for linear LED driving. The device operates over a voltage range from 5V to 42V and regulates the output LED current up to 100mA, set by an external resistor. It is designed for driving LEDs in strings and will reduce current at increasing temperatures to self-protect. The low voltage drop during current regulation allows efficient driving of LED strings with a range of forward voltages and supply voltage tolerances
Inbuilt Over Temperature Protection (OTP) gradually reduces the output current when the chip temperature reaches 125 °C.

2 Rext Calculation

The LED current *Iout* is set by a resistor *Rext* connected from REXT to GND. The REXT pin is driven by a 900mV reference and the resultant REXT current is mirrored to the Driver and OTP stages.

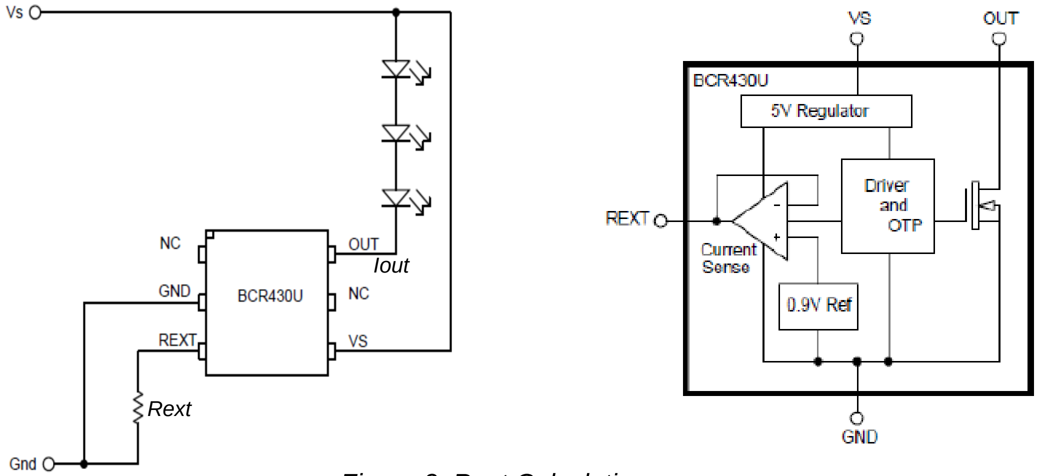


Figure 2: Rext Calculation

There is an exponential relationship between *Rext* and *Iout* expressed by the formula:

$Rext = \left(\frac{Iout}{610.53}\right)^{-1.005632}$ where: *Rext* and *Iout* are expressed in kΩ and mA

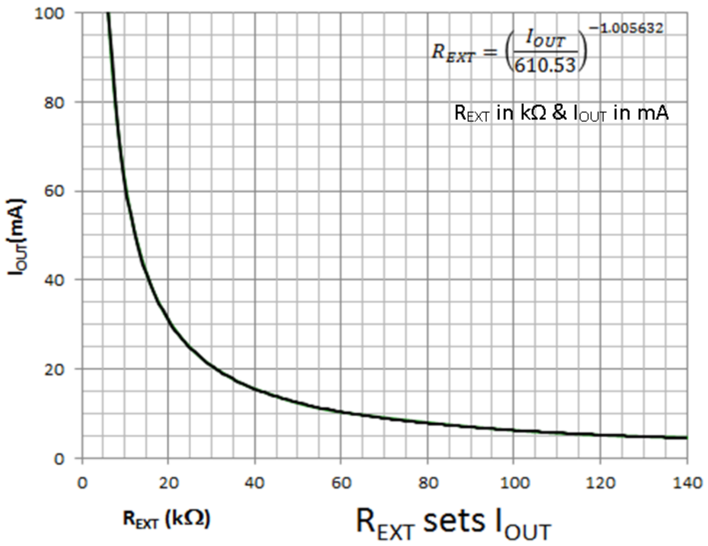


Figure 3: Rext vs Iout

3 Power Dissipation

Power dissipation occurs in several areas and varies according to the operating conditions, however the major influence on power dissipation is the V_{DS} voltage of the output stage.
An example of power dissipation and Junction temperature rise is shown below:

Typical Power Dissipation when V_{DS} = 4V, *Rext* = 13kΩ

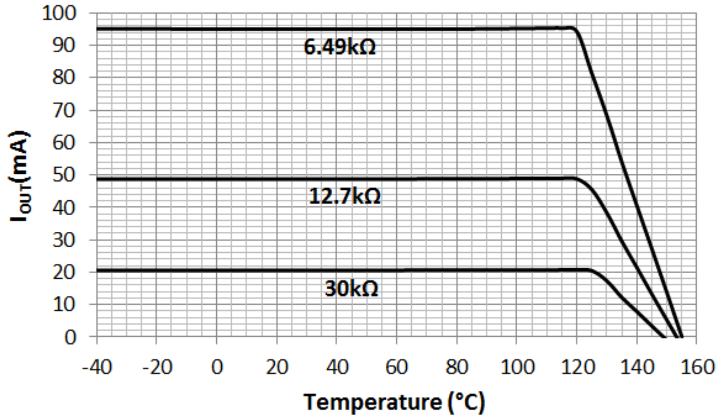
Typical Power Dissipation V_{DS} = 4V, *Rext* = 13kΩ refer to *figure 2*		
Parameter	**Current**	**Power**
Quiescent Current	67µA	2.8mW
Reference Current	69µA	2.9mW
Regulation current	24µA	1mW
Operating Current	125µA	5.3mW
Output Current	50mA	211mW

Figure 4: Power Dissipation

The **BCR430UW6.xlxs** calculator tool can be used to easily set *Rext* value and show power consumption under various operating conditions.

4 Over Temperature Protection (OTP)

Over temperature protection is included to safeguard the device under fault conditions such as short circuit LED's or high ambient temperatures. As the chip temperature increases above 125 °C the output is reduced at a rate of *Isetpoint* / 30 mA per °C rise. The smooth operation maximises LED current and removes flickering.



$T_{JUNCTION}$ vs I_{OUT} with Shutdown

Figure 5: Over Temperature Protection

As V_{DS} increases in the output stage, so will power dissipation and chip temperature. The effects of OTP can be seen in the following simulation which also shows how the ambient temperature and thermal resistance *RthJA* can be adjusted in the SPICE model.

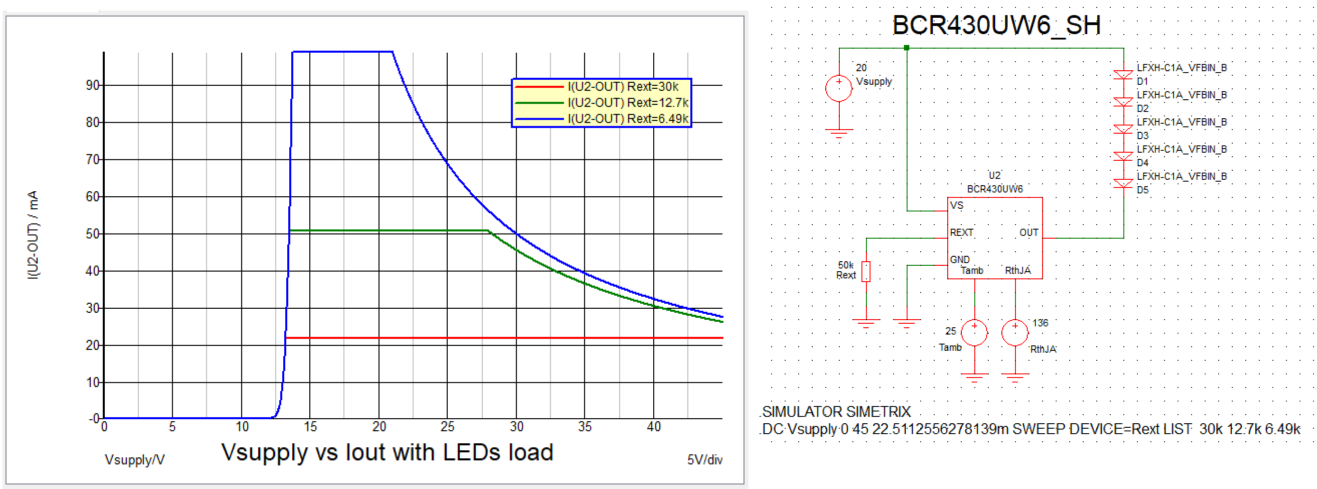


Figure 6: Gradual reduction of output current as Rds losses increase

5 PWM Dimming

Dimming is most efficiently carried out using PWM techniques. This can be achieved by switching either the REXT pin or VS pin.
Switching the VS supply reduces the connection requirements in multiple device systems such as large signs but requires attention to miller effect and transients during power connection.
Note that human visual light level perception and true optical power have a logarithmic relationship where the perceived level is based on the output power ratio:

Perceived power = √ (Output power / Maximum power)

and

Perceived power (%) = 100 x √(Output power (%) / 100)

Converting this to a PWM dimming level:

*Perceived power = √(Maximum power * Duty Cycle)*

Transposing to solve for Output power ratio

Output power ratio = Perceived power ^{2}

and for PWM

Duty Cycle = Perceived power ^{2} */ Maximum power*

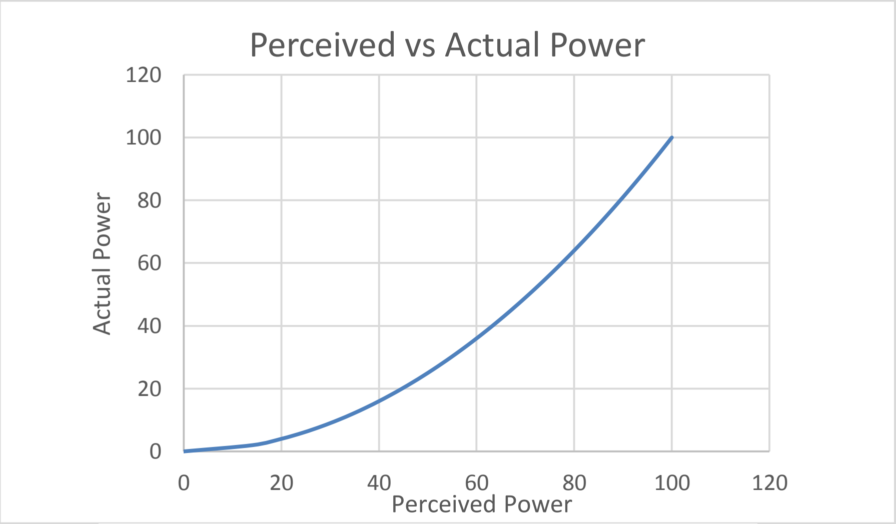


Figure 7: Perceived power vs Actual power

5.1 PWM Safe operating area (SOA)

There are various safety standards for PWM dimming to prevent physiological and safety issues such as IEEE1789. The safe operating area graph from IEEE1789 is reproduced below.

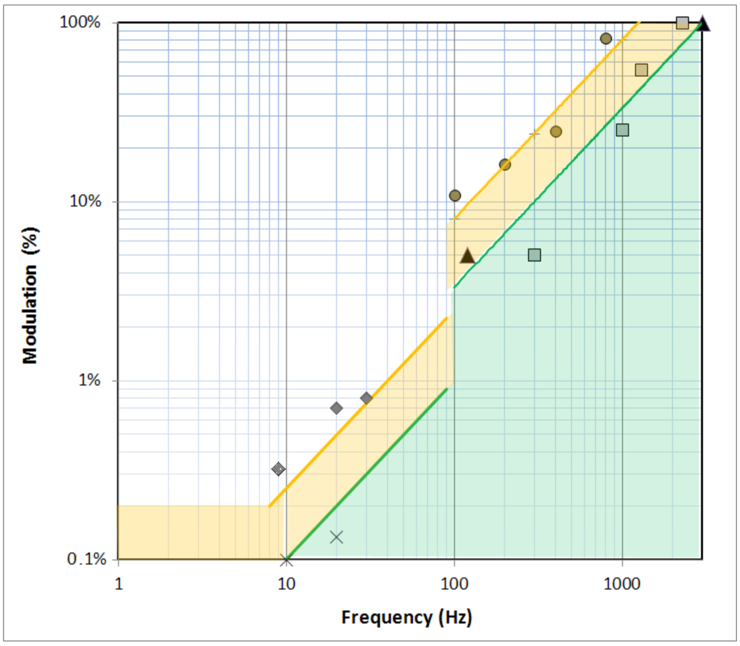


Figure 8: IEEE1789 safe operating area

5.2 PWM Frequency and pulse width

The maximum frequency of operation depends on the dimming requirements and the switching time. The Datasheet specifies worst case tr = 14µs, tf = 3µs so we may consider a minimum duty cycle 40µs as reasonable.

If we want to dim to a perceived level of 10% full brightness the actual level required is:

$$\text{Actual Power} = (\text{Perceived Power})^2 * \text{Maximum Power}$$

$$= 0.1^2 * \text{Maximum Power}$$

$$= 0.01 * \text{Maximum Power}$$

If the minimum duty cycle is 40µs then:

100% duty cycle time = 40µs / 0.01 = 4ms = 250Hz

The table below shows the exponential nature of perceived brightness dimming

Required Cycle Time to achieve Required Dimming at 40uS Duty cycle					
Perceived %	**Percieved Ratio**	**Output Ratio**	**Output %**	**Cycle Time(us)**	**Freq (Hz)**
100	1	1	100	40.000	25000
90	0.9	0.81	81	49.383	20250
80	0.8	0.64	64	62.500	16000
70	0.7	0.49	49	81.633	12250

60	0.6	0.36	36	111.111	9000
50	0.5	0.25	25	160.000	6250
40	0.4	0.16	16	250.000	4000
30	0.3	0.09	9	444.444	2250
20	0.2	0.04	4	1000.000	1000
10	0.1	0.01	1	4000.000	250
9	0.09	0.0081	0.81	4938.272	202.5
8	0.08	0.0064	0.64	6250.000	160
7	0.07	0.0049	0.49	8163.265	122.5
6	0.06	0.0036	0.36	11111.111	90
5	0.05	0.0025	0.25	16000.000	62.5
4	0.04	0.0016	0.16	25000.000	40
3	0.03	0.0009	0.09	44444.444	22.5
2	0.02	0.0004	0.04	100000.000	10
1	0.01	0.0001	0.01	400000.000	2.5

Figure 9: min frequencies and SOA

5.2 REXT Dimming

The most efficient dimming is by PWM of the REXT pin. The value of Rext is calculated for maximum current requirement at 100% duty cycle. Using a GPIO to pull Rext low will turn on the output. The output impedance of the GPIO will have some impact on the required value of Rext. When the GPIO is high (above 900mV) the output will turn off. The REXT pin will clamp at 5V.

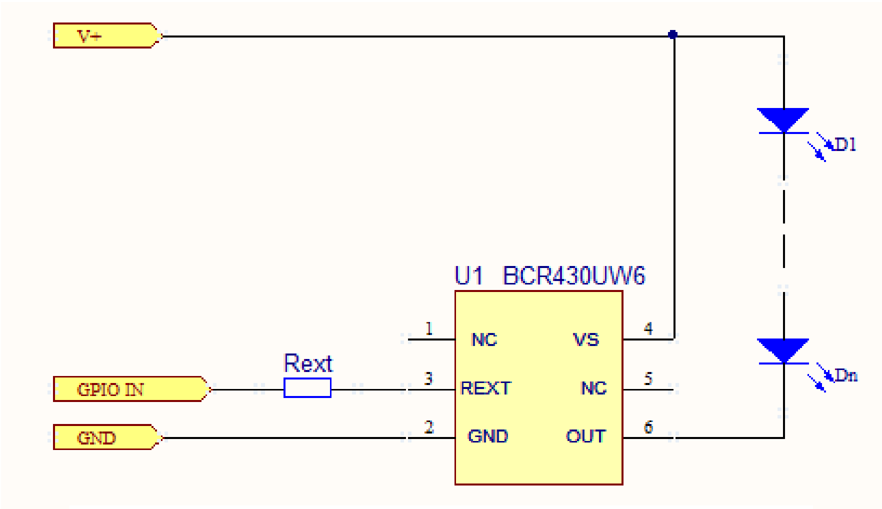


Figure 10: REXT Dimming by GPIO

5.3 Supply Voltage Dimming

PWM dimming can be achieved by modulating the power supply. If the power supply has a fast rise time the drain-gate capacitance of the output transistor may cause the transistor to turn on for ~ 650ns before the control circuit has stabilized. This can be mitigated by increasing the rise time of the power supply to greater than 5µs.

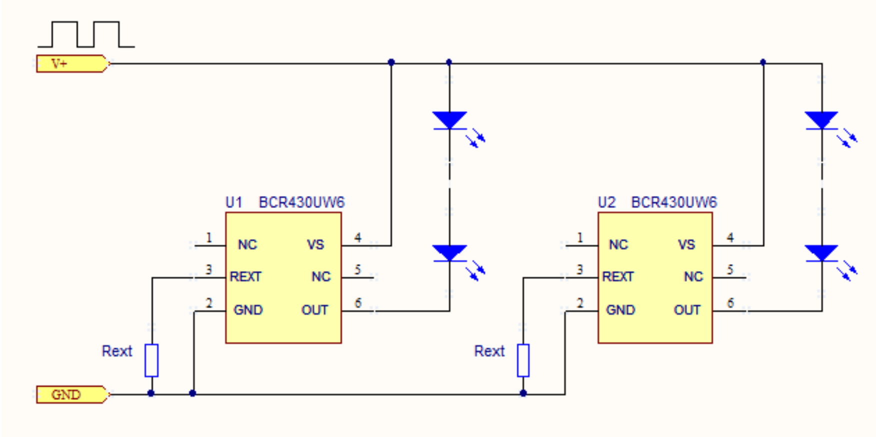


Figure 11: Power Supply PWM Dimming

6 ESD Protection

ESD protection is 2kV HBM. This can be extended to 6kV HBM by placing a 1kΩ resistor in series with the VCC pin.

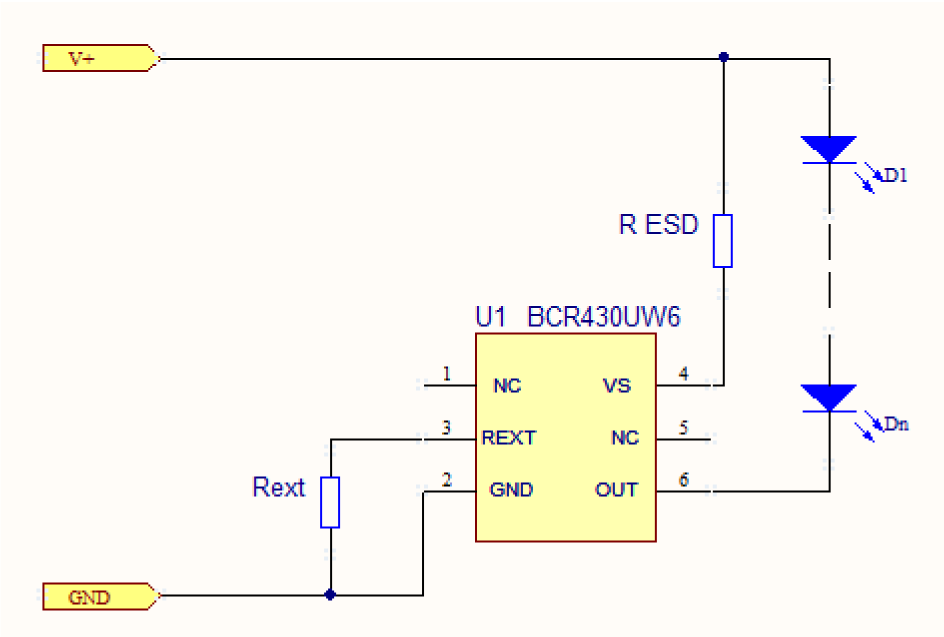


Figure 12: 6kV ESD Protection

7 SPICE Model

A SPICE model BCR430UW6.spice.txt is available on the Diodes website. This is a behavioural model that includes OTP modelling.

The model has extra inputs to set ambient temperature and junction-ambient thermal resistance (RthJA).

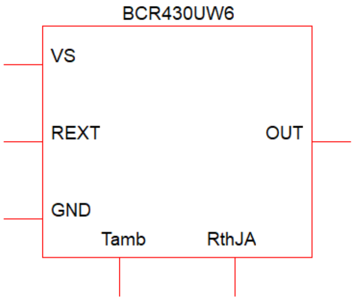
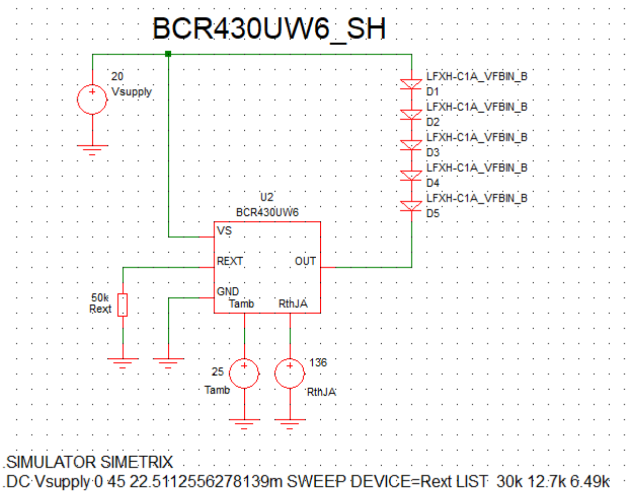


Figure 13: Spice Model

Model Pin Descriptions		
PIN	**NAME**	**FUNCTION**
1	RthJA	Input sets thermal resistance. 1V = 1 °C/W
2	GND	0V
3	REXT	Current setpoint resistor connection
4	VS	V+ supply 0 - 42V
5	Tamb	Input sets ambient temperature. 1 V = 1 °C
6	OUT	Output current sink



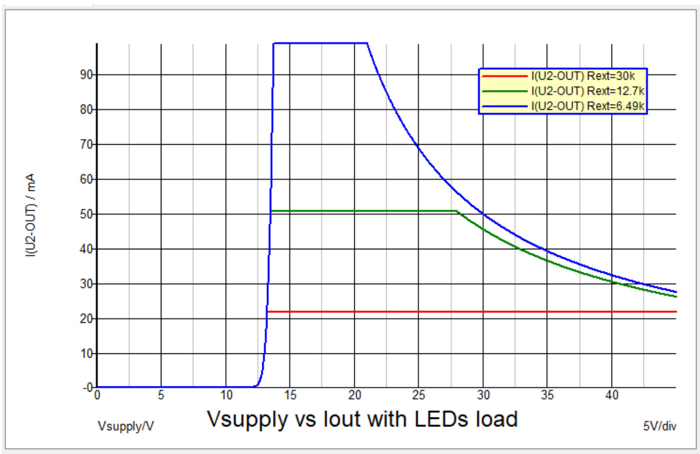


Figure 13: Example of OTP operation as I^2R_{DS} losses increase with Vout

8 Calculator

A calculator **BCR430UW6.Calculator.xlsx** is available on the Diodes website. The calculator enables quick calculation of Rext, power dissipation, operating temperature and PWM ranges.

BCR430 Calculator

Issue 2

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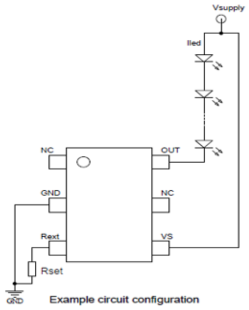
Device Limits	Symbol	BCR430	Units
Maximum supply voltage	Vs_max	45	V
Maximum output voltage	Vo_max	42	V
Maximum output current	Iout_max	100	mA
Maximum Rext current	Iext_max	0.3	mA
Maximum Rext voltage	Vext_max	5	V
Maximum Junction temperature	Tj_max	150	°C
Maximum output saturation voltage	Vo_sat	0.2	V
Maximum power	Pd_max	993	mW

Input system design parameters	Symbol	INPUT	Units	Recommendations/Comments
Vsupply	Vs	20	V	Vs < Vs_max and > (Vleds + Vo_sat)
No of LEDs	N_leds	5		
LED current	Iout	95	mA	Set a value between 5mA - 100mA
Led forward voltage	Vf	3	V	Typically 3.1V
Ambient temperature	Ta	25	°C	Enter a Ta value between -40°C and 150°C
Cu area in mm square	Area	625	mm^2	Enter a Cu area between 25 and 2500
Cu thickness in oz	Weight	2	oz	1 or 2

Output parameters	Symbol	RESULTS	Units
LED chain voltage	Vleds	15	V
Output voltage	Vout	5	V
Current programming resistor	Rext	6.19	kΩ
Power Dissipation in BCR	Pd_BCR	475.00	mW
Power Dissipation in Rext	Pd_Rext	0.13	mW
Total Power	Ptot	1900.00	mW
System efficiency	Effy	75.000	%
Thermal resistance junction-ambient	Rth	132.97905	°C/W
Junction temperature	Tj	88.17	°C



Grey : Results/Outputs
Yellow: Input
White: units and comments

Figure 14: BCR430UW6 Calculator

9 Evaluation Board

An evaluation board is available that allows evaluation of the BCR430UW6 with an onboard string of 8 Liteon LEDs or external LEDs of your choice. Constant current or PWM is selectable. A testpoint is included to facilitate Vout measurement to verify output losses ad LED performance.

9.1 Technical specification

Input Voltage	5 – 42 Vdc
Default Rext	12 kΩ
Default LED current	50 mA
Output Current Range	5 -100 mA
Dimensions	35 mm x 55 mm

9.2 Circuit

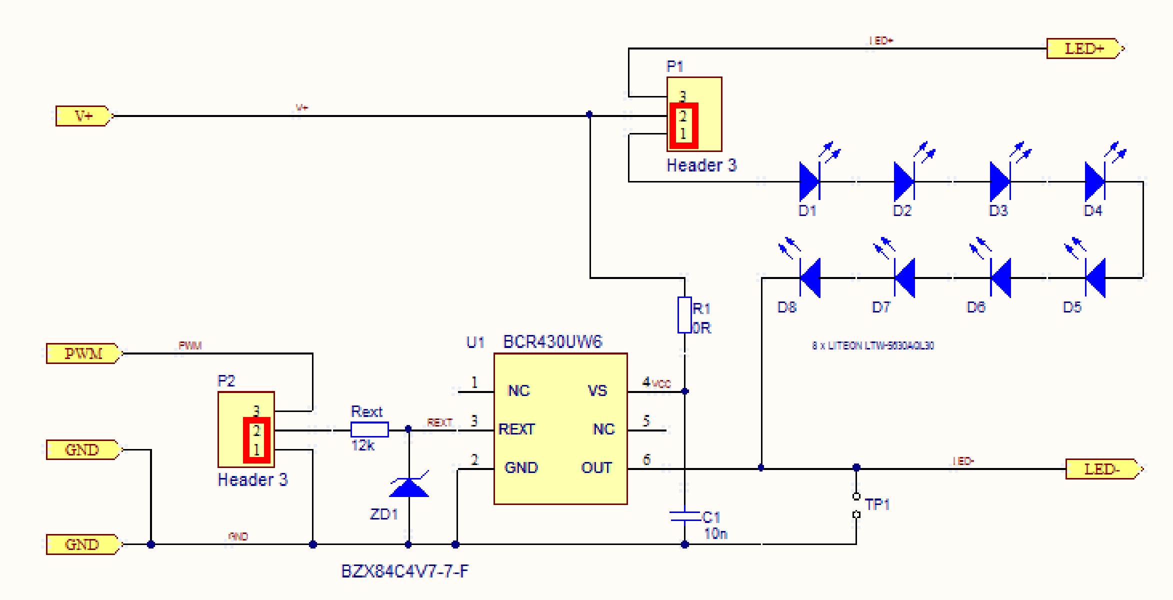


Figure 15: Circuit of BCR430UW6 Evaluation Board

P1 jumper is used to select on-board LED's or external LED's.

P2 jumper is used to select Rext resistor connected to GND (50mA) or to PWM pin for external dimming 5V dc. max

ZD1 protects against over voltage or negative PWM signal

TP1 accepts oscilloscope spring probe to measure OUT voltage

R1 also has PTH pads and can be removed or replaced with a low value for current monitoring or ESD testing

9.3 PCB

The PCB is 2 layer 1.5mm FR4 1oz copper. Thermal relief is provided for LED’s and BCR430UW6.

The LED’s and BCR430UW6 are connected to copper areas top and bottom of 200 mm^2 per device for heat dissipation.

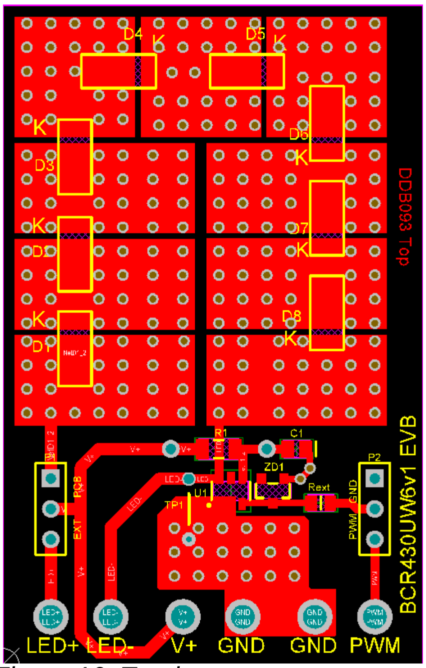


Figure 16: Top layer

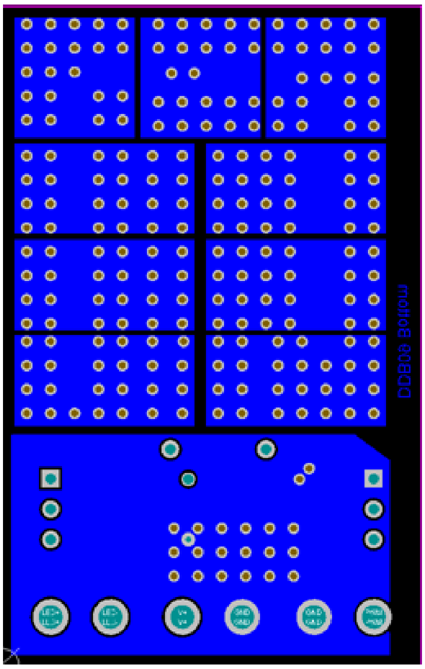


Figure 17: Bottom layer

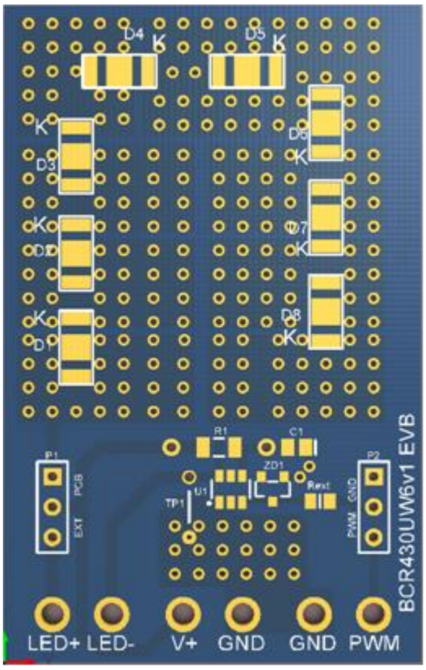


Figure 18: 3D

9.4 Bill of Materials

Bill of Materials		
Designator	Quantity	Value
C1	1	10n 0805 50V
D1-8	8	LTW-5630AQL30
P1, P2	2	3 pin header
R1	1	0R 1206 200V
Rext	1	12k 0805 1% 150V
U1	1	BCR430UW6
ZD1	N.F.	BZX84C4V7-7-F