TPS92611-Q1 汽车单通道线性 LED 驱动器

1 特性

- 符合汽车类应用 要求
- 具有符合 AEC-Q100 标准的下列特性：
  - 温度等级 1 级：–40°C 至 125°C 的环境工作温度范围
  - 器件 HBM ESD 分类等级 H2
  - 器件 CDM ESD 分类等级 C3B
- 提供功能安全
  - 可帮助创建功能安全系统设计的文档
- 具有 PWM 调光功能的单通道恒定电流 LED 驱动器
- 宽输入电压范围：4.5V - 40V
- 恒定输出电流，可通过感应电阻器进行调节
- 高精度电流调节，容差 ±4.6%
- 最大电流：300mA
- 与外部电阻器实现热共享
- 低压降电压（包含电流感应压降）
  - 最大压降：10mA 时为 150mV
  - 最大压降：70mA 时为 400mV
  - 最大压降：150mA 时为 700mV
  - 最大压降：300mA 时为 1.3V
- 诊断和保护
  - LED 开路与短路检测，具有自动恢复功能
  - 在低压降运行情况下支持诊断并具有可调阈值
  - 多达 15 个器件的故障总线，可配置为“连带失效”或“仅失效的通道关闭”
  - 低静态电流和故障模式电流（每个器件小于 250µA）
- 工作结温范围：–40°C 至 150°C

2 应用

- 汽车便利照明：座舱顶灯、车门把手、阅读灯和其他灯具
- 汽车尾灯、中央高位刹车灯、侧面标志灯、盲点监测指示灯、充电口指示灯
- 通用 LED 驱动器应用

3 说明

随着 LED 在汽车 应用中广泛使用，简单的 LED 驱动器越来越受欢迎。与分立式解决方案相比，低成本单片解决方案可降低系统级组件数量，并显著提高电流精度和可靠性。

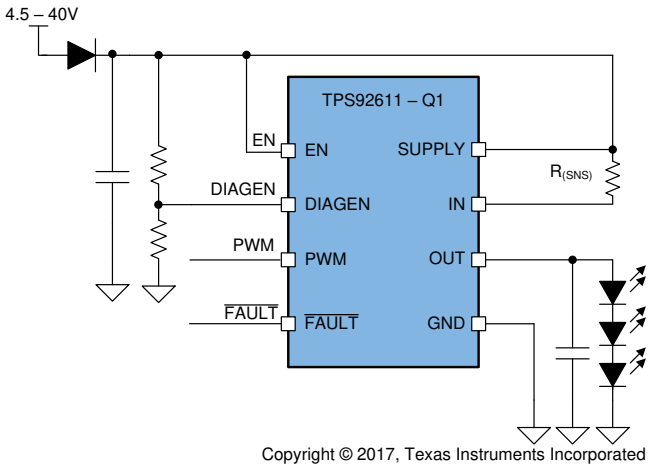
TPS92611-Q1 器件是一款简单的单通道高侧 LED 驱动器，由汽车蓄电池供电。这是一种简单而巧妙的解决方案，能够为单个 LED 灯串提供恒定电流，并具有 LED 诊断功能。此器件的“连带失效”功能可与其他 LED 驱动器（如 TPS9261x-Q1、TPS9263x-Q1 和 TPS9283x-Q1 器件）一起工作，从而满足不同的要求。

器件信息(1)

器件型号	封装	封装尺寸（标称值）
TPS92611-Q1	MSOP (8)	3mm × 3mm

(1) 如需了解所有可用封装，请参阅数据表末尾的可订购产品附录。

典型应用图



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本文档旨在为方便起见，提供有关 TI 产品中文版本的信息，以确认产品的概要。 有关适用的官方英文版本的最新信息，请访问 www.ti.com，其内容始终优先。 TI 不保证翻译的准确性和有效性。 在实际设计之前，请务必参考最新版本的英文版本。

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4 修订历史记录

Changes from Revision A (April 2018) to Revision B **Page**

- 向*特性* 部分添加了提供功能安全的链接 ... 1

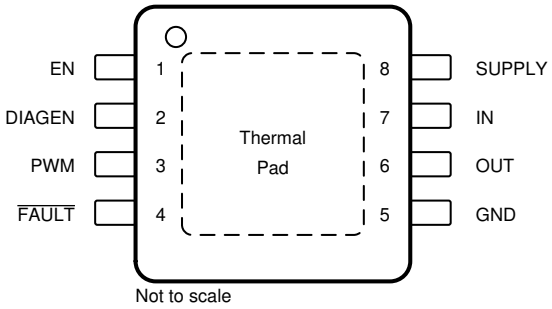
Changes from Original (January 2018) to Revision A **Page**

- 已针对低压降电压特性将“基准”更改为“电流感应” ... 1
- 已将*应用* 部分 ... 1
- Deleted " $V_{(OUT)}$ short to ground" from the $I_{(Retry)}$ parameter description ... 5
- Deleted "closed loop" from the $t_{(PWM_delay_rising)}$ parameter description ... 5
- Deleted "open loop" from the $t_{(PWM_delay_falling)}$ parameter description ... 5
- Changed 图 2 ... 6
- Changed 图 4 and added a condition ... 7
- Changed graph and caption of 图 5 ... 7
- Changed "open-circuit scenarios" to "open-circuit faults" and "legislative" to "regulatory" in the Diagnostics section ... 11
- Deleted two occurrences of "scenario" in the Fault-Bus Output With One-Fails–All-Fail section ... 12
- Change from "dissipating heat using" to " heat sharing with" in the Application Information section ... 14
- Changed from "voltage ranges" to "voltage range is" in the Design Requirements section ... 14
- Added a new paragraph at the end of the Detailed Design Procedure section ... 15
- Added three new sentences to the Single-Channel LED Driver With Heat Sharing section ... 15
- Changed 图 21 ... 16
- Added two new paragraphs to the Detailed Design Procedure section ... 16
- Added the *Power Supply Recommendations* section ... 17

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5 Pin Configuration and Functions

TPS92611-Q1 DGN PowerPAD™ Package
8-Pin MSOP With Exposed Termal Pad
Top View



Not to scale

Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
DIAGEN	2	I	Diagnostics enable, to avoid false open-circuit diagnostics during low-voltage operation
EN	1	I	Device enable
$\overline{\text{FAULT}}$	4	I/O	One-fails–all-fail fault bus
GND	5	—	Ground
IN	7	I	Current input
OUT	6	O	Constant-current output
PWM	3	I	PWM input
SUPPLY	8	I	Device supply voltage

6 Specifications

6.1 Absolute Maximum Ratings

over operating ambient temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
High-voltage input	DIAGEN, EN, IN, PWM, SUPPLY	–0.3	45	V
High-voltage output	OUT	–0.3	45	V
Fault bus	$\overline{\text{FAULT}}$	–0.3	22	V
IN to OUT	$V_{(IN)} – V_{(OUT)}$	–0.3	45	V
SUPPLY to IN	$V_{(SUPPLY)} – V_{(IN)}$	–0.3	1	V
Operating junction temperature, T_J		–40	150	°C
Storage temperature, T_{stg}		–40	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.

6.2 ESD Ratings

TPS92611-Q1				VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002(1)	All pins	±2000	V
		Charged-device model (CDM), per AEC Q100-011	All pins	±500	
			Corner pins (1, 4 and 8)	±750	

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

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6.3 Recommended Operating Conditions

over operating ambient temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
SUPPLY	Device supply voltage	4.5		40	V
IN	Sense voltage	4.4		40	V
PWM	PWM inputs	0		40	V
DIAGEN	Diagnostics enable pin	0		40	V
OUT	Driver output	0		40	V
EN	Device enable	0		40	V
$\overline{\text{FAULT}}$	Fault bus	0		7	V
T_A	Operating ambient temperature	–40		125	°C

6.4 Thermal Information

THERMAL METRIC(1)		TPS92611-Q1 DGN (MSOP) 8 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	60	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	58.7	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	25.6	°C/W
ψ_{JT}	Junction-to-top characterization parameter	1.7	°C/W
ψ_{JB}	Junction-to-board characterization parameter	25.9	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	11.3	°C/W

(1) For more information about traditional and new thermal metrics, see *Semiconductor and IC Package Thermal Metrics*.

6.5 Electrical Characteristics

$V_{(SUPPLY)}$ = 5 V–40 V, T_J = –40°C to 150°C unless otherwise noted

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
BIAS						
$V_{(POR_rising)}$	Supply voltage, POR rising threshold			3.2	4	V
$V_{(POR_falling)}$	Supply voltage, POR falling threshold		2.2	3		V
$I_{(Shutdown)}$	Device shutdown current	EN = LOW		5	10	µA
$I_{(Quiescent)}$	Device standby current	PWM = HIGH, EN = HIGH	0.1	0.2	0.25	mA
$I_{(FAULT)}$	Device current in fault mode	EN = HIGH, PWM = HIGH, $\overline{\text{FAULT}}$ externally pulled LOW	0.1	0.2	0.25	mA
LOGIC INPUTS (DIAGEN, PWM, EN)						
$V_{IL(DIAGEN)}$	Input logic-low voltage, DIAGEN		1.045	1.1	1.155	V
$V_{IH(DIAGEN)}$	Input logic-high voltage, DIAGEN		1.14	1.2	1.26	V
$V_{IL(PWM)}$	Input logic-low voltage, PWM		1.045	1.1	1.155	V
$V_{IH(PWM)}$	Input logic-high voltage, PWM		1.14	1.2	1.26	V
$V_{IL(EN)}$	Input logic-low voltage, EN				0.7	V
$V_{IH(EN)}$	Input logic-high voltage, EN		2			V
$I_{PD(EN)}$	EN pin pulldown current	$V_{(EN)}$ = 12 V	1.5	3.3	4.5	µA

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Electrical Characteristics (continued)

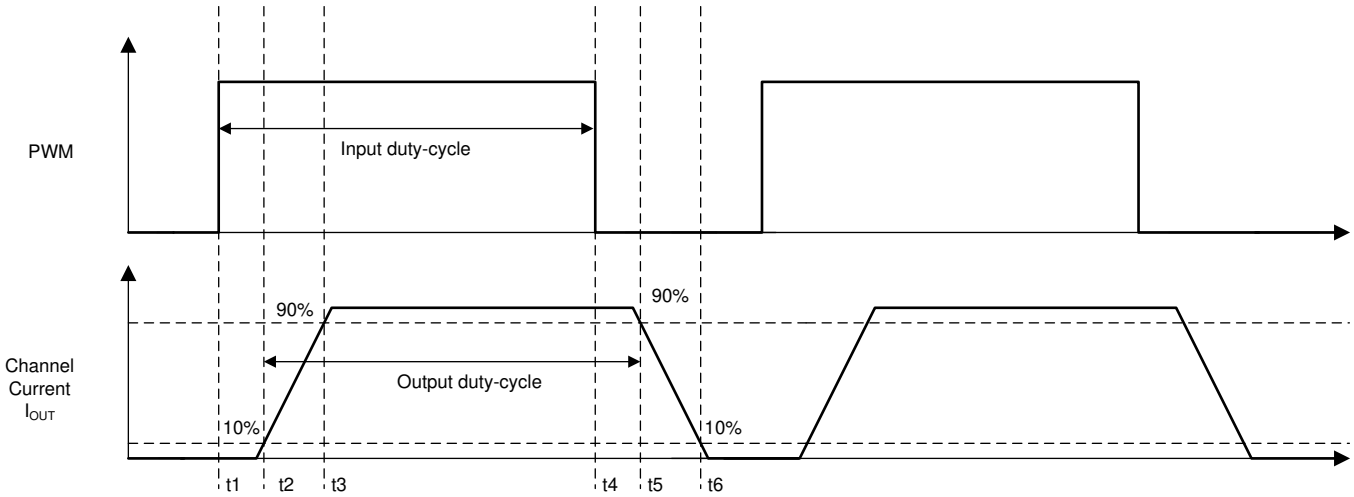
$V_{(SUPPLY)}$ = 5 V–40 V, T_J = –40°C to 150°C unless otherwise noted

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
CONSTANT-CURRENT DRIVER						
$I_{(OUT)}$	Device output-current range	100% duty-cycle	4		300	mA
$V_{(CS_REG)}$	Sense-resistor regulation voltage	T_A = 25°C, $V_{(SUPPLY)}$ = 4.5 V to 18 V	94	98	102	mV
		T_A = –40°C to 125°C, $V_{(SUPPLY)}$ = 4.5 V to 18 V	93.5	98	102.5	
$R_{(CS_REG)}$	Sense-resistor value				24.5	Ω
$V_{(DROPOUT)}$	Voltage dropout from SUPPLY to OUT	$V_{(CS_REG)}$ voltage included, current setting = 10 mA		120	150	mV
		$V_{(CS_REG)}$ voltage included, current setting = 70 mA		250	400	
		$V_{(CS_REG)}$ voltage included, current setting = 150 mA		430	700	
		$V_{(CS_REG)}$ voltage included, current setting = 300 mA		800	1300	
DIAGNOSTICS						
$V_{(OPEN_th_rising)}$	LED open rising threshold, $V_{(IN)}$ – $V_{(OUT)}$		70	100	135	mV
$V_{(OPEN_th_falling)}$	LED open falling threshold, $V_{(IN)}$ – $V_{(OUT)}$		235	290	335	mV
$V_{(SG_th_falling)}$	Channel output $V_{(OUT)}$ short to ground falling threshold		1.14	1.2	1.26	V
$V_{(SG_th_rising)}$	Channel output $V_{(OUT)}$ short to ground rising threshold		0.82	0.865	0.91	V
$I_{(Retry)}$	Channel output retry current	$V_{(OUT)}$ = 0 V	0.64	1.08	1.528	mA
FAULT						
$V_{IL(FAULT)}$	Logic-input low threshold				0.7	V
$V_{IH(FAULT)}$	Logic-input high threshold		2			V
$V_{OL(FAULT)}$	Logic-output low threshold	With 500-µA external pullup			0.4	V
$V_{OH(FAULT)}$	Logic-output high threshold	With 1-µA external pulldown, $V_{(SUPPLY)}$ = 12 V	5		7	V
$I_{(FAULT_pulldown)}$	$\overline{FAULT}$ internal pulldown current		500	750	1000	µA
$I_{(FAULT_pullup)}$	$\overline{FAULT}$ internal pullup current		5	8	12	µA
THERMAL PROTECTION						
$T_{(TSD)}$	Thermal shutdown junction temperature threshold			172		°C
$T_{(TSD_HYS)}$	Thermal shutdown junction temperature hysteresis			15		°C

6.6 Timing Requirements

		MIN	NOM	MAX	UNIT
$t_{(PWM_delay_rising)}$	PWM rising edge delay, 50% PWM voltage to 10% of output current, t2 – t1 as shown in 图 1		17		µs
$t_{(PWM_delay_falling)}$	PWM falling edge delay, 50% PWM voltage to 90% of output current, t5 – t4 as shown in 图 1		21		µs
$t_{(TSD_deg)}$	Thermal overtemperature deglitch timer		60		µs
$t_{(DEVICE_STARTUP)}$	EN rising edge to 10% output current at 150-mA set current and 12-V supply voltage		100	150	µs
$t_{(OPEN_deg)}$	LED open-circuit fault-deglitch time	80	125	175	µs
$t_{(SG_deg)}$	Channel-output short-to-ground detection deglitch time	80	125	175	µs
$t_{(Recover_deg)}$	Recovery deglitch time		16		µs

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图 1. Output Timing Diagram

6.7 Typical Characteristics

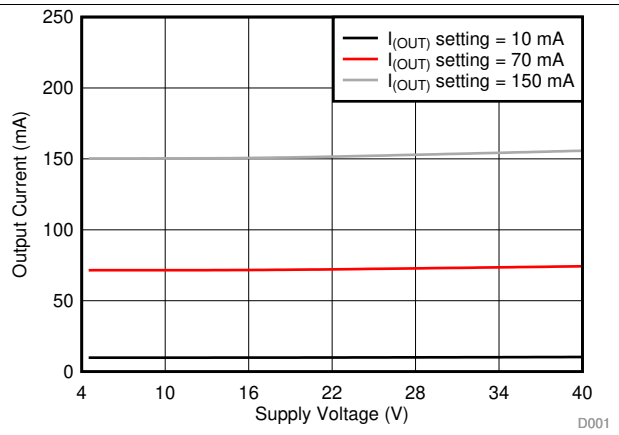


图 2. Output Current vs Supply Voltage

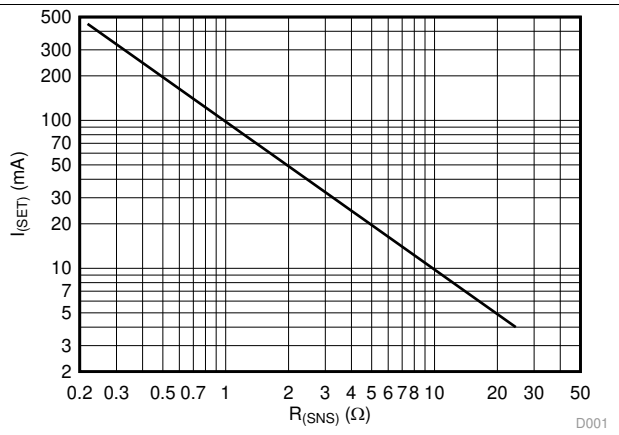
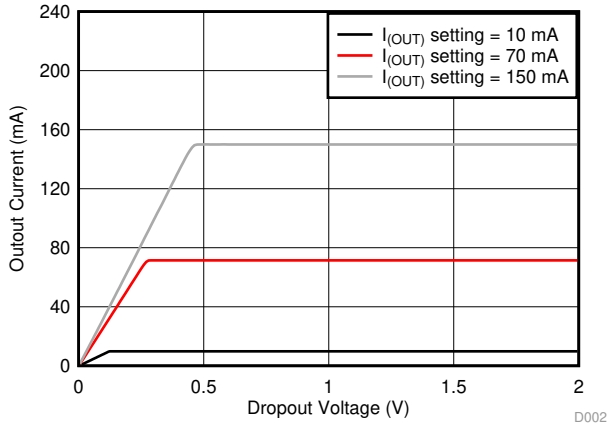


图 3. Output Current vs Current-Sense Resistor

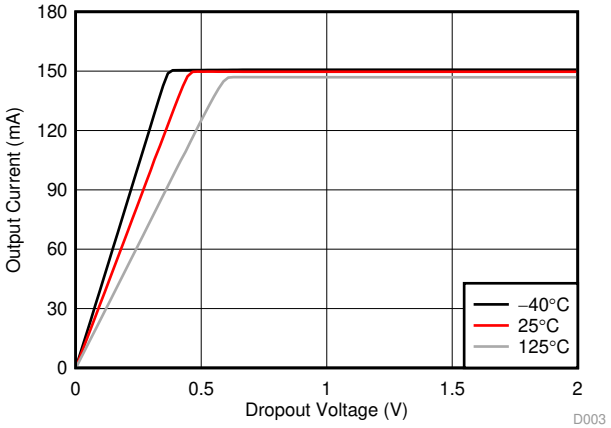
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Typical Characteristics (接下页)



T_A = 25°C

图 4. Output Current vs Dropout Voltage



$I_{(OUT)}$ setting = 150 mA

图 5. Output Current vs Dropout Voltage

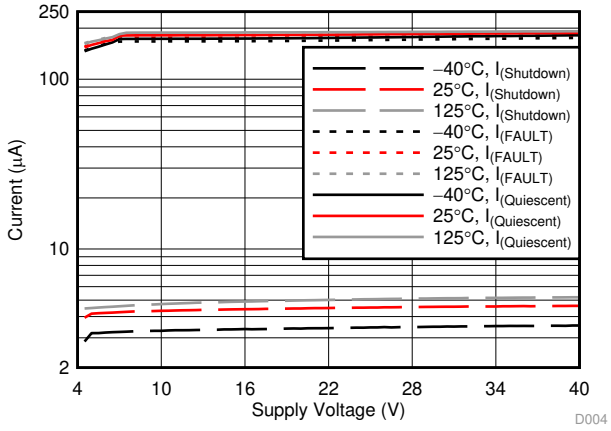


图 6. Shutdown, Quiescent, and Fault Current vs Supply Voltage

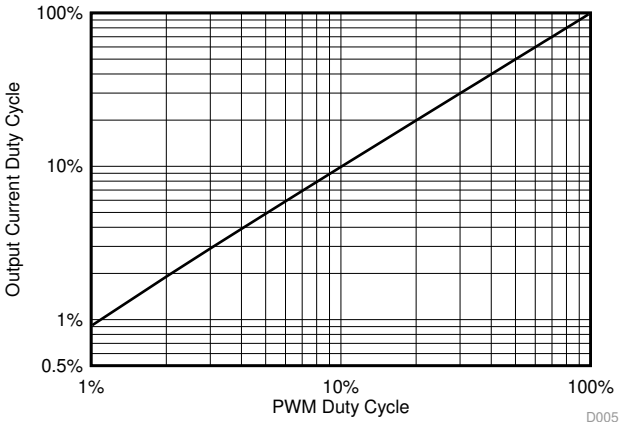
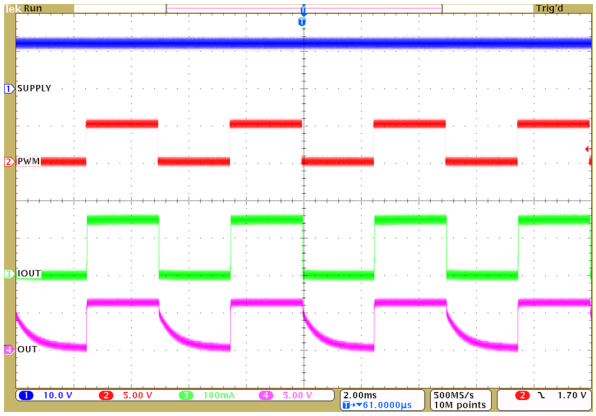
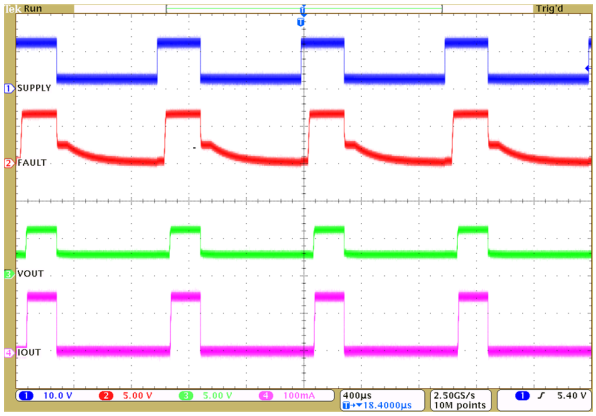


图 7. PWM Output Duty Cycle vs Input Duty Cycle



Ch.1 = $V_{(SUPPLY)}$ Ch. 2 = $V_{(PWM)}$ Ch. 3 = $I_{(OUT)}$
Ch.4 = $V_{(OUT)}$ $f_{(PWM)}$ = 200 Hz Duty-cycle = 50%

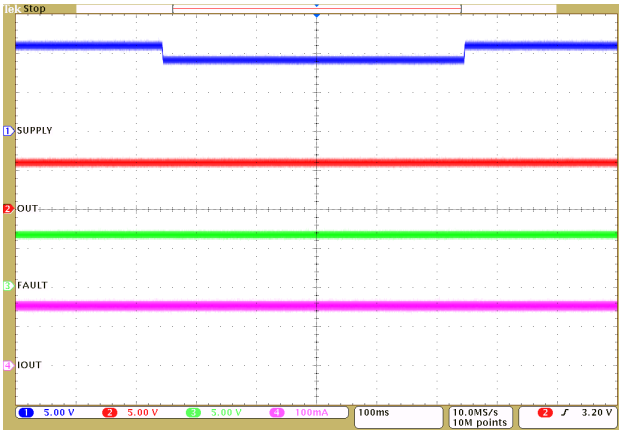
图 8. PWM Dimming via External Input



Ch. 1 = $V_{(SUPPLY)}$ Ch. 2 = $\overline{FAULT}$ Ch. 3 = $V_{(OUT)}$
Ch. 4 = $I_{(OUT)}$ $f_{(PWM)}$ = 1000 Hz Duty cycle = 30%
SUPPLY dimming between 2.5 V and 12 V $\overline{FAULT}$ floating

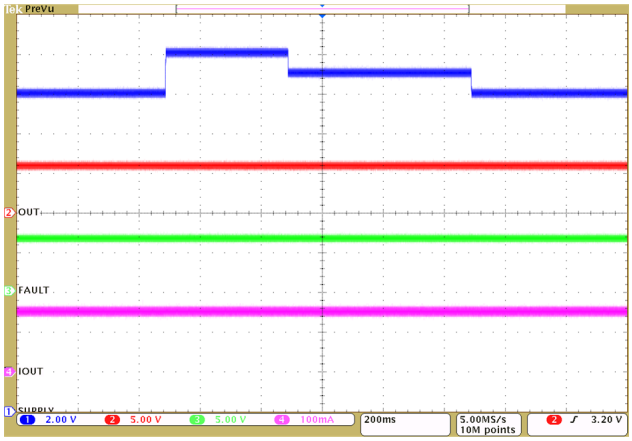
图 9. PWM Dimming via Power Supply

Typical Characteristics (接下页)



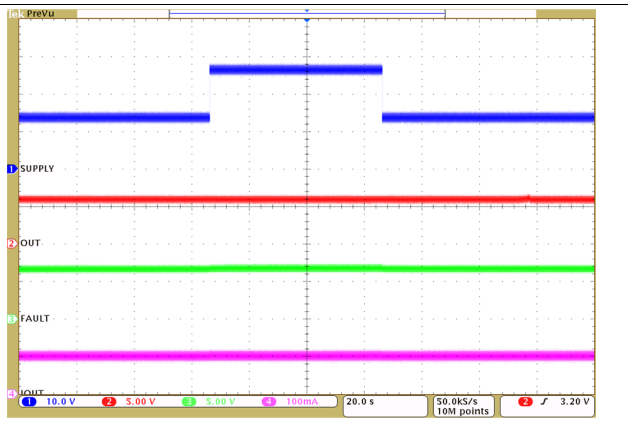
Ch. 1 = SUPPLY Ch. 2 = $V_{(OUT)}$ Ch. 3 = $\overline{FAULT}$
Ch. 4 = $I_{(OUT)}$

图 10. Transient Undervoltage



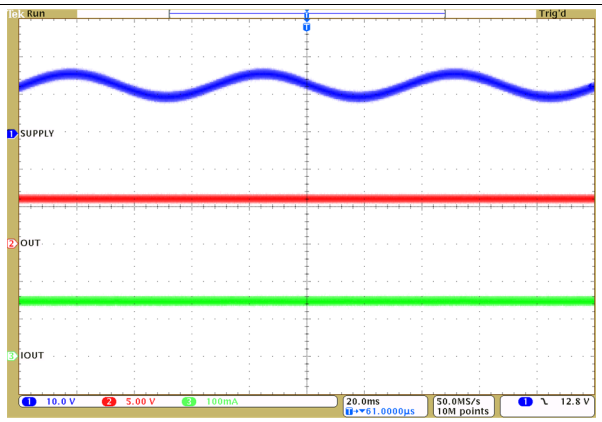
Ch. 1 = SUPPLY Ch. 2 = $V_{(OUT)}$ Ch. 3 = $\overline{FAULT}$
Ch. 4 = $I_{(OUT)}$

图 11. Transient Overvoltage



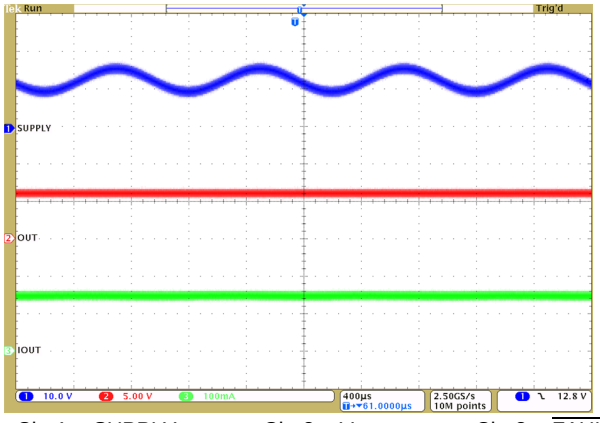
Ch. 1 = SUPPLY Ch. 2 = $V_{(OUT)}$ Ch. 3 = $\overline{FAULT}$
Ch. 4 = $I_{(OUT)}$

图 12. Jump Start



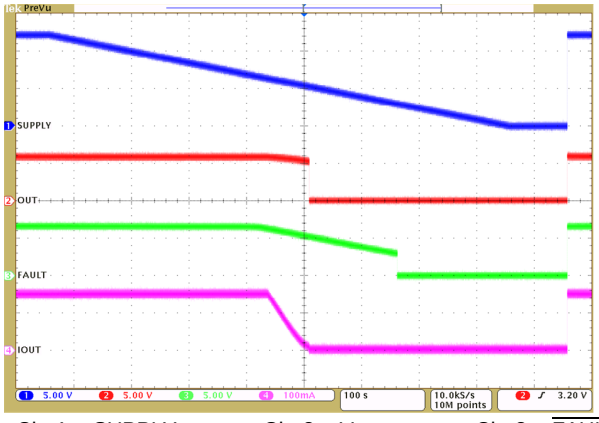
Ch. 1 = SUPPLY Ch. 2 = $V_{(OUT)}$ Ch. 3 = $\overline{FAULT}$
Ch. 4 = $I_{(OUT)}$

图 13. Superimposed Alternating Voltage, 15-Hz



Ch. 1 = SUPPLY Ch. 2 = $V_{(OUT)}$ Ch. 3 = $\overline{FAULT}$
Ch. 4 = $I_{(OUT)}$

图 14. Superimposed Alternating Voltage, 1-kHz

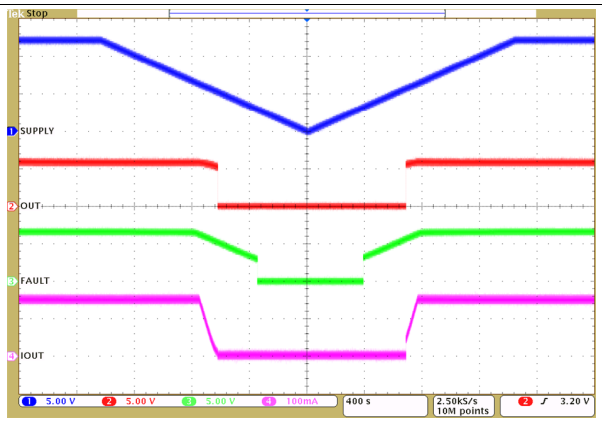


Ch. 1 = SUPPLY Ch. 2 = $V_{(OUT)}$ Ch. 3 = $\overline{FAULT}$
Ch. 4 = $I_{(OUT)}$

图 15. Slow Decrease, Quick Increase of Supply Voltage

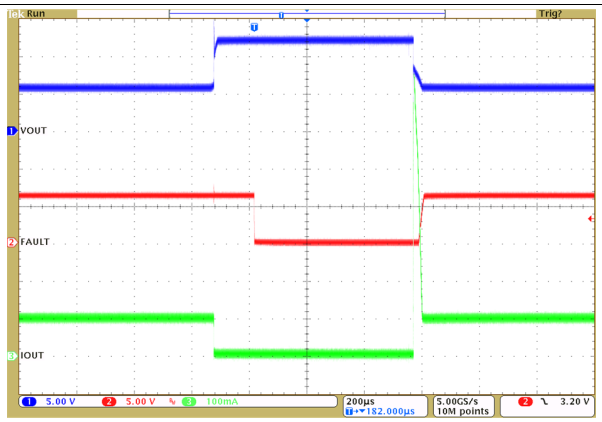
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Typical Characteristics (接下页)



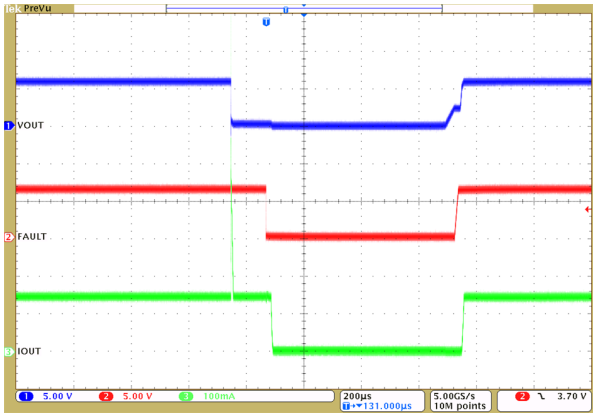
Ch. 1 = SUPPLY Ch. 2 = $V_{(OUT)}$ Ch. 3 = $\overline{FAULT}$
Ch. 4 = $I_{(OUT)}$

图 16. Slow Decrease and Slow Increase of Supply Voltage



Ch. 1 = $V_{(OUT)}$ Ch. 2 = $\overline{FAULT}$ Ch. 3 = $I_{(OUT)}$

图 17. LED Open-Circuit Protection and Recovery



Ch. 1 = $V_{(OUT)}$ Ch. 2 = $\overline{FAULT}$ Ch. 3 = $I_{(OUT)}$

图 18. LED Short-Circuit Protection and Recovery

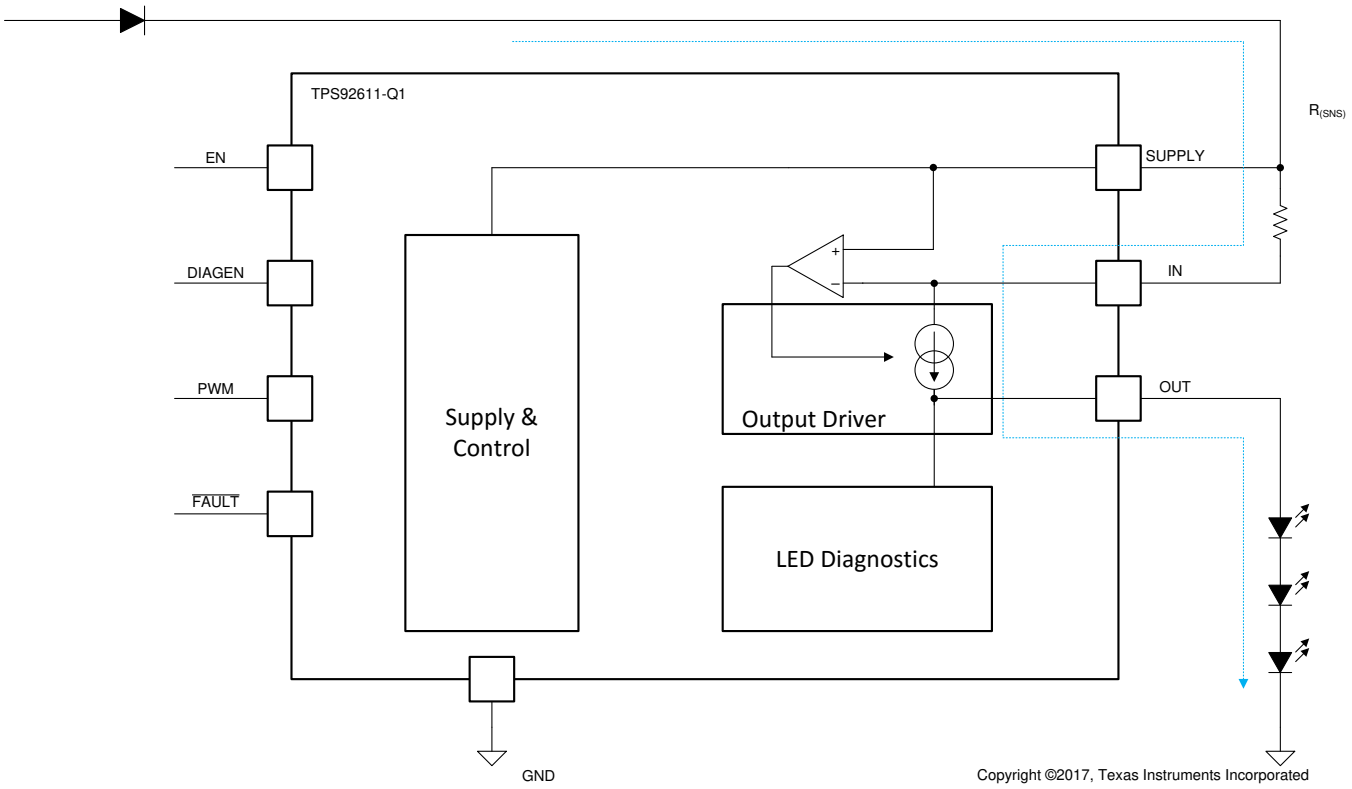
7 Detailed Description

7.1 Overview

The TPS92611-Q1 device is one of a family of single-channel linear LED drivers. The family provides a simple solution for automotive LED applications. Different package options in the family provide a variety of current ranges and diagnostic options. The TPS92611-Q1 device in an MSOP-8 package supports LED open-circuit detection and short-to-ground detection. A one-fails–all-fail fault bus allows the TPS92611-Q1 device to be used together with the TPS9261x-Q1, TPS9263x-Q1, and TPS9283x-Q1 families.

The output current can be set by an external $R_{(SNS)}$ resistor. Current flows from the supply through the $R_{(SNS)}$ resistor into the internal current source and to the LEDs.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Device Bias

7.3.1.1 Power-On Reset (POR)

The TPS92611-Q1 device has an internal power-on-reset (POR) function. When power is applied to SUPPLY, the internal POR holds the device in the reset condition until $V_{(SUPPLY)}$ reaches $V_{(POR_rising)}$.

7.3.1.2 Low-Quiescent-Current Fault Mode

The TPS92611-Q1 device consumes minimal quiescent current when it is in fault mode. If the $\overline{FAULT}$ voltage is externally pulled LOW, the device shuts down the output driver.

If the device detects an internal fault, it pulls the $\overline{FAULT}$ output LOW to signal a fault alarm on the one-fails–all-fail fault bus.

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Feature Description (接下页)

7.3.2 Constant-Current Driver

The TPS92611-Q1 device has a high-side constant-current integrated driver. The device senses channel current with an external high-side current-sense resistor, $R_{(SNS)}$. A current regulation loop drives an internal transistor and regulates the current-sense voltage at the current-sense resistor to $V_{(CS_REG)}$. When the output driver is in regulation, the output current can be set using the following equation.

$$I_{(OUT)} = \frac{V_{(CS_REG)}}{R_{(SNS)}} \quad (1)$$

7.3.3 Device Enable

The TPS92611-Q1 device has an enable input EN. When EN is low, the device is in sleep mode with ultralow quiescent current $I_{(Shutdown)}$. This low current helps to save system-level current consumption in applications where battery voltage directly connects to the device without high-side switches.

7.3.4 PWM Dimming

The TPS92611-Q1 device supports PWM dimming via PWM input dimming and supply dimming.

The PWM input functions as an enable for the output current. When the PWM input is low, the device also disables the diagnostic features.

Supply dimming applies PWM dimming on the power input. For an accurate PWM threshold, TI recommends using a resistor divider on the PWM input stage to set the PWM threshold higher than $V_{(POR_rising)}$.

7.3.5 Diagnostics

The TPS92611-Q1 device provides advanced diagnostics and fault protection features for automotive exterior lighting systems. The device is able to detect and protect from LED string short-to-GND and LED string open-circuit faults.It also supports a one-fails–all-fail fault bus that could flexibly fit different regulatory requirements.

7.3.5.1 DIAGEN

The TPS92611-Q1 device supports the DIAGEN pin with an accurate threshold to disable the open-load diagnostic function. With a resistor divider, the DIAGEN pin can be used to sense SUPPLY voltage with a resistor-programmable threshold. With the DIAGEN feature, the device is able to avoid false error reports due to low dropout voltage and to drive maximum current in low-dropout mode when the input voltage is not high enough for current regulation.

When $V_{(DIAGEN)}$ is higher than the $V_{IH(DIAGEN)}$ threshold, the device enables the LED open-circuit diagnostic. When $V_{(DIAGEN)}$ is lower than the $V_{IL(DIAGEN)}$ threshold, the device disables the LED open-circuit diagnostic.

7.3.5.2 Low-Dropout Mode

When the supply voltage drops, the TPS92611-Q1 device tries to regulate current by driving internal transistors in the linear region, also known as low-dropout mode, because the voltage across the sense resistor fails to reach the regulation target.

In low-dropout mode, the open-circuit diagnostic must be disabled. Otherwise, the device treats the low-dropout mode as an open-circuit fault. The DIAGEN pin is used to avoid false diagnostics on the output channel due to low supply voltage.

When the DIAGEN voltage is low, open-circuit detection is ignored. When the DIAGEN voltage is high, open-circuit detection returns to normal operation.

In low-dropout mode, a parallel diode and current-limiting resistor are recommended to clamp between SUPPLY and IN (across the sense resistor) in case of a large current pulse during recovery.

7.3.5.3 Open-Circuit Detection

The TPS92611-Q1 device has LED open-circuit detection. Open-circuit detection monitors the output voltage when the channel is in the ON state. Open-circuit detection is only enabled when DIAGEN is HIGH. A short-to-battery fault is also detected as an LED open-circuit fault.

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Feature Description (接下页)

The device monitors dropout-voltage differences between the IN and OUT pins when PWM is HIGH. The voltage difference $V_{(IN)} – V_{(OUT)}$ is compared with the internal reference voltage $V_{(OPEN_th_rising)}$ to detect an LED open-circuit failure. If $V_{(IN)} – V_{(OUT)}$ falls below the $V_{(OPEN_th_rising)}$ voltage longer than the deglitch time of $t_{(OPEN_deg)}$, the device detects an open-circuit fault. Once an LED open-circuit failure is detected, the constant-current source pulls the fault bus down. During the deglitch time period, if $V_{(IN)} – V_{(OUT)}$ rises above $V_{(OPEN_th_falling)}$, the deglitch timer is reset.

When the PWM input is in auto-retry, the device keeps the output ON to retry if the PWM input is HIGH; the device sources a small current $I_{(retry)}$ from IN to OUT to retry when the PWM input is LOW. In either scenario, once a faulty channel recovers, the device resumes normal operation and releases the $\overline{\text{FAULT}}$ pulldown.

7.3.5.4 Short-to-GND Detection

The TPS92611-Q1 device has LED short-to-GND detection. Short-to-GND detection monitors the output voltage when the channel is in the ON state. Once a short-to-GND LED failure is detected, the device turns off the output channel and retries automatically, ignoring the PWM input. If the retry mechanism detects removal of the LED short-to-GND fault, the device resumes normal operation.

The device monitors the $V_{(OUT)}$ voltage and compares it with the internal reference voltage to detect a short-to-GND failure. If $V_{(OUT)}$ falls below $V_{(SG_th_rising)}$ longer than the deglitch time of $t_{(SG_deg)}$, the device asserts the short-to-GND fault and pulls $\overline{\text{FAULT}}$ low. During the deglitching time period, if $V_{(OUT)}$ rises above $V_{(SG_th_falling)}$, the timer is reset.

Once the device has detected a short-to-GND fault, the device turns off the output channel and retries automatically with a small current. When retrying, the device sources a small current $I_{(retry)}$ from IN to OUT to pull up the LED loads continuously. Once auto-retry detects output voltage rising above $V_{(SG_th_falling)}$, it clears the short-to-GND fault and resumes normal operation.

7.3.5.5 Overtemperature Protection

The TPS92611-Q1 device monitors device junction temperature. When the junction temperature reaches thermal shutdown threshold $T_{(TSD)}$, the output shuts down. Once junction temperature falls below $T_{(TSD)} – T_{(TSD_HYS)}$, the device resumes normal operation. During overtemperature protection, the fault bus is pulled low.

7.3.6 Fault-Bus Output With One-Fails–All-Fail

The TPS92611-Q1 device has a fault bus for diagnostics output. In normal operation, $\overline{\text{FAULT}}$ is weakly pulled up by an internal pullup current source $I_{(FAULT_pullup)}$ higher than $V_{OH(FAULT)}$. If any fault occurs, the fault bus is strongly pulled low by the internal pulldown current source $I_{(FAULT_pulldown)}$. Once $V_{(\overline{FAULT})}$ falls below $V_{IL(FAULT)}$, all outputs shut down for protection. The faulty channel keeps retrying until the fault is removed.

If $\overline{\text{FAULT}}$ is externally pulled up with a current larger than $I_{(FAULT_pulldown)}$, the one-fails–all-fail function is disabled and only the faulty channel is turned off.

The fault bus is able to support up to 15 pieces of TPS9261x-Q1, TPS9263x-Q1, or TPS9283x-Q1 devices.

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Feature Description (接下页)

表 1. Fault Table With DIAGEN = HIGH

FAULT BUS STATUS	FAULT TYPE	DETECTION MECHANISM	CHANNEL STATE	DEGLITCH TIME	FAULT BUS	FAULT HANDLING ROUTINE	FAULT RECOVERY
$\overline{\text{FAULT}}$ floating or externally pulled up	Open-circuit or short-to-supply	$V_{(IN)} - V_{(OUT)} < V_{(OPEN_th_rising)}$	On	$t_{(OPEN_deg)}$	Constant-current pulldown	Device works normally with $\overline{\text{FAULT}}$ pin pulled low. Device sources $I_{(retry)}$ current when PWM is LOW. Device keeps output normal when PWM is HIGH.	Auto recover
	Short-to-ground	$V_{(OUT)} < V_{(SG_th_rising)}$	On	$t_{(SG_deg)}$	Constant-current pulldown	Device turns output off and retries with constant current $I_{(retry)}$, ignoring the PWM input.	Auto recover
	Over-temperature	$T_J > T_{(TSD)}$	On or off	$t_{(TSD_deg)}$	Constant-current pulldown	Devices turns output off.	Auto recover
Externally pulled low	Device turns output off						

表 2. Fault Table With DIAGEN = LOW

FAULT BUS STATUS	FAULT TYPE	DETECTION MECHANISM	CHANNEL STATE	DEGLITCH TIME	FAULT BUS	FAULT HANDLING ROUTINE	FAULT RECOVERY
$\overline{\text{FAULT}}$ floating or externally pulled up	Open-circuit or short-to-supply	Ignored					
	Short-to-ground	$V_{OUT} < V_{(SG_th_rising)}$	On	$t_{(SG_deg)}$	Constant-current pulldown	Device turns output off and retries with constant current $I_{(retry)}$, ignoring the PWM input.	Auto recover
	Over-temperature	$T_J > T_{(TSD)}$	On or off	$t_{(TSD_deg)}$	Constant-current pulldown	Devices turns output off.	Auto recover
Externally pulled low	Device turns output off						

7.4 Device Functional Modes

7.4.1 Undervoltage Lockout, $V_{(SUPPLY)} < V_{(POR_rising)}$

When the device is in undervoltage lockout mode, the TPS92611-Q1 device disables all functions until the supply rises above the POR-rising threshold.

7.4.2 Normal Operation $V_{(SUPPLY)} \geq 4.5$ V

The device drives an LED string in normal operation. With enough voltage drop across SUPPLY and OUT, the device is able to drive the output in constant-current mode.

7.4.3 Low-Voltage Dropout

When the device drives an LED string in low-dropout mode, if the voltage drop is less than the open-circuit detection threshold, the device may report a false open. Set the DIAGEN threshold higher than the LED string voltage to avoid a false open-circuit detection.

7.4.4 Fault Mode

When the device detects an open or shorted LED, the device tries to pull down the $\overline{\text{FAULT}}$ pin with a constant current. If the fault bus is pulled down, the device switches to fault mode and consumes a fault current of $I_{(FAULT)}$.

8 Application and Implementation

注

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.

8.1 Application Information

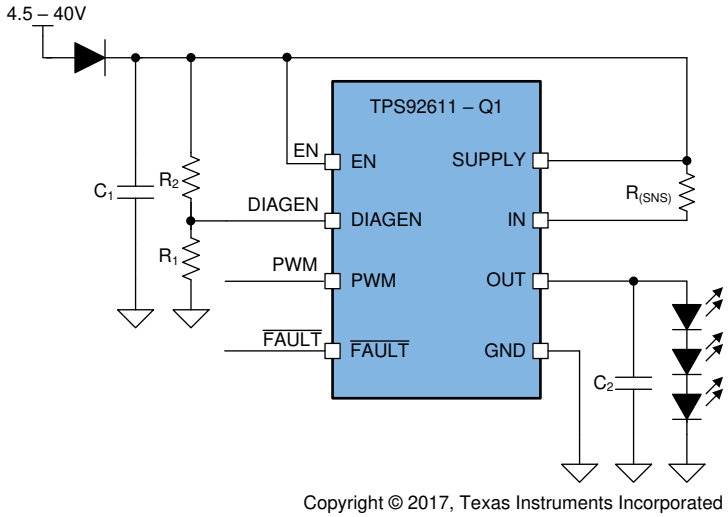
In automotive lighting applications, thermal performance and LED diagnostics are always design challenges for linear LED drivers.

The TPS92611-Q1 device is capable of detecting LED open-circuit and LED short-circuit failures. To further increase current-driving capability, the TPS92611-Q1 device supports heat sharing with an external parallel resistor as shown in 图 21. This technique provides the low-cost solution of using external resistors to dissipate heat due to high input voltage, and still keeps high accuracy of the total current output. Note that the one-fails–all-fail feature is not supported by this topology.

8.2 Typical Application

8.2.1 Single-Channel LED Driver With Diagnostics

The TPS92611-Q1 device can be a good fit for LED driver applications with diagnostics requirements. In many cases, LED diagnostics are mandatory for applications such as automotive exterior lighting.



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图 19. Typical Application Diagram

8.2.1.1 Design Requirements

Input voltage range is 9 V to 16 V, LED maximum forward voltage V_{fmax} = 2.5 V, minimum forward voltage V_{fmin} = 1.9 V, current $I_{(LED)}$ = 50 mA.

8.2.1.2 Detailed Design Procedure

Current setting by a sense resistor is as described in 公式 1.

$$R_{(SNS)} = \frac{V_{(CS_REG)}}{I_{(LED)}} = 1.96\Omega \quad (2)$$

LED-string maximum forward voltage = 3 × 2.5 V = 7.5 V.

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Typical Application (接下页)

With 400-mV headroom reserved for the TPS92611-Q1 device between SUPPLY and OUT, the TPS92611-Q1 device must disable open-circuit detection when the supply voltage is below 7.9 V by using the DIAGEN feature.

$$V_{IL(DIAG,min)} = \frac{7.9 \times R_1}{R_1 + R_2} \quad (3)$$

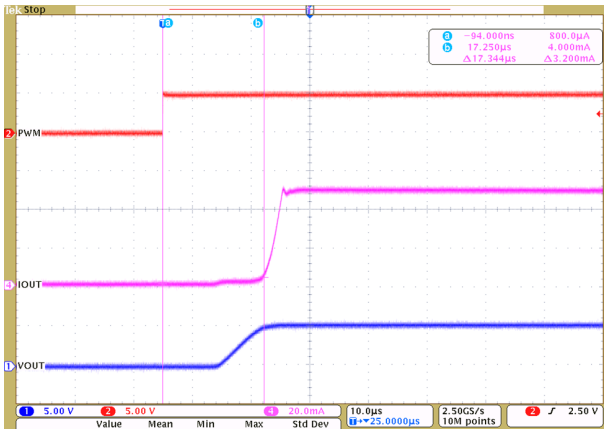
Set R_1 = 10 kΩ, R_2 = 65.6 kΩ.

Total device power consumption at worst case is with 16-V input and LEDs at minimal forward voltage.

$$P_{(Max)} = (V_{(SUPPLY)} - V_{(CS_REG)} - V_{(OUT)}) \times I_{(LED)} + V_{(SUPPLY)} \times I_{(Quiescent)}$$
$$= (16 - 3 \times 1.9 - 0.098) \times 0.05 + 16 \times 0.00025 = 0.5141\,W \quad (4)$$

TI recommends to add capacitors C_1 and C_2 at SUPPLY and OUT. TI recommends C_1 of 1 µF and 100 nF close to the SUPPLY pin, and C_2 of 10 nF close to the OUT pin. A larger capacitor for C_1 or C_2 is helpful for EMC and ESD; however, it takes a longer time to charge up the capacitor and could affect PWM dimming performance.

8.2.1.3 Application Curve



Ch. 1 = $V_{(OUT)}$ Ch. 2 = $V_{(PWM)}$ Ch. 4 = $I_{(OUT)}$

图 20. Output Current With PWM Input

8.2.2 Single-Channel LED Driver With Heat Sharing

Using parallel resistors, thermal performance can be improved by balancing current between the TPS92611-Q1 device and the external resistors as follows. As the current-sense resistor controls the total LED string current, the LED string current $I_{(LED)}$ is set by $V_{(CS_REG)}$ / $R_{(SNS)}$, while the TPS92611-Q1 current $I_{(DRIVE)}$ and parallel resistor current $I_{(P)}$ combine to the total current. Note that the device is not able to control the parallel resistor path, thus TI does not suggest to use one-fails–all-fail with this topology. For PWM applications, TI suggests to add an external bipolar switch at the bottom of LED strings. The PWM input and bipolar switch inputs must be tied together to minimize delay mismatch and to avoid false open-circuit faults.

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Typical Application (接下页)

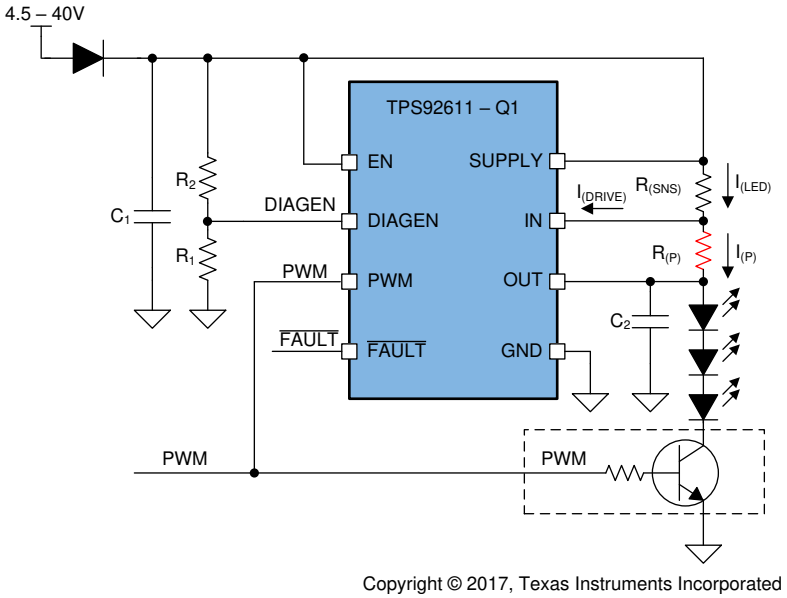


图 21. Heat Sharing With a Parallel Resistor

8.2.2.1 Design Requirements

Input voltage range is 9 V to 16 V, LED maximum forward voltage V_{fmax} = 2.5 V, minimum forward voltage V_{fmin} = 1.9 V, current $I_{(LED)}$ = 200 mA.

8.2.2.2 Detailed Design Procedure

In linear LED driver applications, the input voltage variation contributes to most of the thermal concerns. The resistor current, as indicated by Ohm's law, depends on the voltage across the external resistors. The TPS92611-Q1 controls the driver current $I_{(DRIVE)}$ to attain the desired total current. If $I_{(P)}$ increases, the TPS92611-Q1 device decreases $I_{(DRIVE)}$ to compensate, and vice versa.

While in low-dropout mode, the voltage across the $R_{(P)}$ resistor may be close to zero, so that almost no current can flow through the external resistor $R_{(P)}$.

When the input voltage is high, the parallel-resistor current $I_{(P)}$ is proportional to the voltage across the parallel resistor $R_{(P)}$. The parallel resistor $R_{(P)}$ takes the majority of the total string current, generating maximum heat. The device must prevent current from draining out to ensure current regulation capability.

In this case, the parallel resistor value must be carefully calculated to ensure that 1) enough output current is achieved in low-dropout mode, 2) thermal dissipation for both the TPS92611-Q1 device and the resistor is within their thermal dissipation limits, and 3) device current in the high-voltage mode is above the minimal output-current requirement.

TI recommends to add capacitors C_1 and C_2 at SUPPLY and OUT. TI recommends C_1 of 1 µF and 100 nF close to the SUPPLY pin, and C_2 of 10 nF close to the OUT pin. A larger capacitor for C_1 or C_2 is helpful for EMC and ESD; however, it takes a longer time to charge up the capacitor and could affect PWM dimming performance. Current setting by a sense resistor is as described in 公式 1.

$$R_{(SNS)} = \frac{V_{(CS_REG)}}{I_{(LED)}} = 0.49\Omega \quad (5)$$

LED-string maximum forward voltage = 3 × 2.5 V = 7.5 V.

Parallel resistor $R_{(P)}$ is recommended to consume 1/2 of the total current at maximum supply voltage.

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Typical Application (接下页)

$$R_{(P)} = \frac{V_{(SUPPLY)} - V_{(CS_REG)} - V_{(OUT)}}{0.5 \times I_{(LED)}} = \frac{16 - 3 \times 1.9 - 0.098}{0.5 \times 0.2} \approx 100\Omega \quad (6)$$

Total device power consumption is maximum at 16 V input and LED minimal forward voltage.

$$P_{(DEV_MAX)} = (V_{(SUPPLY)} - V_{(CS_REG)} - V_{(OUT)}) \times \left(I_{(LED)} - \frac{V_{(SUPPLY)} - V_{(CS_REG)} - V_{(OUT)}}{R_{(P)}} \right) + V_{(SUPPLY)} \times I_{(Quiescent)}$$
$$= (16 - 3 \times 1.9 - 0.098) \times 0.1 + 16 \times 0.00025 = 1.0242 \text{ W} \quad (7)$$

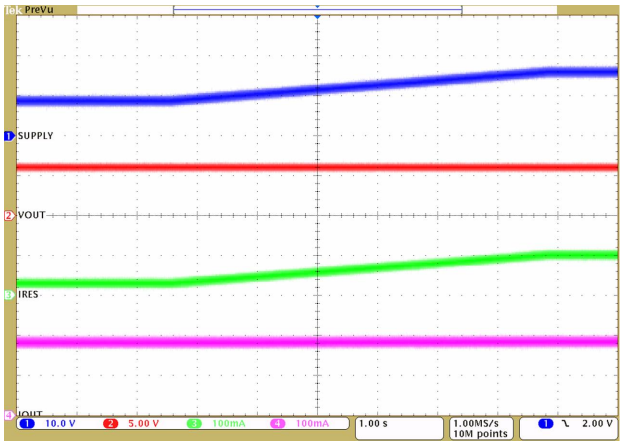
Resistor $R_{(P)}$ maximum power consumption is at 16-V input.

$$P_{(RP_MAX)} = \frac{(V_{(SUPPLY)} - V_{(CS_REG)} - V_{(OUT)})^2}{R_{(P)}} + V_{(SUPPLY)} \times I_{(Quiescent)}$$
$$= \frac{(16 - 3 \times 1.9 - 0.098)^2}{100} = 1.04 \text{ W} \quad (8)$$

Users must consider the maximum power of both of the device and the parallel resistor.

For PWM scenarios, a non-power bipolar transistor with a base current-limiting resistor of 10 kΩ can modulate the output current together with the device PWM function.

8.2.2.3 Application Curve



Ch. 1 = $V_{(SUPPLY)}$ Ch. 2 = $V_{(OUT)}$ Ch. 3 = $I_{(P)}$
Ch. 4 = $I_{(LED)}$ Supply voltage increases from 9 V to 16 V

图 22. Constant Output Current With Increasing Supply Voltage

9 Power Supply Recommendations

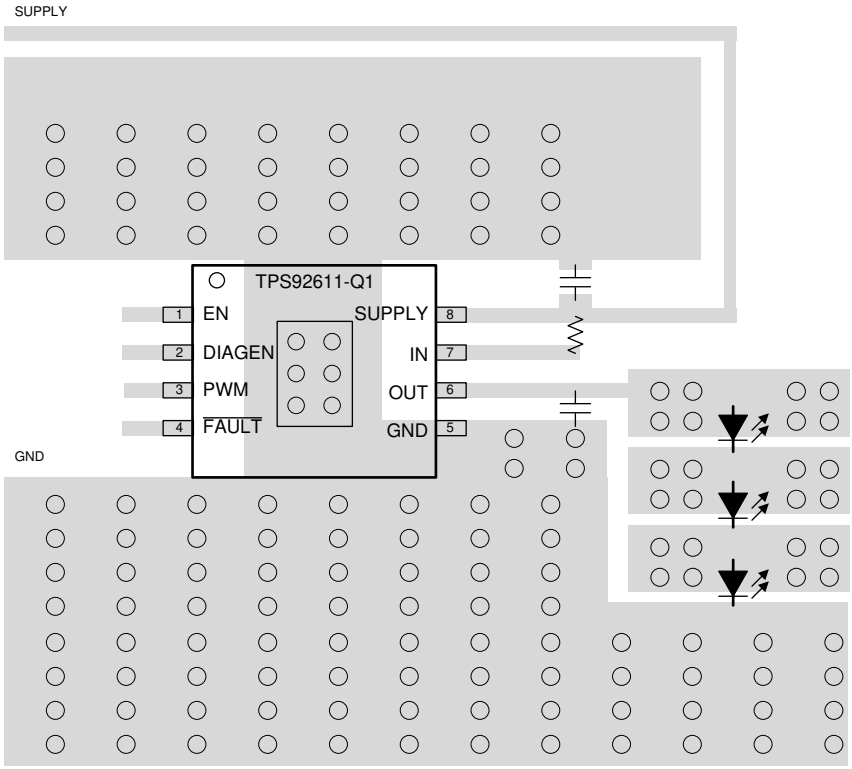
The TPS92611-Q1 device is qualified for automotive applications. The normal power supply connection is therefore to an automobile electrical system that provides a voltage within the range specified in the *Recommended Operating Conditions*.

10 Layout

10.1 Layout Guidelines

Thermal dissipation is the primary consideration for TPS92611-Q1 layout. TI recommends good thermal dissipation area connected to thermal pads with thermal vias.

10.2 Layout Example



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图 23. TPS92611-Q1 Example Layout Diagram

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11 器件和文档支持

11.1 文档支持

11.1.1 相关文档

如需相关文档，请参阅：

- *《TPS92610-Q1 汽车单通道线性 LED 驱动器》*
- *《TPS92612-Q1 汽车单通道线性 LED 驱动器》*
- *《TPS92610-Q1 EVM 用户指南》*
- *《如何在汽车外部照明应用中计算 TPS92630-Q1 最大输出 电流》*
- *《适用于中央高位刹车灯 (CHMSL) 的汽车线性 LED 驱动器参考设计》*
- *《适用于中央高位刹车灯 (CHMSL) 的汽车线性 LED 驱动器参考设计》*

11.2 接收文档更新通知

要接收文档更新通知，请导航至 ti.com.cn 上的器件产品文件夹。单击右上角的*通知我*进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

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ESD 的损坏小至导致微小的性能降级，大至整个器件故障。 精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

11.6 Glossary

SLYZ022 — *TI Glossary*.

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

12 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是适用于指定器件的最新数据。数据如有变更，恕不另行通知，且不会对此文档进行修订。如需获取此数据表的浏览器版本，请查看左侧的导航面板。

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TPS92611QDGNRQ1	Active	Production	HVSSOP (DGN) | 8	2500 | LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	1N3X
TPS92611QDGNRQ1.A	Active	Production	HVSSOP (DGN) | 8	2500 | LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	1N3X

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts 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.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

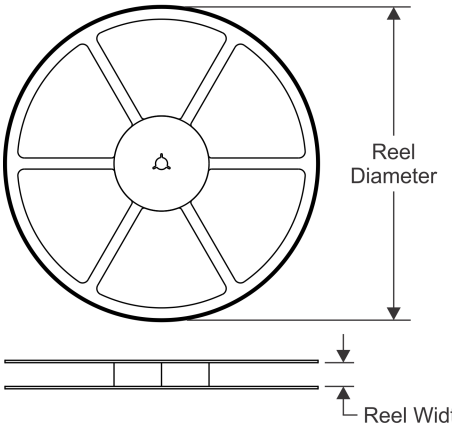
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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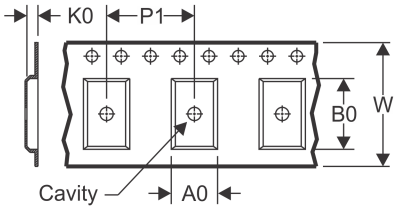
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TAPE AND REEL INFORMATION

REEL DIMENSIONS

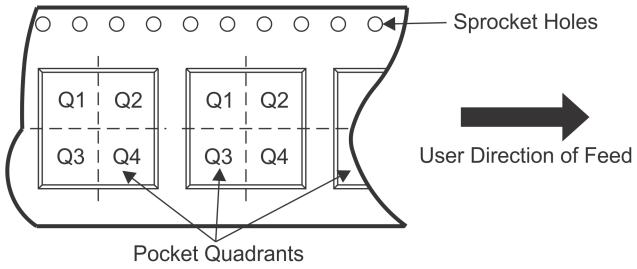


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

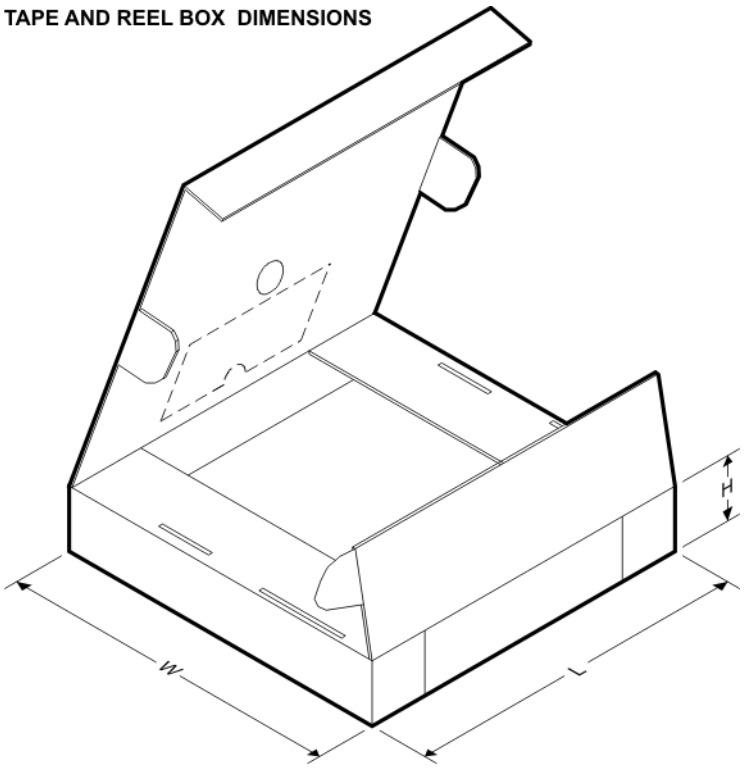
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS92611QDGNRQ1	HVSSOP	DGN	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS92611QDGNRQ1	HVSSOP	DGN	8	2500	366.0	364.0	50.0

GENERIC PACKAGE VIEW

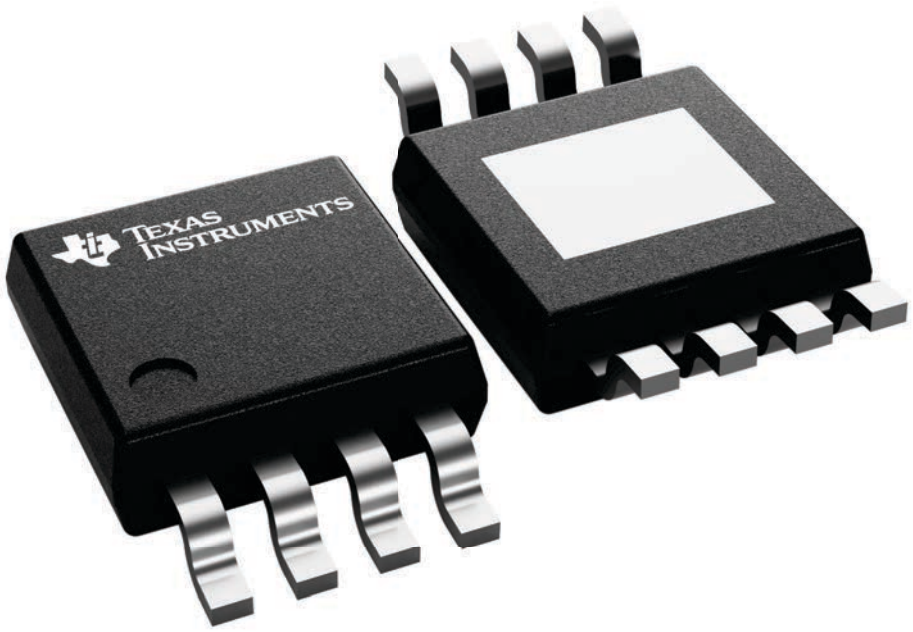
DGN 8

PowerPAD™ HVSSOP - 1.1 mm max height

3 x 3, 0.65 mm pitch

SMALL OUTLINE PACKAGE

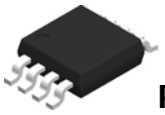
This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



4225482/B

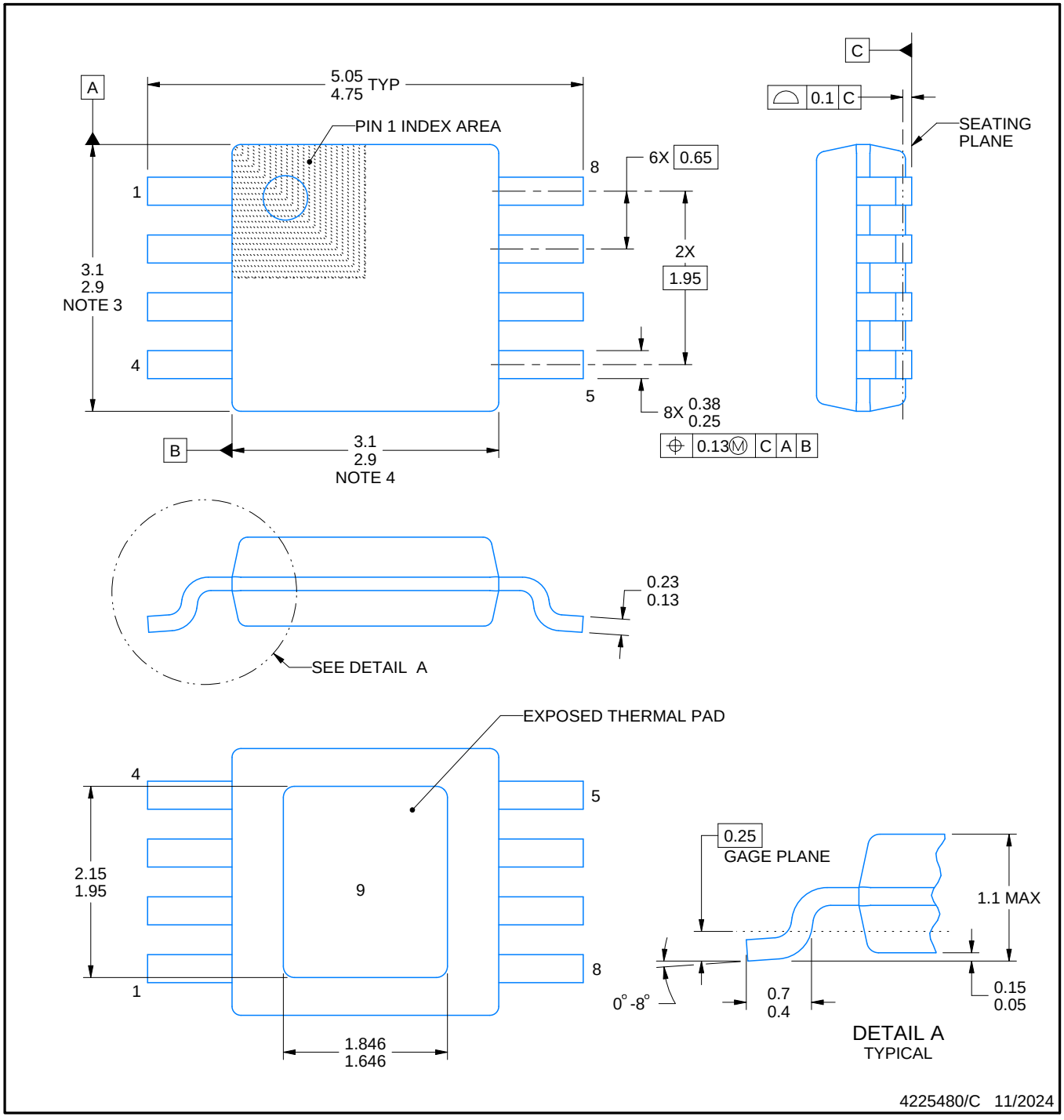
PACKAGE OUTLINE

DGN0008G



PowerPAD™ HVSSOP - 1.1 mm max height

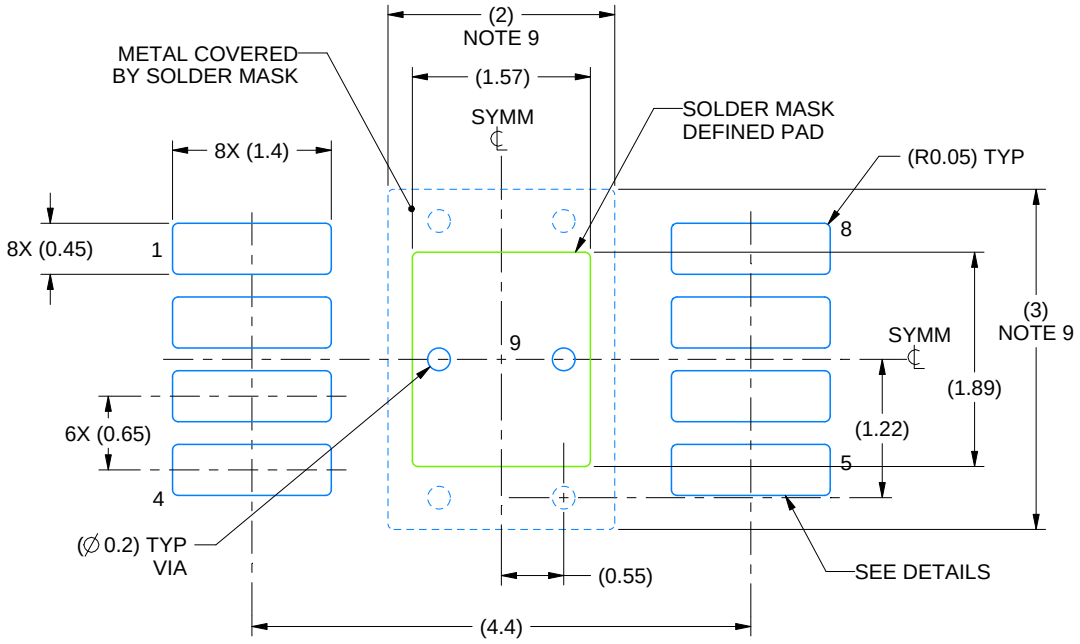
SMALL OUTLINE PACKAGE



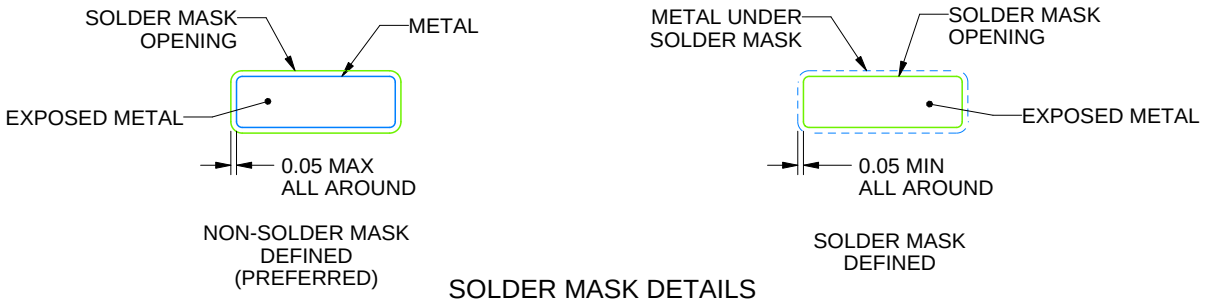
PowerPAD is a trademark of Texas Instruments.

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 15X

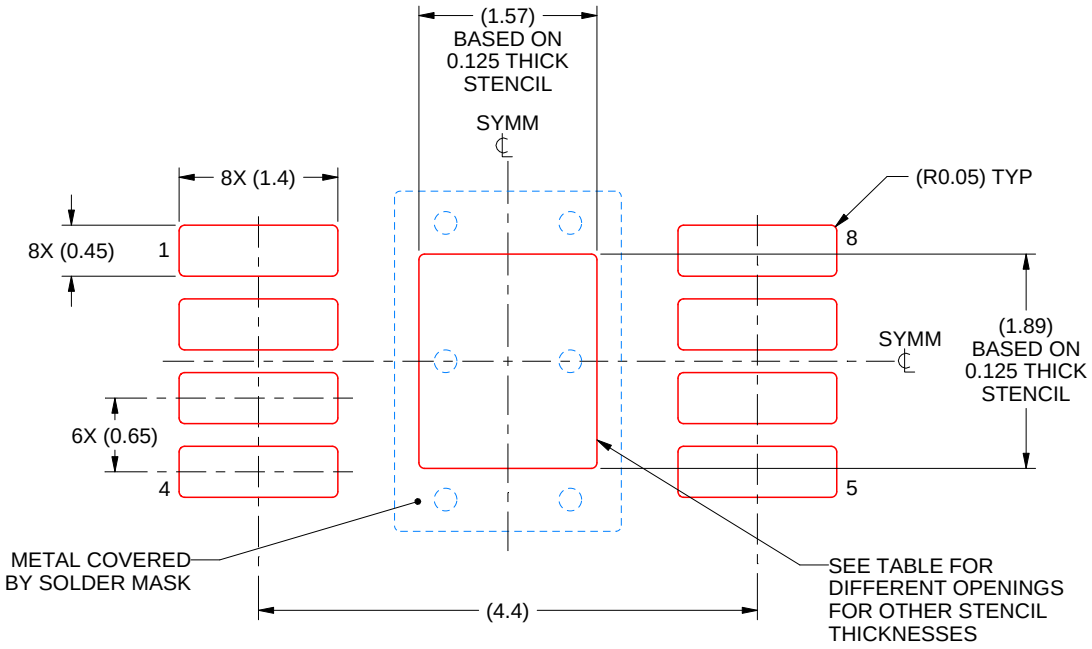


SOLDER MASK DETAILS

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NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
9. Size of metal pad may vary due to creepage requirement.



SOLDER PASTE EXAMPLE
EXPOSED PAD 9:
100% PRINTED SOLDER COVERAGE BY AREA
SCALE: 15X

STENCIL THICKNESS	SOLDER STENCIL OPENING
0.1	1.76 X 2.11
0.125	1.57 X 1.89 (SHOWN)
0.15	1.43 X 1.73
0.175	1.33 X 1.60

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NOTES: (continued)

10. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
11. Board assembly site may have different recommendations for stencil design.

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