# TPS2511 USB 专用充电端口控制器和限流电源开关

## 1 特性

- 支持将 D+ 线路短接至 D- 线路的 USB DCP
- 支持在 D+ 线路上应用 2V 电压而在 D- 线路上应用 2.7V 电压的 USB DCP（或在 D+ 线路上应用 2.7V 电压
  而在 D- 线路上应用 2V 电压的 USB DCP）
- 支持在 D+ 和 D- 线路上应用 1.2V 电压的 USB DCP
- 为所连接器件自动切换 D+ 和 D- 线路连接
- 针对输出短路保护的断续模式
- 具有用于 USB 线缆补偿的 $\overline{\text{CS}}$ 引脚
- 可编程电流限值（ILIM_SET 引脚）
- 在 2.3A（典型值）时具有精确的 ±10% 电流限制
- 70mΩ（典型值）高侧 MOSFET
- 兼容 USB 2.0 和 3.0 电源开关要求
- 工作电压范围：4.5V 至 5.5V
- 采用 8 引脚 MSOP-PowerPAD™封装

## 2 应用范围

- 车载 USB 电源充电器
- 具有 USB 端口的交流/直流适配器
- 其他 USB 充电器

## 3 说明

TPS2511 器件是 USB 专用充电端口 (DCP) 控制器和限流电源开关。它具有自动检测特性，可监控 USB 数据线路电压，并在数据线路上自动提供正确的电气特征，以便在下列专用充电方案中为器件兼容进行充电：
1. 分压器 DCP，需要分别在 D+ 和 D- 线路上应用 2.7V 和 2V 电压，或者分别在 D+ 和 D- 线路上应用 2V 和 2.7V 电压
2. BC1.2 DCP，需要将 D+ 线路短接至 D- 线路
3. D+ 和 D- 线路上的电压均为 1.2V

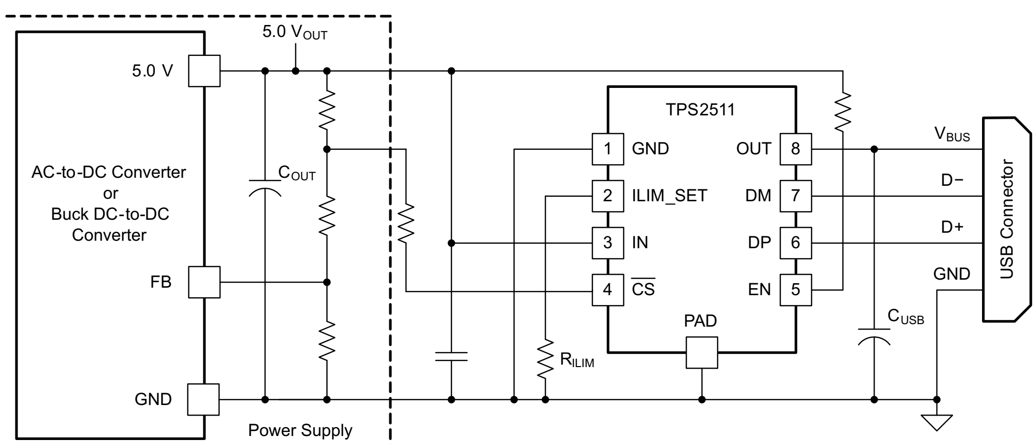
TPS2511 是一款 70mΩ 配电开关，适用于可能出现大型容性负载和短路问题的 应用 。此器件还在输出 (OUT) 电压少于 3.8V（典型值）时或者在过载情况下发生过热保护时提供打嗝模式。精准且可编程的电流限值为 应用提供了灵活性和便利性。TPS2511 提供一个 $\overline{\text{CS}}$ 引脚来进行 USB 线缆电阻补偿和一个 EN 引脚来控制器件的导通和关断。

器件信息[(1)]

| 器件型号 | 封装 | 封装尺寸（标称值） |
|---|---|---|
| TPS2511 | MSOP-PowerPAD（8） | 3.00mm x 3.00mm |

(1) 如需了解所有可用封装，请参阅产品说明书末尾的可订购产品附录。

简化电路原理图



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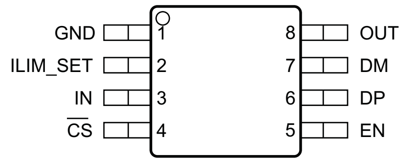
# 4 修订历史记录

**Changes from Original (June 2012) to Revision A** — **Page**

- 添加了 *ESD 额定值* 表、*特性 说明* 部分、*器件功能模式*、*应用和实施* 部分、*电源建议* 部分、*布局* 部分、*器件和文档支持* 部分以及*机械、封装和可订购信息* 部分 ... 1
- 已删除 *订购信息* 表，请参阅文档末尾的 POA。 ... 1

# 5 Pin Configuration and Functions

**DGN Package**
**8-Pin MSOP With PowerPAD™**
**Top View**




## Pin Functions

| PIN | | TYPE[(1)] | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| $\overline{CS}$ | 4 | O | Active-low, open-drain output. When OUT current is more than approximately half of the current limit set by a resistor on ILIM_SET pin, the output is active low. Maximum sink current is 10 mA. |
| DM | 7 | I/O | Connected to the D– or D+ line of USB connector. Provide the correct voltage with an attached portable equipment for DCP detection, high impedance while disabled. |
| DP | 6 | I/O | Connected to the D+ or D– line of USB connector. Provide the correct voltage with an attached portable equipment for DCP detection, high impedance while disabled. |
| EN | 5 | I | Logic-level control input. When it is high, turns power switch on, when it is low, turns power switch off and turns DP and DM into the high impedance state. |
| GND | 1 | G | Ground connection. |
| ILIM_SET | 2 | I | External resistor used to set current limiting Threshold. TI recommends 16.9 kΩ ≤ $R_{ILIM\_SET}$ ≤ 750 kΩ. |
| IN | 3 | P | Power supply input voltage connected to the power switch. Connect a ceramic capacitor with a value of 0.1-µF or greater from the IN pin to GND as close to the device as possible. |
| OUT | 8 | O | Power-switch output. Connect to VBUS of USB |
| PowerPAD | PowerPAD | G | Ground connection. |

(1) G = Ground, I = Input, O = Output, P = Power

# 6 Specifications

## 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| Voltage | IN | Supply voltage | –0.3 | 7 | V |
| | EN, ILIM_SET | Input voltage | –0.3 | 7 | |
| | OUT, $\overline{CS}$ | | –0.3 | 7 | |
| | IN to OUT | | –7 | 7 | |
| | DP output voltage | DM output | –0.3 | IN+0.3 or 5.7 | |
| | DP input voltage | DM input | –0.3 | IN+0.3 or 5.7 | |
| Current | DP input current, DM input current | Continuous output sink current | | 35 | mA |
| | DP output current, DM output current | Continuous output source current | | 35 | |
| | $\overline{CS}$ | Continuous output sink current | | 10 | |
| | ILIM_SET | Continuous output source current | Internally limited | | |
| Temperature | Operating junction temperature, $T_J$ | | Internally limited | | |
| | Storage temperature, $T_{stg}$ | | –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.

## 6.2 ESD Ratings

| | | | | VALUE | UNIT |
|---|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1) | All pins except 6 and 7 | ±2000 | V |
| | | | Pins 6 and 7 | ±7500 | |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101(2) | | ±500 | |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

## 6.3 Recommended Operating Conditions

voltages are referenced to GND (unless otherwise noted), positive current are into pins.

| | | MIN | MAX | UNIT |
|---|---|---|---|---|
| $V_{IN}$ | Input voltage of IN | 4.5 | 5.5 | V |
| $V_{\overline{CS}}$ | Input voltage of $\overline{CS}$ | 0 | 5.5 | |
| $V_{EN}$ | Input voltage of EN | 0 | 5.5 | |
| $V_{DP}$ | DP data line input voltage | 0 | 5.5 | |
| $V_{DM}$ | DM data line input voltage | 0 | 5.5 | |
| $I_{DP}$ | Continuous sink/source current | | ±10 | mA |
| $I_{DM}$ | Continuous sink/source current | | ±10 | |
| $I_{\overline{CS}}$ | Continuous sink current | | 2 | |
| $I_{OUT}$ | Continuous output current of OUT | | 2.2 | A |
| $R_{ILIM\_SET}$ | A resistor of current limit, ILIM_SET to GND | 16.9 | 750 | kΩ |
| $T_J$ | Operating junction temperature | –40 | 125 | ºC |

## 6.4 Thermal Information

| THERMAL METRIC(1) | | TPS2511 DGN (MSOP-PowerPAD) 8 PINS | UNIT |
|---|---|---|---|
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 65.2 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 53.3 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 36.9 | °C/W |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 3.9 | °C/W |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 36.6 | °C/W |
| $R_{\theta JC(bot)}$ | Junction-to-case (bottom) thermal resistance | 13.4 | °C/W |

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

## 6.5 Electrical Characteristics

Conditions are –40°C ≤ ($T_J$ = $T_A$) ≤ 125°C, 4.5 V ≤ $V_{IN}$ ≤ 5.5 V, $V_{EN}$ = $V_{IN}$ and $R_{ILIM\_SET}$ = 22.1 kΩ. Positive current are into pins. Typical values are at 25°C. All voltages are with respect to GND (unless otherwise noted).

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **POWER SWITCH** | | | | | | |
| $R_{DS(on)}$ | Static drain-source ON-state resistance | $I_{OUT}$ = 2 A | | 70 | 120 | mΩ |
| | | $I_{OUT}$ = 2 A, –40ºC ≤ ($T_J$ =$T_A$) ≤ 85ºC | | 70 | 105 | |
| | | $I_{OUT}$ = 2 A, $T_J$ =$T_A$ = 25ºC | | 70 | 84 | |
| $I_{REV}$ | Reverse leakage current | $V_{OUT}$ = 5.5 V, $V_{IN}$ = $V_{EN}$ = 0 V | | 0.01 | 2 | µA |
| **DISCHARGE** | | | | | | |
| $R_{DCHG}$ | Discharge resistance | $V_{OUT}$ = 4 V | 400 | 500 | 630 | Ω |
| **CURRENT LIMIT** | | | | | | |
| $I_{OS}$ | OUT short-circuit current limit | $R_{ILIM\_SET}$ = 44.2 kΩ | 1060 | 1160 | 1270 | mA |
| | | $R_{ILIM\_SET}$ = 22.1 kΩ | 2110 | 2300 | 2550 | |
| | | $R_{ILIM\_SET}$ = 16.9 kΩ | 2760 | 3025 | 3330 | |
| **HICCUP MODE** | | | | | | |
| $V_{OUT\_SHORT}$ | OUT voltage threshold of going into hiccup mode | $V_{IN}$ = 5 V, $R_{ILIIM\_SET}$ = 210 kΩ | 3.6 | 3.8 | 4.1 | V |
| **UNDERVOLTAGE LOCKOUT** | | | | | | |
| $V_{UVLO}$ | IN UVLO threshold voltage, rising | | 3.9 | 4.1 | 4.3 | V |
| | Hysteresis(1) | | | 100 | | mV |
| **SUPPLY CURRENT** | | | | | | |
| $I_{IN\_OFF}$ | Disabled, IN supply current | $V_{EN}$ = 0 V, $V_{IN}$ = 5.5 V, –40ºC ≤ $T_J$ ≤ 85ºC | | 0.1 | 2 | µA |
| $I_{IN\_ON}$ | Enabled, IN supply current | $V_{EN}$ = $V_{IN}$, $R_{ILIM\_SET}$ = 210 kΩ | | 180 | 230 | |
| **THERMAL SHUTDOWN** | | | | | | |
| | Temperature rising threshold(1) | Not in current limit | 155 | | | ºC |
| | | In current limit | 135 | | | |
| | Hysteresis (1) | | | 10 | | |
| **OUT CURRENT DETECTION** | | | | | | |
| $I_{HCC\_TH}$ | Load detection current threshold, rising (1) | $R_{ILIM\_SET}$ = 22.1 kΩ | | 1060 | | mA |
| | | $R_{ILIM\_SET}$ = 44.2 kΩ | | 560 | | |
| $I_{HCC\_TH\_HYS}$ | Load detection current Hysteresis(1) | $R_{ILIM\_SET}$ = 22.1 kΩ | | 230 | | mA |
| | | $R_{ILIM\_SET}$ = 44.2 kΩ | | 120 | | |
| $V_{\overline{CS}}$ | $\overline{CS}$ output active-low voltage(1) | $I_{\overline{CS}}$ = 1 mA | 0 | 80 | 140 | mV |

(1) Specified by design. Not production tested.

## Electrical Characteristics (continued)

Conditions are –40°C ≤ ($T_J$ = $T_A$) ≤ 125°C, 4.5 V ≤ $V_{IN}$ ≤ 5.5 V, $V_{EN}$ = $V_{IN}$ and $R_{ILIM\_SET}$ = 22.1 kΩ. Positive current are into pins. Typical values are at 25°C. All voltages are with respect to GND (unless otherwise noted).

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **ENABLE INPUT (EN)** | | | | | | |
| $V_{EN\_TRIP}$ | EN threshold voltage, falling | | 0.9 | 1.1 | 1.65 | V |
| $V_{EN\_TRIP\_HYS}$ | Hysteresis | | 100 | 200 | 300 | mV |
| $I_{EN}$ | Leakage current | $V_{EN}$ = 0 V or $V_{EN}$ = 5.5 V | –0.5 | | 0.5 | µA |
| **BC 1.2 DCP MODE (SHORT MODE)** | | | | | | |
| $R_{DPM\_SHORT}$ | DP and DM shorting resistance | $V_{DP}$ = 0.8 V, $I_{DM}$ = 1 mA | | 125 | 200 | Ω |
| $R_{DCHG\_SHORT}$ | Resistance between DP/DM and GND | $V_{DP}$ = 0.8 V | 400 | 700 | 1300 | kΩ |
| $V_{DPL\_TH\_DETACH}$ | Voltage threshold on DP under which the device goes back to divider mode | | 310 | 330 | 350 | mV |
| $V_{DPL\_TH\_DETACH\_HYS}$ | Hysteresis | | | 50 (1) | | mV |
| **DIVIDER MODE** | | | | | | |
| $V_{DP\_2.7V}$ | DP output voltage | $V_{IN}$ = 5 V | 2.57 | 2.7 | 2.84 | V |
| $V_{DM\_2.0V}$ | DM output voltage | $V_{IN}$ = 5 V | 1.9 | 2 | 2.1 | V |
| $R_{DP\_PAD1}$ | DP output impedance | $I_{DP}$ = –5 µA | 24 | 30 | 40 | kΩ |
| $R_{DM\_PAD1}$ | DM output impedance | $I_{DM}$ = –5 µA | 24 | 30 | 40 | kΩ |
| **1.2 V / 1.2 V MODE** | | | | | | |
| $V_{DP\_1.2V}$ | DP output voltage | $V_{IN}$ = 5 V | 1.12 | 1.2 | 1.28 | V |
| $V_{DM\_1.2V}$ | DM output voltage | $V_{IN}$ = 5 V | 1.12 | 1.2 | 1.28 | V |
| $R_{DP\_PAD2}$ | DP output impedance | $I_{DP}$ = –5 uA | 80 | 105 | 130 | kΩ |
| $R_{DM\_PAD2}$ | DM output impedance | $I_{DM}$ = –5 uA | 80 | 105 | 130 | kΩ |

## 6.6 Switching Characteristics

Conditions are –40°C ≤ ($T_J$ = $T_A$) ≤ 125°C, 4.5 V ≤ $V_{IN}$ ≤ 5.5 V, $V_{EN}$ = $V_{IN}$ and $R_{ILIM\_SET}$ = 22.1 kΩ. Positive current are into pins. Typical values are at 25°C. All voltages are with respect to GND (unless otherwise noted).

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| **POWER SWITCH** | | | | | | |
| $t_r$ | OUT voltage rise time | $C_L$ = 1 µF, $R_L$ = 100 Ω, $V_{IN}$ = 5 V see Figure 1, Figure 3 | | 1 | 1.5 | ms |
| $t_f$ | OUT voltage fall time | $C_L$ = 1 µF, $R_L$ = 100 Ω, $V_{IN}$ = 5 V see Figure 1, Figure 3 | 0.2 | 0.35 | 0.5 | ms |
| **CURRENT LIMIT** | | | | | | |
| $t_{IOS}$ | Short circuit response time (1) | $V_{IN}$ = 5 V, $R_L$ = 50 mΩ, 2 inches lead length, See Figure 4 | | 1.5 | | µs |
| **HICCUP MODE** | | | | | | |
| $t_{OS\_DEG}$ | ON-time of hiccup mode (1) | $V_{IN}$ = 5 V, $R_L$ = 0 | | 16 | | ms |
| $t_{SC\_TURN\_OFF}$ | OFF-time of hiccup mode (1) | $V_{IN}$ = 5 V, $R_L$ = 0 | | 12 | | s |
| **OUT CURRENT DETECTION** | | | | | | |
| $t_{CS\_EN}$ | $\overline{CS}$ deglitch time during turning on (1) | $I_{\overline{CS}}$ = 1 mA | | 8 | | ms |
| **ENABLE INPUT (EN)** | | | | | | |
| $t_{on}$ | OUT voltage turnon time | $C_L$ = 1 µF, $R_L$ = 100 Ω, see Figure 1, Figure 2 | | 2.6 | 5 | ms |
| $t_{off}$ | OUT voltage turnoff time | $C_L$ = 1 µF, $R_L$ = 100 Ω, see Figure 1, Figure 2 | | 1.7 | 3 | ms |

(1) Specified by design. Not production tested.

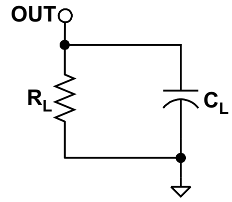



Figure 1. Output Rise and Fall Test Load

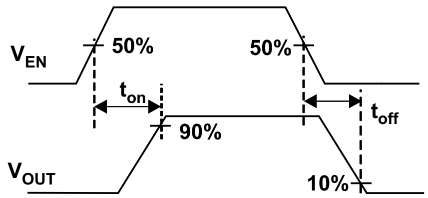



Figure 2. Enable Timing, Active High Enable

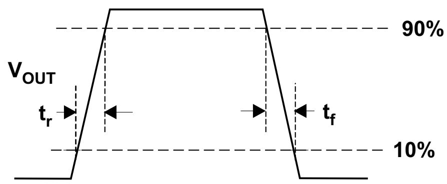



Figure 3. Power On and Power Off

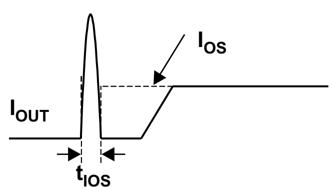



Figure 4. Output Short-Circuit Parameters

## 6.7 Typical Characteristics

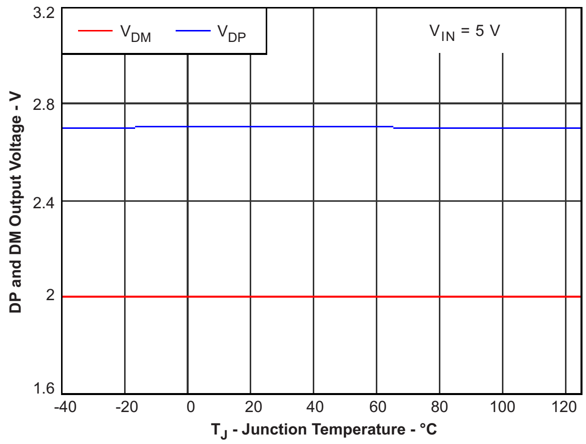



**Figure 5. DP and DM Output Voltage vs Temperature**

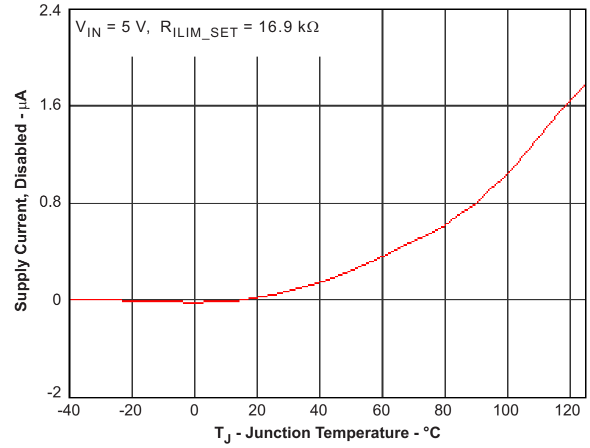



**Figure 6. Supply Current Disabled vs Temperature**

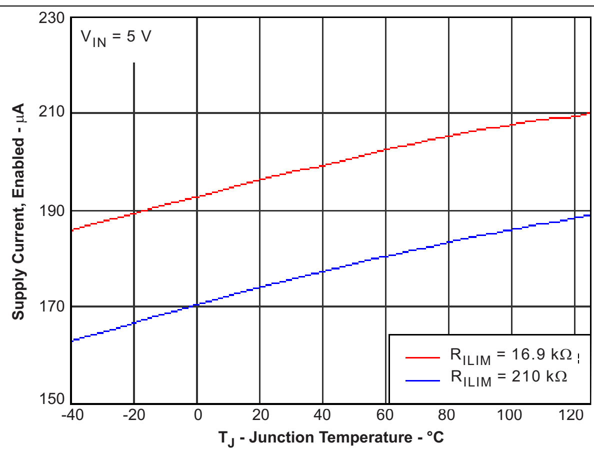



**Figure 7. Supply Current Enabled vs Temperature**

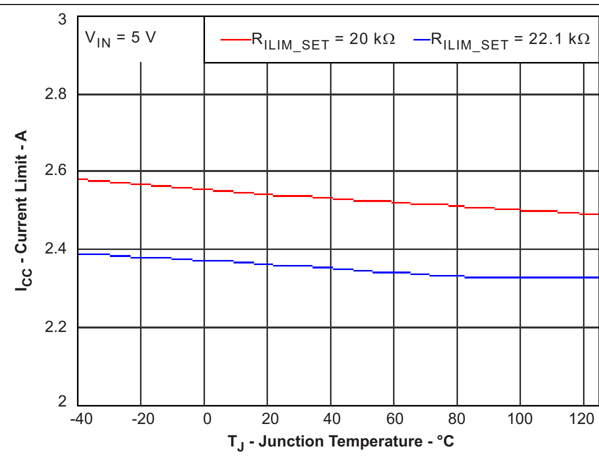



**Figure 8. Current Limit vs Temperature**

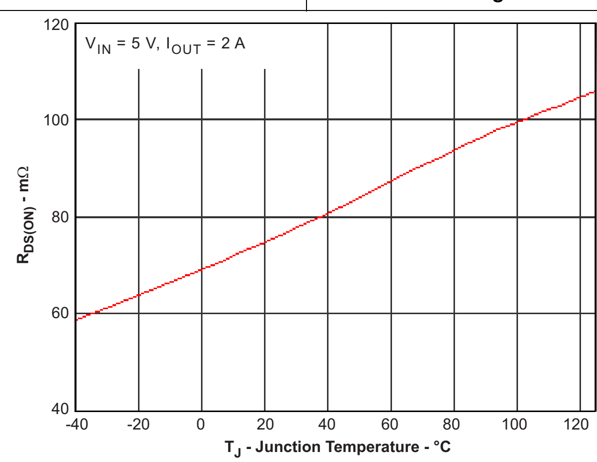



**Figure 9. Power Switch ON-Resistance ($R_{DS(ON)}$) vs Temperature**

# 7 Detailed Description

## 7.1 Overview

The following overview references various industry standards. TI always recommends consulting the latest standard to ensure the most recent and accurate information.

Rechargeable portable equipment requires an external power source to charge its batteries. USB ports are convenient locations for charging because of an available 5-V power source. Universally accepted standards are required to ensure host and client-side devices meet the power management requirements. Traditionally, USB host ports following the USB 2.0 Specification must provide at least 500 mA to downstream client-side devices. Because multiple USB devices can be attached to a single USB port through a bus-powered hub, it is the responsibility of the client-side device to negotiate the power allotment from the host to ensure the total current draw does not exceed 500 mA. The TPS2511 provides 100 mA of current to each USB device. Each USB device can subsequently request more current, which is granted in steps of 100 mA up 500 mA total. The host may grant or deny the request based on the available current.

Additionally, the success of the USB technology makes the micro-USB connector a popular choice for wall adapter cables. This allows a portable device to charge from both a wall adapter and USB port with only one connector.

One common difficulty has resulted from this. As USB charging has gained popularity, the 500-mA minimum defined by the USB 2.0 Specification or 900 mA defined in the USB 3.0 Specification, has become insufficient for many handsets, tablets, and personal media players (PMP), which have a higher-rated charging current. Wall adapters and car chargers can provide much more current than 500 mA or 900 mA to fast charge portable devices. Several new standards have been introduced defining protocol handshaking methods that allow host and client devices to acknowledge and draw additional current beyond the 500 mA (defined in the USB 2.0 Specification) or 900 mA (defined in the USB 3.0 Specification) minimum while using a single micro-USB input connector.

The TPS2511 supports three of the most common protocols:

- USB Battery Charging Specification, Revision 1.2 (BC1.2)
- Chinese Telecommunications Industry Standard YD/T 1591-2009
- Divider Mode

In these protocols there are three types of charging ports defined to provide different charging current to client-side devices. These charging ports are defined as:

- Standard downstream port (SDP)
- Charging downstream port (CDP)
- Dedicated charging port (DCP)

The BC1.2 Specification defines a charging port as a downstream facing USB port that provides power for charging portable equipment.

Table 1 lists different port operating modes according to the BC1.2 Specification.

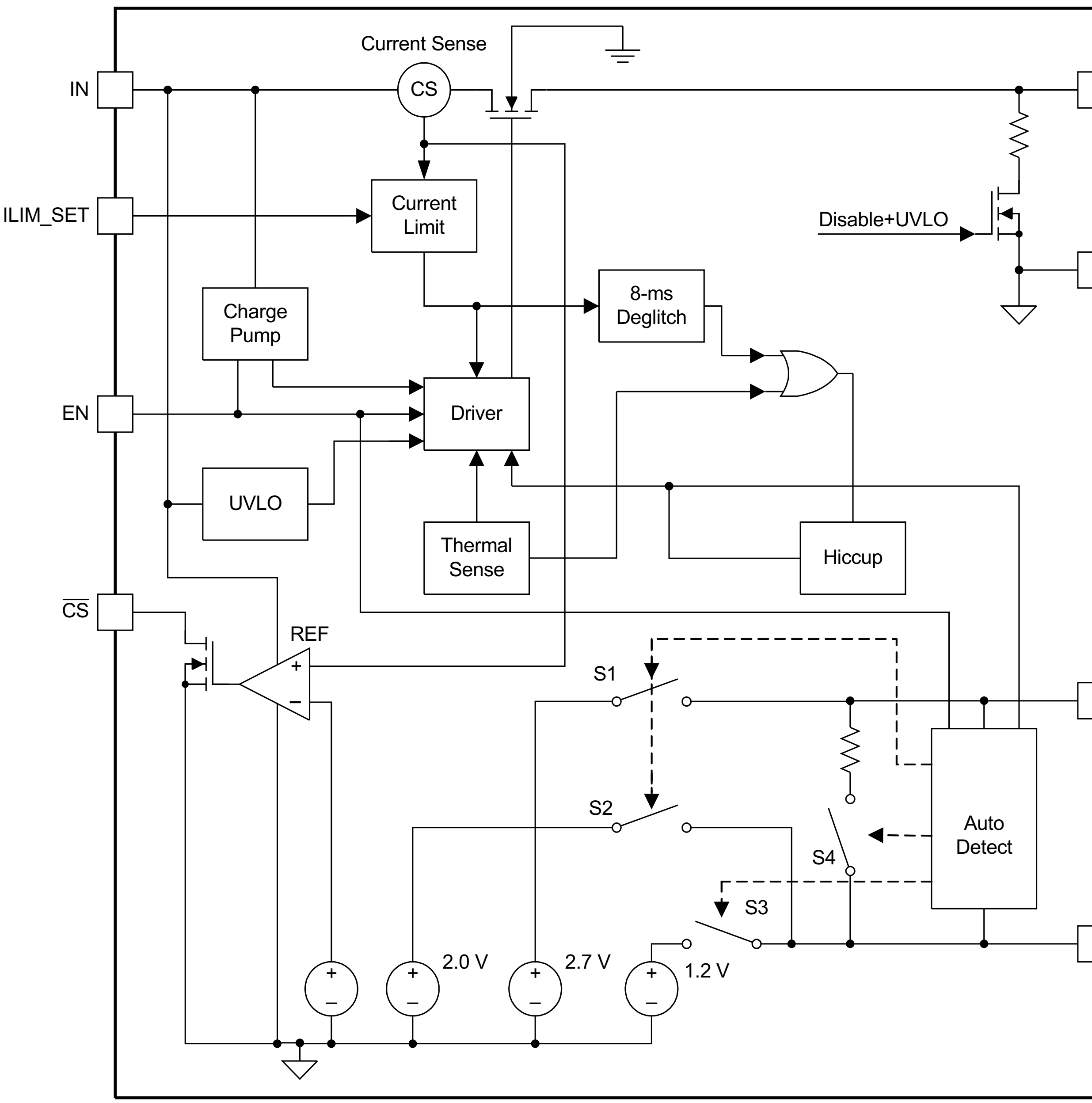
**Table 1. Operating Modes Table**

| PORT TYPE | SUPPORTS USB 2.0 COMMUNICATION | MAXIMUM ALLOWABLE CURRENT DRAWN BY PORTABLE EQUIPMENT (A) |
|---|---|---|
| SDP (USB 2.0) | Yes | 0.5 |
| SDP (USB 3.0) | Yes | 0.9 |
| CDP | Yes | 1.5 |
| DCP | No | 1.5 |

The BC1.2 Specification defines the protocol necessary to allow portable equipment to determine what type of port it is connected to so that it can allot its maximum allowable current drawn. The hand-shaking process is two steps. During step one, the primary detection, the portable equipment outputs a nominal 0.6-V output on its D+ line and reads the voltage input on its D– line. The portable device concludes it is connected to a SDP if the voltage is less than the nominal data detect voltage of 0.3 V. The portable device concludes that it is connected to a Charging Port if the D– voltage is greater than the nominal data detect voltage of 0.3 V and less than 0.8 V.

The second step, the secondary detection, is necessary for portable equipment to determine between a CDP and a DCP. The portable device outputs a nominal 0.6-V output on its D– line and reads the voltage input on its D+ line. The portable device concludes it is connected to a CDP if the data line being remains is less than the nominal data detect voltage of 0.3 V. The portable device concludes it is connected to a DCP if the data line being read is greater than the nominal data detect voltage of 0.3 V and less than 0.8 V.

## 7.2 Functional Block Diagram





## 7.3 Feature Description

### 7.3.1 Overcurrent Protection

During an overload condition, the TPS2511 maintains a constant output current and reduces the output voltage accordingly. If the output voltage falls to less than 3.8 V for 16 ms, the TPS2511 turns off the output for a period of 12 seconds as shown in Figure 10. This operation is referred to as hiccup mode. The device stays in hiccup mode (power cycling) until the overload condition is removed. Therefore the average output current is significantly reduced to greatly improve the thermal stress of the device while the OUT pin is shorted.

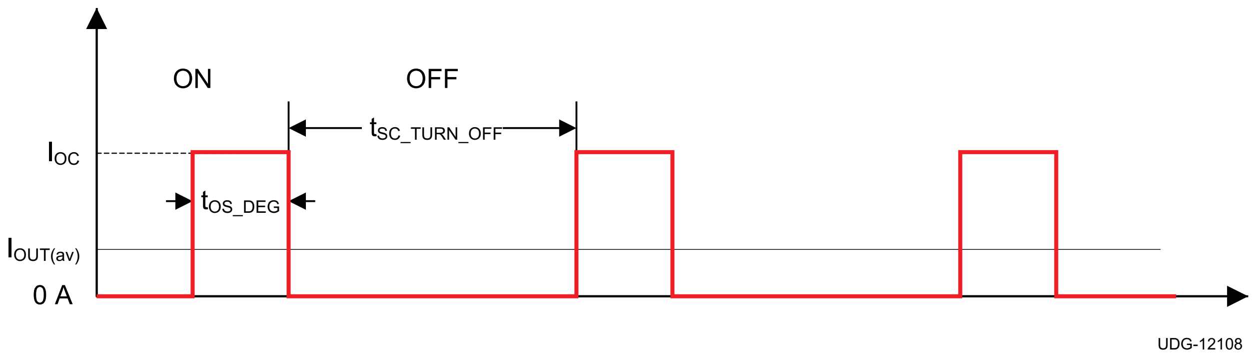



**Figure 10. OUT Pin Short-Circuit Current in Hiccup Mode**

Two possible overload conditions can occur. In the first condition, the output has been shorted before the device is enabled or before the voltage of IN has been applied. The TPS2511 senses the short and immediately switches into hiccup mode of constant-current limiting. In the second condition, a short or an overload occurs while the device is enabled. At the instant the overload occurs, high currents may flow for several microseconds before the current limit circuit can react. The device operates in constant-current mode for a period of 16 ms after the current limit circuit has responded, then switches into hiccup mode (power cycling).

## Feature Description (continued)

### 7.3.2 Current Limit Threshold

The TPS2511 has a current limiting threshold that is externally programmed with a resistor. Equation 1 and Figure 11 help determine the typical current limit threshold.

$$I_{OS\_TYP} = \frac{51228}{R_{ILIM}}$$

where

- $I_{OS\_TYP}$ is in mA and $R_{ILIM}$ is in kΩ
- $I_{OS\_TYP}$ has a better accuracy if $R_{ILIM}$ is less than 210 kΩ (1)

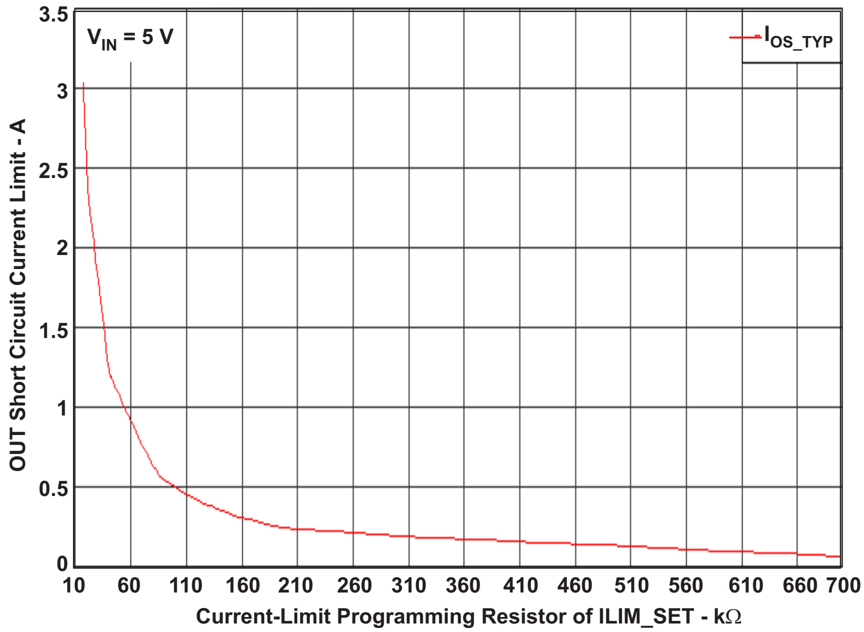



**Figure 11. Typical Current Limit vs Programming Resistor**

### 7.3.3 Current-Sensing Report ($\overline{CS}$)

The $\overline{CS}$ open-drain output is asserted immediately when the OUT pin current is more than about half of the current limit set by a resistor on ILIM_SET pin. Built-in hysteresis improves the ability to resist current noise on the OUT pin. The $\overline{CS}$ output is active low. The recommended operating sink current is less than 2 mA and maximum sink current is 10 mA.

### 7.3.4 Undervoltage Lockout (UVLO) and Enable (EN)

The undervoltage lockout (UVLO) circuit disables the power switch and other functional circuits until the input voltage reaches the UVLO turnon threshold. Built-in hysteresis prevents unwanted oscillations on the output due to input voltage drop from large current surges.

The logic input of the EN pin disables all of the internal circuitry while maintaining the power switch off. A logic-high input on the EN pin enables the driver, control circuits, and power switch. The EN input voltage is compatible with both TTL and CMOS logic levels.

### 7.3.5 Soft Start, Reverse Blocking, and Discharge Output

The power MOSFET driver incorporates circuitry that controls the rise and fall times of the output voltage to limit large current and voltage surges on the input supply, and provides built-in soft-start functionality. The TPS2511 power switch blocks current from the OUT pin to the IN pin when turned off by the UVLO or disabled. The TPS2511 includes an output discharge function. A 500-Ω (typical) discharge resistor dissipates stored charge and leakage current on the OUT pin when the device is in UVLO or disabled. However as this circuit is biased from the IN pin, the output discharge is not active when the input approaches 0 V.

## Feature Description (continued)

### 7.3.6 Thermal Sense

The TPS2511 provides thermal protection from two independent thermal-sensing circuits that monitor the operating temperature of the power distribution switch and turnoff for 12 s (typical) if the temperature exceeds recommended operating conditions. The device operates in constant-current mode during an overcurrent condition and OUT pin voltage is greater than 3.8 V (typical), which has a relatively large voltage drop across power switch. The power dissipation in the package is proportional to the voltage drop across the power switch, so the junction temperature rises during the overcurrent condition. The first thermal sensor turns off the power switch when the die temperature exceeds 135°C and the device is within the current limit. The second thermal sensor turns off the power switch when the die temperature exceeds 155°C regardless of whether the power switch is in current limit. Hysteresis is built into both thermal sensors, and the switch turns on after the device has cooled approximately 10°C. The switch continues to cycle off and on until the fault is removed.

### 7.3.7 $V_{BUS}$ Voltage Drop Compensation

Figure 12 shows a USB charging design using the TPS2511. In general, $V_{BUS}$ has some voltage loss due to USB cable resistance and TPS2511 power switch ON-state resistance. The sum of voltage loss is likely several hundred millivolts from 5-$V_{OUT}$ to $V_{PD\_IN}$ that is the input voltage of PD while the high charging current charges the PD. For example, in Figure 13, assuming that the loss resistance is 170 mΩ (includes 100 mΩ of USB cable resistance and 70 mΩ of power switch resistance) and 5 $V_{OUT}$ is 5 V, the input voltage of PD ($V_{PD\_IN}$) is about 4.66 V at 2 A (see Figure 13).

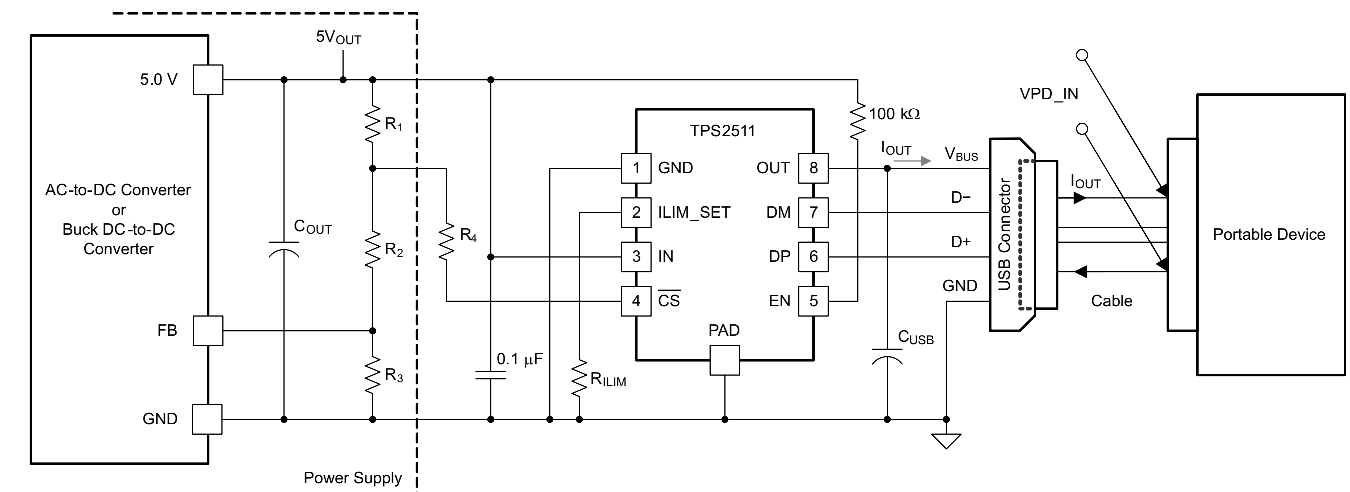





**Figure 12. TPS2511 Charging System Schematic Diagram**

The charging current of most portable devices is less than their maximum charging current while $V_{PD\_IN}$ is less than the certain voltage value. Furthermore, actual charging current of PD decreases with input voltage falling. Therefore, a portable devices cannot accomplish a fast charge with its maximum charging rated current if $V_{BUS}$ voltage drop across the power path is not compensated at the high charging current. The TPS2511 provides CS pin to report the high charging current for USB chargers to increase the 5-$V_{OUT}$ voltage. This is shown by the solid lines of Figure 13.

## Feature Description (continued)

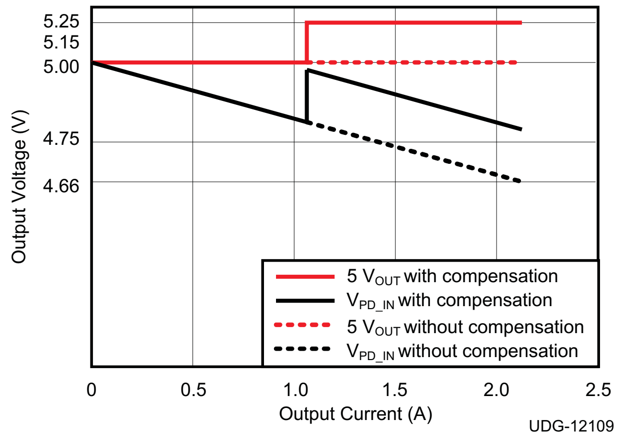



**Figure 13. TPS2511 $\overline{CS}$ Function**

Equation 2 through Equation 5 refer to Figure 12.

The power supply output voltage is calculated in Equation 2.

$$5V_{OUT} = \frac{(R_1 + R_2 + R_3) \times V_{FB}}{R_3} \tag{2}$$

5 $V_{OUT}$ and $V_{FB}$ are known. If $R_3$ is given and $R_1$ is fixed, $R_2$ can be calculated. The 5 $V_{OUT}$ voltage change with compensation is shown in Equation 3 and Equation 4.

$$\Delta V = \frac{(R_2 + R_3) \times R_1 \times V_{FB}}{R_3 \times R_4} \tag{3}$$

$$\Delta V = \left( \frac{5V_{OUT}}{V_{FB}} - \frac{R_1}{R_3} \right) \frac{R_1 \times V_{FB}}{R_4} \tag{4}$$

If $R_1$ is less than $R_3$, then Equation 4 can be simplified as Equation 5.

$$\Delta V \approx \frac{5V_{OUT} \times R_1}{R_4} \tag{5}$$

### 7.3.8 Divide Mode Selection of 5-W and 10-W USB Chargers

The TPS2511 provides two types of connections between the DP pin and the DM pin and between the D+ data line and the D– data line of the USB connector for a 5-W USB charger and a 10-W USB charger with a single USB port. For a 5-W USB charger, the DP pin is connectd to the D– line and the DM pin is connected to the D+ line. This is shown in Figure 16 and Figure 17. It is necessary to apply DP and DM to D+ and D– of USB connector for 10-W USB chargers. See Figure 14 and Figure 15. Table 2 shows different charging schemes for both 5-W and 10-W USB charger solutions

**Table 2. Charging Schemes for 5-W and 10-W USB Chargers**

| USB CHARGER TYPE | CONTAINING CHARGING SCHEMES | | |
|---|---|---|---|
| 5-W | Divider1 | 1.2 V on both D+ and D– Lines | BC1.2 DCP |
| 10-W | Divider2 | 1.2 V on both D+ and D– Lines | BC1.2 DCP |

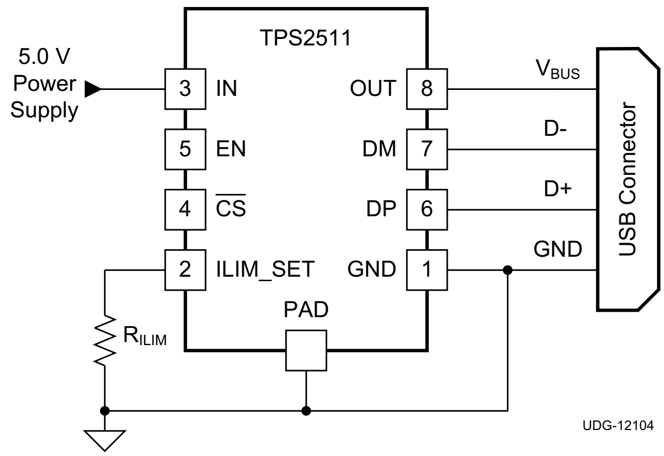



Figure 14. 10-W USB Charger Application With Power Switch

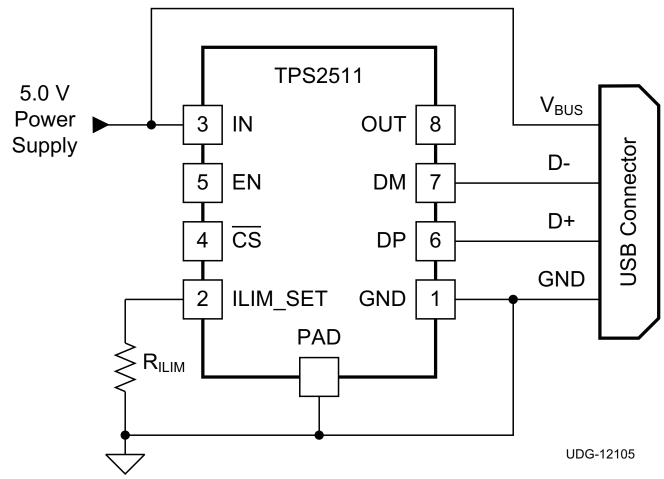



Figure 15. 10-W USB Charger Application Without Power Switch

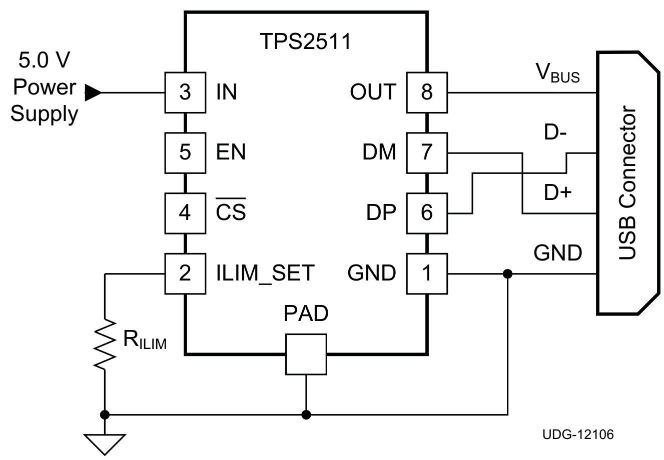



Figure 16. 5-W USB Charger Application With Power Switch

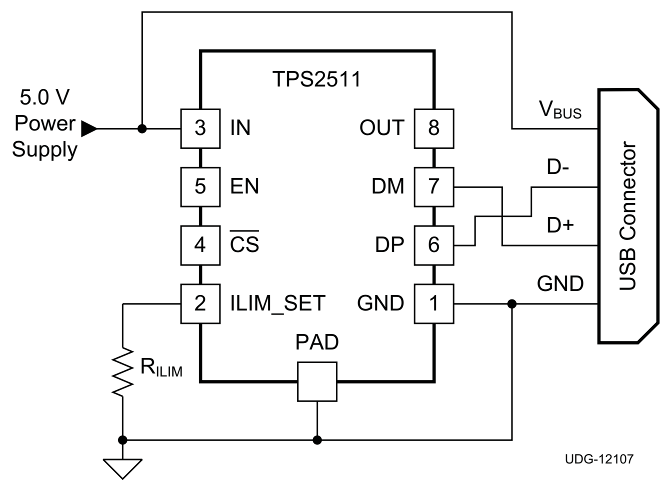



Figure 17. 5-W USB Charger Application Without Power Switch

## 7.4 Device Functional Modes

### 7.4.1 Dedicated Charging Port (DCP)

A dedicated charging port (DCP) is a downstream port on a device that outputs power through a USB connector, but is not capable of enumerating a downstream device, which generally allows portable devices to fast charge at their maximum rated current. A USB charger is a device with a DCP, such as a wall adapter or car power adapter. A DCP is identified by the electrical characteristics of its data lines. The following DCP identification circuits are usually used to meet the handshaking detections of different portable devices.

#### *7.4.1.1 Short the D+ Line to the D– Line*

The USB BC1.2 Specification and the Chinese Telecommunications Industry Standard YD/T 1591-2009 define that the D+ and D– data lines must be shorted together with a maximum series impedance of 200 Ω. This is shown in Figure 18.

## Device Functional Modes (continued)

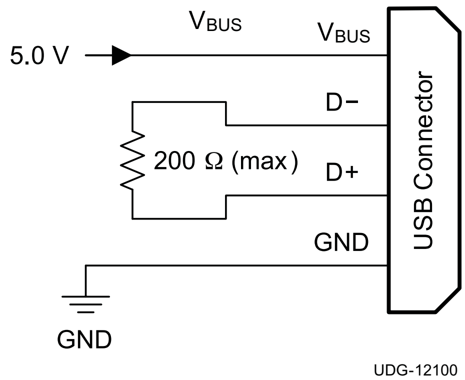



**Figure 18. DCP Short Mode**

#### *7.4.1.2 Divider1 (DCP Applying 2 V on D+ Line and 2.7 V on D– Line) or Divider2 (DCP Applying 2.7 V on D+ Line and 2 V on D– Line)*

There are two charging schemes for divider DCP. They are named after Divider1 and Divider2 DCPs that are shown in Figure 19 and Figure 20. The Divider1 charging scheme is used for 5-W adapters, Divider1 applies 2 V to the D+ line and 2.7 V to the D– data line. The Divider2 charging scheme is used for 10-W adapters and applies 2.7 V on the D+ line and 2 V is applied on the D– line.

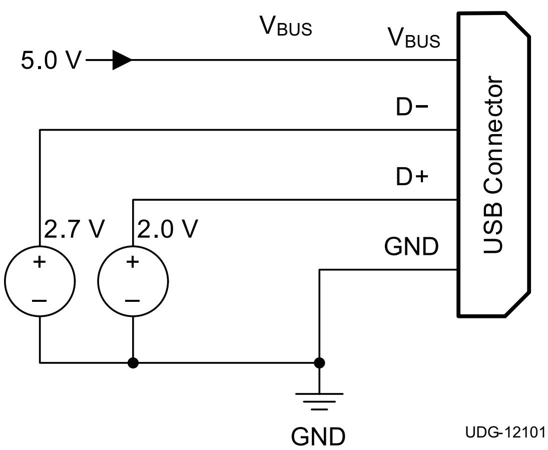



**Figure 19. Divider1 DCP**

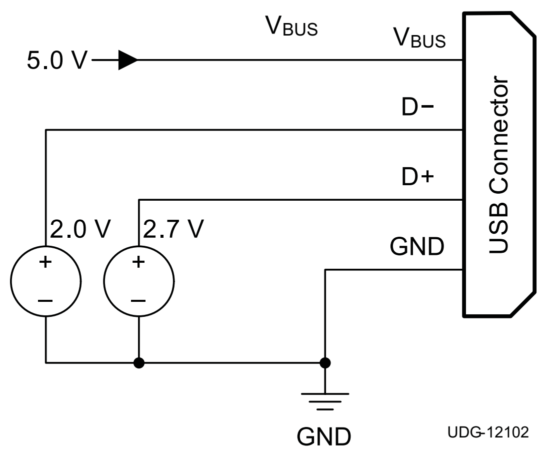



**Figure 20. Divider2 DCP**

#### *7.4.1.3 Applying 1.2 V to the D+ Line and 1.2 V to the D– Line*

As shown in Figure 21, some tablet USB chargers require 1.2 V on the shorted data lines of the USB connector. The maximum resistance between the D+ line and the D– line is 200 Ω.

## Device Functional Modes (continued)

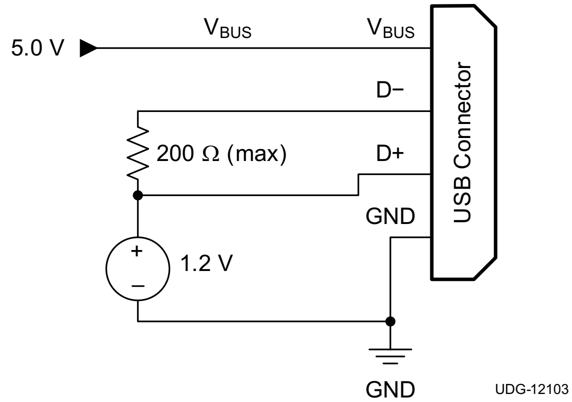



**Figure 21. DCP Applying 1.2 V to the D+ Line and 1.2 V to the D– Line**

The TPS2511 is a combination of a current-limiting USB power switch and an USB DCP identification controller. Applications include vehicle power charger, wall adapters with USB DCP and other USB chargers. The TPS2511 DCP controller has the auto-detect feature that monitors the D+ and D– line voltages of the USB connector, providing the correct electrical characteristics on the DP and DM pins for the correct detections of compliant portable devices to fast charge. These portable devices include smart phones, 5-V tablets, and personal media players.

The TPS2511 power-distribution switch is intended for applications where heavy capacitive loads and short circuits are likely to be encountered, incorporating a 70-mΩ, N-channel MOSFET in a single package. This device provides hiccup mode when in current limit and OUT voltage is less than 3.8 V (typical) or an over-temperature protection occurs under an overload condition. Hiccup mode operation can reduce the output short-circuit current down to several milliamperes. The TPS2511 provides a logic-level enable EN pin to control the device turnon and turnoff and an open-drain output $\overline{CS}$ for compensating $V_{BUS}$ to account for cable I × R voltage loss.

### 7.4.2 DCP *Auto-Detect*

The TPS2511 integrates an *auto-detect* feature to support divider mode, short mode and 1.2 V / 1.2 V mode. If a divider device is attached, 2.7 V is applied to the DP pin and 2 V is applied to the DM pin. If a BC1.2-compliant device is attached, the TPS2511 automatically switches into short mode. If a device compliant with the 1.2 V / 1.2 V charging scheme is attached, 1.2 V is applied on both the DP pin and the DM pin. The functional diagram of DCP auto-detect feature is shown in Figure 22.

## Device Functional Modes (continued)

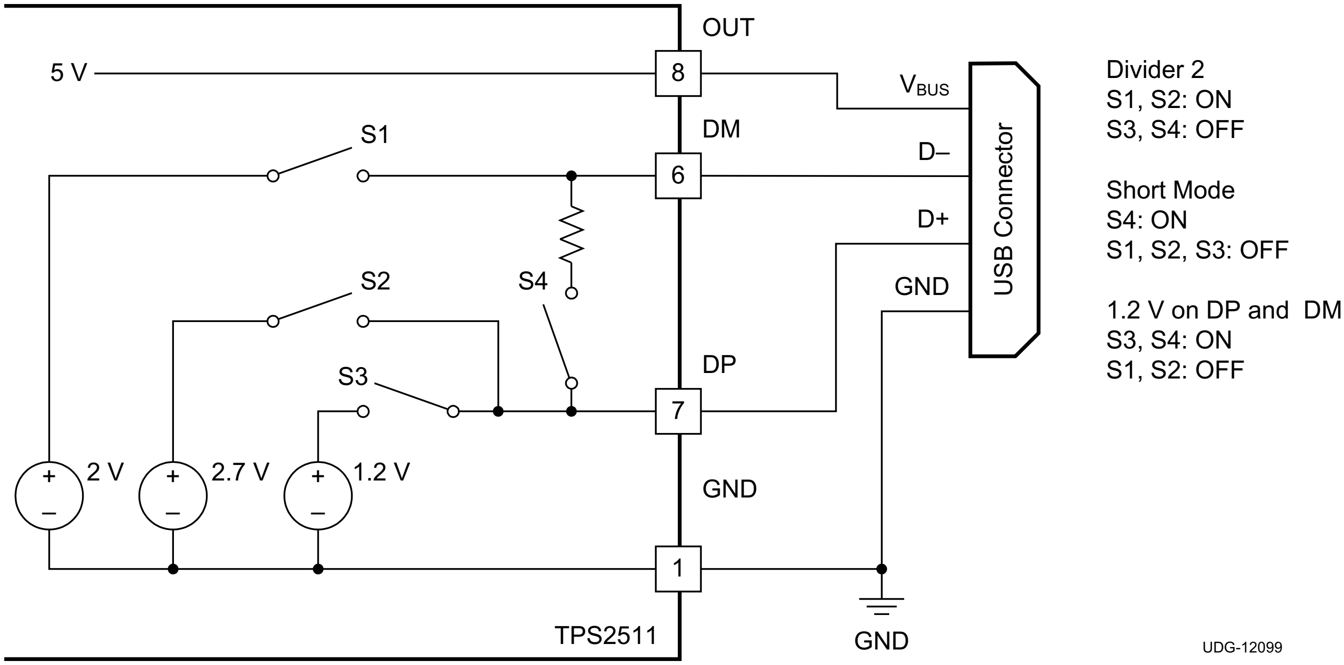



**Figure 22. TPS2511 DCP Auto-Detect Functional Diagram**

# 8 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.

## 8.1 Application Information

The TPS2511 is a USB-dedicated charging-port controller and power switch with cable compensation. It is typically used for wall adapter or power bank as a USB charging controller and overcurrent protector.

## 8.2 Typical Application

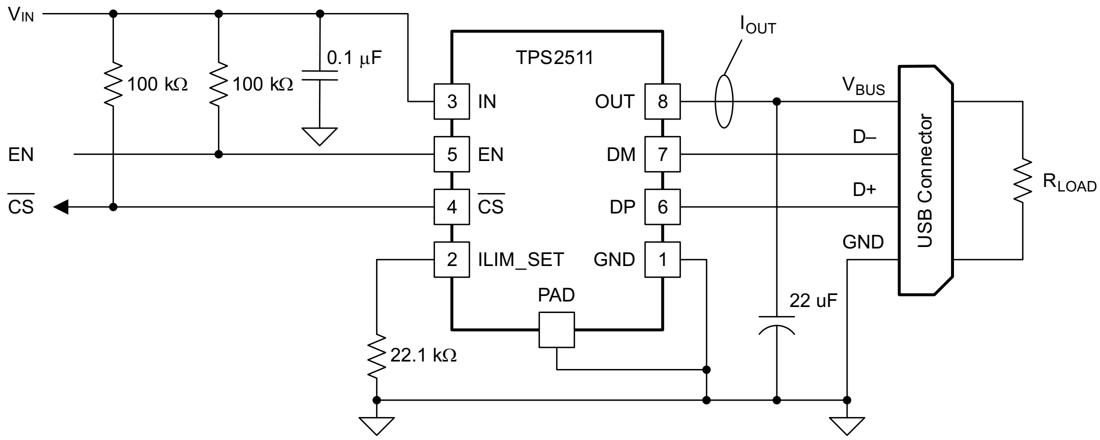



**Figure 23. Test Circuit for System Operation**

### 8.2.1 Design Requirements

For this design example, request IOS; Minimum must exceed 2100 mA.

When choosing the power switch, TI recommends following these general steps:

1. Determine the voltage of the power rail, 3.3 V or 5 V, and then choose the operation range of power switch can cove power rail.
2. Determine the normal operation current; for example, the maximum allowable current drawn by portable equipment for USB 2.0 port is 500 mA, so the normal operation current is 500 mA and the minimum current limit of power switch must exceed 500 mA to avoid false trigger during normal operation.
3. Determine 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.

### 8.2.2 Detailed Design Procedure

The user-programmable $R_{ILIM}$ resistor on the ILIMIT_SET pin sets the current limit. The TPS2511 uses an internal regulation loop to provide a regulated voltage on the ILIM_SET pin. The current limiting threshold is proportional to the current sourced out of the ILIM_SET pin. The recommended 1% resistor range for $R_{ILIM}$ is from 16.9 kΩ to 750 kΩ to ensure stability of the internal regulation loop, although not exceeding 210 kΩ results in a better accuracy. Many applications require that the minimum current limit remain above a certain current

## Typical Application (continued)

level or that the maximum current limit remain below a certain current level, so it is important to consider the tolerance of the overcurrent threshold when selecting a value for $R_{ILIM}$. Equation 6 and Equation 7 calculate the resulting overcurrent thresholds for a given external resistor value ($R_{ILIM}$). The traces routing the $R_{ILIM}$ resistor to the TPS2511 must be as short as possible to reduce parasitic effects on the current limit accuracy. The equations along with Figure 24 and Figure 25 can be used to estimate the minimum and maximum variation of the current limit threshold for a predefined resistor value. This variation disregards the inaccuracy of the resistor itself.

$$I_{OS\_MIN} = \frac{51228}{R_{ILIM}^{1.030}}$$

where

- $I_{OS\_MIN}$ is in mA
- $R_{ILIM}$ is in kΩ (6)

$$I_{OS\_MAX} = \frac{51228}{R_{ILIM}^{0.967}}$$

where

- $I_{OS\_MAX}$ is in mA
- $R_{ILIM}$ is in kΩ (7)

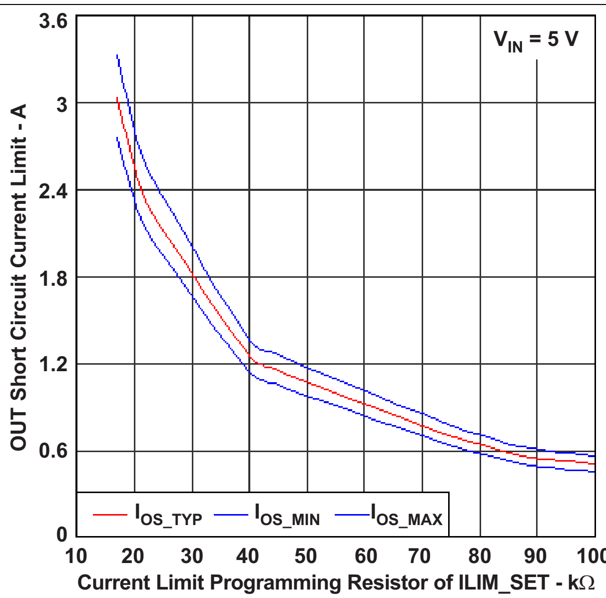



**Figure 24. Current Limit Threshold vs Current Limit Resistance**

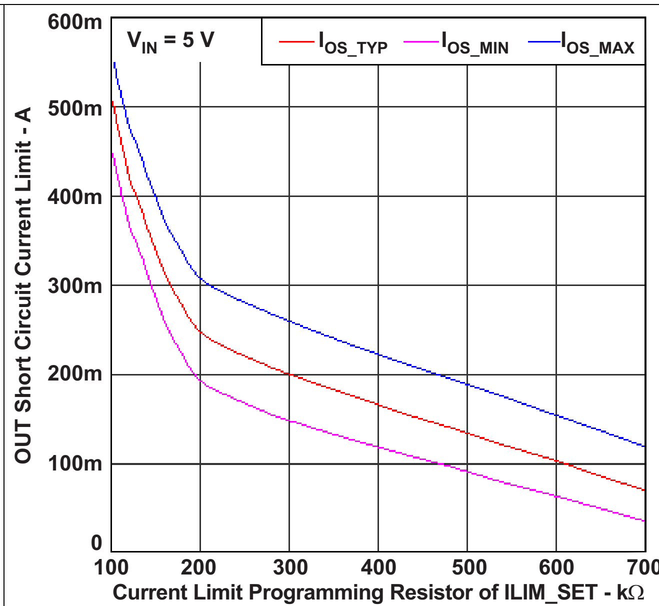



**Figure 25. Current Limit Threshold vs Current Limit Resistance**

For this example design, as shown in Equation 8, $I_{OS\_MIN}$ = 2100 mA.

$$I_{OS\_MIN} = \frac{51228}{R_{ILIM}^{1.03}} = 2100 \text{ mA} \quad (8)$$

$$R_{ILIM} = \left(\frac{51228}{I_{OS\_MIN}}\right)^{\frac{1}{1.03}} = \left(\frac{51228}{2100}\right)^{\frac{1}{1.03}} = 22.227 \text{ k}\Omega \quad (9)$$

## Typical Application (continued)

Including resistor tolerance, target nominal resistance value given by Equation 10.

$$R_{ILIM} = \frac{22.227\ k\Omega}{1.01\,k\Omega} = 22.007\ k\Omega \quad (10)$$

Choose Equation 11.

$$R_{ILIM} = 22\ k\Omega \quad (11)$$

#### *8.2.2.1 Input and Output Capacitance*

Input and output capacitance improves the performance of the device; the actual capacitance must be optimized for the particular application. For all applications, TI recommends placing a 0.1-µF or greater ceramic bypass capacitor between IN and GND, 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 TPS2511 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.

TI recommends placing at least a 22-µF ceramic capacitor or higher-value electrolytic capacitor on the output pin when large transient currents are expected on the output to reduce the undershoot, which is caused by the inductance of the output power bus just after a short has occurred and the TPS2511 has abruptly reduced OUT current. Energy stored in the inductance drives the OUT voltage down and potentially negative as it discharges.

### 8.2.3 Application Curves

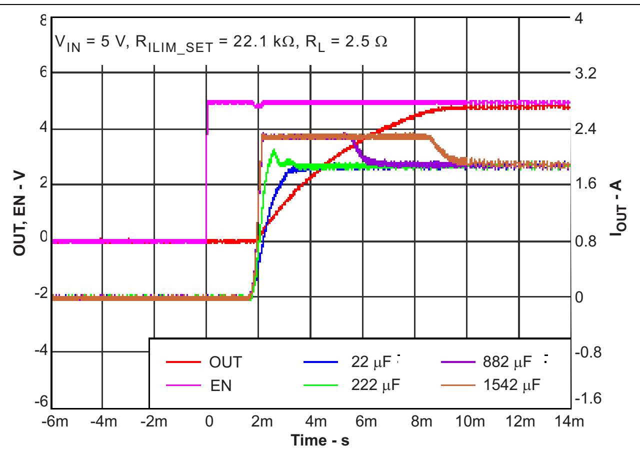



**Figure 26. Inrush Current With Different Capacitance Load**

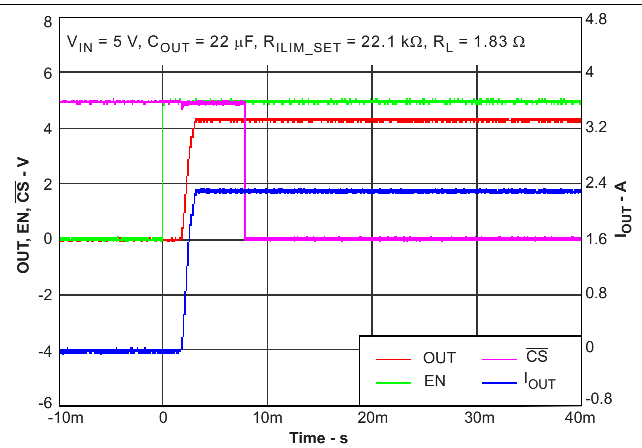



**Figure 27. Enable into 1.83-Ω Load**

## Typical Application (continued)

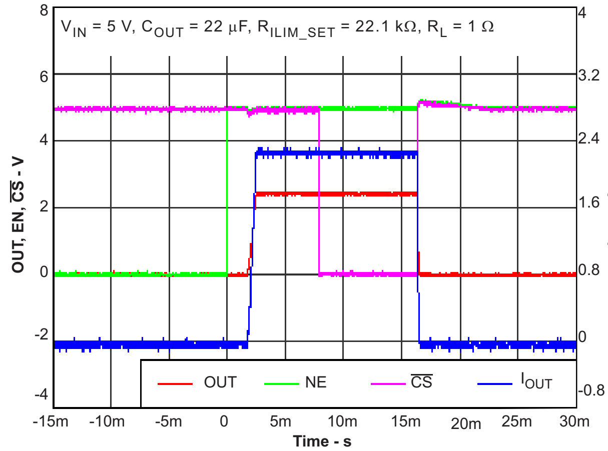



**Figure 28. Enable into 1-Ω Load**

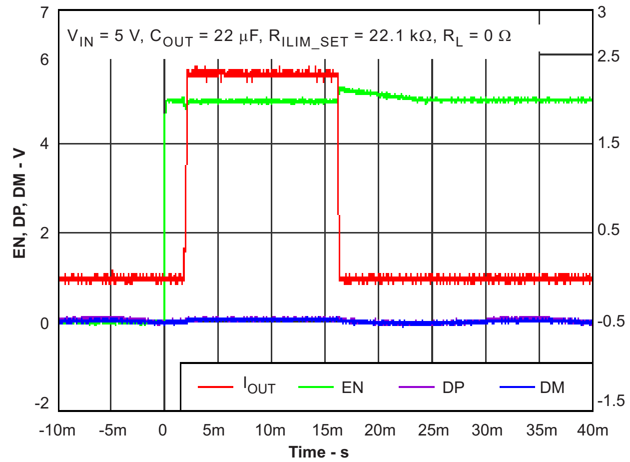



**Figure 29. Enable into Short**

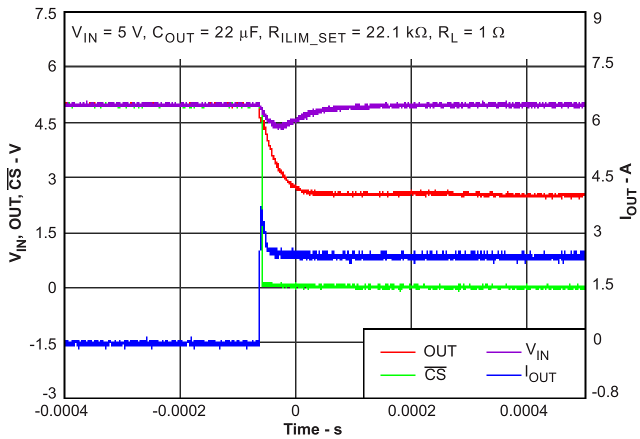



**Figure 30. 1-Ω Load Applied**

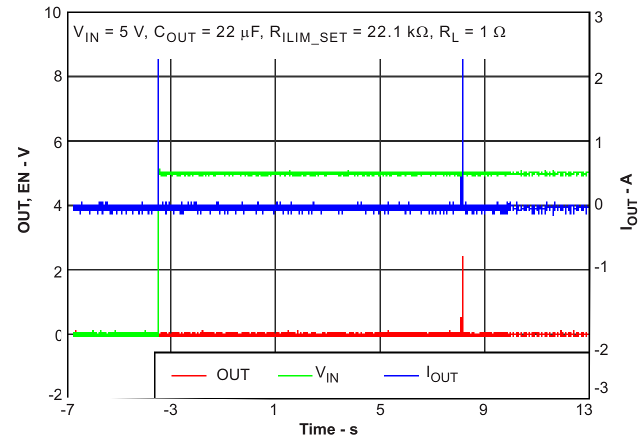



**Figure 31. Hiccup Mode While Enabled into 1-Ω Load**

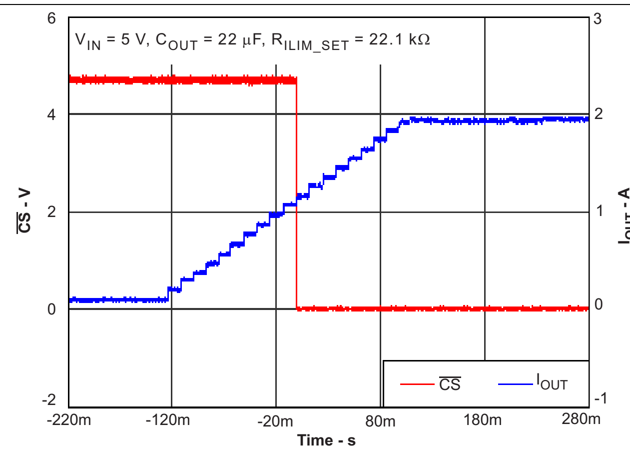



**Figure 32. Output Current-Sensing Report**

# 9 Power Supply Recommendations

Design of the devices is for operation from an input voltage supply range of 4.5 V to 5.5 V. The current capability of the power supply must exceed the maximum current limit of the power switch.

# 10 Layout

## 10.1 Layout Guidelines

- **TPS2511 placement.** Place the TPS2511 near the USB output connector and at least 22-µF OUT pin filter capacitor. Connect the exposed PowerPAD to the GND pin and to the system ground plane using a via array.
- **IN pin bypass capacitance.** Place the 0.1-µF bypass capacitor near the IN pin and make the connection using a low-inductance trace.
- **ILIM_SET pin connection.** Current limit setpoint accuracy can be compromised by stray leakage from a higher voltage source to the ILIM_SET pin. Ensure that there is adequate spacing between IN pin copper or trace and ILIM_SET pin trace to prevent contaminant buildup during the PCB assembly process. The traces routing the $R_{ILIM}$ resistor to the device must be as short as possible to reduce parasitic effects on the current limit accuracy.
- **DP and DM consideration.** Route these traces as differential micro-strips. For DP and DM, there is no internal IEC ESD cell, refer to application note *Effective System ESD Protection Guidelines:TPS251x USB Charging Port Controllers* for these 2 pins' IEC ESD design guideline.

## 10.2 Layout Example

For the trace routing of DP and DM, no strictly request must route these traces as micro-strips with nominal differential impedance of 90 Ω because no USB 2.0 high-speed data transmission on these data line. But because there is no internal IEC ESD cell, TI recommends placing IEC ESD cell on DP and DM trace close to USB connector.

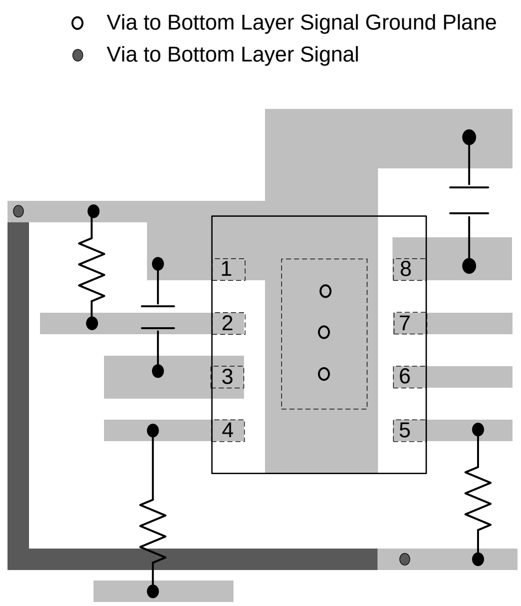



**Figure 33. Layout Recommendation**

# 11 器件和文档支持

## 11.1 文档支持

### 11.1.1 相关文档

请参阅如下相关文档：

*《高效系统 ESD 保护指南：TPS251x USB 充电端口控制器》*(SLVA800)

## 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 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。

## 11.3 社区资源

下列链接提供到 TI 社区资源的连接。链接的内容由各个分销商"按照原样"提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的 《使用条款》。

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**设计支持** ***TI 参考设计支持*** 可帮助您快速查找有帮助的 E2E 论坛、设计支持工具以及技术支持的联系信息。

## 11.4 商标

PowerPAD, E2E are trademarks of Texas Instruments.
All other trademarks are the property of their respective owners.

## 11.5 静电放电警告

这些装置包含有限的内置 ESD 保护。 存储或装卸时，应将导线一起截短或将装置放置于导电泡棉中，以防止 MOS 门极遭受静电损伤。

## 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。这些信息是指定器件的最新可用数据。这些数据如有变更，恕不另行通知和修订此文档。如欲获取此数据表的浏览器版本，请参阅左侧的导航。

## 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) |
|---|---|---|---|---|---|---|---|---|---|
| TPS2511DGN | Active | Production | HVSSOP (DGN) \| 8 | 80 \| TUBE | Yes | NIPDAUAG | Level-2-260C-1 YEAR | -40 to 125 | 2511 |
| TPS2511DGNR | Active | Production | HVSSOP (DGN) \| 8 | 2500 \| LARGE T&R | Yes | NIPDAUAG | Level-2-260C-1 YEAR | -40 to 125 | 2511 |

(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.

**Important Information and Disclaimer:**The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**OTHER QUALIFIED VERSIONS OF TPS2511 :**

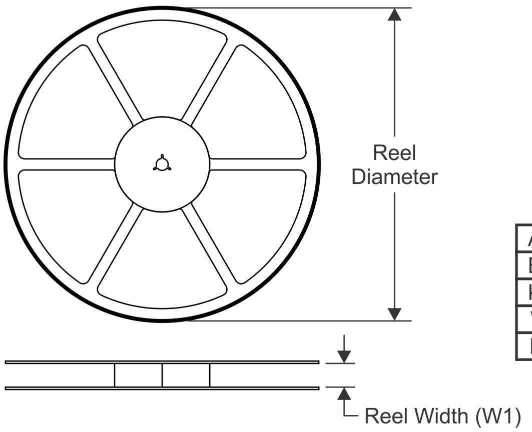
- Automotive : TPS2511-Q1

NOTE: Qualified Version Definitions:

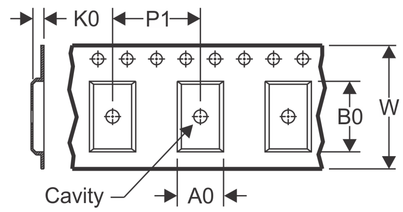
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

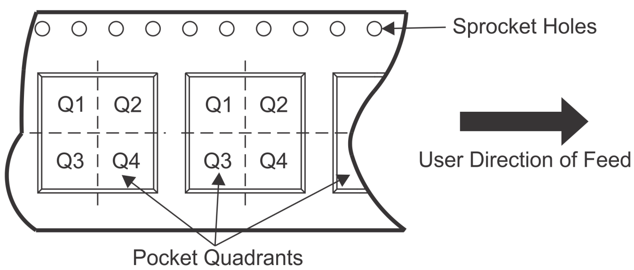



**TAPE DIMENSIONS**




| | |
|---|---|
| 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 |

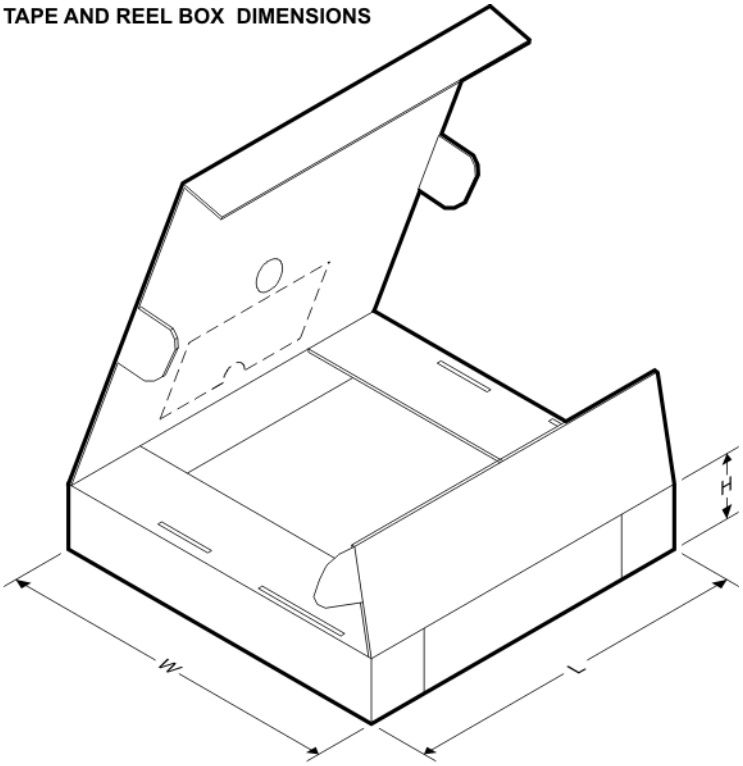
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TPS2511DGNR | HVSSOP | DGN | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |

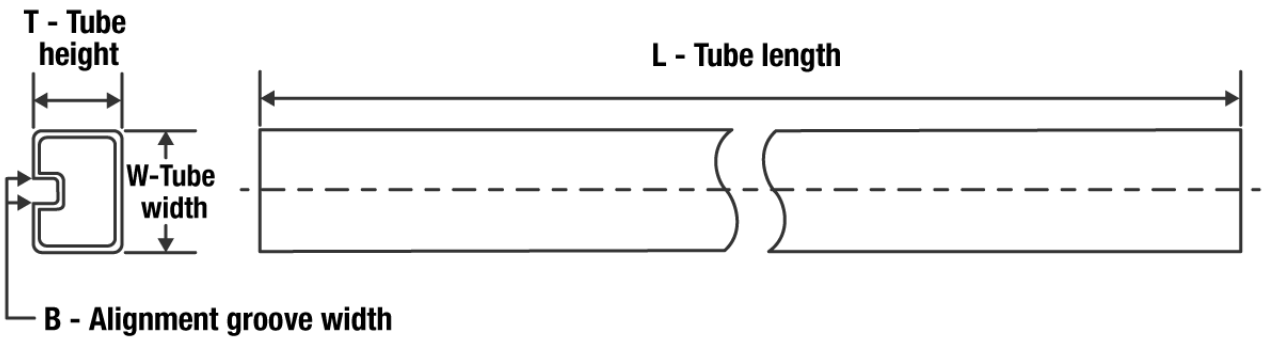
**TAPE AND REEL BOX DIMENSIONS**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| TPS2511DGNR | HVSSOP | DGN | 8 | 2500 | 366.0 | 364.0 | 50.0 |

## TUBE




*All dimensions are nominal

| Device | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (µm) | B (mm) |
|---|---|---|---|---|---|---|---|---|
| TPS2511DGN | DGN | HVSSOP | 8 | 80 | 330 | 6.55 | 500 | 2.88 |

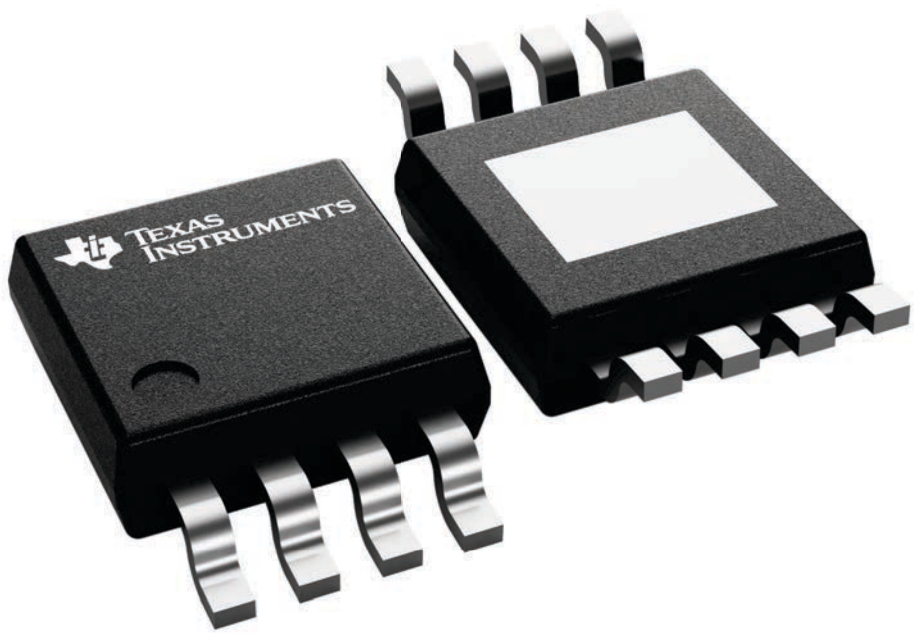
# DGN 8

## 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.



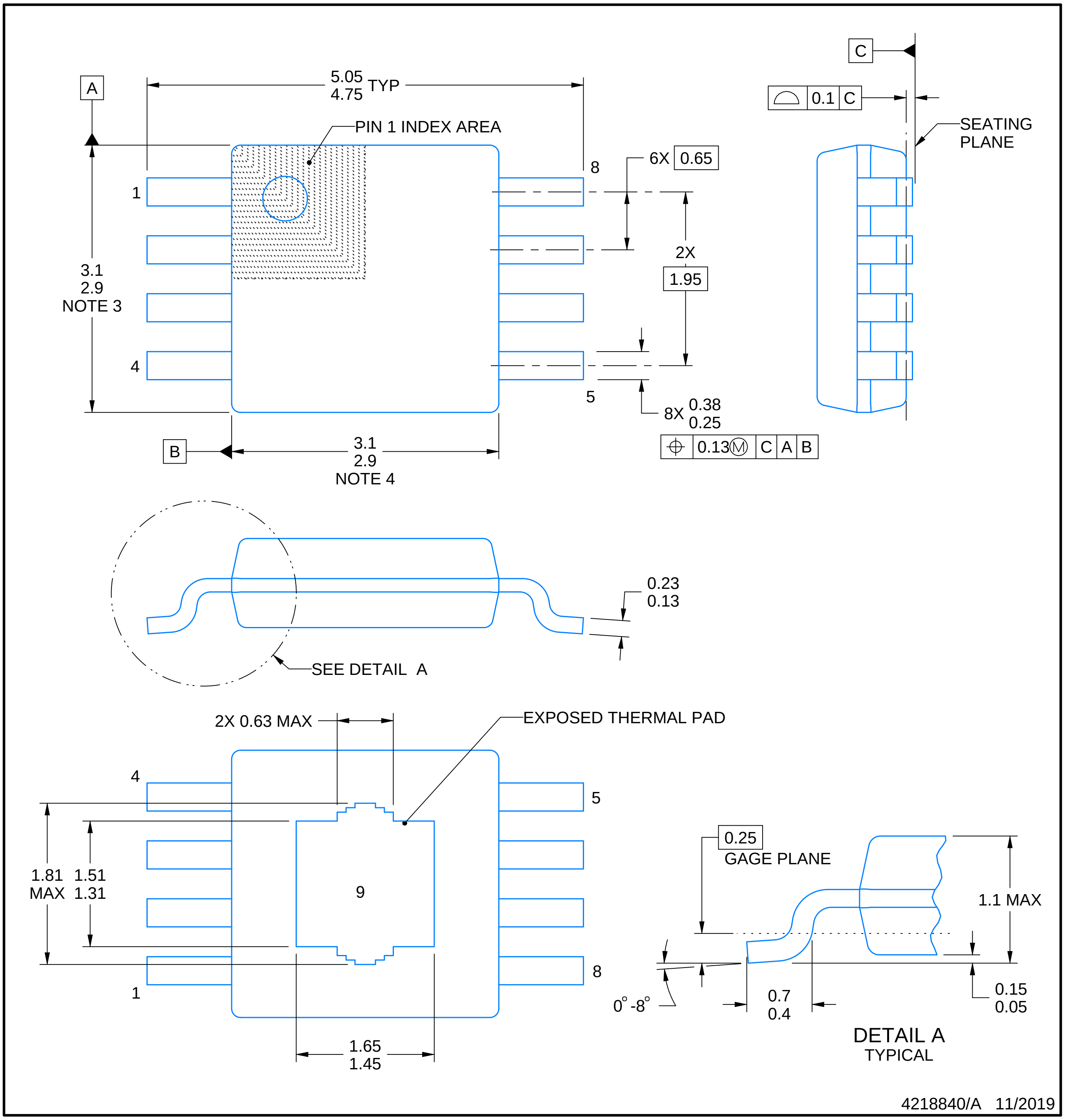

4225482/B

# PACKAGE OUTLINE

## DGN0008E

## PowerPAD™ VSSOP - 1.1 mm max height

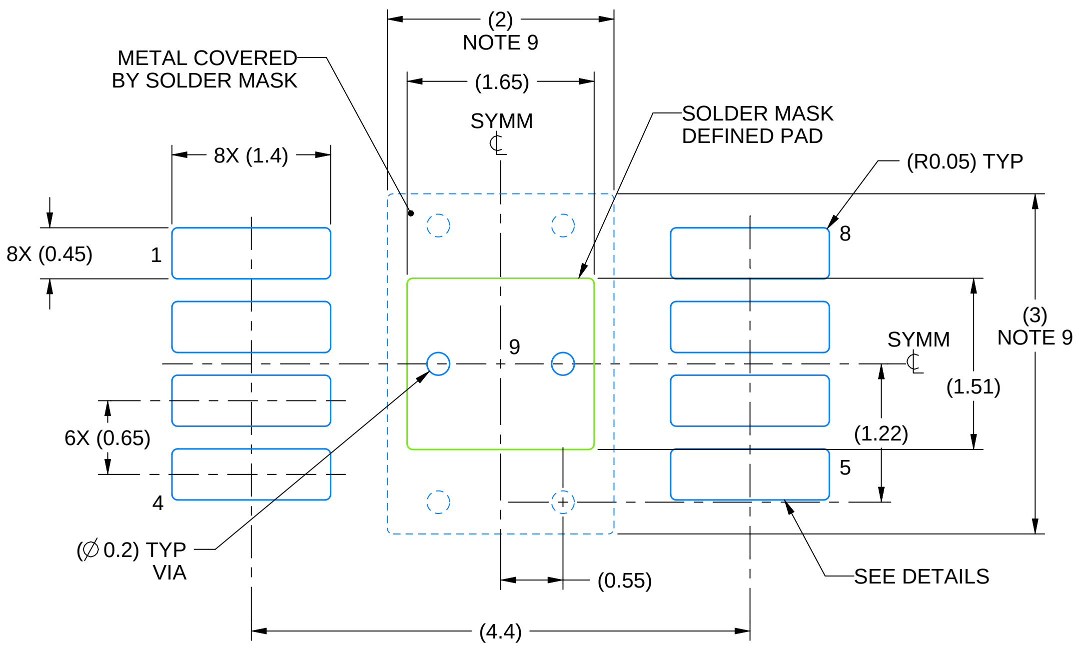
SMALL OUTLINE PACKAGE



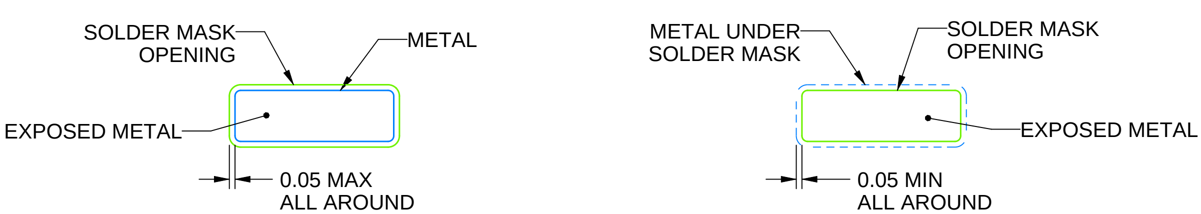

PowerPAD is a trademark of Texas Instruments.

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




NON-SOLDER MASK
DEFINED
(PREFERRED)

SOLDER MASK
DEFINED

SOLDER MASK DETAILS

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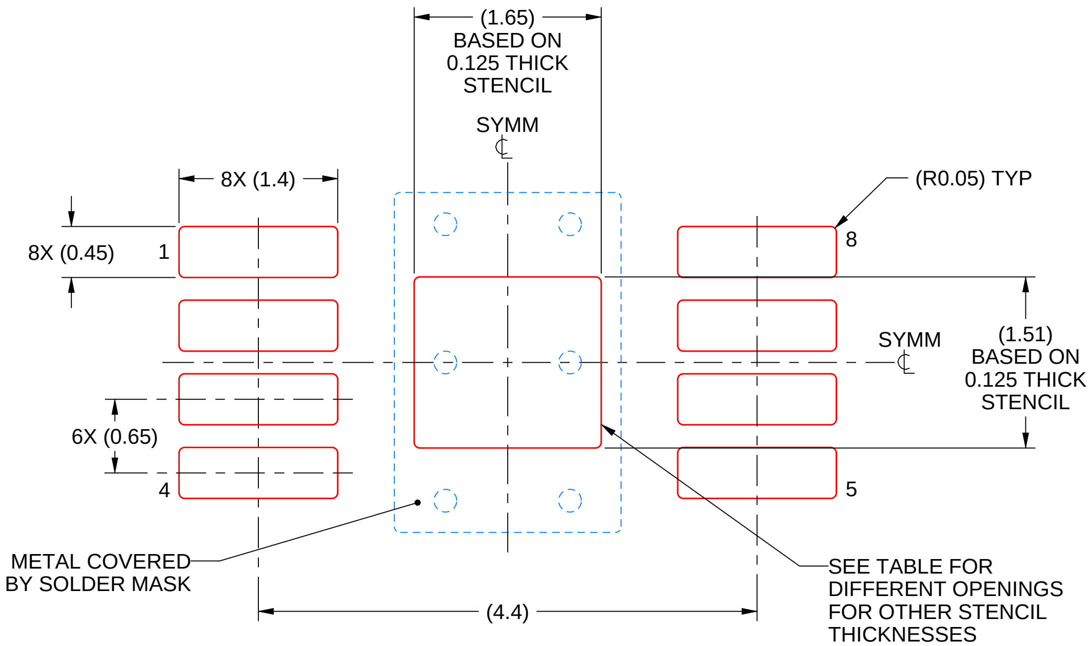
NOTES: (continued)

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 | 1.84 X 1.69 |
| 0.125 | 1.65 X 1.51 (SHOWN) |
| 0.15 | 1.51 X 1.38 |
| 0.175 | 1.39 X 1.28 |

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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.