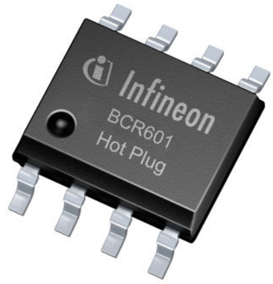
BCR601 hot plug IC with voltage feedback to primary side

60V linear LED controller IC for dimmable LED driver with ripple suppression, overvoltage, overtemperature and hot plug protection

Features



- Supply voltage 8 V to 60 V,
- Supports use of NPN bipolar transistors and NMOSFETs,
- 100 Hz/120 Hz supply voltage ripple suppression,
- Supports an optocoupler voltage feedback loop to primary side minimizing power losses,
- 3% analog dimming of LED current by a resistor or DC voltage at the *MFIO* pin,
- R_{set} functionality at *MFIO* pin,
- LED current precision ±3%.

Protection features

- Hot plug protection to minimize LED inrush current,
- Overvoltage protection,
- Overtemperature protection.

Target applications

- LED driver.

Advantages with respect to discrete solutions

- Low BOM count,
- Lower assembly cost,
- Smaller form factor,
- Higher reliability due to less parts and soldering joints.

Product validation

Qualified for industrial applications according to the relevant tests of JEDEC47/20/22.

Device information

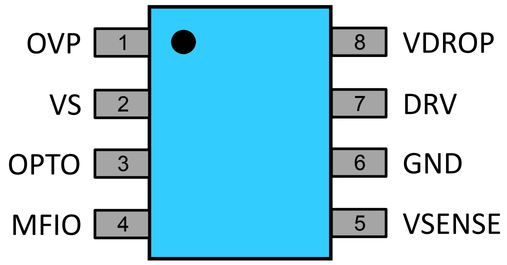


Figure 1 **Pin definition PG-DSO-8 pin out**

Table 1 **Part information**

Type	Package	Configuration	Marking code
60V Linear Voltage and Current Control Chip BCR601	PG-DSO-8	n.a.	BCR601

Description

BCR601 is a linear LED controller IC regulating the LED current by means of an external driver transistor. BCR601 supports use of NPN bipolar transistors and NMOS MOSFETs to cover a wide LED current and power range.

BCR601 provides feedback to the primary side via an optocoupler to control the output voltage of the primary side converter, e.g. a flyback. The control loop minimizes the voltage overhead and power dissipation of the external driver transistor. The voltage overhead can be adjusted by external configuration according to application needs.

BCR601 suppresses the voltage ripple of the power supply driving a constant LED current for better light quality.

The LED current is fully scalable by dimensioning an external current sense resistor.

The embedded hot plug protection allows plug in and plug out of the LED load during operation reducing LED current overshoots and related LED life time degradations.

The adjustable overvoltage protection will provide feedback to the primary side by the optocoupler in case the supply voltage exceeds the threshold.

The overtemperature protection will dim the LED current if the BCR601 junction temperature threshold is exceeded. In this case the LED current will be reduced to 30% of the nominal current. Once the junction temperature drops below the temperature hysteresis nominal LED current is resumed.

The BCR601 is a perfect fit for LED applications by combining small form factor with low cost. Through its higher integration, BOM savings and ensuring long lifetime of LEDs, this controller has many advantages compared to discrete solutions.

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1 Pin configuration

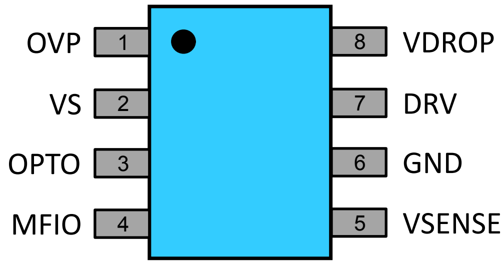


Figure 2 Pin definition PG-DSO-8 pin out

Table 2 Pin configuration

Pin no.	Pin name	Pin type	Function
1	*OVP*	Input	Supply voltage measurement for overvoltage protection
2	*VS*	Input	Supply voltage
3	*OPTO*	Output	Output to control the optocoupler current
4	*MFIO*	Input	Multifunctional IO for resistive and DC voltage dimming
5	*VSENSE*	Input	Measurement of V_{sense} voltage
6	*GND*	GND	IC ground
7	*DRV*	Output	Driver output to control base or gate of the external transistor
8	*VDROP*	Input	Measurement of Vdrop voltage

2 Functional description

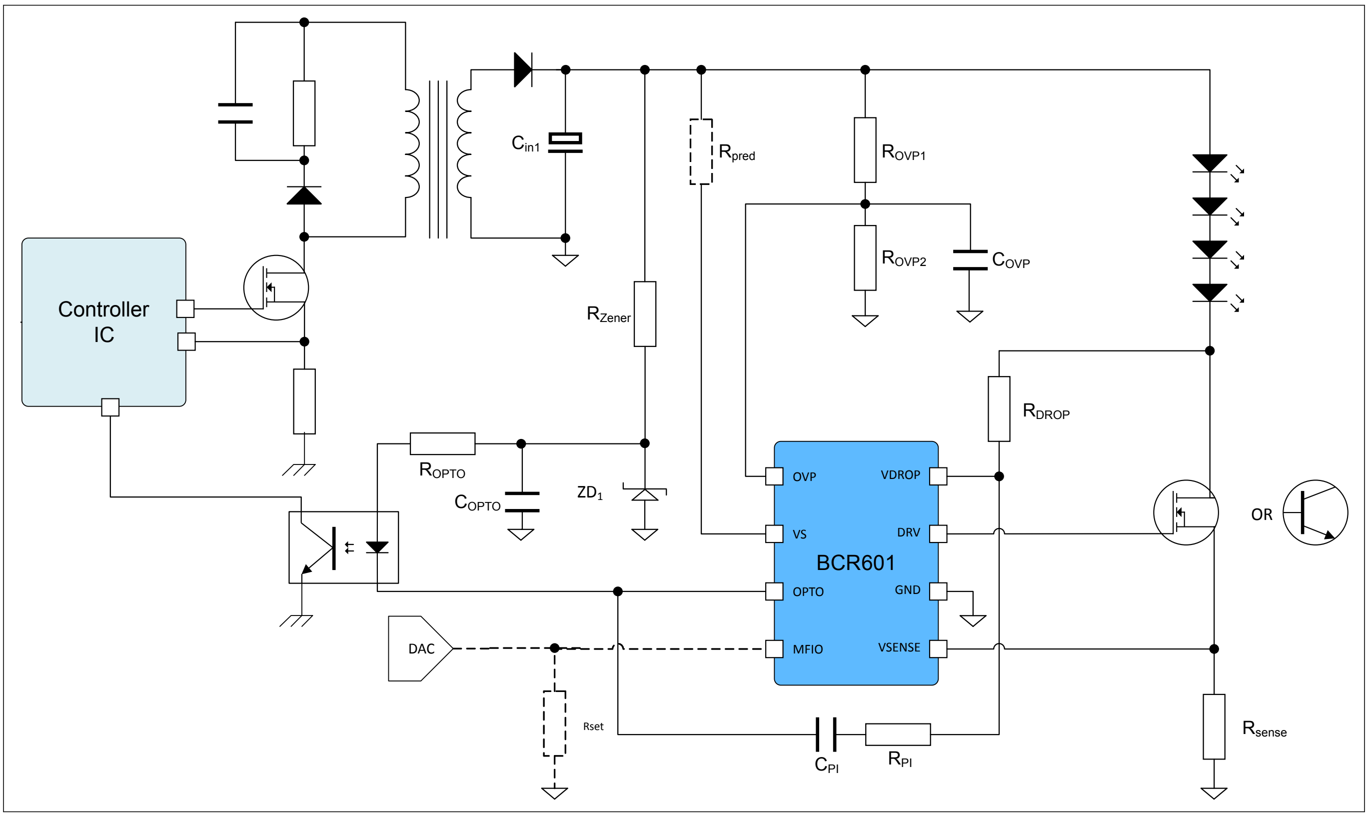


Figure 3 **Typical application circuit**

Application hints

1. External driver transistors

   BCR601 is able to drive NPN transistors as well as NMOSFETs. NPN transistors can be used for LED currents up to several hundred of mA while NMOSFETs are preferable for high LED currents. The smaller current using BJTs is caused by the DC current gain value h_{FE} value of the used BJT. E.g. a typical h_{FE} of 75 limits the application to a maximum below 750 mA.
2. Supply voltage of BCR601

   To drive higher output currents into an external NPN driver transistor it might be necessary to limit the supply voltage of BCR601 significantly below 60 V to reduce power dissipation inside the IC. This can be achieved either by adding a series resistor R_{pred} between supply voltage and *VS* pin of BCR601 or by operating BCR601 by an auxiliary winding of the power supply providing a lower IC supply voltage as e.g. 8 V.

Dimming mechanism

For dimming of the LED current a DC voltage is applied to the *MFIO* input signal.

1. Analog dimming: input voltage V_{MFIO} at pin *MFIO*. Continuous dimming from 3% dimming level up to 100% is embedded into a 100% ceiling plateau and an hysteresis range to off. Static dimming to a fixed value can be done via the resistor R_{set}.

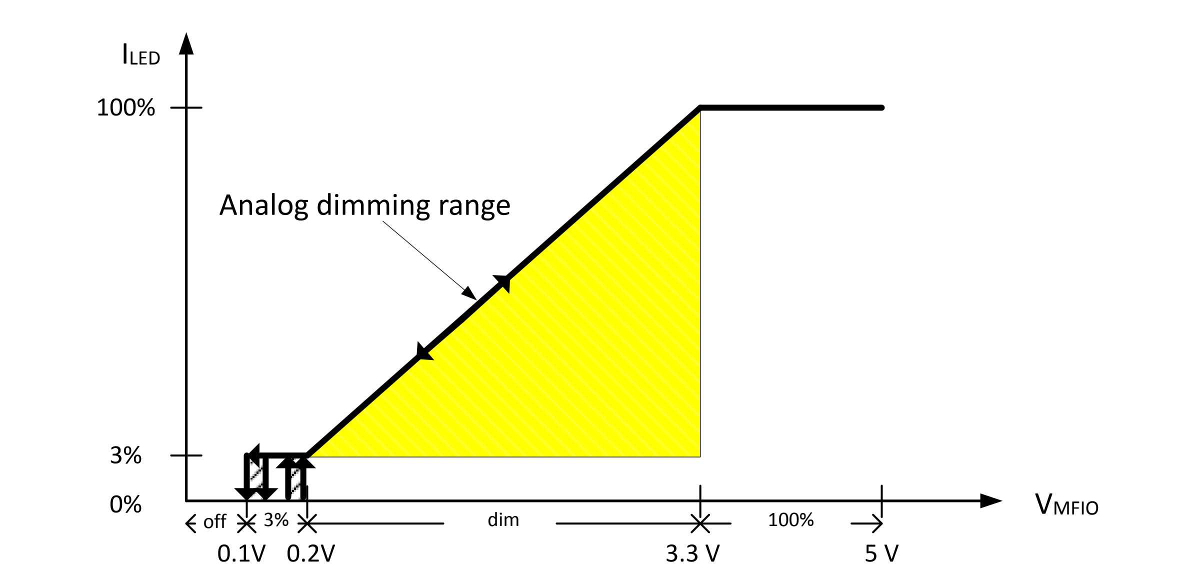
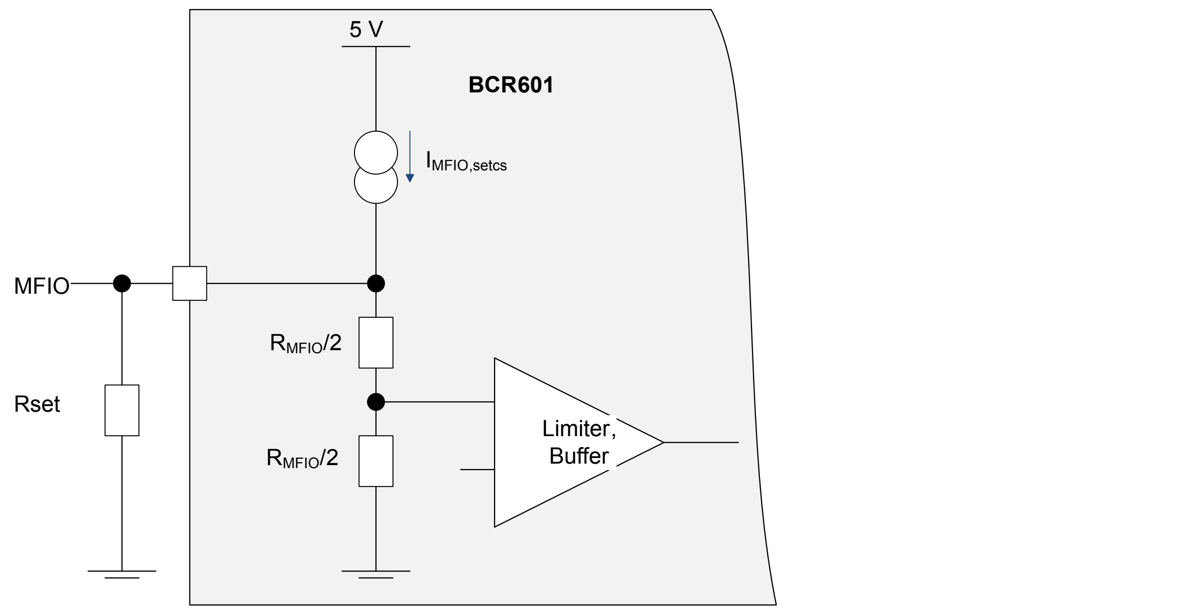


Figure 4 **Analog dimming**

2. For analog dimming using R_{set} and internal MFIO current, the internal pull-down has to be taken into account. For proper dimensioning refer to ***Figure 5***.



$$V_{MFIO} = I_{MFIO,\,setcs} \frac{R_{set} * R_{MFIO}}{R_{set} + R_{MFIO}}$$

$$R_{set} = \frac{V_{MFIO} * R_{MFIO}}{I_{MFIO,\,setcs} * R_{set} - V_{MFIO}}$$

Figure 5 **R_{set} dimensioning for resistor dimming**

- $R_{MFIO.typical}$ = 285 kΩ,
- $I_{MFIO,setcs,typical}$ = 20 µA.

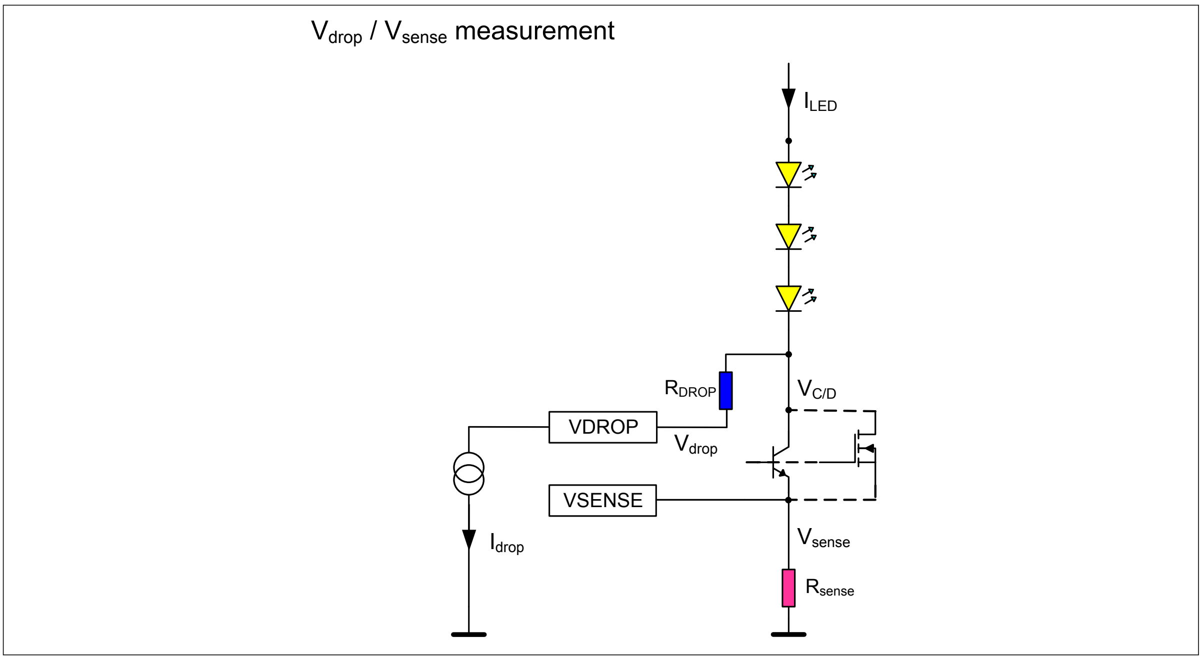


Figure 6 **VDROP versus VSENSE measurement**

BCR601 incorporates two control loops:

1. Fast LED current control loop

In a proper design, the converter output voltage ripple will drop across the external power transistor (drain voltage $V_{C/D}$) and "consumed" by the power transistor, so that the voltage across the LED string is constant. The LED current is sensed by the current sense resistor R_{sense}. The fast LED current control loop regulates the power transistor to keep the LED current constant. LED current is defined by the equation.

$I_{LED} = V_{sense} / R_{sense}$

$V_{C/D}$ needs to be set high enough to make sure that BCR601 can regulate the power transistor to conduct a constant LED current. To enable adjustment of $V_{C/D}$ BCR601 has an integrated constant current sink I_{drop} at pin *VDROP*. By the external resistor R_{DROP} the collector/drain voltage $V_{C/D}$ with respect to V_{drop} is defined by the following equation.

$V_{C/D} = V_{drop} + I_{drop} \cdot R_{DROP}$

If $V_{C/D}$ is chosen too low, LED current will drop because either NPN h_{FE} will drop too low and BCR601 I_{DRV} reaches its maximum sourcing current, or NMOSFET drain to source resistance R_{DSon} cannot be reduced further more as V_{DRV} of BCR601 reaches its upper limit . As a result the output voltage ripple will modulate the LED current and flicker might become visible. If $V_{C/D}$ is chosen too high, power loss in the external power transistor will be high, resulting in low power efficiency and increased effort in heat dissipation of the power transistor.

2. Slow control loop for the primary side output voltage

In typical application, the primary side controller is integrated with active PFC function. The output voltage contains an unavoidable ripple of 100 Hz (at 50 Hz grid) or 120 Hz (at 60 Hz grid). The crossover frequency of the control loop must be much smaller than the ripple frequency, so that the ripple voltage is not regulated and the power factor is not deteriorated. This is realized by the RC compensation network (R_{PI}, R_{DROP}, C_{PI} and C_{DROP}) connected between *OPTO* pin and *VDROP* pin.

3 Thermal characteristics

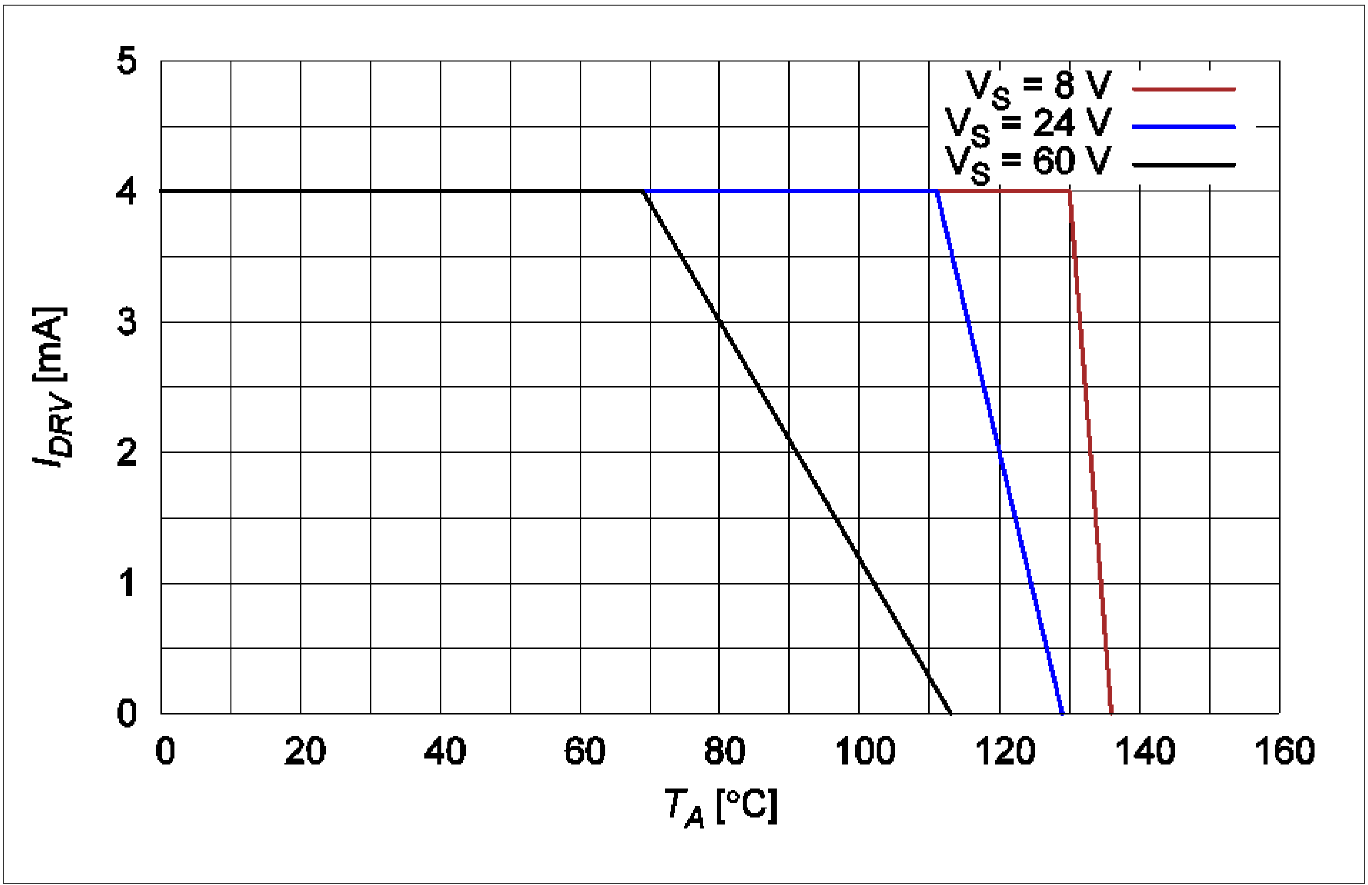


Figure 7 Maximum permitted effective output source current out of pin *DRV* into external driver transistor for a design example of 4 mA DC driver

The maximum permitted effective driver source current shown in ***Figure 7*** can be calculated by following equation:

$$I_{DRV} = \frac{\frac{T_{OTP,\,min} - T_A}{R_{thJA}} - V_S \cdot I_S - \frac{V_S}{2} \cdot \frac{I_{OPTO}}{2}}{V_S} = \frac{T_{OTP,\,min} - T_A}{V_S \cdot R_{thJA}} - I_S - \frac{I_{OPTO}}{4}$$

The equation considers the power dissipation caused by current consumption of the IC itself and the optocoupler current. If driver current exceeds the calculated threshold the lower specified limit of the overtemperature protection will be exceeded and OTP might be triggered.

$T_{OTP,on,\,min}$ The lower spec limit of the overtemperature protection threshold should not be exceeded to avoid triggering the OTP.

I_{OPTO} The maximum optocoupler sink current into pin *OPTO* when IC fully turns on the current sink. Besides the spec limits of BCR601 the maximum current is also limited by the optocoupler supply voltage and external pull-up resistor.

4 Absolute maximum ratings

Table 3 Maximum ratings

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Junction temperature	T_J	–40	–	160	°C	–
Supply voltage	V_S	0	–	65	V	–
Input voltage at pin *VDROP*	V_{DROP}	0	–	65	V	–
Input voltage at pin *VSENSE*	V_{sense}	0	–	3.6	V	–
Input voltage at pin *OPTO*	V_{OPTO}	0	–	65	V	–
Input voltage at pin *OVP*	V_{OVP}	0	–	3.6	V	–
Input voltage at *MFIO*	V_{MFIO}	0	-	5.0	V	-
Power dissipation	P_{tot}	–	–	360	mW	V_S = 60 V, I_S = 2 mA, I_{DRV} = - 4 mA
ESD robustness	$V_{ESD,HBM}$	–	–	1.5	kV	HBM acc. to JEDEC JS-001
	$V_{ESD,CDM}$	-	-	500	V	CDM acc. to JEDEC JS-002

Attention: ***Stresses above the maximum values listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Maximum ratings are absolute ratings. Exceeding only one of these values may cause irreversible damage to the component.***

Table 4 Maximum thermal resistance

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Thermal resistance junction to ambient	$R_{thJA,0}$	–	–	180	K/W	JEDEC 1s0p (JESD 51-3) footprint without extra cooling area
	$R_{thJA,300}$	–	–	135		JEDEC 1s0p (JESD 51-3) with 300 mm² cooling area
	$R_{thJA,600}$	–	–	125		JEDEC 1s0p (JESD 51-3) with 600 mm² cooling area

5 Operating conditions

Table 5 Operating conditions

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Junction temperature	T_J	–40	–	160	°C	–
Supply voltage	V_S	0	–	60	V	–
Input voltage at pin *VDROP*	V_{DROP}	0	–	60	V	–
Input voltage at pin *OPTO*	V_{OPTO}	0	–	60	V	–

6 Electrical characteristics

Note: All parameters are measured at T_A *= 25 °C, VS = 45 V, unless otherwise specified.*

Note: $I_{LED,target}$ *current is the undimmed current at a VSENSE voltage drop of 400 mV typical.*

Table 6 DC characteristics

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
IC system						
Supply voltage	V_S	8	–	60	V	Operational supply voltage range
Supply undervoltage lock-in	$V_{S,uvli}$	–	–	8	V	–
Supply undervoltage lock-out	$V_{S,uvlo}$	6.7	–	–	V	–
Supply current	I_S	-2.2	–	-	mA	$I_{DRV, source}$ = 0 mA
Voltage at pin *OPTO*	V_{OPTO}	3	–	–	V	To achieve I_{OPTO} = 2 mA
Optocoupler sink current	I_{OPTO}	-3.6	–	-2	mA	Sink current range of pin *OPTO* if $V_{OPTO,min}$ with V_{OVP} = 0.2 V
Optocoupler leakage current	$I_{OPTO,leakage}$	-80	–	-	µA	V_{OVP} = 0.8 V, V_{OPTO} = 3 V, V_{DROP} = 0.2 V
Sense voltage	V_{SENSE}	388	400	412	mV	Closed loop reference voltage of pin *VSENSE*, $I_{LED} = V_{sense} / R_{sense}$ at V_{MFIO} = *3.3 V*
Voltage at pin *VDROP*	$V_{DROP,5}$	0.275	–	–	V	At I_{OPTO}= 100 µA (5 % of full range), V_{OVP} < 1.1 V
Voltage at pin *VDROP*	V_{DROP}	0.295	0.31	0.325	V	At I_{OPTO}= 1mA (50 % of full range), V_{OVP} < 1.1 V
Voltage at pin *VDROP*	$V_{DROP,95}$	–	–	0.345	V	At I_{OPTO} = 1.95 mA (95 % of full range), V_{OVP} < 1.1 V
Sink current at pin VDROP	I_{DROP}	-6.9	-5.5	-4.1	µA	Constant current sink at pin *VDROP*
Hot plug						
Hot plug *VSENSE* threshold	$V_{sense, HP}$	–	8	–	mV	*VSENSE* level at which hot plug event is detected
Driver						
Driver source current capability	$I_{DRV, source}$	10	-	-	mA	Source current range of pin *DRV* to drive NPN base/NMOS gate

Table 6 DC characteristics (continued)

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Driver sink current capability	$I_{DRV, sink}$	-	-	-10	mA	Sink current range of pin *DRV* to discharge NPN base/NMOS gate
Driver source voltage	V_{DRV}	4.5	5	5.5	V	Max. output voltage of pin *DRV*
Analog dimming						
MFIO output source current	$I_{MFIO, setcs}$	18	20	22	µA	For R_{SET} < 10 kΩ, in parallel internal pull-down R_{MFIO} connected, refer to ***Figure 3***
MFIO output voltage	$V_{MFIO, setcs}$	–	4.2	–	V	MFIO output voltage at MFIO open
MFIO pull-down resistor	R_{MFIO}	228	285	342	kΩ	Internal pull down resistor at pin *MFIO*
MFIO turn-off range	$V_{MFIO, off}$	0	–	0.1	V	Threshold for analog dimming to off
MFIO turn-on range	$V_{MFIO,on}$	0.17	–	0.195	V	Threshold for analog dimming to on
MFIO dimming range	$V_{MFIO, dim}$	0.2	–	3.3	V	Minimum to maximum LED current
MFIO full current range	$V_{MFIO, 100\%}$	3.3	–	5	V	MFIO range always at 100% I_{LED}
DC LED dimming	$I_{LEDmin, ana}$ / $I_{LEDmin, target}$	–	3	–	%	Minimum dimming LED current level at $MFIO_{dim}$ = 0.15 V
LED current chip to chip variation at selected dimming level	$\Delta I_{LED,dim}$ / $I_{LED,dim}$	-20	–	20	%	Max variation at minimum MFIO dimming level
		-10		10		Max variation for dimming level higher than minimum
LED current accuracy						
LED current accuracy	$I_{LED, acc}$	-3	–	3	%	Closed loop LED current accuracy without dimming atV_{MFIO} = 3.3 V
Overvoltage protection OVP						
Overvoltage protection minimum voltage	$V_{OVP,min}$	0.1	–	–	V	Minimum voltage required at pin *OVP*
Overvoltage protection threshold, OVP on	$V_{OVP,on,10}$	1.11	1.15	1.19	V	At 10% $I_{OPTO-OVP}$ range ~0.2 mA, V_{DROP} = 0.2 V

Table 6 DC characteristics (continued)

Parameter	Symbol	Values			Unit	Note or test condition
		Min.	Typ.	Max.		
Overvoltage protection threshold, OVP on	$V_{OVP,on}$	1.15	1.20	1.24	V	At $I_{OPTO-OVP}$ = 2 mA, V_{DROP} = 0.2 V
Optocoupler sink current at OVP active	$I_{OPTO,OVP}$	-3.2	–	-2.1	mA	Sink current range of pin *OPTO* at $V_{OPTO,min}$ = 3 V with V_{OVP} = 1.3 V and V_{DROP} = 0.2 V
OVP pull down resistor	R_{OVP}	100	120	140	kΩ	Internal pull-down resistor at pin *OVP*
Overtemperature protection OTP						
Overtemperature protection threshold, turn on	$T_{OTP, on}$	140	–	155	°C	Junction threshold temperature to trigger overtemperature protection in standby, I_{DRV} = 0.1 mA and *VS* = 45 V
Overtemperature protection threshold, turn off	$T_{OTP, off}$	120	–	135	°C	Junction threshold temperature to exit overtemperature protection in standby, I_{DRV} = 0.1 mA and *VS* = 45 V
Sense voltage in OTP case	$V_{sense, OTP}$ / $V_{sense, target}$	–	30	–	%	Reduction factor at pin *VSENSE* (nominal 400 mV) if OTP has been triggered, $I_{LED, OTP}$ = $V_{sense,OTP}$ / R_{sense}
Overtemperature protection hysteresis	$T_{OTP, Hys}$	–	20	–	°C	–

7 Package information

Note: Dimension in mm

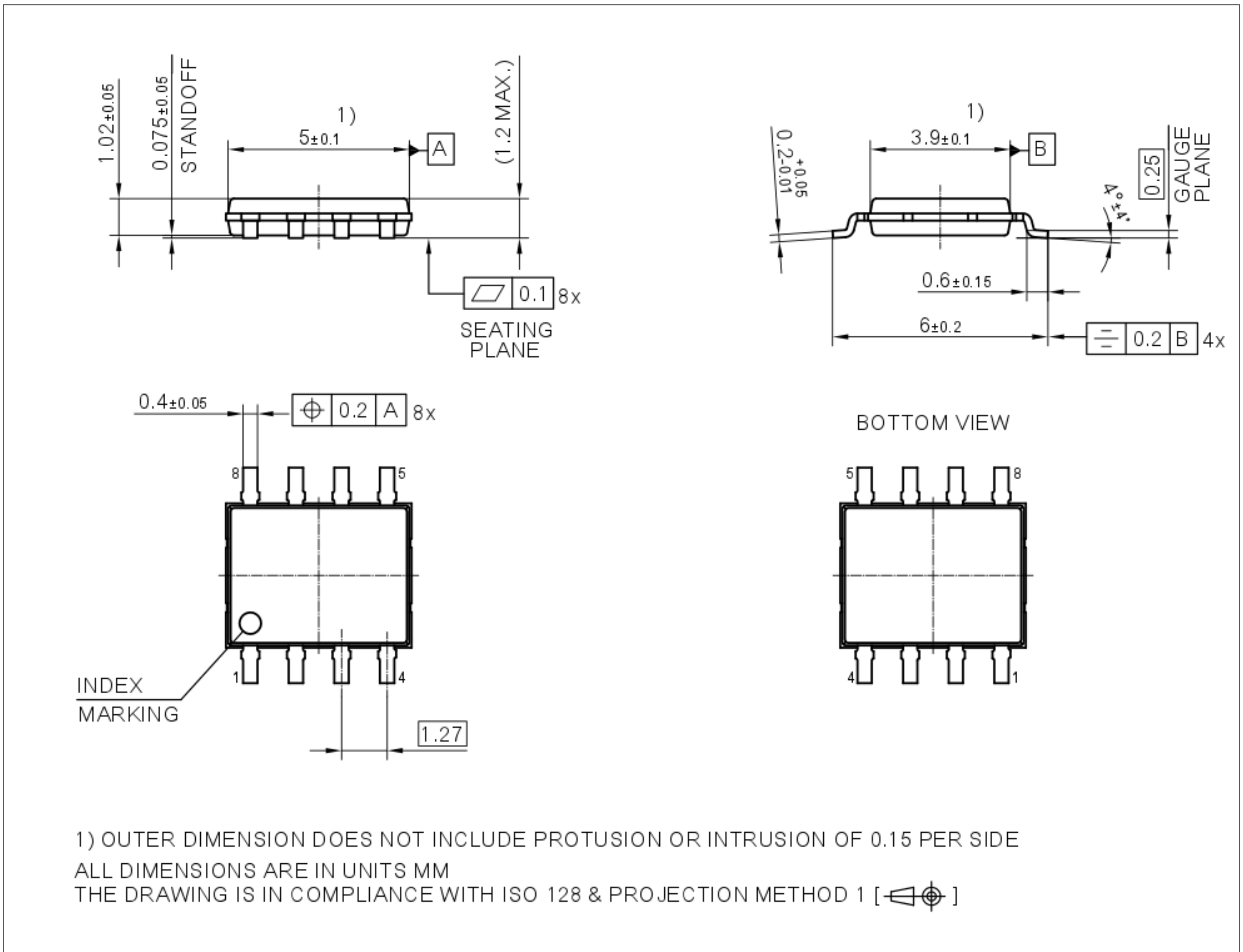


Figure 8 Package outline DSO-8

8 References

Revision history

Document version	Date of release	Description of changes
1.0	2018-11-23	• Public release
1.1	2018-12-3	• Parameter update

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