XR46004

600mA High Voltage Adjustable Current Regulator with Enable Control

August 2, 2021

Description

The XR46004 is a high voltage, low dropout current regulator of output current up to 600mA in maximum. Users can adjust the output current from 100mA to 600mA through an external resistor, RSET, which gives users flexibility in controlling the light intensity of the LEDs. Further, the LED brightness is adjustable via the OE pin with a Pulse Width Modulation signal.

The thermal protection function protects the IC from over temperature damage. Also, the exposed thermal pad enhances the package power dissipation.

FEATURES

- 600mA maximum output current
- Output current adjustable via external resistor
- 3μs fast response output stage enable control
- Output sustaining voltage up to 75V
- Wide supply voltage range: 5V to 50V
- TO-252-5L package
- Green package

APPLICATIONS

- Map lights
- Accent lights
- Projector lights

Typical Application

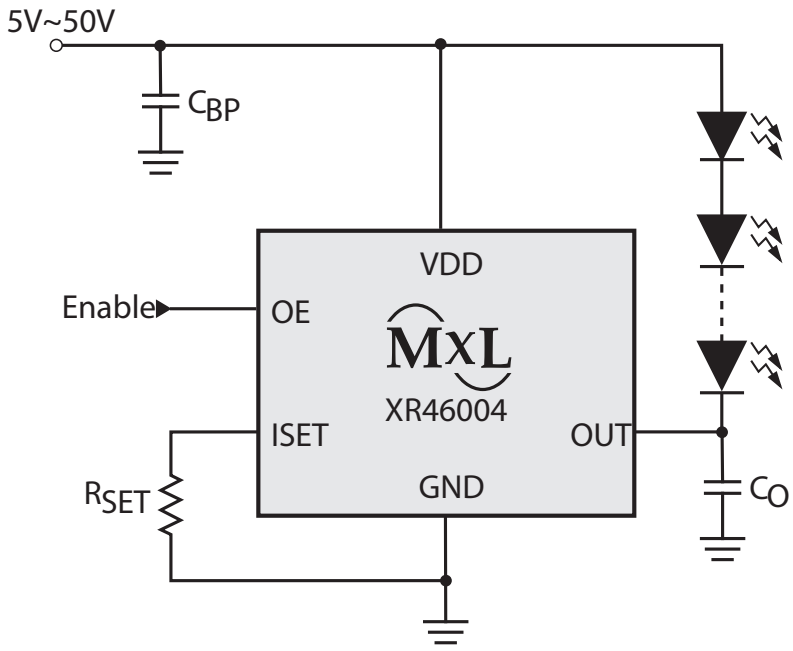


Figure 1. Typical Application

Absolute Maximum Ratings

Stresses beyond the limits listed below may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Supply voltage, V_{DD} 55V

Output sustaining voltage, V_{OUT} 75V

Output sink current, I_{OUT} 700mA

Output enable voltage, V_{OE} 10V

Storage temperature range ..... -40°C to 150°C

Lead temperature (soldering, 10 seconds) ..... 260°C

Operating Conditions

Supply voltage, V_{DD} ..... 5V to 50V

Output enable voltage, V_{OE} 6V

Output sink current, I_{OUT} ..... 100mA to 600mA

Operating junction temperature, T_J ..... -40°C to125°C

Maximum operating junction temperature, T_J ..... 150°C

AEC-Q100 ..... Class 1

Electrical Characteristics

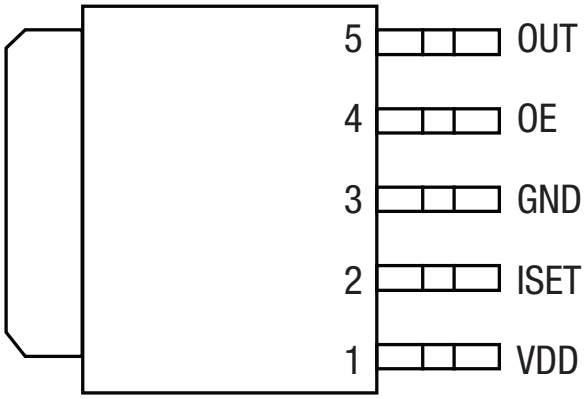
Specifications are for Operating Junction Temperature of T_J = 25°C only; limits applying over the full Operating Junction Temperature range are denoted by a "•". Typical values represent the most likely parametric norm at T_J = 25°C, and are provided for reference purposes only. Unless otherwise noted, values are at V_{DD} = 24V.

Symbol	Parameter	Conditions		Min	Typ	Max	Units
	Output current	V_{OUT} = 0.5V, R_{SET} = 3kΩ		185	200	216	mA
			•	175		230	
		V_{OUT} = 0.5V, R_{SET} = 1.71kΩ		342	360	381	
			•	325		398	
		V_{OUT} = 1.0V, R_{SET} = 1kΩ			620		
	SET current range			200		1400	µA
	Minimum output current	I_{SET} = 200µA, V_{OUT} = 0.5V			100		mA
	Maximum output current	I_{SET} = 1200µA, V_{OUT} = 1V			600		mA
	Output dropout voltage	I_{SET} = 700µA(1)			0.35		V
	Load regulation	V_{OUT} = 0.5V to 3V				3	mA/V
	Line regulation	V_{OUT} = 0.5V, I_{OUT} = 350mA, V_{DD} = 5V to 50V			0.08	0.15	%/V
	Thermal shutdown junction temperature	Hysteresis = 20°C(2)			160		°C
	Thermal shutdown hysteresis				20		°C
	"Low" input voltage			0		0.8	V
	"High" input voltage	Must be lower than V_{DD}		2		Min {V_{DD}, 6}	V
	"Low" input current	V_{OE} = GND		-20		20	µA
	"High" input current	V_{OE} = 5V		-5.0		5.0	µA
	Output enable delay time	OE from Low to High, V_{OUT} = 0.5V, I_{OUT} = 350mA, 50%(2)			3		µs
	Output disable delay time	OE from High to Low, V_{OUT} = 0.5V, I_{OUT} = 350mA, 50%(2)			3		µs
	Supply current consumption					5	mA

NOTES:

1. Output dropout voltage: 90% x $I_{OUT(VOUT=500mV)}$
2. Guarantee by design, not by production test.

Pin Configuration



TO-252-5L, Top View

Pin Functions

Pin Number	Pin Name	Description
1	VDD	Power supply pin.
2	ISET	Output current setting pin. Connect a resistor RSET between the ISET and GND for setting the LED driving current. $I_{OUT(mA)} = \frac{630}{R_{SET(k\Omega)}} - 10$ This pin must be connected to ground with a 1kΩ or higher value resistor.
3	GND	Ground pin.
4	OE	Output stage enable control pin. High enables the OUT pin. It can be left floating for normally on.
5	OUT	Constant current output pin. Sink current is decided by the current on RSET connected to ISET pin.
Thermal Tab (GND)		Heat dissipation pad. Connect to the ground plane and GND pins in the PCB layout. Must be soldered to electrical ground on the PCB.

NOTE:
The thermal tab is suggested connect to GND on PCB. And thermal conductivity will be improved, if a copper foil on PCB is soldered with thermal pad.

Typical Performance Characteristics

Unless otherwise noted, T_A = 25°C.

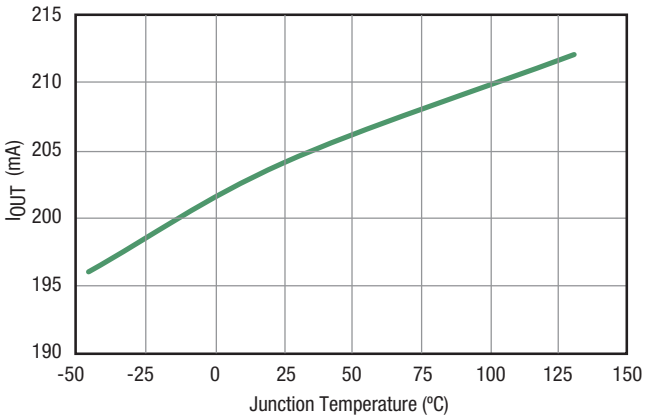


Figure 2: I_{OUT} @ 200mA vs. Junction Temperature, R_{SET} = 3kΩ

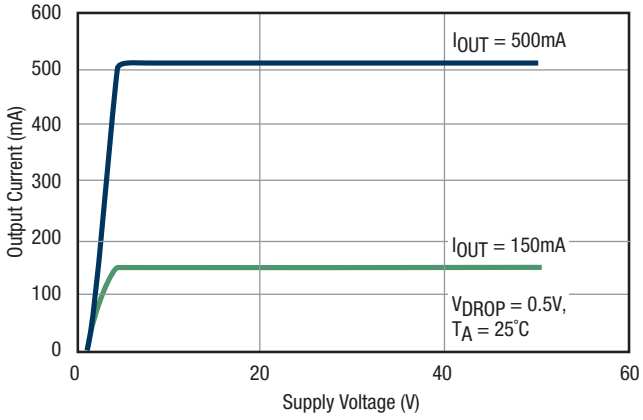


Figure 3: Output Current vs. Supply Voltage

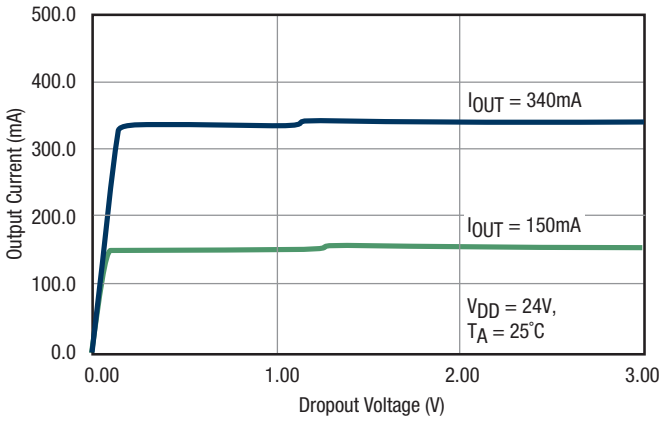


Figure 4: Output Current vs. Dropout Voltage

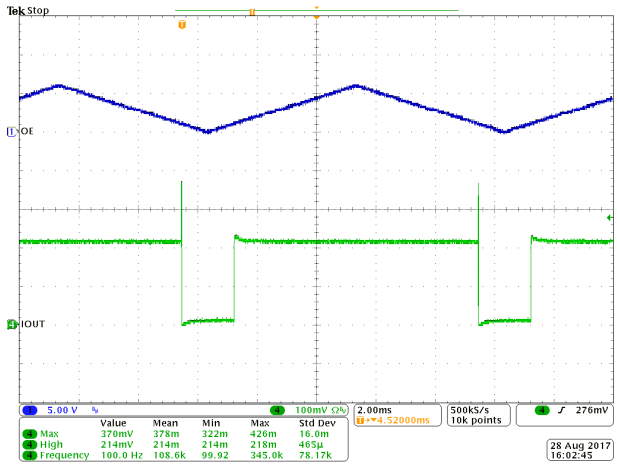


Figure 5: V_{OUT} Sink Current. OE Pin Slow Ramp 0-6V, I_{SET} = 3KΩ, V_{DROP} = 0.5V

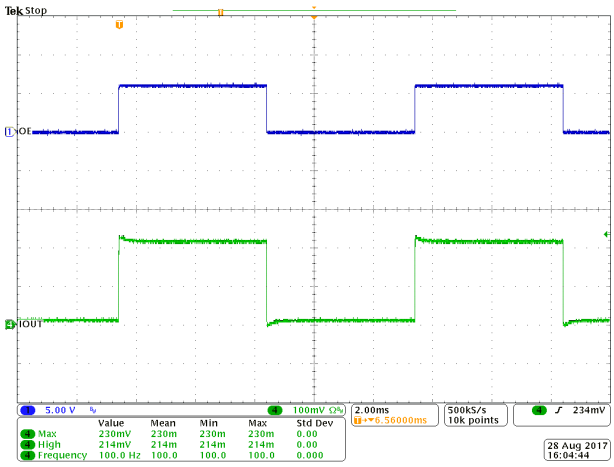


Figure 6: V_{OUT} Sink Current. OE Pin 6V Square Wave, I_{SET} = 3KΩ, V_{DROP} = 0.5V

Functional Block Diagram

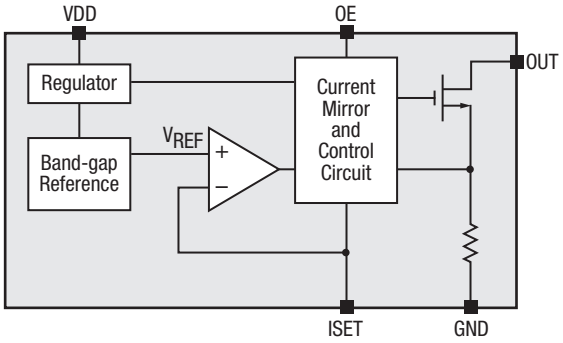


Figure 7. Functional Block Diagram

Applications Information

The XR46004 is a high voltage, low dropout current regulator for output current up to 600mA in maximum. The OE pin is used for enabling/disabling the output stage of the chip. The current can be linearly adjusted through a variable resister connected to the ISET pin, or by a PWM control signal via the OE pin. Although the absolute maximum rating of the OUT pin is 75V, the dropout voltage between the OUT pin and the GND pin should not be too large when the current is sinking because the thermal dissipation capability of the package is limited. Here are some of the typical application examples:

DC Voltage Input

As shown in Figure 8, any DC voltage between 5V and 50V can be adopted as power source V_{DD} for typical application of XR46004 as long as the voltage between the OUT pin and the GND pin (V_{DD} voltage minus the total forward voltage drop of the LED string) is larger than the dropout voltage needed for that expecting current. If 50V ~ 75V voltage is adopted as the power source to the positive end of the LED string, one Zener shunt regulator can be used to provide appropriate voltage to the VDD pin, as shown in Figure 9.

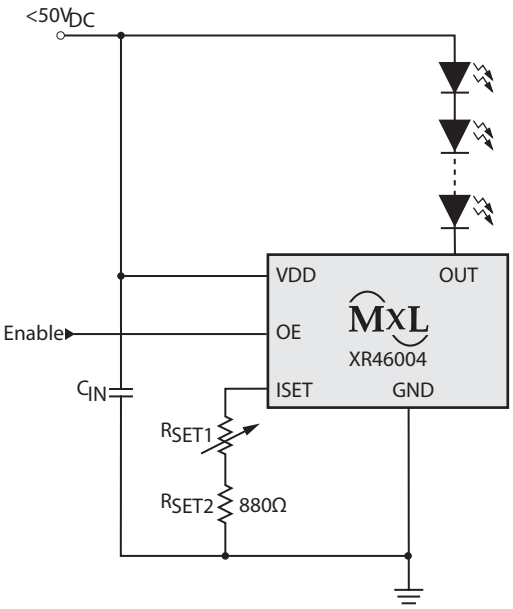


Figure 8. DC Voltage Input Application (<50V_{DC})

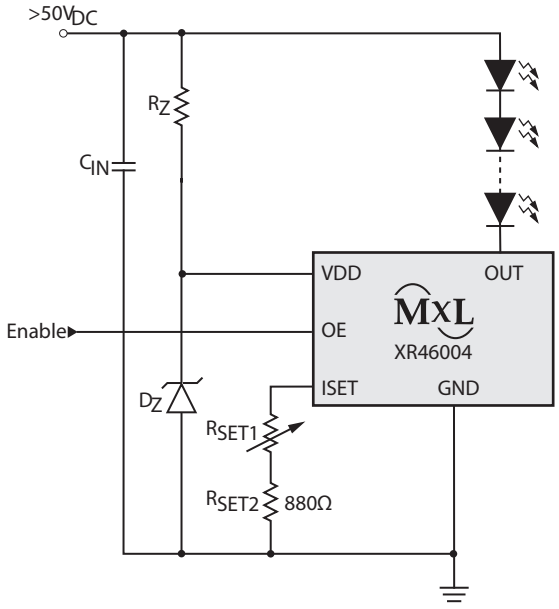


Figure 9. DC Voltage Input Application (>50V_{DC})

Applications Information (Continued)

If a ceramic capacitor is selected as the input capacitor, C_{IN}, without any electrolytic capacitor connected in parallel, sometimes there may be high voltage spike on the input voltage line when V_{IN} is switching on or off in the testing stage or the mass production stage. The peak of the voltage spike may be higher than 50V (supply voltage range of the VDD pin) even when the normal V_{IN} level is much less than 50V. An RC filter, R_{IN} and C_{IN2}, is recommended at the VDD pin in order to prevent the voltage spike from damaging the VDD pin, as shown in the following circuit diagram.

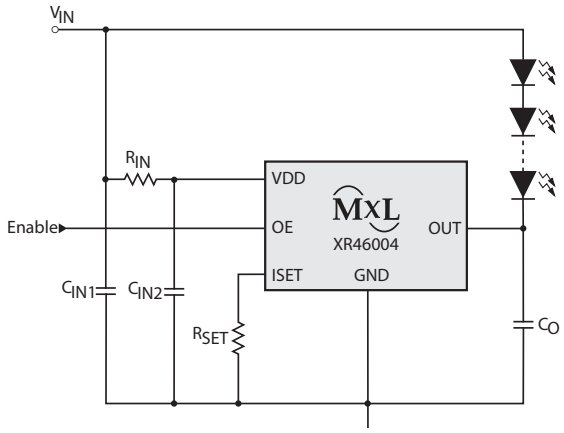


Figure 10. DC Voltage Input Application with Ceramic Input Capacitor

Output Capacitance

Figure 10 shows the application schematic where an output capacitor, C_O, is added to the circuit. LED AC impedances can vary widely and in some applications a 10uF capacitor is required between the OUT pin and ground to avoid oscillation in the current control circuit. It is recommended that an output capacitor be included in all designs as a “De-Populate” and if testing finds oscillation in the drive current, the capacitor may then be populated. If the OE pin is used to turn off the LEDs, the OUT pin voltage will rise to the V_{IN} voltage, so the voltage rating of the capacitor must take this into consideration. When derating ceramic capacitors based on the DC bias, use the voltage on the OUT pin when the LEDs are on. This voltage is usually <1V which results in little derating.

LED Backlight Solution

XR46004 can coordinate with any type of DC-to-DC converter through a feedback path to realized LED backlight module. The number of LEDs in the string is variable even with certain fixed power source since the output voltage of the DC-to-DC converter can be modulated according to the feedback signal.

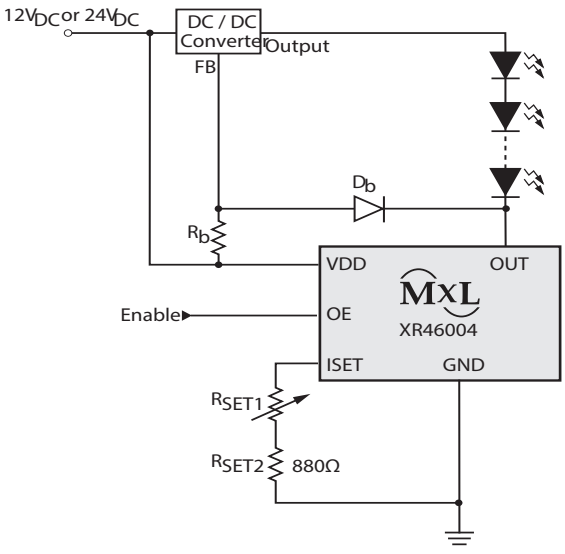


Figure 11. LED Backlight Solution

Applications Information (Continued)

AC Voltage Input

XR46004 can work with any kind of well-known or well-developed switch-mode power supply system. Simply cut off the internal feedback path of the power supply system and then feed the signal from XR46004 back to the power supply system instead.

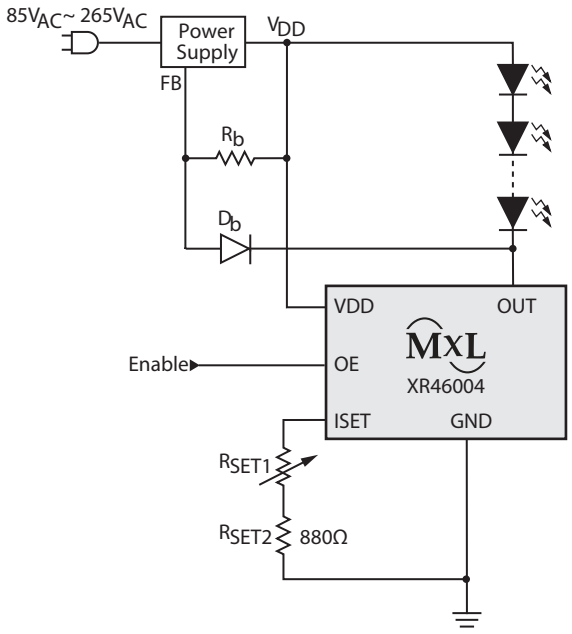


Figure 12. AC Voltage Application

Thermal Consideration

The maximum power dissipation for a single-output regulator is:

$P_{D(MAX)} = (V_{IN(MAX)} - V_{F(NOM)}) \times I_{OUT(NOM)} + V_{IN(MAX)} \times I_Q = V_{OUT(MAX)} \times I_{OUT(NOM)} + V_{IN(MAX)} \times I_Q$

Where, $V_{F(NOM)}$ = the nominal LED total forward voltage

- $I_{OUT(NOM)}$ = the nominal output current = the nominal LED current
- I_Q = the quiescent current of the regulator
- $V_{IN(MAX)}$ = the maximum input voltage
- $V_{OUT(MAX)}$ = the maximum voltage drop between OUT pin and GND pin

Then, $\theta_{JA} = (150°C - T_A)/P_D$

Applications Information (Continued)

Thermal Calculation

The XR46004 has an internal power and thermal limiting circuitry designed to protect the device under overload conditions. However, maximum junction temperature ratings should not be exceeded under continuous normal load conditions. The thermal protection circuit of the XR46004 prevents the device from damage due to excessive power dissipation. When the device junction temperature rises to approximately 150°C, the regulator will be turned off. When the power consumption is over about 1000mW (TO-252 package, at T_A = 70°C), an additional heat sink is required to control the junction temperature below 125°C.

The junction temperature is:

$T_J = P_D (\theta_{JT} + \theta_{CS} + \theta_{SA}) + T_A$

- P_D: dissipated power
- θ_{JT}: thermal resistance from the junction to the mounting tab of the package
  - For TO-252 package, θ_{JT} = 7.0 °C/W
- θ_{CS}: thermal resistance through the interface between the IC and the surface on which it is mounted (typically, θ_{CS} < 1.0°C /W)
- θ_{SA}: thermal resistance from the mounting surface to ambient (thermal resistance of the heat sink)

If a PC Board copper is going to be used as a heat sink, below table can be used to determine the appropriate size of copper foil required. For multi-layered PCB, these layers can also be used as a heat sink. They can be connected with several through-hole vias.

PCB θ_{SA} (°C /W)	59	45	38	33	27	24	21
PCB heat sink size (mm2)	500	1000	1500	2000	3000	4000	5000

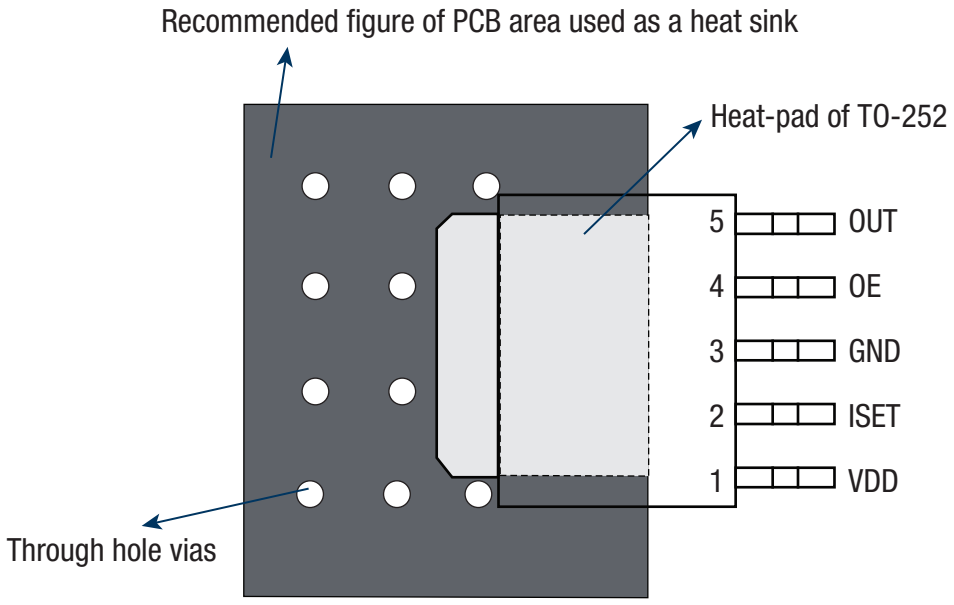
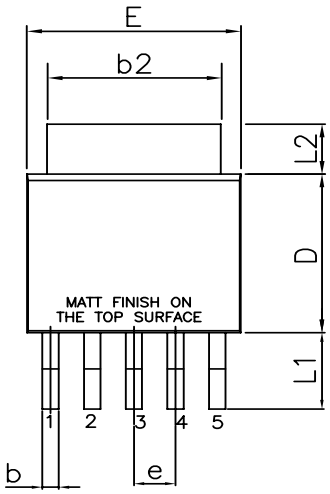


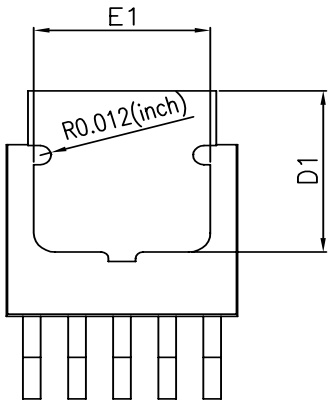
Figure 13. Recommended PCB for Heat Sink

Mechanical Dimensions

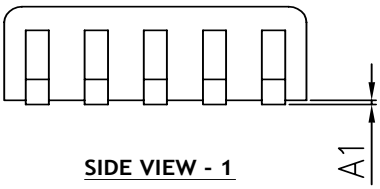
TO-252-5L



TOP VIEW



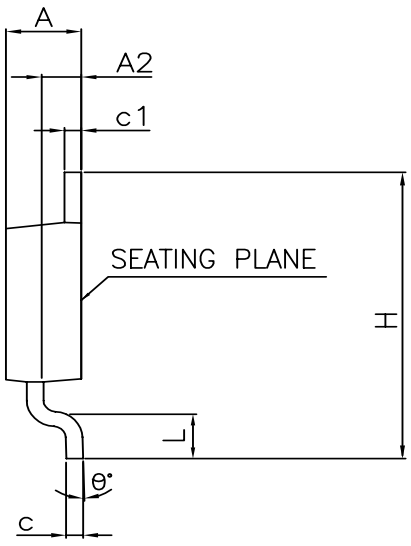
BOTTOM VIEW



SIDE VIEW - 1

SYMBOLS	DIMENSIONS IN INCH		DIMENSIONS IN MILLIMETER	
	MIN.	MAX.	MIN.	MAX.
A	0.086	0.094	2.18	2.39
A1	0.000	0.005	0.00	0.13
A2	0.040	0.050	1.02	1.27
b	0.020 TYP.		0.51 TYP.	
b2	0.205	0.215	5.21	5.46
c	0.018	0.023	0.46	0.58
c1	0.018	0.023	0.46	0.58
D	0.210	0.220	5.33	5.59
D1	0.180	0.208	4.57	5.30
E	0.250	0.265	6.35	6.73
E1	0.150	0.220	3.81	5.60
e	0.050 BSC.		1.27 BSC.	
H	0.370	0.410	9.40	10.41
L	0.055	0.070	1.40	1.78
L1	0.105 REF.		2.67 REF.	
L2	0.05	0.08	1.27	2.03
θ	0°	4°	0°	4°

TERMINAL DETAILS



SIDE VIEW - 2

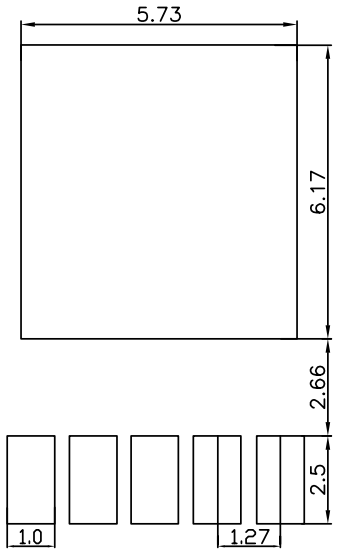
- ALL DIMENSIONS ARE IN MILLIMETERS, ANGLES ARE IN DEGREES.
- DIMENSIONS AND TOLERANCE PER JEDEC TO-252.

Drawing No.: POD-00000100

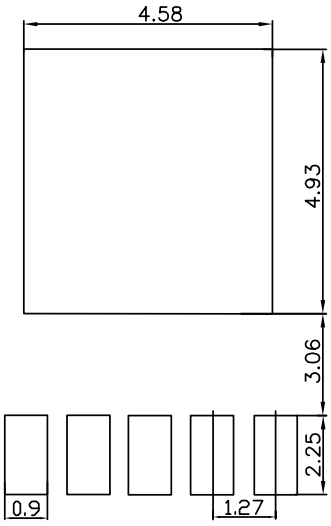
Revision: C

Recommended Land Pattern and Stencil

TO-252-5L



TYPICAL RECOMMENDED LAND PATTERN



TYPICAL RECOMMENDED STENCIL

Drawing No.: POD-00000100

Revision: C

Ordering Information

Part Number	Operating Temperature Range	AEC-Q100 Qualified	Lead-Free	Package	Packaging Method
XR46004ETCTR-Q	-40°C ≤ T_J ≤ 125°C	Yes	Yes	TO-252-5L	Tape and reel
XR46004ETCTR	-40°C ≤ T_J ≤ 125°C	No	Yes	TO-252-5L	Tape and reel

NOTE: For most up-to-date Ordering Information and additional information on environmental rating, refer to www.maxlinear.com/XR46004

Revision History

Revision	Date	Description
1A	December 2017	Initial release.
1B	June 2018	Updated Mechanical Dimensions with Max D1/E1.
1C	August 2, 2021	Updated: ■ "AEC-Q100 Qualified" removed from the document tile. ■ Updated "XR46004-Q" intances replaced to "XR46004". ■ "Automotive AEC-Q100 Qualified" removed from "Features" section. ■ "Ordering Information" table. ■ "exar. com" references updated as "maxlinear.com". ■ Dislaimer/Legal page.

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