

## TPS2559-Q1 高精度可调式限流配电开关

### 1 特性

- 适用于汽车电子应用 具有符合 AEC-Q100 标准的下列结果：
  - 器件人体放电模式 (HBM) 静电放电 (ESD) 分类等级 H2
  - 器件组件充电模式 (CDM) ESD 分类等级 C5
- 2.5V 至 6.5V 工作电压范围
- 1.2 至 4.7A 的可调节电流  $I_{LIMIT}$  (4.7A 时的限流精度为  $\pm 4.7\%$ )
- 3.5 $\mu$ s 短路关断响应时间 (典型值)
- 13m $\Omega$  高侧金属氧化物半导体场效应晶体管 (MOSFET)
- 2 $\mu$ A 最大待机电源电流
- 内置软启动
- 禁用时提供反向电流阻断
- 8kV/15kV 系统级静电放电 (ESD) 能力
- 具有可湿性侧面的 10 引脚小外形尺寸无引线 (3mm x 3mm) 封装

### 2 应用

- 汽车类 USB 端口/集线器
- 汽车类内部负载开关

### 3 说明

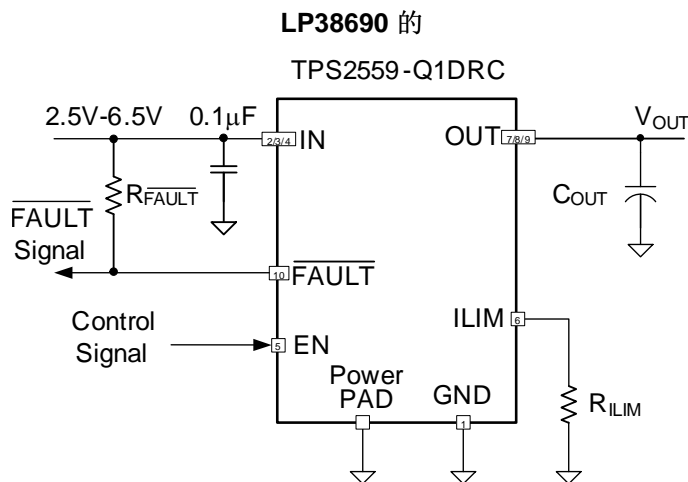
TPS2559-Q1 配电开关专门用于需要低电阻、高精度限流开关或使用高容性负载的应用。TPS2559-Q1 最高可提供 5.5A 的持续负载电流，通过单个接地电阻即可实现精确限流。当输出负载超出限流阈值时，可通过切换至恒流模式使输出电流保持在一个安全的级别。过载事件期间，输出电流被限制在由  $R_{ILIM}$  设定的级别。如果出现持续过载，TPS2559-Q1 将进入热关断模式，从而避免自身发生损坏。

对电源开关的上升和下降次数进行控制以最大程度降低接通或关断期间的电流冲击。在过流或过热情况下， $\overline{FAULT}$  逻辑输出被置为低电平。

器件信息<sup>(1)</sup>

器件型号	封装	封装尺寸 (标称值)
TPS2559-Q1	超薄小外形尺寸无引线 (VSON) (10)	3.00mm x 3.00mm

(1) 要了解所有可用封装，请见数据表末尾的可订购产品附录。



## 目录

<b>1</b>	特性 .....	<b>1</b>	9.1	Overview .....	<b>10</b>
<b>2</b>	应用 .....	<b>1</b>	9.2	Functional Block Diagram .....	<b>10</b>
<b>3</b>	说明 .....	<b>1</b>	9.3	Feature Description .....	<b>10</b>
<b>4</b>	修订历史记录 .....	<b>2</b>	9.4	Device Functional Modes .....	<b>11</b>
<b>5</b>	<b>Device Comparison Table</b> .....	<b>3</b>	<b>10</b>	<b>Application and Implementation</b> .....	<b>12</b>
<b>6</b>	<b>Pin Configuration and Functions</b> .....	<b>3</b>	10.1	Application Information .....	<b>12</b>
<b>7</b>	<b>Specifications</b> .....	<b>4</b>	10.2	Typical Application .....	<b>12</b>
7.1	Absolute Maximum Ratings .....	<b>4</b>	<b>11</b>	<b>Power Supply Recommendations</b> .....	<b>19</b>
7.2	ESD Ratings .....	<b>4</b>	<b>12</b>	<b>Layout</b> .....	<b>20</b>
7.3	Recommended Operating Conditions .....	<b>4</b>	12.1	Layout Guidelines .....	<b>20</b>
7.4	Thermal Information .....	<b>4</b>	12.2	Layout Example .....	<b>20</b>
7.5	Electrical Characteristics .....	<b>5</b>	<b>13</b>	<b>器件和文档支持</b> .....	<b>21</b>
7.6	Timing Requirements .....	<b>6</b>	13.1	社区资源 .....	<b>21</b>
7.7	Typical Characteristics .....	<b>7</b>	13.2	商标 .....	<b>21</b>
<b>8</b>	<b>Parameter Measurement Information</b> .....	<b>9</b>	13.3	静电放电警告 .....	<b>21</b>
<b>9</b>	<b>Detailed Description</b> .....	<b>10</b>	13.4	Glossary .....	<b>21</b>
			<b>14</b>	<b>机械、封装和可订购信息</b> .....	<b>21</b>

## 4 修订历史记录

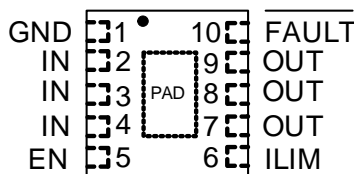
日期	修订版本	注释
2015 年 12 月	*	首次发布。

## 5 Device Comparison Table

Device	Operation Range (V)	OCP Mode	ICONT. Adj. Range (A)	$R_{DS(on)}$ (m $\Omega$ )	$I_{OS}$ tolerance	Package
TPS2559-Q1	2.5 - 6.5	Auto Retry	5.5	13	$\pm 4.7\%$ at 4.7 A	DRC (SON-10)
TPS2553-Q1	2.5 - 6.5	Auto Retry	1.2	85 (DBV)	$\pm 6.8\%$ at 1.3 A	DBV (SOT-23)
TPS2556/7-Q1	2.5 - 6.5	Auto Retry	5	22	$\pm 6.3\%$ at 4.5 A	DRB (SON-8)
TPS2561A-Q1 (Dual Channels)	2.5 - 6.5	Auto Retry	2.5	44	2.1 A to 2.5 A	DRC (SON-10)
TPS25200-Q1 (With OVP protection)	2.5 - 6.5 (Withstand up to 20V)	Auto Retry	2.5	60	$\pm 6.3\%$ at 2.7 A	DRV (SON-6)

## 6 Pin Configuration and Functions

**DRC Package  
SON-10 (10 Pins)  
Top View**



**Pin Functions**

PIN		TYPE	DESCRIPTION
NAME	NO.		
GND	1		Ground connection, connect externally to PowerPAD
IN	2,3,4	I	Input voltage, connect a 0.1 $\mu$ F or greater ceramic capacitor from IN to GND as close to the IC as possible
EN	5	I	Enable input, logic high turns on power switch.
ILIM	6	O	External resistor used to set current-limit threshold; recommended. $24.9 \text{ k}\Omega \leq R_{(ILIM)} \leq 100 \text{ k}\Omega$ .
OUT	7,8,9	O	Power-switch output
$\overline{\text{FAULT}}$	10	O	Active-low open-drain output, asserted during over-current or overtemperature conditions.
PowerPAD™	PAD		Internally connected to GND; used to heat-sink the part to the circuit board traces. Connect PowerPAD to GND pin externally.

## 7 Specifications

### 7.1 Absolute Maximum Ratings

 over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup> <sup>(2)</sup>

		MIN	MAX	UNIT
Voltage range	IN, OUT, EN, ILIM, $\overline{\text{FAULT}}$	-0.3	7	V
	IN to OUT	-7	7	V
Continuous output current, $I_{\text{OUT}}$	OUT	Internally Limited		mA
Continuous $\overline{\text{FAULT}}$ sink current		20		mA
ILIM source current		Internally Limited		mA
Maximum junction temperature, $T_{\text{J}}$		-40	to OTSD2	°C
Storage temperature, $T_{\text{stg}}$		-65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) Voltages are referenced to GND unless otherwise noted.

### 7.2 ESD Ratings

			VALUE	UNIT	
$V_{\text{(ESD)}}$	Electrostatic discharge <sup>(1)</sup>	Human body model (HBM), ESD stress voltage, all pins <sup>(2)</sup>	±2000	V	
		Charged device model (CDM), ESD stress voltage, all pins <sup>(3)</sup>	±750		
		System Level <sup>(4)</sup>	Contact discharge		±8000
			Air discharge		±15000

- (1) Electrostatic discharge (ESD) to measure device sensitivity or immunity to damage caused by assembly-line electrostatic discharges into the device.
- (2) The passing level per AEC-Q100 Classification H2.
- (3) The passing level per AEC-Q100 Classification C5.
- (4) Surges per EN61000-4-2, 1999 applied between USB and output ground of the TPS2559EVM ([SLUUB15](#)) evaluation module (documentation available on the Web.) These were the test levels, not the failure threshold.

### 7.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	MAX	UNIT
$V_{\text{IN}}$	Input voltage, IN	2.5	6.5	V
$V_{\text{EN}}$	Input voltage, EN	0	6.5	V
$I_{\text{OUT}}$	Continuous output current of OUT	5.5		A
	Continuous $\overline{\text{FAULT}}$ sink current	10		mA
$R_{\text{(ILIM)}}$	Recommended resistor limit range <sup>(1)</sup>	24.9	100	k $\Omega$
$T_{\text{J}}$	Operating junction temperature	-40	125	°C

- (1)  $R_{\text{(ILIM)}}$  is the resistor from ILIM pin to GND and ILIM pin can be shorted to GND.

### 7.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		TPS2559-Q1	UNIT
		DRC (10 PINS)	
$R_{\theta\text{JA}}$	Junction-to-ambient thermal resistance	40.6	°C/W
$R_{\theta\text{JC(top)}}$	Junction-to-case (top) thermal resistance	45.5	°C/W
$R_{\theta\text{JB}}$	Junction-to-board thermal resistance	15.9	°C/W
$\Psi_{\text{JT}}$	Junction-to-top characterization parameter	0.4	°C/W
$\Psi_{\text{JB}}$	Junction-to-board characterization parameter	15.7	°C/W
$R_{\theta\text{JC(bot)}}$	Junction-to-case (bottom) thermal resistance	2.8	°C/W

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

## 7.5 Electrical Characteristics

Conditions are  $-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ ,  $2.5\text{ V} \leq V_{\text{IN}} \leq 6.5\text{ V}$ ,  $V_{(\text{EN})} = V_{\text{IN}}$ ,  $R_{(\text{ILIM})} = 49.9\text{ k}\Omega$ . Positive current are into pins. Typical value is at  $25^{\circ}\text{C}$ . All voltages are with respect to GND (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>POWER SWITCH</b>						
$R_{\text{DS(on)}}$	Input - Output Resistance <sup>(1)</sup>	$T_J = 25^{\circ}\text{C}$		13	16	m $\Omega$
		$-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$			21	
<b>ENABLE INPUT EN</b>						
	EN turn on/off threshold		0.66		1.1	V
	Hysteresis			55 <sup>(2)</sup>		mV
$I_{(\text{EN})}$	Input current	$V_{(\text{EN})} = 0\text{ V}$ or $V_{(\text{EN})} = 6.5\text{ V}$	-1		1	$\mu\text{A}$
<b>CURRENT LIMIT</b>						
$I_{\text{OS}}$	OUT short circuit current limit	$R_{(\text{ILIM})} = 24.9\text{ k}\Omega$	4490	4730	4931	mA
		$R_{(\text{ILIM})} = 44.2\text{ k}\Omega$	2505	2660	2805	
		$R_{(\text{ILIM})} = 49.9\text{ k}\Omega$	2215	2360	2490	
		$R_{(\text{ILIM})} = 61.9\text{ k}\Omega$	1780	1900	2015	
		$R_{(\text{ILIM})} = 100\text{ k}\Omega$	1080	1180	1265	
		ILIM pin short to GND ( $R_{(\text{ILIM})} = 0$ )	5860	6700	7460	
<b>SUPPLY CURRENT</b>						
$I_{(\text{IN\_OFF})}$	Disabled, IN supply current	$V_{(\text{EN})} = 0\text{ V}$ , No load on OUT		0.1	2	$\mu\text{A}$
$I_{(\text{IN\_ON})}$	Enabled, IN supply current	$R_{(\text{ILIM})} = 100\text{ k}\Omega$ , no load on OUT		97	125	$\mu\text{A}$
		$R_{(\text{ILIM})} = 24.9\text{ k}\Omega$ , no load on OUT		107	135	
$I_{(\text{REV})}$	Reverse leakage current	$V_{\text{OUT}} = 6.5\text{ V}$ , $V_{\text{IN}} = 0\text{ V}$ , $T_J = 25^{\circ}\text{C}$ , Measure $I_{\text{OUT}}$		0.01	1	$\mu\text{A}$
<b>UNDERVOLTAGE LOCKOUT</b>						
$V_{\text{UVLO}}$	IN rising UVLO threshold voltage		2.36	2.45		V
	Hysteresis			35 <sup>(2)</sup>		mV
<b>FAULT</b>						
$V_{\text{OL}}$	Output low voltage	$I_{\text{FAULT}} = 1\text{ mA}$			180	mV
	Off-state leakage	$V_{\text{FAULT}} = 6.5\text{ V}$			1	$\mu\text{A}$
<b>THERMAL SHUTDOWN</b>						
OTSD2	Thermal shutdown threshold		155			$^{\circ}\text{C}$
OTSD1	Thermal shutdown threshold in current-limit		135			
	Hysteresis			20 <sup>(2)</sup>		

(1) Pulse-testing techniques maintain junction temperature close to ambient temperature. Thermal effects must be taken into account separately

(2) These parameters are provided for reference only, and don't constitute part of TI's published device specifications for purposes of TI's product warranty.

## 7.6 Timing Requirements

Conditions are  $-40^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$ ,  $2.5\text{ V} \leq V_{\text{IN}} \leq 6.5\text{ V}$ ,  $V_{(\text{EN})} = V_{\text{IN}}$ ,  $R_{(\text{ILIM})} = 49.9\text{ k}\Omega$ . Positive current are into pins. Typical value is at  $25^{\circ}\text{C}$ . All voltages are with respect to GND (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT	
<b>POWER SWITCH</b>							
$t_r$	OUT voltage rise time	$V_{\text{IN}} = 6.5\text{ V}$	2.6	3.44	5.2	ms	
		$V_{\text{IN}} = 2.5\text{ V}$	1.3	2.01	3.9		
$t_f$	OUT voltage fall time	$V_{\text{IN}} = 6.5\text{ V}$	0.7	0.89	1.3		
		$V_{\text{IN}} = 2.5\text{ V}$	0.42	0.58	1.04		
		$C_L = 1\text{ }\mu\text{F}$ , $R_L = 100\text{ }\Omega$ , See <a href="#">Figure 13</a>					
<b>ENABLE INPUT EN</b>							
$t_{\text{on}}$	OUT voltage turn-on time	$C_L = 1\text{ }\mu\text{F}$ , $R_L = 100\text{ }\Omega$ , See <a href="#">Figure 14</a>				15	ms
$t_{\text{off}}$	OUT voltage turn-off time					8	
<b>CURRENT LIMIT</b>							
$t_{\text{IOS}}$	Short-circuit response time <sup>(1)</sup>	$V_{\text{IN}} = 5\text{ V}$ , $R_{\text{SHORT}} = 50\text{ m}\Omega$ , See <a href="#">Figure 15</a>	3.5 <sup>(1)</sup>			$\mu\text{s}$	
<b>FAULT</b>							
	$\overline{\text{FAULT}}$ deglitch	$\overline{\text{FAULT}}$ assertion or de-assertion due to overcurrent condition	6	9	13	ms	

(1) This parameter is provided for reference only and does not constitute part of TI's published device specifications for purposes of TI's product warranty

### 7.7 Typical Characteristics

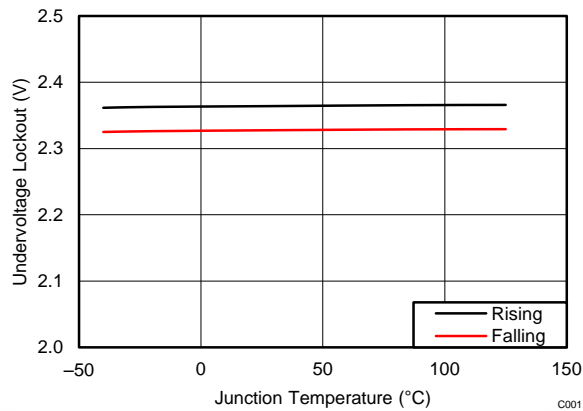


Figure 1. Under-voltage Lockout (UVLO) vs Temperature

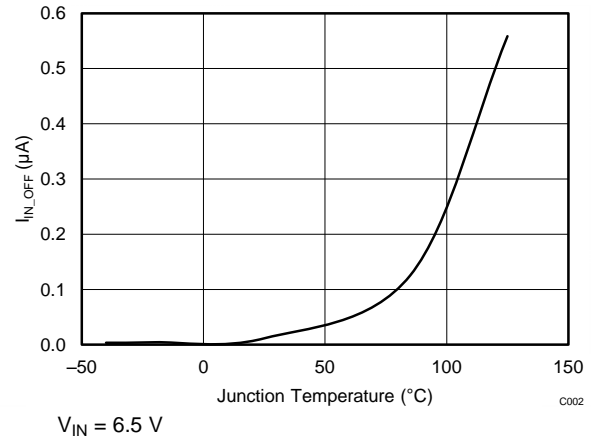


Figure 2. Supply Current, Output Disabled ( $I_{IN\_OFF}$ ) vs Temperature

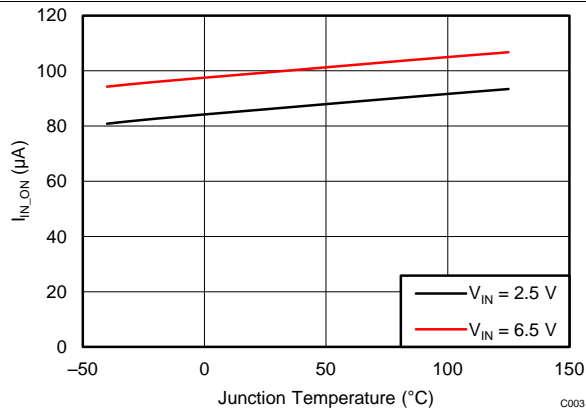


Figure 3. Supply Current, Output Enabled ( $I_{IN\_ON}$ ) vs Temperature

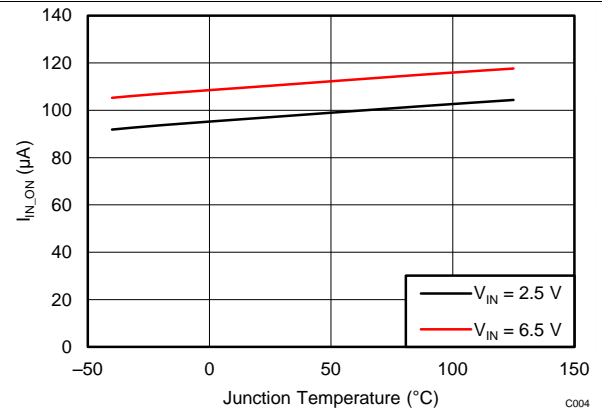


Figure 4. Supply Current, Output Enabled ( $I_{IN\_ON}$ ) vs Temperature

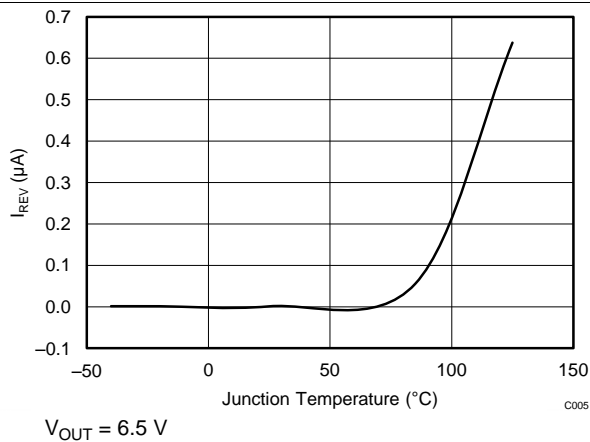


Figure 5. Reverse Leakage Current ( $I_{REV}$ ) v. Temperature

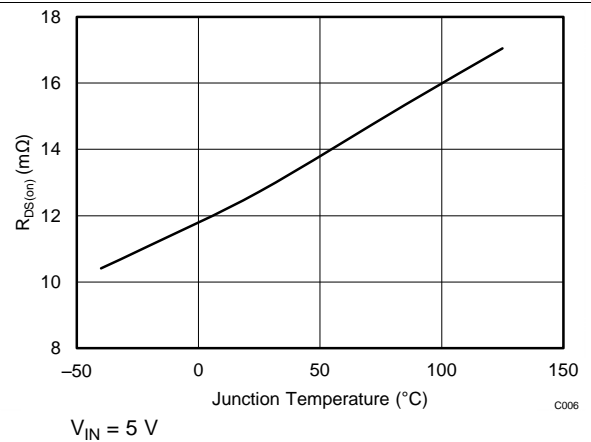


Figure 6. Input-Output Resistance ( $R_{DS(on)}$ ) vs Temperature

Typical Characteristics (continued)

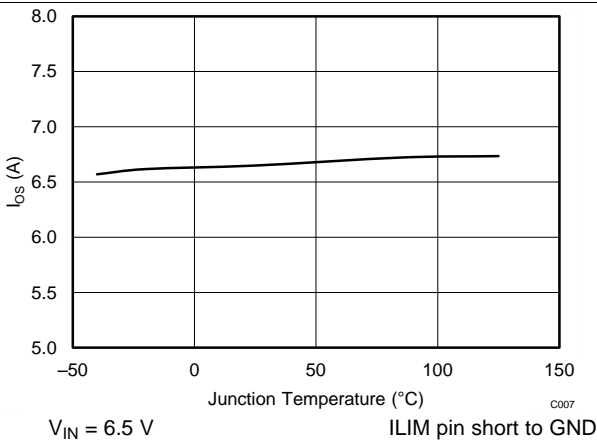


Figure 7. Short Circuit Current ( $I_{OS}$ ) vs Temperature

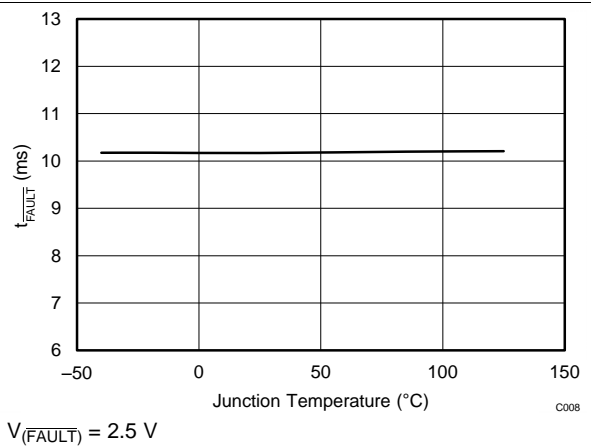


Figure 8. Deglitch Time ( $t_{FAULT}$ ) vs Temperature

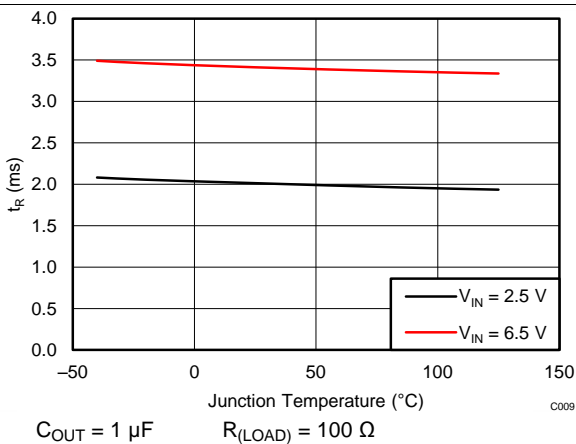


Figure 9. Output Rise Time ( $t_R$ ) vs Temperature

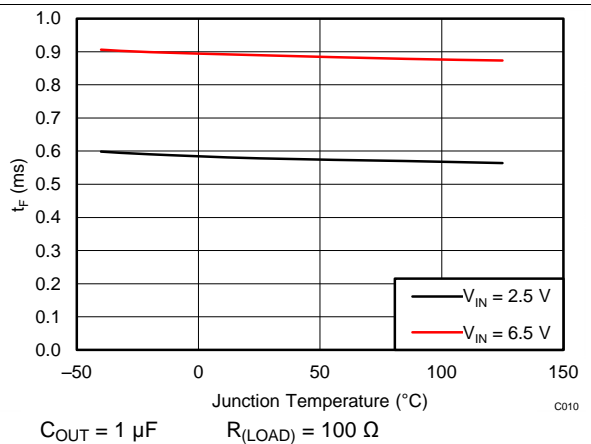


Figure 10. Output Fall Time ( $t_F$ ) vs Temperature

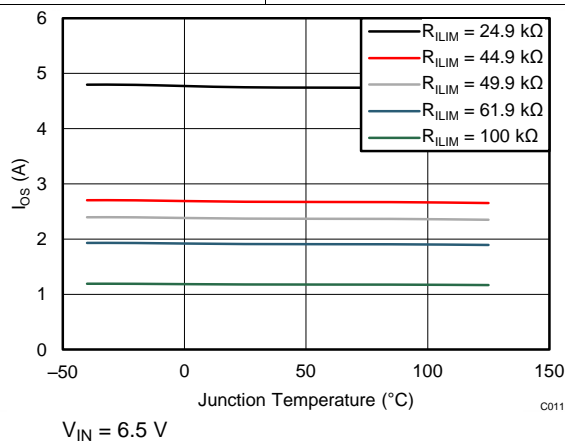


Figure 11. Short Circuit Current ( $I_{OS}$ ) vs Temperature



## 8 Parameter Measurement Information

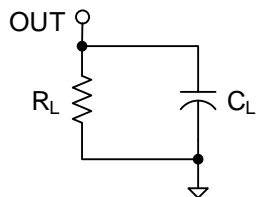


Figure 12. Output Rise/Fall time Test Load

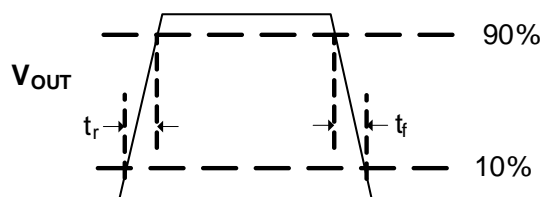


Figure 13. Power-On and Off Timing

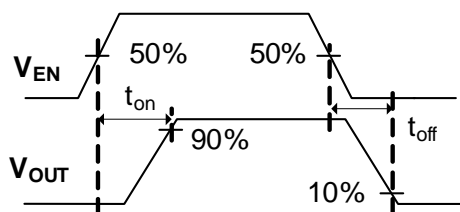


Figure 14. Enable Timing, Active High Enable

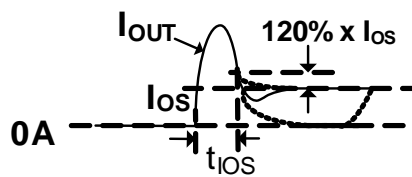


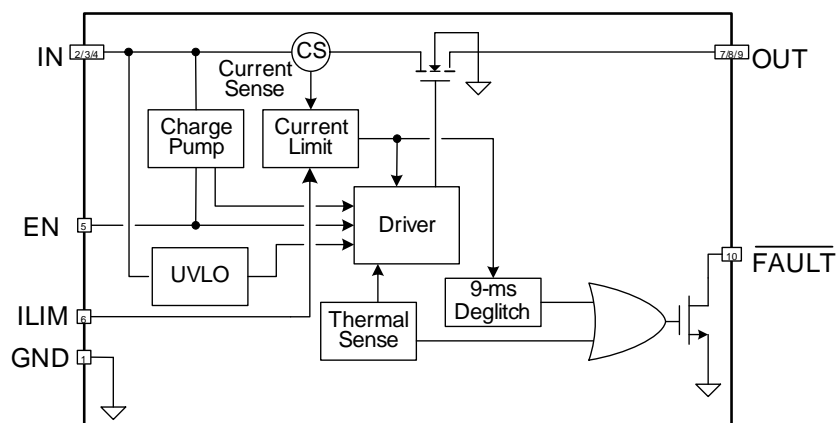
Figure 15. Output Short Circuit Parameters

## 9 Detailed Description

### 9.1 Overview

The TPS2559-Q1 is a current-limited, power-distribution switch using N-channel MOSFETs for applications where short circuits or heavy capacitive loads will be encountered. This device allows the user to program the current-limit via an external resistor and the maximum continuous output current up to 5.5 A. This device incorporates an internal charge pump and the gate drive circuitry necessary to drive the N-channel MOSFET. The charge pump supplies power to the driver circuit and provides the necessary voltage to pull the gate of the MOSFET above the source. The charge pump operates from input voltages as low as 2.5 V and requires little supply current. The driver controls the gate voltage of the power switch. The driver incorporates circuitry that controls the rise and fall times of the output voltage to limit large current and voltage surges and provides built-in soft-start functionality. The TPS2559-Q1 limits the output current to the programmed current-limit threshold  $I_{OS}$  during an overcurrent or short-circuit event by reducing the charge pump voltage driving the N-channel MOSFET and operating it in the linear range of operation. The result of limiting the output current to  $I_{OS}$  reduces the output voltage at OUT because N-channel MOSFET is no longer fully enhanced.

### 9.2 Functional Block Diagram



### 9.3 Feature Description

#### 9.3.1 Thermal Sense

The TPS2559-Q1 self protects by using two independent thermal sensing circuits that monitor the operating temperature of the power switch and disable operation if the temperature exceeds recommended operating conditions. The TPS2559-Q1 device operates in constant-current mode during an over-current condition, which increases the voltage drop across power switch. The power dissipation in the package is proportional to the voltage drop across the power switch, which increases the junction temperature during an over-current condition. The first thermal sensor (OTSD1) turns off the power switch when the die temperature exceeds 135°C (min) and the part is in current limit. Hysteresis is built into the thermal sensor, and the switch turns on after the device has cooled approximately 20°C.

The TPS2559-Q1 also has a second ambient thermal sensor (OTSD2). The ambient thermal sensor turns off the power switch when the die temperature exceeds 155°C (min) regardless of whether the power switch is in current limit and will turn on the power switch after the device has cooled approximately 20°C. The TPS2559-Q1 continues to cycle off and on until the fault is removed.

## Feature Description (continued)

### 9.3.2 Overcurrent Protection

The TPS2559-Q1 responds to overcurrent conditions by limiting their output current to  $I_{OS}$ . When an overload condition is present, the device maintains a constant output current, with the output voltage determined by  $(I_{OS} \times R_{LOAD})$ . Two possible overload conditions can occur.

The first condition is when a short circuit or partial short circuit is present when the device is powered-up or enabled. The output voltage is held near zero potential with respect to ground and the TPS2559-Q1 ramps the output current to  $I_{OS}$ . The TPS2559-Q1 limits the current to  $I_{OS}$  until the overload condition is removed or the device begins to thermal cycle (see [Figure 24](#)).

The second condition is when a short circuit, partial short circuit, or transient overload occurs while the device is enabled and powered on. The device responds to the overcurrent condition within time  $t_{IOS}$  (see [Figure 15](#)). The response speed and shape will vary with the overload level, input circuit, and rate of application. The current-limit response will vary between simply settling to  $I_{OS}$ , or turnoff and controlled return to  $I_{OS}$ . Similar to the previous case, the TPS2559-Q1 limits the current to  $I_{OS}$  until the overload condition is removed or the device begins to thermal cycle.

The TPS2559-Q1 thermal cycles if an overload condition is present long enough to activate thermal limiting in any of the above cases. The device turns off when the junction temperature exceeds 135°C (min) while in current limit. The device remains off until the junction temperature cools 20°C (typ) and then restarts. The TPS2559-Q1 cycles on/off until the overload is removed (see [Figure 25](#)).

### 9.3.3 $\overline{\text{FAULT}}$ Response

The  $\overline{\text{FAULT}}$  open-drain output is asserted (active low) during an over-current or over-temperature condition. The TPS2559-Q1 asserts the  $\overline{\text{FAULT}}$  signal until the fault condition is removed and the device resumes normal operation. The TPS2559-Q1 is designed to eliminate false  $\overline{\text{FAULT}}$  reporting by using an internal delay "deglitch" circuit for over-current (9-ms typ.) conditions without the need for external circuitry. This ensures that  $\overline{\text{FAULT}}$  is not accidentally asserted due to normal operation such as starting into a heavy capacitive load. The deglitch circuitry delays entering and leaving current-limit induced fault conditions. The  $\overline{\text{FAULT}}$  signal is not deglitched when the MOSFET is disabled due to an over-temperature condition but is deglitched after the device has cooled and begins to turn on. This unidirectional deglitch prevents  $\overline{\text{FAULT}}$  oscillation during an over-temperature event.

## 9.4 Device Functional Modes

### 9.4.1 Operation with $V_{IN}$ Undervoltage Lockout (UVLO) Control

The undervoltage lockout (UVLO) circuit disables the power switch until the input voltage reaches the UVLO turn-on threshold. Built-in hysteresis prevents unwanted on/off cycling due to input voltage droop during turn on.

### 9.4.2 Operation with EN Control

The logic enable controls the power switch and device supply current. The supply current is reduced to less than 2- $\mu\text{A}$  when a logic low is present on EN. A logic high input on EN enables the driver, control circuits, and power switch. The enable input is compatible with both TTL and CMOS logic levels.

## 10 Application and Implementation

### NOTE

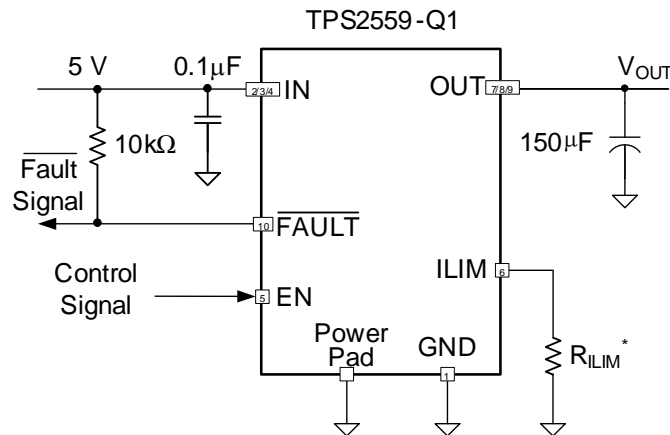
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 10.1 Application Information

The TPS2559-Q1 current limited power switch uses N-channel MOSFETs in applications requiring up to 5.5 A of continuous load current. The device enters constant-current mode when the load exceeds the current limit threshold.

The TPS2559-Q1 power switch is used to protect the up-stream power supply when the output is overloaded.

### 10.2 Typical Application



**Figure 16. Typical TPS2559-Q1 Power Switch**

Use the  $I_{OS}$  in the [Electrical Characteristics](#) table or  $I_{OS}$  in [Equation 1](#) to select the  $R_{ILIM}$ .

#### 10.2.1 Design Requirements

For this design example, use the following as the input parameters.

DESIGN PARAMETERS	EXAMPLE VALUE
Input Operation Voltage	5 V
Rating Current	3A or 4.5A
Minimum Current Limit	3A
Maximum Current Limit	5A

When choose power switch, there are some several general steps:

1. What is the power rail, 3.3 V or 5 V, and then choose the operation range of power switch can cover the power rail.
2. What is the normal operation current, for example, the maximum allowable current drawn by portable equipment for USB 2.0 port is 500mA, so the normal operation current is 500mA and the minimum current limit of power switch must exceed 500 mA to avoid false trigger during normal operation.
3. What is the maximum allowable current provided by up-stream power, and then decide the maximum current limit of power switch that must lower it to ensure power switch can protect the up-stream power when overload is encountered at the output of power switch.

---

**NOTE**

Choosing power switch with tighter current limit tolerance can loosen the up-stream power supply design.

---

## 10.2.2 Detailed Design Procedure

### 10.2.2.1 Step by Step Design Procedure

To begin the design process a few parameters must be decided upon. The designer needs to know the following:

- Normal Input Operation Voltage
- Rating Current
- Minimum Current Limit
- Maximum Current Limit

### 10.2.2.2 Input and Output Capacitance

Input and output capacitance improves the performance of the device; the actual capacitance should be optimized for the particular application. For all applications, a 0.1µF or greater ceramic bypass capacitor between IN and GND is recommended as close to the device as possible for local noise decoupling. This precaution reduces ringing on the input due to power-supply transients. Additional input capacitance may be needed on the input to reduce voltage undershoot from exceeding the UVLO of other load share one power rail with TPS2559-Q1 or overshoot from exceeding the absolute-maximum voltage of the device during heavy transient conditions. This is especially important during bench testing when long, inductive cables are used to connect the evaluation board to the bench power supply.

Output capacitance is not required, but placing a high-value electrolytic capacitor on the output pin is recommended when large transient currents are expected on the output to reduce the undershoot, which caused by the inductance of the output power bus just after a short has occurred and the TPS2559-Q1 has abruptly reduced OUT current. Energy stored in the inductance will drive the OUT voltage down and potentially negative as it discharges.

### 10.2.2.3 Programming the Current-Limit Threshold

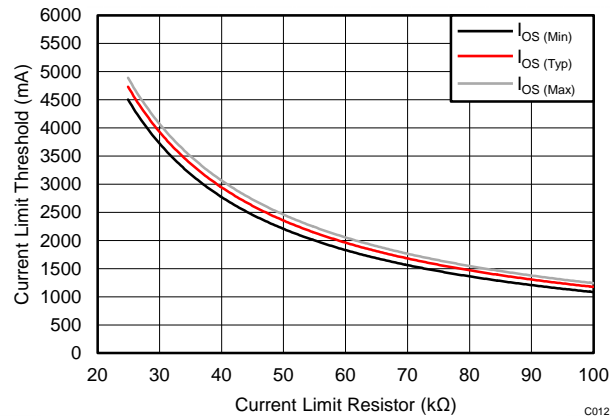
The overcurrent threshold is user programmable via an external resistor. The TPS2559-Q1 uses an internal regulation loop to provide a regulated voltage on the ILIM pin. The current-limit threshold is proportional to the current sourced out of ILIM. The recommended 1% resistor range for  $R_{(ILIM)}$  is  $24.9\text{ k}\Omega \leq R_{(ILIM)} \leq 100\text{ k}\Omega$  to ensure stability of the internal regulation loop.

When ILIM pin short to GND (single point failure), maximum current limit is less than 8 A over temperature and process variation.

Many applications require that the minimum current limit is above a certain current level or that the maximum current limit is below a certain current level, so it is important to consider the tolerance of the overcurrent threshold when selecting a value for  $R_{(ILIM)}$ . The equations and the graph below can be used to estimate the minimum and maximum variation of the current-limit threshold for a predefined resistor value within  $R_{(ILIM)}$  is  $24.9\text{ k}\Omega \leq R_{(ILIM)} \leq 100\text{ k}\Omega$ . This variation is an approximation only and does not take into account, for example, the resistor tolerance. For examples of more-precise variation of  $I_{OS}$  refer to the current-limit section of the [Electrical Characteristics](#) table.

$$\begin{aligned}
 I_{OSmax}(\text{mA}) &= \frac{118848\text{ V}}{R_{(ILIM)}^{0.9918}\text{ k}\Omega} + 30 \\
 I_{OSnom}(\text{mA}) &= \frac{118079\text{ V}}{R_{(ILIM)}^{1.0008}\text{ k}\Omega} \\
 I_{OSmin}(\text{mA}) &= \frac{113325\text{ V}}{R_{(ILIM)}^{1.0010}\text{ k}\Omega} - 47
 \end{aligned}
 \tag{1}$$

$$24.9\text{ k}\Omega \leq R_{(ILIM)} \leq 100\text{ k}\Omega$$


**Figure 17. Current-Limit vs  $R_{(ILIM)}$** 

#### 10.2.2.4 Design Above a Minimum Current Limit

Some applications require that current limiting cannot occur below a certain threshold. For this example, assume that 3 A must be delivered to the load so that the minimum desired current-limit threshold is 3000 mA. Use the  $I_{OS}$  equations and Figure 17 to select  $R_{(ILIM)}$ .

$$I_{OSmin}(mA) = 3000 \text{ mA}$$

$$I_{OSmin}(mA) = \frac{113325 \text{ V}}{R_{(ILIM)}^{1.0010} \text{ k}\Omega} - 47$$

$$R_{(ILIM)}(k\Omega) = \left( \frac{113325}{I_{OS(min)} + 47} \right)^{\frac{1}{1.0010}} = \left( \frac{113325}{3000 + 47} \right)^{\frac{1}{1.0010}} = 37.06 \text{ k}\Omega \quad (2)$$

Select the closest 1% resistor less than the calculated value:  $R_{(ILIM)} = 36.5 \text{ k}\Omega$ . This sets the minimum current-limit threshold at 3016 A.

$$I_{OSmin}(mA) = \frac{113325 \text{ V}}{R_{(ILIM)}^{1.0010} \text{ k}\Omega} - 47 = \frac{113325}{(36.5 \times 1.01)^{1.0010}} - 47 = 3016 \text{ mA} \quad (3)$$

Use the  $I_{OS}$  equations, Figure 17, and the previously calculated value for  $R_{(ILIM)}$  to calculate the maximum resulting current-limit threshold.

$$I_{OSmax}(mA) = \frac{118848}{R_{(ILIM)}^{0.9918}} + 30 = \frac{118848}{(36.5 \times 0.99)^{0.9918}} + 30 = 3417 \text{ mA} \quad (4)$$

The resulting maximum current-limit threshold minimum is 3016 mA and maximum is 3417 mA with a  $36.5 \text{ k}\Omega \pm 1\%$ .

#### 10.2.2.5 Design Below a Maximum Current Limit

Some applications require that current limiting must occur below a certain threshold. For this example, assume that 5A must be delivered to the load so that the minimum desired current-limit threshold is 5000 mA. Use the  $I_{OS}$  equations and Figure 17 to select  $R_{(ILIM)}$ .

$$I_{OSmax}(mA) = 5000 \text{ mA}$$

$$I_{OSmax}(mA) = \frac{118848}{R_{(ILIM)}^{0.9918} \text{ k}\Omega} + 30$$

$$R_{(ILIM)}(k\Omega) = \left( \frac{118848}{I_{OS(max)} - 30} \right)^{\frac{1}{0.9918}} = \left( \frac{118848}{5000 - 30} \right)^{\frac{1}{0.9918}} = 24.55 \text{ k}\Omega \quad (5)$$

Select the closest 1% resistor less than the calculated value:  $R_{ILIM} = 24.9 \text{ k}\Omega$ . This sets the maximum current-limit threshold at 4950 A.

$$I_{OSmax}(\text{mA}) = \frac{118848}{R_{(ILIM)}^{0.9918} \text{ k}\Omega} + 30 = \frac{118848}{(24.9 \times 0.99)^{0.9918}} + 30 = 4980 \text{ mA} \quad (6)$$

Use the  $I_{OS}$  equations, [Figure 17](#), and the previously calculated value for  $R_{(ILIM)}$  to calculate the minimum resulting current-limit threshold.

$$I_{OSmin}(\text{mA}) = \frac{113325}{R_{(ILIM)}^{1.0010}} - 47 = \frac{113325}{(24.9 \times 1.01)^{1.0010}} - 47 = 4445 \text{ mA} \quad (7)$$

The resulting minimum current-limit threshold minimum is 4445 mA and maximum is 4980 mA with a  $24.9 \text{ k}\Omega \pm 1\%$ .

### 10.2.2.6 Accounting for Resistor Tolerance

The previous sections described the selection of  $R_{(ILIM)}$  given certain application requirements and the importance of understanding the current-limit threshold tolerance. The analysis focused only on the TPS2559-Q1 is bounded by an upper and lower tolerance centered on a nominal resistance. The additional  $R_{ILIM}$  resistance tolerance directly affects the current-limit threshold accuracy at a system level. [Table 1](#) shows a process that accounts for worst-case resistor tolerance assuming 1% resistor values.

Step one follows the selection process outlined in the application examples above.

Step two determines the upper and lower resistance bounds of the selected resistor.

Step three uses the upper and lower resistor bounds in the  $I_{OS}$  equations to calculate the threshold limits.

It is important to use tighter tolerance resistors, that is, 0.5% or 0.1%, when precision current limiting is desired.

**Table 1. Common  $R_{(ILIM)}$  Resistor Selections**

DESIRED NOMINAL CURRENT LIMIT (mA)	IDEAL RESISTOR (k $\Omega$ )	CLOSEST 1% RESISTOR (k $\Omega$ )	RESISTOR TOLERANCE		ACTUAL LIMITS		
			1% LOW (k $\Omega$ )	1% HIGH (k $\Omega$ )	$I_{OS}$ MIN (mA)	$I_{OS}$ NOM (mA)	$I_{OS}$ MAX (mA)
1250	94.1	93.1	92.2	94	1152.7	1263.7	1368.2
1500	78.4	78.7	77.9	79.5	1372.5	1495.1	1610.9
1750	67.2	66.5	65.8	67.2	1633.2	1769.7	1893.3
2000	58.8	59	58.4	59.6	1847	1994.8	2133.7
2250	52.3	52.3	51.8	52.8	2089.9	2550.6	2400.9
2500	47.1	47.5	47	48	2306	2478.2	2638.4
2750	42.8	43.2	42.8	43.6	2540.5	2725.1	2895.8
3000	39.2	39.2	38.8	39.6	2804.8	3003.4	3185.7
3250	36.2	36.5	36.1	36.9	3016	3225.7	3417.2
3500	33.6	34	33.7	34.3	3241.4	3463.1	3664.1
3750	31.4	31.6	31.3	31.9	3491.5	3726.4	3937.8
4000	29.4	29.4	29.1	29.7	3756.5	4005.4	4227.7
4250	27.7	28	27.7	28.3	3946.9	4205.9	4435.8
4500	26.2	26.1	25.8	26.4	4237.9	4512.3	4753.9
4750	24.8	24.9	24.7	25.1	4444.6	4729.9	4979.6

### 10.2.2.7 Power Dissipation and Junction Temperature

The low on-resistance of the N-channel MOSFET allows small surface-mount packages to pass large currents. It is good design practice to estimate power dissipation and junction temperature. The below analysis gives an approximation for calculating junction temperature based on the power dissipation in the package. However, it is important to note that thermal analysis is strongly dependent on additional system level factors. Such factors include air flow, board layout, copper thickness and surface area, and proximity to other devices dissipating power. Good thermal design practice must include all system level factors in addition to individual component analysis. Begin by determining the  $r_{DS(on)}$  of the N-channel MOSFET relative to the input voltage and operating temperature. As an initial estimate, use the highest operating ambient temperature of interest and read  $r_{DS(on)}$  from the typical characteristics graph. Using this value, the power dissipation can be calculated using [Equation 8](#):

$$P_D = r_{DS(on)} \times I_{OUT}^2 \quad (8)$$

Where:

$P_D$  = Total power dissipation (W)

$r_{DS(on)}$  = Power switch on-resistance ( $\Omega$ )

$I_{OUT}$  = Maximum current-limit threshold (A)

This step calculates the total power dissipation of the N-channel MOSFET.

Finally, calculate the junction temperature:

$$T_J = P_D \times \theta_{JA} + T_A \quad (9)$$

Where:

$T_A$  = Ambient temperature ( $^{\circ}\text{C}$ )

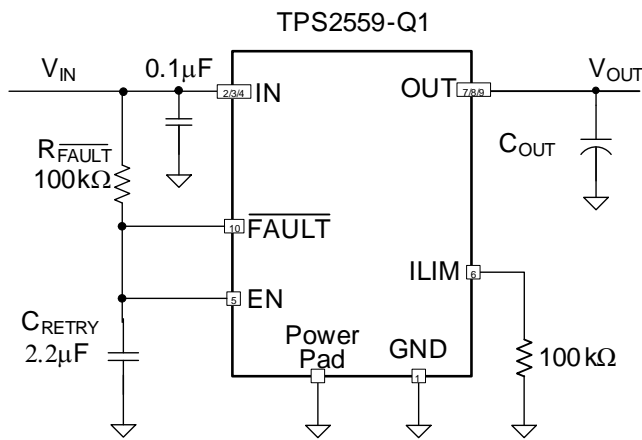
$\theta_{JA}$  = Thermal resistance ( $^{\circ}\text{C}/\text{W}$ )

$P_D$  = Total power dissipation (W)

Compare the calculated junction temperature with the initial estimate. If they are not within a few degrees, repeat the calculation using the "refined"  $r_{DS(on)}$  from the previous calculation as the new estimate. Two or three iterations are generally sufficient to achieve the desired result. The final junction temperature is highly dependent on thermal resistance  $\theta_{JA}$  and thermal resistance is highly dependent on the individual package and board layout.

### 10.2.2.8 Auto-Retry

Some applications require that an overcurrent condition disables the part momentarily during a fault condition and re-enables after a pre-set time. This *auto-retry* functionality can be implemented with an external resistor and capacitor. During a fault condition,  $\overline{\text{FAULT}}$  pulls low EN. The part is disabled when EN is pulled below the turn-off threshold, and  $\overline{\text{FAULT}}$  goes high impedance allowing  $C_{(RETRY)}$  to begin charging. The part re-enables when the voltage on EN reaches the turn-on threshold. The part will continue to cycle in this manner until the fault condition is removed. The auto-retry cycling time is determined by the resistor/capacitor time constant, TPS2559-Q1 turn on time and  $\overline{\text{FAULT}}$  deglitch time (see [Figure 28](#)).



**Figure 18. Auto-Retry Circuit**



Some applications require auto-retry functionality and the ability to enable/disable with an external logic signal. Figure 19 shows how an external logic signal can drive EN through  $R_{(FAULT)}$  and maintain auto-retry functionality. The resistor/capacitor time constant determines the auto-retry time-out period.

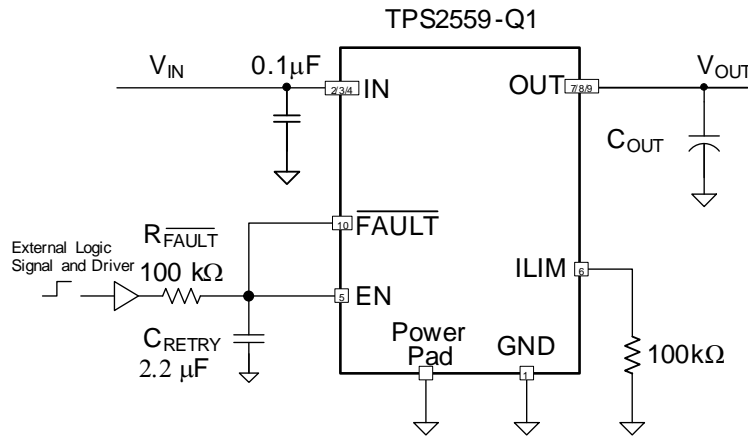


Figure 19. Auto-Retry Circuit with External EN Signal

If need to implement latch-off, refer to application report (SLVA282A).

#### 10.2.2.9 Two-level Current-limit

Some applications require different current-limit thresholds depending on external system conditions. Figure 20 shows an implementation for an externally-controlled, two-level current-limit circuit. The current-limit threshold is set by the total resistance from ILIM to GND (see previously discussed [Programming the Current-Limit Threshold](#) section). A logic-level input enables/disables MOSFET Q1 and changes the current-limit threshold by modifying the total resistance from ILIM to GND (see [Figure 29](#) and [Figure 30](#)). Additional MOSFET/resistor combinations can be used in parallel to Q1/R2 to increase the number of additional current-limit levels.

#### NOTE

ILIM should never be driven directly with an external signal.

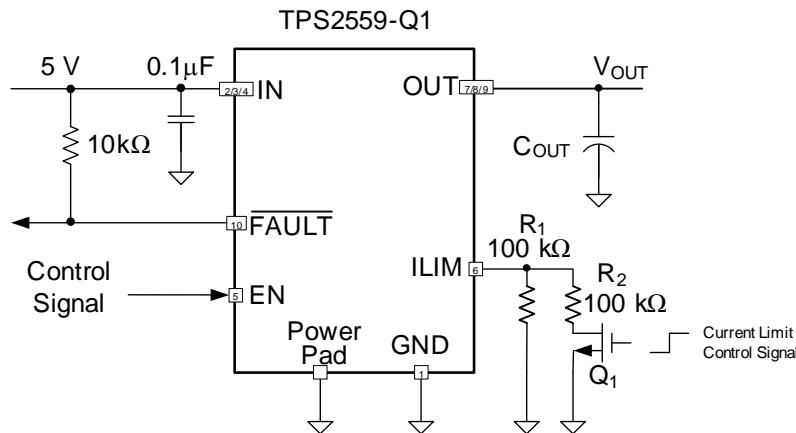


Figure 20. Two-Level Current-Limit Circuit

10.2.3 Application Curves

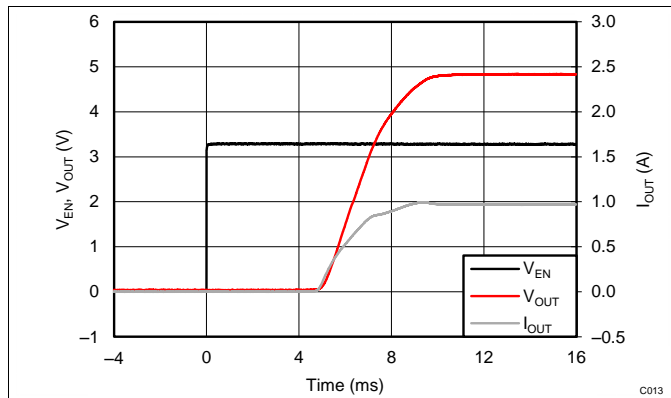


Figure 21. Output Rise with 150µF // 5Ω

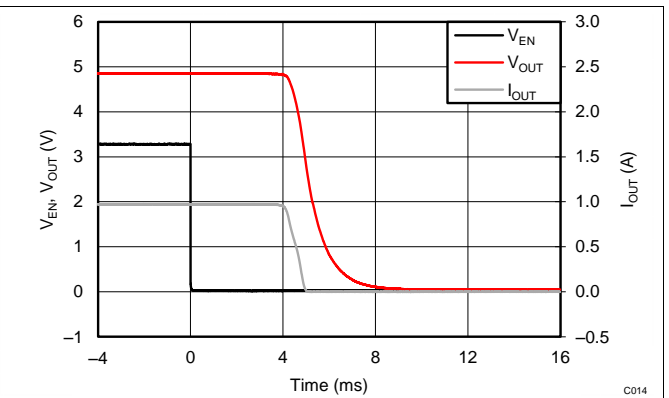


Figure 22. Output Fall with 150µF // 5Ω

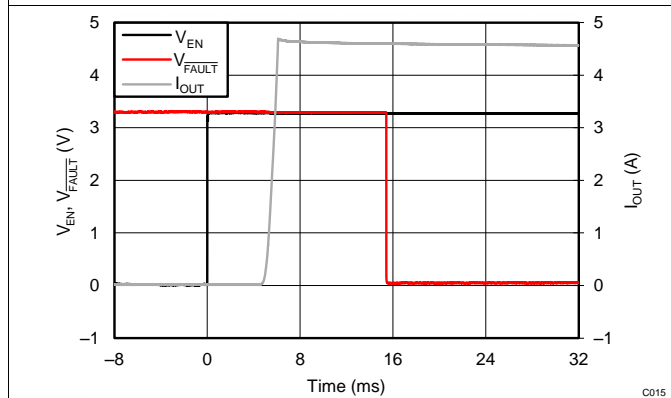


Figure 23. Enable into Output Short

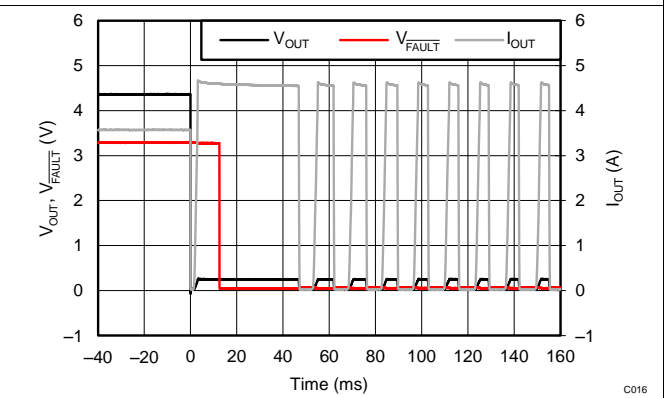


Figure 24. Full Load to Output Short Transient Response

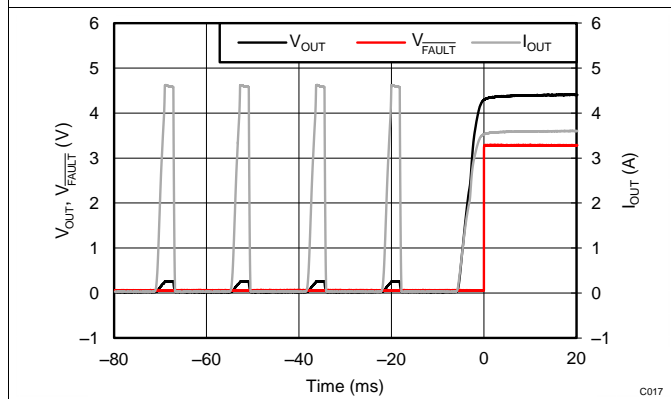


Figure 25. Output Short to Full Load Recovery Response

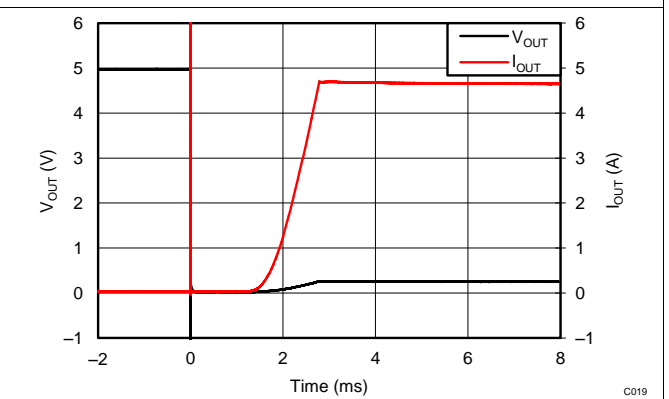


Figure 26. 50mΩ Hot-Short

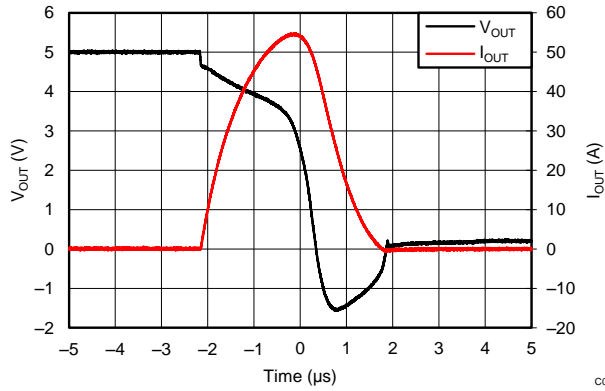


Figure 27. 50mΩ Hot-Short Response Time

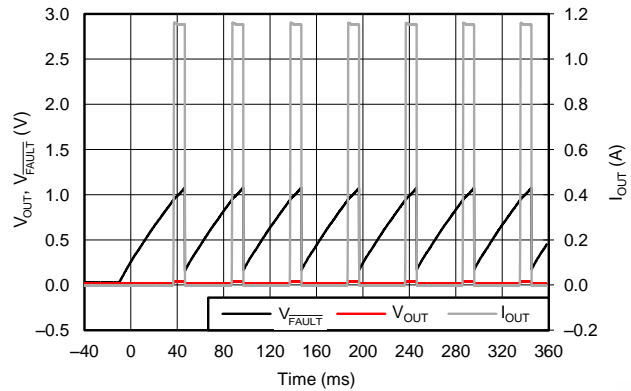


Figure 28. Auto-Retry Cycle

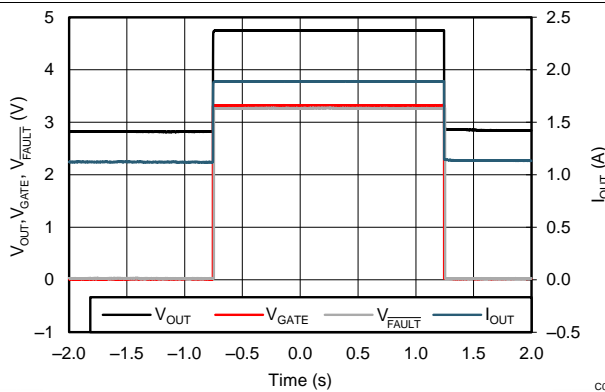


Figure 29. Two Level Current Limit with  $R_{LOAD} = 2.5 \Omega$

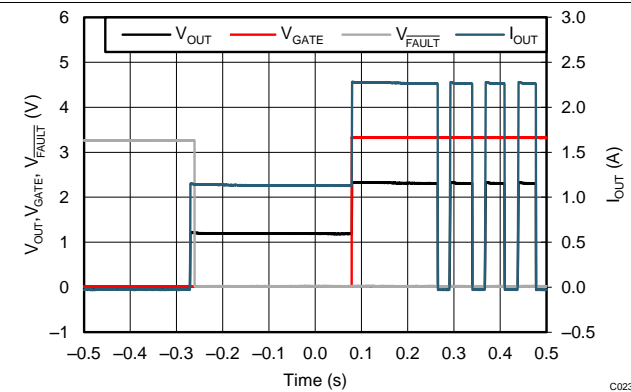


Figure 30. Two Level Current Limit with  $R_{LOAD} = 1\Omega$

## 11 Power Supply Recommendations

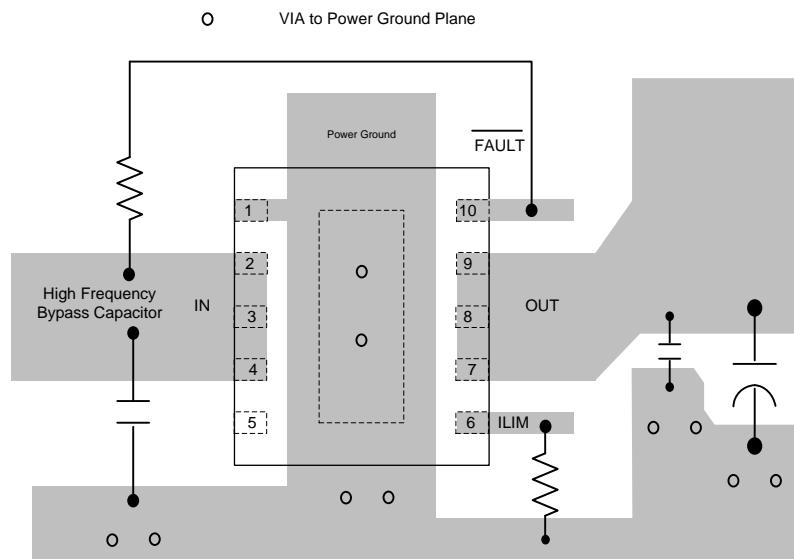
Design of the devices is for operation from an input voltage supply range of 2.5 V to 6.5 V. The current capability of the power supply should exceed the maximum current limit of the power switch.

## 12 Layout

### 12.1 Layout Guidelines

- Place the 100-nF bypass capacitor near the IN and GND pins, and make the connections using a low-inductance trace.
- Placing a high-value electrolytic capacitor and a 100-nF bypass capacitor on the output pin is recommended when large transient currents are expected on the output.
- The traces routing the  $R_{ILIM}$  resistor to the device should be as short as possible to reduce parasitic effects on the current limit accuracy.
- The PowerPAD should be directly connected to PCB ground plane using wide and short copper trace.

### 12.2 Layout Example



**Figure 31. TPS2559-Q1 Board Layout**

## 13 器件和文档支持

### 13.1 社区资源

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

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### 13.4 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 14 机械、封装和可订购信息

以下页中包括机械、封装和可订购信息。这些信息是针对指定器件可提供的最新数据。这些数据会在无通知且不对本文档进行修订的情况下发生改变。欲获得该数据表的浏览器版本，请查阅左侧的导航栏。

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	产品		应用
数字音频	<a href="http://www.ti.com.cn/audio">www.ti.com.cn/audio</a>	通信与电信	<a href="http://www.ti.com.cn/telecom">www.ti.com.cn/telecom</a>
放大器和线性器件	<a href="http://www.ti.com.cn/amplifiers">www.ti.com.cn/amplifiers</a>	计算机及周边	<a href="http://www.ti.com.cn/computer">www.ti.com.cn/computer</a>
数据转换器	<a href="http://www.ti.com.cn/dataconverters">www.ti.com.cn/dataconverters</a>	消费电子	<a href="http://www.ti.com.cn/consumer-apps">www.ti.com.cn/consumer-apps</a>
DLP® 产品	<a href="http://www.dlp.com">www.dlp.com</a>	能源	<a href="http://www.ti.com.cn/energy">www.ti.com.cn/energy</a>
DSP - 数字信号处理器	<a href="http://www.ti.com.cn/dsp">www.ti.com.cn/dsp</a>	工业应用	<a href="http://www.ti.com.cn/industrial">www.ti.com.cn/industrial</a>
时钟和计时器	<a href="http://www.ti.com.cn/clockandtimers">www.ti.com.cn/clockandtimers</a>	医疗电子	<a href="http://www.ti.com.cn/medical">www.ti.com.cn/medical</a>
接口	<a href="http://www.ti.com.cn/interface">www.ti.com.cn/interface</a>	安防应用	<a href="http://www.ti.com.cn/security">www.ti.com.cn/security</a>
逻辑	<a href="http://www.ti.com.cn/logic">www.ti.com.cn/logic</a>	汽车电子	<a href="http://www.ti.com.cn/automotive">www.ti.com.cn/automotive</a>
电源管理	<a href="http://www.ti.com.cn/power">www.ti.com.cn/power</a>	视频和影像	<a href="http://www.ti.com.cn/video">www.ti.com.cn/video</a>
微控制器 (MCU)	<a href="http://www.ti.com.cn/microcontrollers">www.ti.com.cn/microcontrollers</a>		
RFID 系统	<a href="http://www.ti.com.cn/rfidsys">www.ti.com.cn/rfidsys</a>		
OMAP应用处理器	<a href="http://www.ti.com.cn/omap">www.ti.com.cn/omap</a>		
无线连通性	<a href="http://www.ti.com.cn/wirelessconnectivity">www.ti.com.cn/wirelessconnectivity</a>	德州仪器在线技术支持社区	<a href="http://www.deyisupport.com">www.deyisupport.com</a>

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**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPS2559QWDRCRQ1	ACTIVE	VSON	DRC	10	3000	RoHS & Green	SN	Level-2-260C-1 YEAR	-40 to 125	2559Q	<b>Samples</b>
TPS2559QWDRCTQ1	ACTIVE	VSON	DRC	10	250	RoHS & Green	SN	Level-2-260C-1 YEAR	-40 to 125	2559Q	<b>Samples</b>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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## GENERIC PACKAGE VIEW

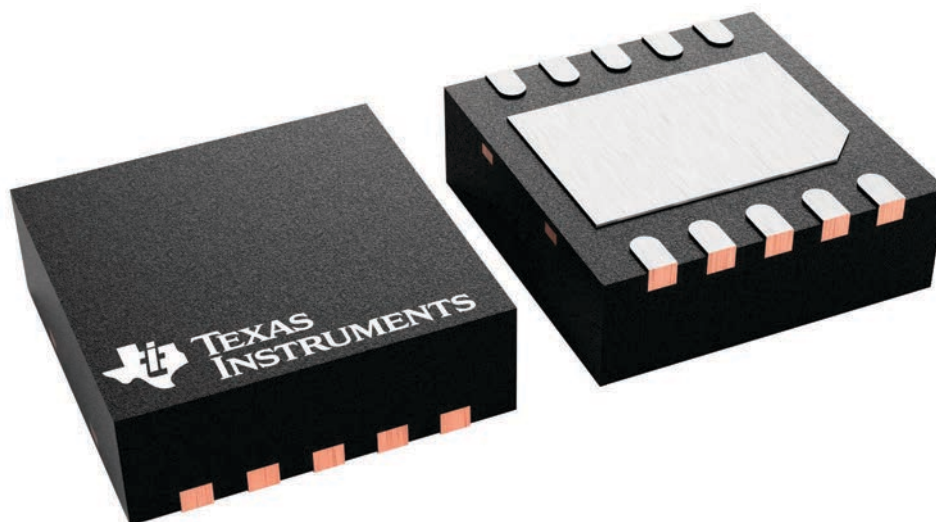
**DRC 10**

**VSON - 1 mm max height**

3 x 3, 0.5 mm pitch

PLASTIC SMALL OUTLINE - NO LEAD

This image is a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.



4226193/A

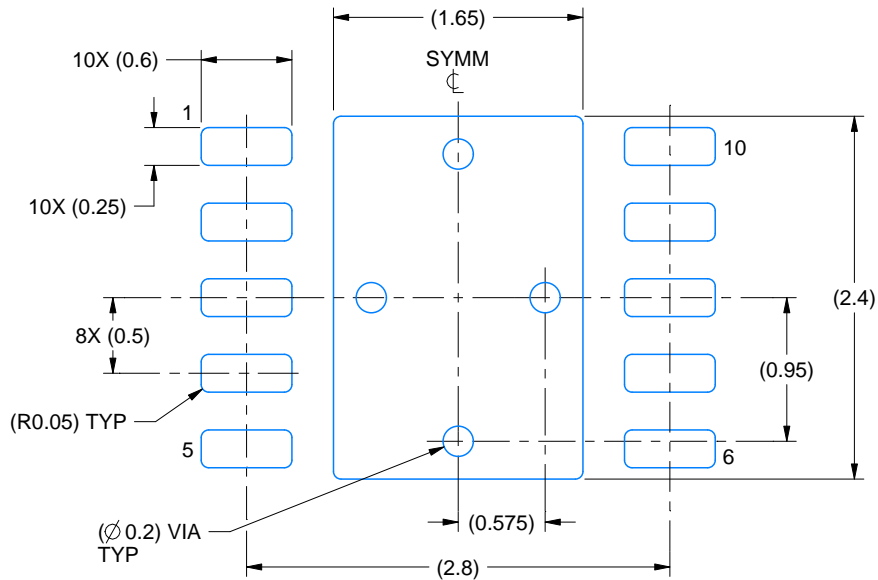


# EXAMPLE BOARD LAYOUT

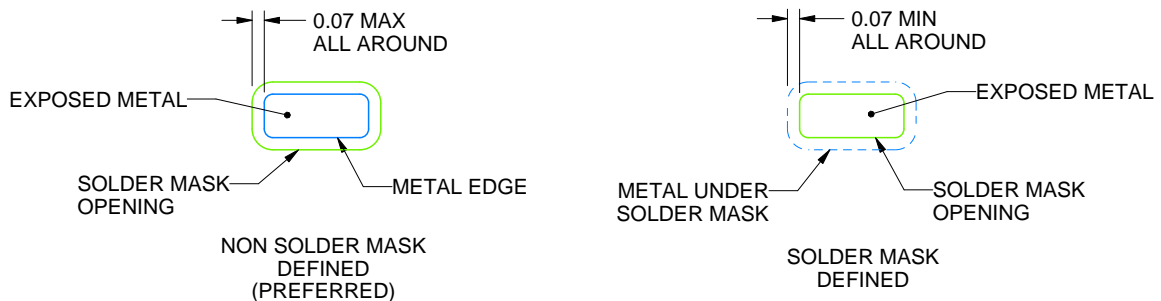
DRC0010K

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:20X



SOLDER MASK DETAILS

4222059/B 02/2018

NOTES: (continued)

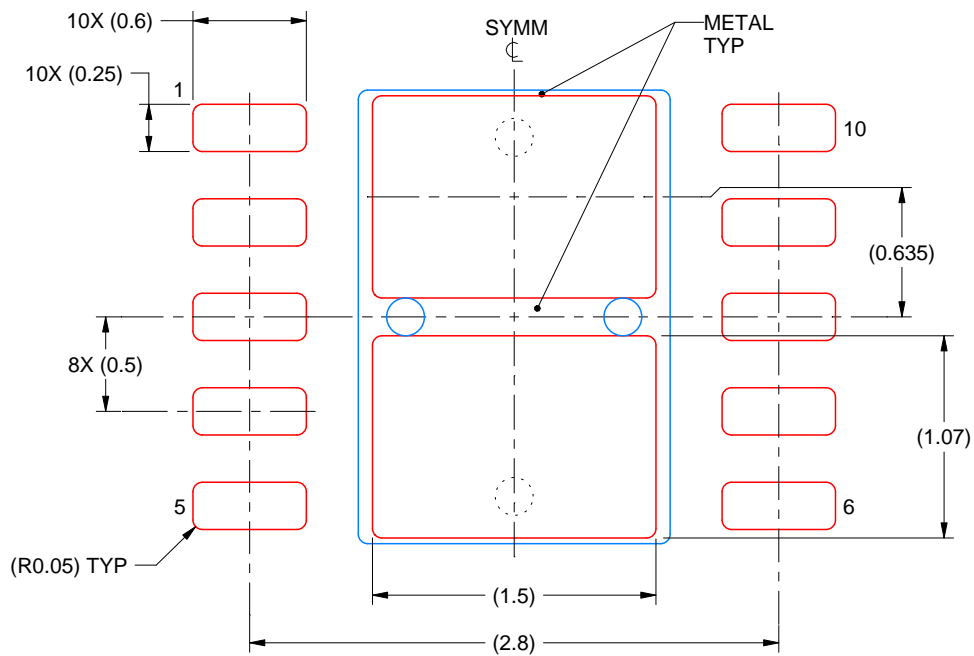
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/slua271](http://www.ti.com/lit/slua271)).

# EXAMPLE STENCIL DESIGN

DRC0010K

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD  
81% PRINTED SOLDER COVERAGE BY AREA  
SCALE:25X

4222059/B 02/2018

NOTES: (continued)

5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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