

TPS92611-Q1 車載シングルチャネル・リニアLEDドライバ

1 特長

- 車載アプリケーションに対応
- 下記内容でAEC-Q100認定済み：
 - 温度グレード1: 動作時周囲温度範囲 $-40^{\circ}\text{C} \sim 125^{\circ}\text{C}$
 - デバイスHBM ESD分類レベルH2
 - デバイスCDM ESD分類レベルC3B
- **機能安全対応**
 - 機能安全システムの設計に役立つ資料を利用可能
- PWM調光機能付きシングルチャネル定電流LEDドライバ
- 広い入力電圧範囲: $4.5\text{V} \sim 40\text{V}$
- 定出力電流、センス抵抗により調整可能
- 高精度の電流レギュレーション: 許容誤差 $\pm 4.6\%$
- 最大電流: 300mA
- 外付け抵抗との熱共有
- 低いドロップアウト電圧(電流検出の電圧降下を含む)
 - 最大ドロップアウト: 150mV (10mA時)
 - 最大ドロップアウト: 400mV (70mA時)
 - 最大ドロップアウト: 700mV (150mA時)
 - 最大ドロップアウト: 1.3V (300mA時)
- **診断および保護**
 - LED開路および短絡検出と自動回復
 - 診断イネーブルと可変スレッショルドによる低ドロップアウト動作
 - 最大15デバイスのフォルト・バス、どれか1つに障害が発生すれば全体を障害とするか、障害の発生したチャンネルのみをオフにするかを選択可能
 - 静止電流およびフォルト・モード電流が低い(デバイスあたり $250\mu\text{A}$ 未満)
- 動作時の接合部温度範囲: $-40^{\circ}\text{C} \sim 150^{\circ}\text{C}$

2 アプリケーション

- 車載補助照明: ドーム型ライト、ドアハンドル、読書灯、その他のランプ
- 車載リアランプ、センター・ハイマウント・ストップ・ランプ、サイド・マーカ、死角検出インジケータ、充電インレット・インジケータ
- 汎用LEDドライバ・アプリケーション

3 概要

LEDが車載アプリケーションに広く使われているなか、シンプルなLEDドライバの人気の高まっています。ディスクリート・ソリューションに比べて、低コストのモノリシック・ソリューションではシステム・レベルの部品数を減らし、電流の精度や信頼性を大幅に高めることができます。

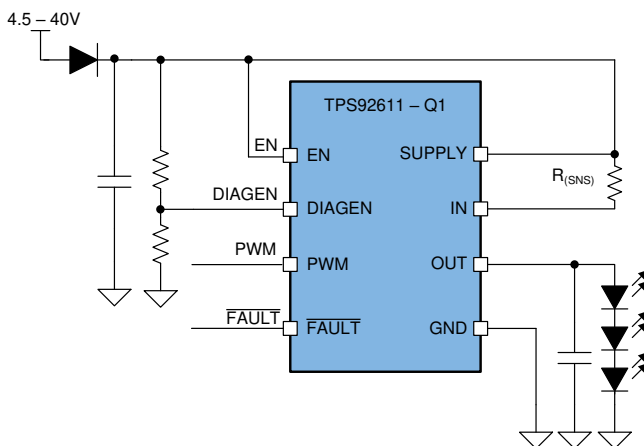
TPS92611-Q1デバイスは、自動車用バッテリーで動作する、シンプルなシングルチャネルのハイサイドLEDドライバです。単純かつ洗練されたソリューションで、LED診断機能を持ち、単一のLEDストリングに一定電流を供給できます。どれか1つに障害が発生すれば全体を障害とする機能は、TPS9261x-Q1、TPS9263x-Q1、TPS9283x-Q1といった他のLEDドライバとの連係が可能であるため、さまざまな要求に対応できます。

製品情報⁽¹⁾

型番	パッケージ	本体サイズ(公称)
TPS92611-Q1	MSOP (8)	3mmx3mm

(1) 提供されているすべてのパッケージについては、巻末の注文情報を参照してください。

代表的なアプリケーションの図



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4 改訂履歴

Revision A (April 2018) から Revision B に変更

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• 「 特長 」セクションに機能安全対応のリンクを追加	1
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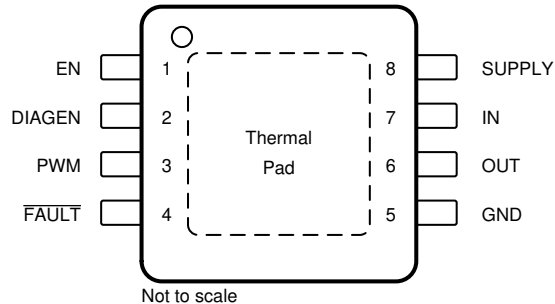
2018年1月発行のものから更新

Page

• 「低いドロップアウト電圧」の特長で、「基準」を「電流検出」に変更	1
• 「アプリケーション」セクションで「充電インジケータ」を「充電インレット・インジケータ」に変更	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 図 2	6
• Changed 図 4 and added a condition	7
• Changed graph and caption of 図 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 図 21	16
• Added two new paragraphs to the Detailed Design Procedure section	16
• Added the Power Supply Recommendations section	17

5 Pin Configuration and Functions

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



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
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	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⁾	±2000	V
		Charged-device model (CDM), per AEC Q100-011	±500	
			Corner pins (1, 4 and 8)	

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

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	UNIT
		DGN (MSOP)	
		8 PINS	
$R_{\theta JA}$	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

 $V_{(SUPPLY)} = 5\text{ V} - 40\text{ V}$, $T_J = -40^\circ\text{C}$ 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	$V_{(EN)} = 12\text{ V}$	1.5	3.3	4.5	μA

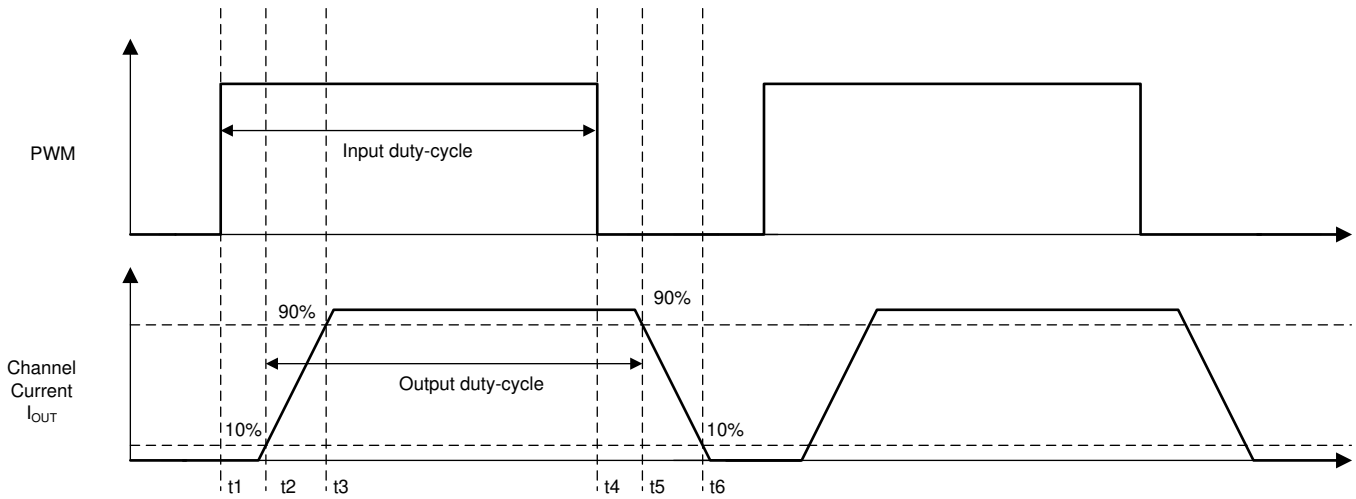
Electrical Characteristics (continued)

 $V_{(SUPPLY)} = 5\text{ V} - 40\text{ V}$, $T_J = -40^\circ\text{C}$ 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	$T_A = 25^\circ\text{C}$, $V_{(SUPPLY)} = 4.5\text{ V}$ to 18 V	94	98	102	mV
		$T_A = -40^\circ\text{C}$ to 125°C , $V_{(SUPPLY)} = 4.5\text{ V}$ 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	$V_{(OUT)} = 0\text{ V}$	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, $V_{(SUPPLY)} = 12\text{ V}$	5		7	V
$I_{(FAULT_pulldown)}$	$\overline{\text{FAULT}}$ internal pulldown current		500	750	1000	μA
$I_{(FAULT_pullup)}$	$\overline{\text{FAULT}}$ internal pullup current		5	8	12	μA
THERMAL PROTECTION						
$T_{(TSD)}$	Thermal shutdown junction temperature threshold			172		$^\circ\text{C}$
$T_{(TSD_HYS)}$	Thermal shutdown junction temperature hysteresis			15		$^\circ\text{C}$

6.6 Timing Requirements

		MIN	NOM	MAX	UNIT
$t_{(PWM_delay_rising)}$	PWM rising edge delay, 50% PWM voltage to 10% of output current, $t_2 - t_1$ as shown in Fig. 1		17		μs
$t_{(PWM_delay_falling)}$	PWM falling edge delay, 50% PWM voltage to 90% of output current, $t_5 - t_4$ as shown in Fig. 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

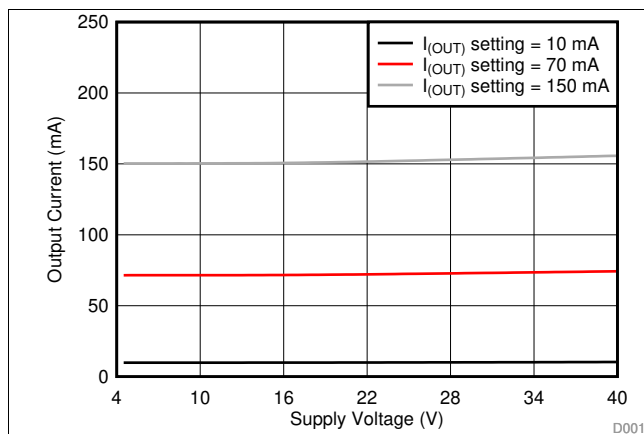


图 2. Output Current vs Supply Voltage

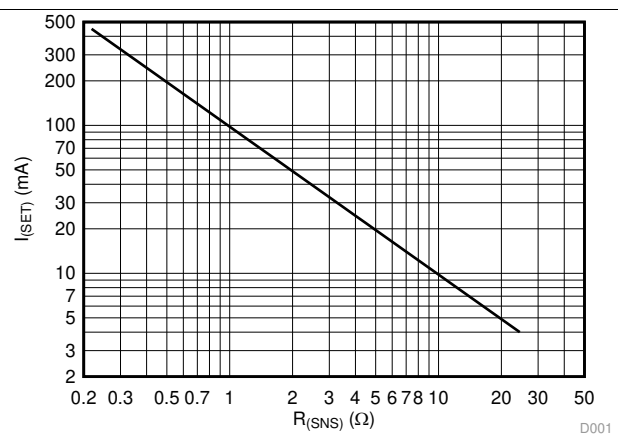


图 3. Output Current vs Current-Sense Resistor

Typical Characteristics (continued)

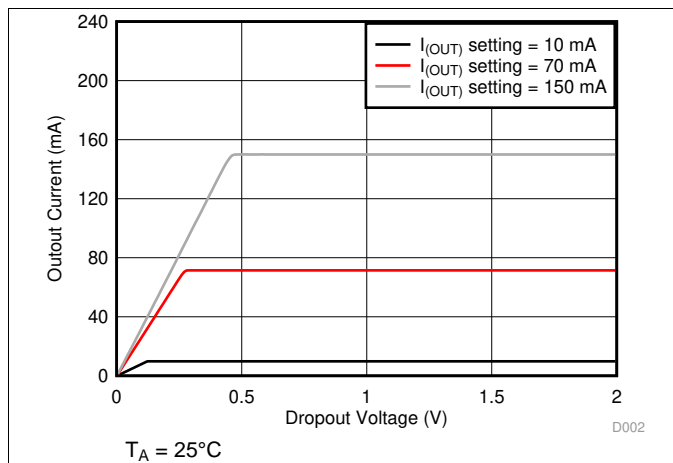


图 4. Output Current vs Dropout Voltage

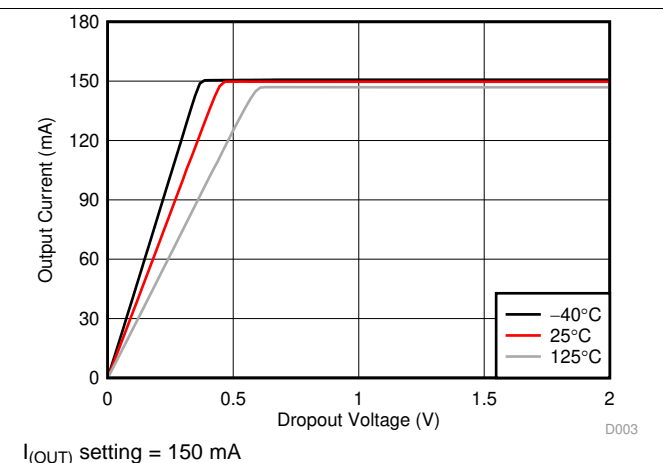


图 5. Output Current vs Dropout Voltage

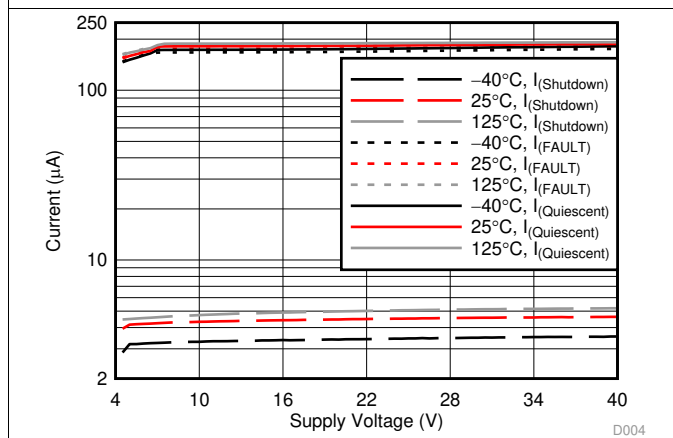


图 6. Shutdown, Quiescent, and Fault Current vs Supply Voltage

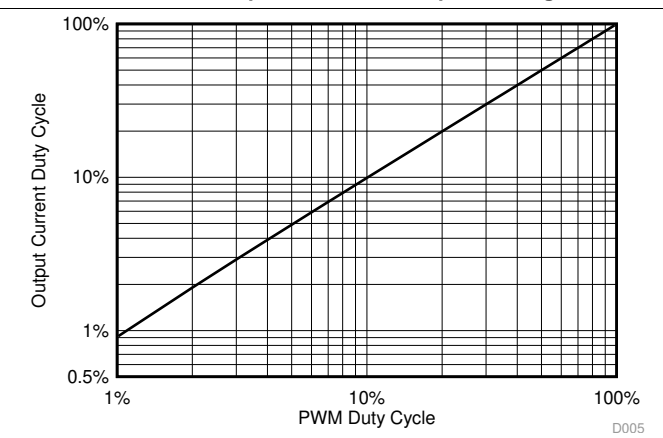


图 7. PWM Output Duty Cycle vs Input Duty Cycle

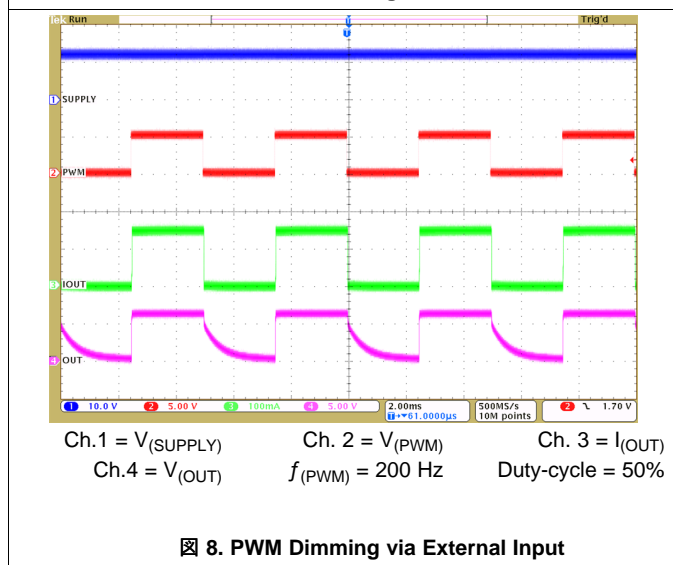


图 8. PWM Dimming via External Input

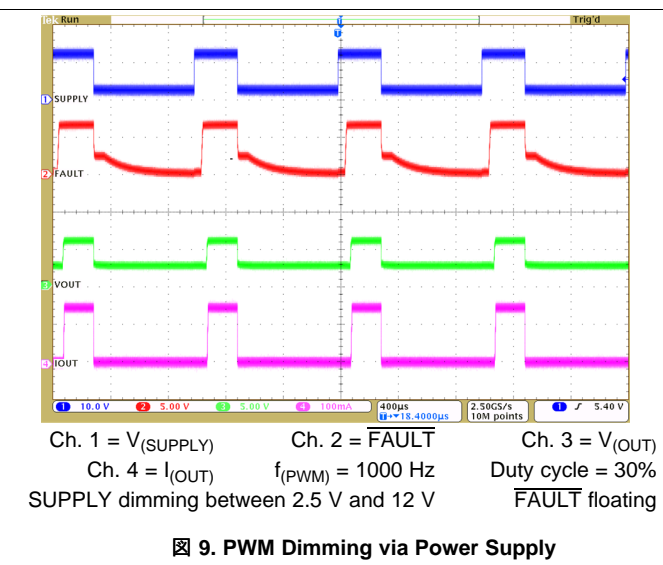
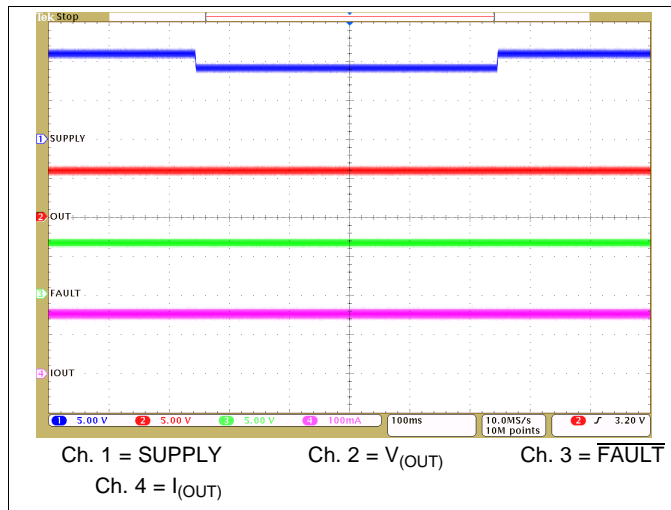
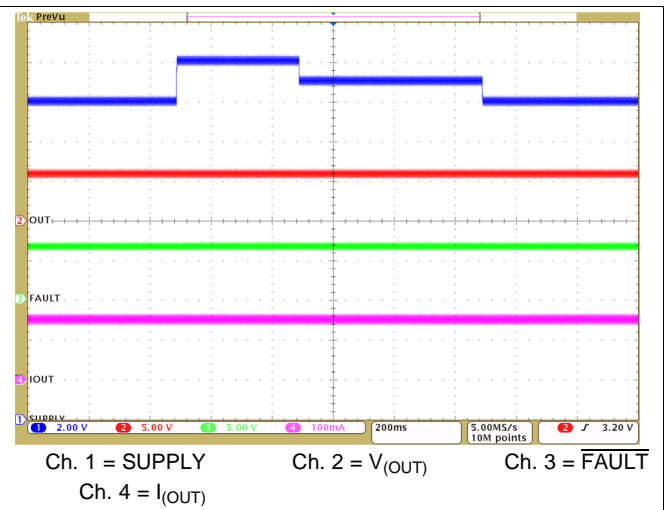


图 9. PWM Dimming via Power Supply

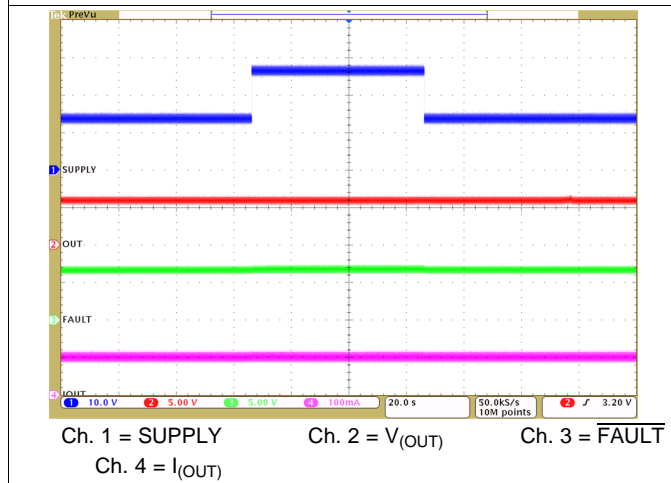
Typical Characteristics (continued)



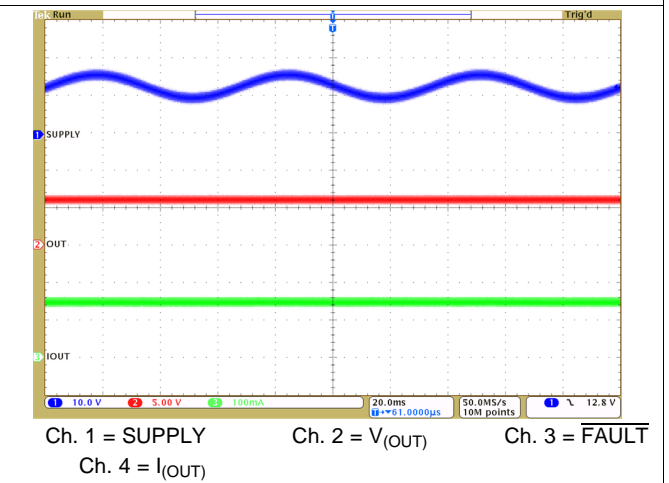
10. Transient Undervoltage



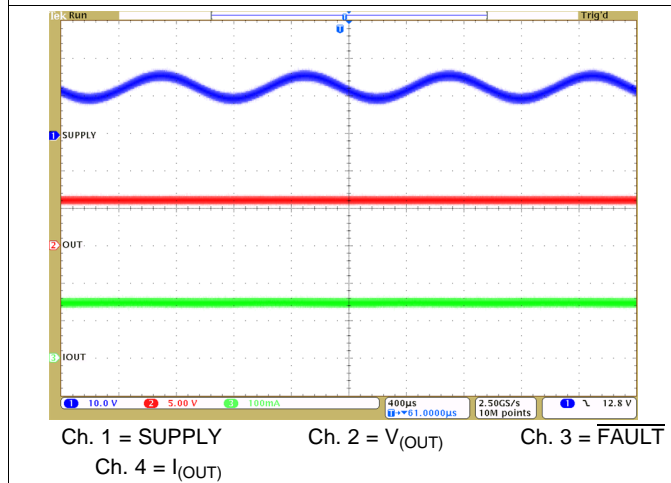
11. Transient Overvoltage



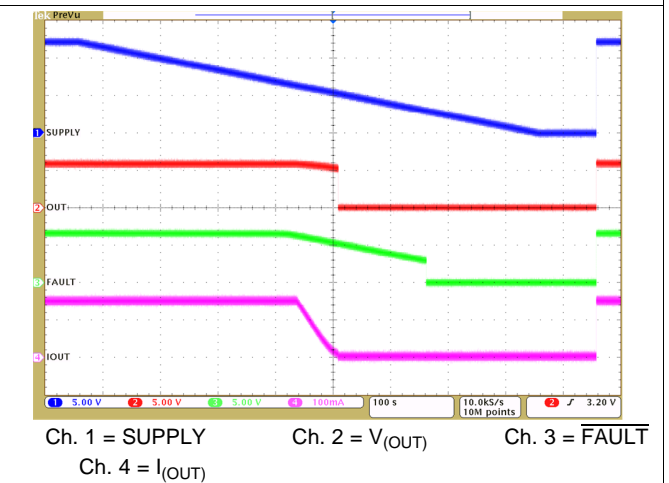
12. Jump Start



13. Superimposed Alternating Voltage, 15-Hz

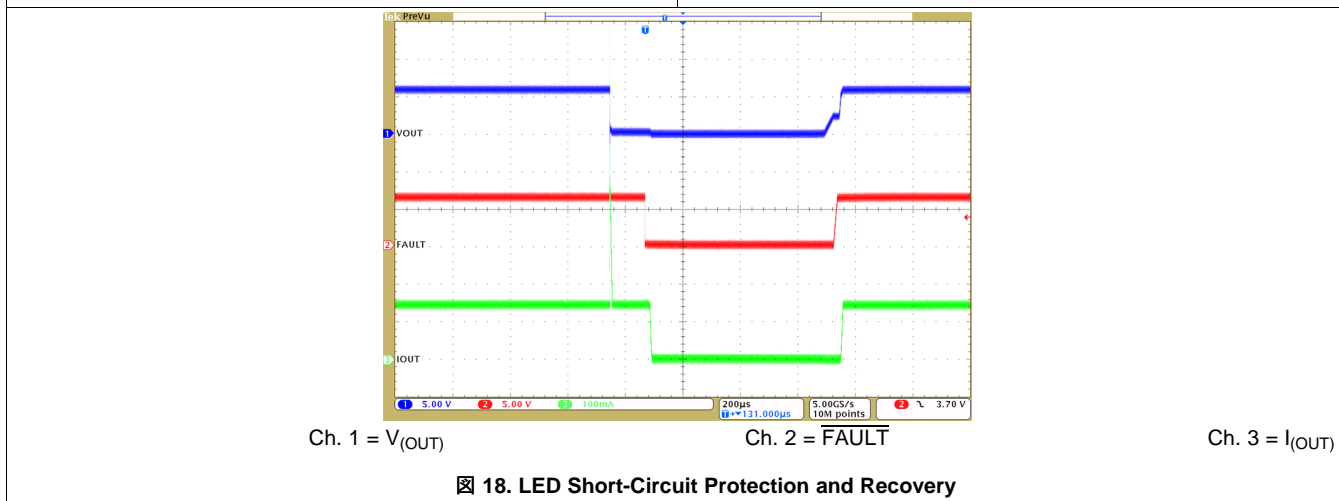
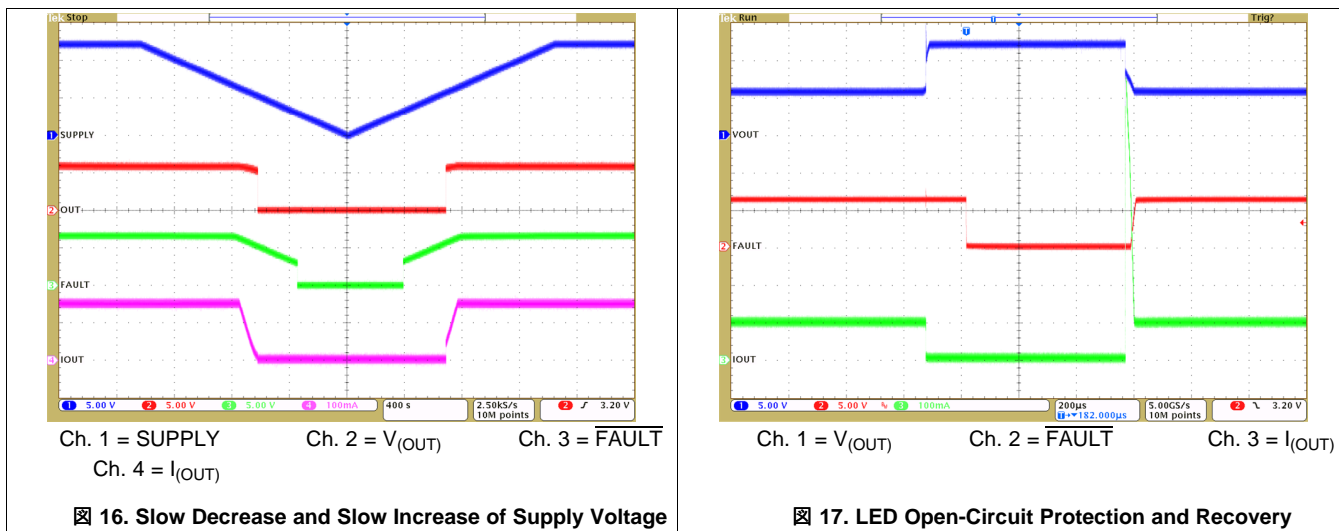


14. Superimposed Alternating Voltage, 1-kHz



15. Slow Decrease, Quick Increase of Supply Voltage

Typical Characteristics (continued)



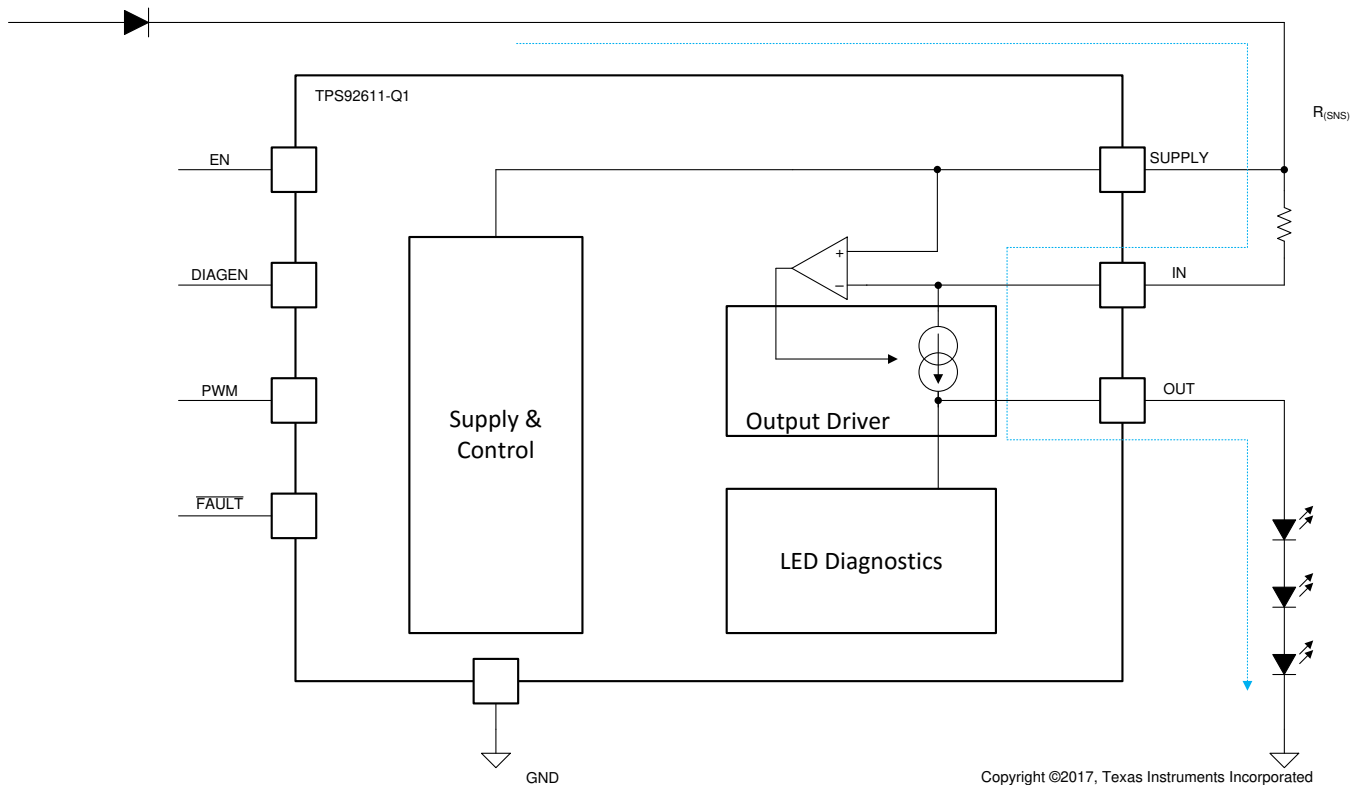
7 Detailed Description

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.

Feature Description (continued)

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.

Feature Description (continued)

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{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{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{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 $V_{(FAULT)}$ falls below $V_{IL(FAULT)}$, all outputs shut down for protection. The faulty channel keeps retrying until the fault is removed.

If \overline{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.

Feature Description (continued)
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
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 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
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 $V_{(SUPPLY)} \geq 4.5\text{ V}$

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 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

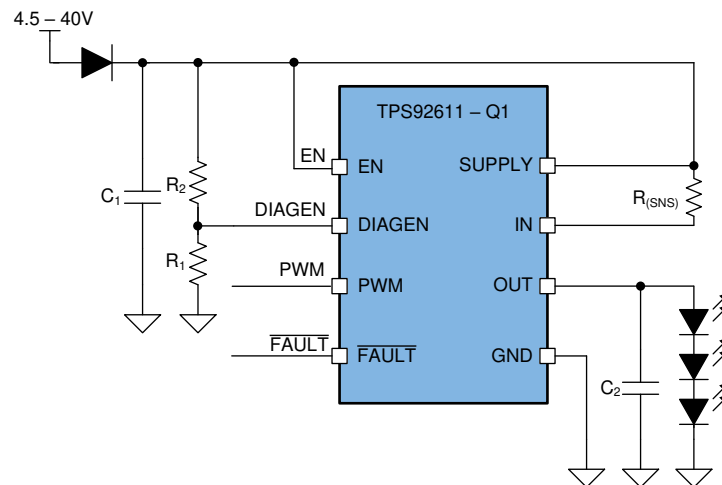
In automotive lighting applications, thermal performance and LED diagnostics are always design challenges for linear LED drivers.

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 [Figure 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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Figure 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 [Equation 1](#).

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

(2)

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

Typical Application (continued)

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.

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

Set $R_1 = 10 \text{ k}\Omega$, $R_2 = 65.6 \text{ k}\Omega$.

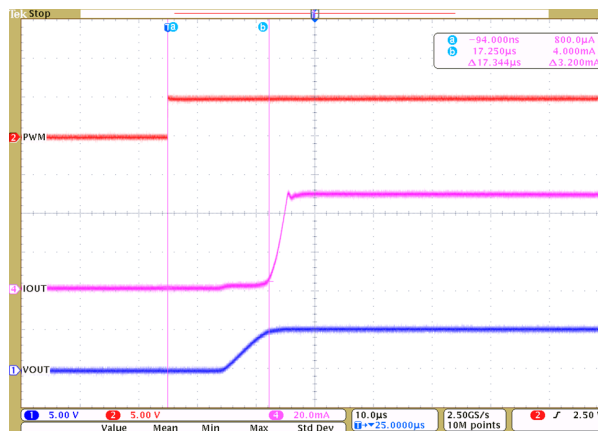
Total device power consumption at worst case is with 16-V input and LEDs at minimal forward voltage.

$$P_{(Max)} = (V_{(SUPPLY)} - V_{(CS_REG)} - V_{(OUT)}) \times I_{(LED)} + V_{(SUPPLY)} \times I_{(Quiescent)}$$

$$= (16 - 3 \times 1.9 - 0.098) \times 0.05 + 16 \times 0.00025 = 0.5141 \text{ W} \tag{4}$$

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



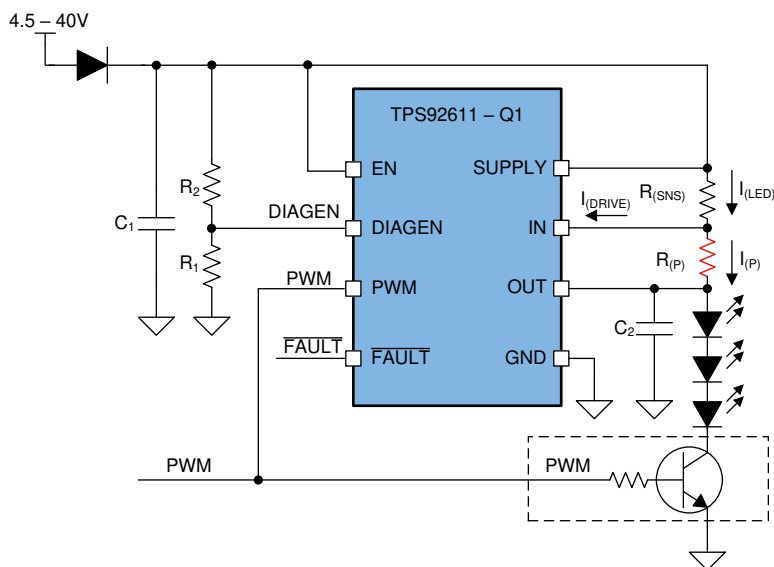
Ch. 1 = $V_{(OUT)}$ Ch. 2 = $V_{(PWM)}$ Ch. 4 = $I_{(OUT)}$

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.

Typical Application (continued)



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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 μ F 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 式 1.

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

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.

Typical Application (continued)

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

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.

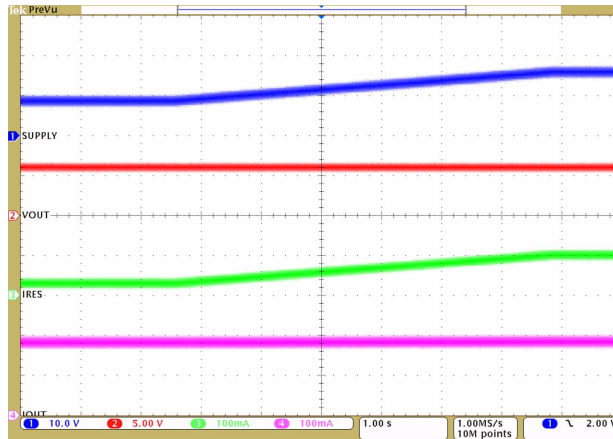
$$P_{(RP_MAX)} = \frac{(V_{(SUPPLY)} - V_{(CS_REG)} - V_{(OUT)})^2}{R_{(P)}} + V_{(SUPPLY)} \times I_{(Quiescent)}$$

$$= \frac{(16 - 3 \times 1.9 - 0.098)^2}{100} = 1.04 \text{ W} \quad (8)$$

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 k Ω 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

☒ 22. Constant Output Current With Increasing Supply Voltage

9 Power Supply Recommendations

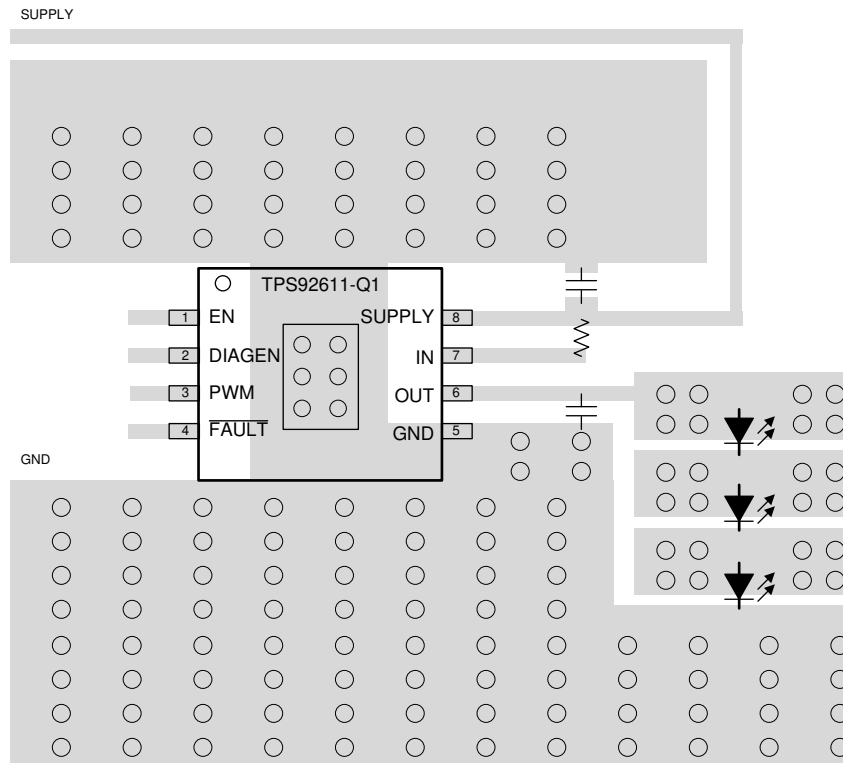
The TPS92611-Q1 device is qualified for automotive applications. The normal power supply connection is therefore to an automobile electrical system that provides a voltage within the range specified in the [Recommended Operating Conditions](#).

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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23. TPS92611-Q1 Example Layout Diagram

11 デバイスおよびドキュメントのサポート

11.1 ドキュメントのサポート

11.1.1 関連資料

関連資料については、以下を参照してください。

- 『[TPS92610-Q1 車載シングルチャネル・リニアLEDドライバ](#)』
- 『[TPS92612-Q1 車載シングルチャネル・リニアLEDドライバ](#)』
- 『[TPS92610-Q1 EVMユーザー・ガイド](#)』
- 『[車外照明アプリケーションにおけるTPS92630-Q1の最大出力電流の計算方法](#)』
- 『[センター・ハイマウント・ストップ・ランプ\(CHMSL\)用の車載リニアLEDドライバのリファレンス・デザイン](#)』
- 『[センター・ハイマウント・ストップ・ランプ\(CHMSL\)用の車載リニアLEDドライバのリファレンス・デザイン](#)』

11.2 ドキュメントの更新通知を受け取る方法

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11.3 コミュニティ・リソース

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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11.6 Glossary

[SLYZ022](#) — *TI Glossary*.

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

12 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。これらの情報は、指定のデバイスに対して提供されている最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

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
TPS92611QDGNRQ1	ACTIVE	HVSSOP	DGN	8	2500	RoHS & Green	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	1N3X	Samples

(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.

OBSELETE: 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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TAPE AND REEL INFORMATION

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

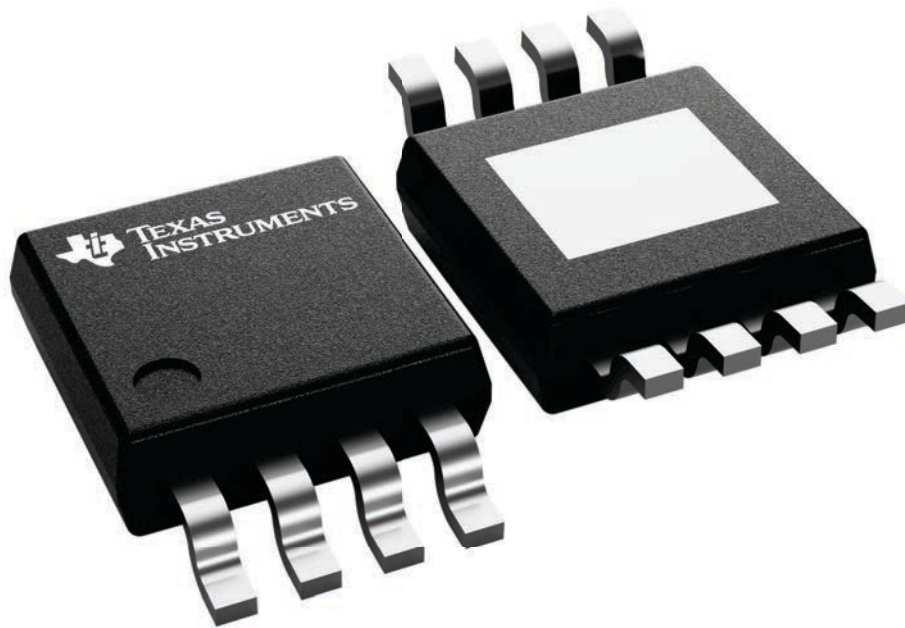
DGN 8

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.



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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.

EXAMPLE BOARD LAYOUT

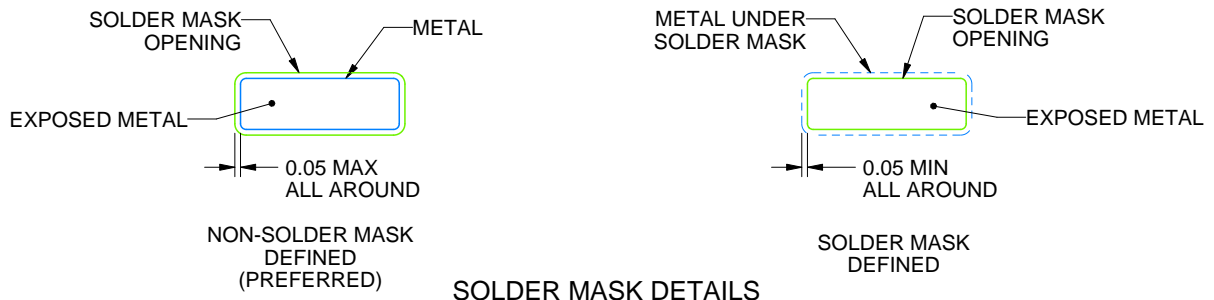
DGN0008G

PowerPAD™ VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



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.

EXAMPLE STENCIL DESIGN

DGN0008G

PowerPAD™ VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



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.

重要なお知らせと免責事項

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