# TPS2294x Low-input-voltage Current-limited Load Switches With Shut Off And Auto-Restart Feature

## 1 Features

- Input Voltage Range: 1.62 V to 5.5 V
- Low ON resistance
  - $r_{ON}$ = 0.4 Ω at $V_{IN}$ = 5.5 V
  - $r_{ON}$ = 0.5 Ω at $V_{IN}$ = 3.3 V
  - $r_{ON}$ = 0.6 Ω at $V_{IN}$ = 2.5 V
  - $r_{ON}$ = 0.8 Ω at $V_{IN}$ = 1.8 V
- Minimum Current Limit: 40 mA or 100 mA
- Undervoltage Lockout (UVLO)
- Thermal Shutdown
- Shutdown Current < 1 µA
- Fast Current Limit Response Time
- Fault Blanking
- Auto Restart
- 1.8-V Compatible Control Input Thresholds
- ESD Performance Tested Per JESD 22
  - 4000-V Human-Body Model (A114-B, Class II)
  - 1000-V Charged-Device Model (C101)
- Tiny SC-70 (DCK) Package
- UL Recognized Component (UL File 169910)
- Evaluated to IEC 60950-1, Ed 2, Am1, Annex CC, Test Program 2 with CB Report

## 2 Applications

- Low-Current Sensor Protection
- HDMI Connector Protection
- Notebooks
- PDAs
- GPS Devices
- MP3 Players
- Peripheral Ports

## 3 Description

The TPS22941/2/3/4/5 load switches provide protection to systems and loads in high-current conditions. The devices contain a 0.4-Ω current-limited P-channel MOSFET that can operate over an input voltage range of 1.62 V to 5.5 V. Current is prevented from flowing when the MOSFET is off. The switch is controlled by an on/off input (ON), which is capable of interfacing directly with low-voltage control signals. The TPS22941/2/3/4/5 includes thermal shutdown protection that prevents damage to the device when a continuous over-current condition causes excessive heating by turning off the switch.

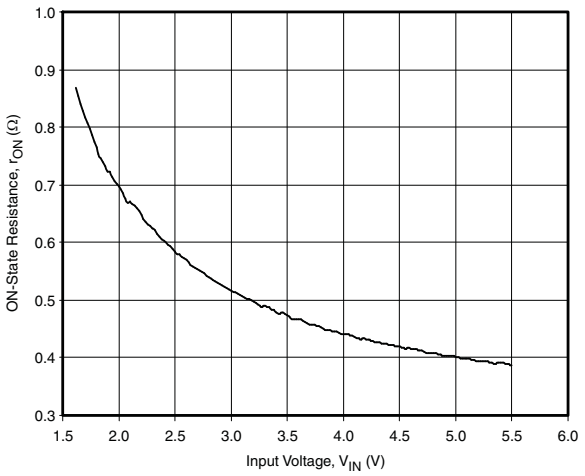
These devices provide an integrated, robust solution to provide current limiting the output current to a safe level by switching into a constant-current mode when the ouptut load exceeds the current-limit threshold. The OC logic output asserts low during overcurrent, undervoltage, or overtemperature conditions. These additional features make the TPS22941/2/3/4/5 an ideal solution for applications where current limiting is necessary.

This family of devices are available in a SC70-5 (DCK) package. It is characterized for operation over the free-air temperature range of –40°C to 85°C.

**Device Information(1)**

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|---|---|---|
| TPS22941 | SC70 (5) | 2.00mm × 2.10 mm |
| TPS22942 | | |
| TPS22943 | | |
| TPS22944 | | |
| TPS22945 | | |

(1) For all available packages, see the orderable addendum at the end of the datasheet.



# Table of Contents



## 4 Revision History

**Changes from Revision C (November 2009) to Revision D** **Page**

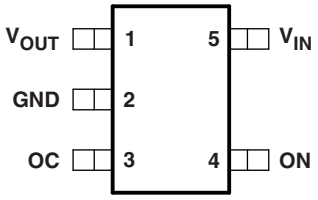
- Added *Handling Rating* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section ... 1

# 5 Device Comparison Table

| DEVICE | MINIMUM CURRENT LIMIT (mA) | CURRENT LIMIT BLANKING TIME (ms) | AUTO-RESTART TIME (ms) | ON PIN ACTIVITY |
|---|---|---|---|---|
| TPS22941 | 40 | 10 | 80 | Active LOW |
| TPS22942 | 100 | 10 | 80 | Active LOW |
| TPS22943 | 40 | 0 | N/A | Active HIGH |
| TPS22944 | 100 | 0 | N/A | Active HIGH |
| TPS22945 | 100 | 10 | 80 | Active HIGH |

# 6 Pin Configuration and Functions

**DCK PACKAGE**
**(TOP VIEW)**




**Pin Functions**

| PIN | | TYPE | DESCRIPTION |
|---|---|---|---|
| NAME | SOT (DCK) PIN NO. | | |
| $V_{OUT}$ | 1 | O | Switch Output. Place ceramic bypass capacitor(s) between this terminal and GND. See the *Application Information* section for more information. |
| GND | 2 | – | Ground |
| OC | 3 | O | Over current output flag: active LOW, open drain output that indicates an over current, supply under voltage, or over temperature state. |
| ON | 4 | I | Switch control input. Do not leave floating. |
| $V_{IN}$ | 5 | I | Switch Input. Place ceramic bypass capacitor(s) between this terminal and GND. See the *Application Information* section for more information. |

# 7 Specifications

## 7.1 Absolute Maximum Ratings(1)

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_I$ | Input voltage range | $V_{IN}$, $V_{OUT}$, ON | –0.3 | 6 | V |
| $T_J$ | Operating junction temperature range | | Internally Limited | | °C |

(1) Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

## 7.2 Handling Ratings

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $T_{stg}$ | Storage temperature range | | –65 | 150 | °C |
| $V_{ESD}$ | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(1) | –4 | 4 | kV |
| | | Charged device model (CDM), per JEDEC specification JESD22-C101, all pins(2) | –1 | 1 | |

(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.

## 7.3 Recommended Operating Conditions

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

| | | MIN | MAX | UNIT |
|---|---|---|---|---|
| $V_{IN}$ | Input voltage | 1.62 | 5.5 | V |
| $V_{OUT}$ | Output voltage | | $V_{IN}$ | |
| $T_A$ | Ambient free-air temperature | –40 | 85 | °C |

## 7.4 Thermal Information

| THERMAL METRIC(1) | | TPS22941/2/3/4/5 DCK 5 PINS | UNIT |
|---|---|---|---|
| $\theta_{JA}$ | Junction-to-ambient thermal resistance | 294 | °C/W |
| $\theta_{JC(top)}$ | Junction-to-case (top) thermal resistance | 59.2 | |
| $\theta_{JB}$ | Junction-to-board thermal resistance | 95.4 | |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 0.7 | |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 93.9 | |
| $\theta_{JC(bot)}$ | Junction-to-case (bottom) thermal resistance | N/A | |

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

## 7.5 Electrical Characteristics

$V_{IN}$ = 1.62 V to 5.5 V, $T_A$ = –40°C to 85°C (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | $T_A$ | MIN | TYP(1) | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $I_{IN}$ | Quiescent current | $I_{OUT}$ = 0 mA, | $V_{IN}$ = 1.62 V to 5.5 V | Full | | 40 | 80 | µA |
| $I_{IN(OFF)}$ | OFF-State supply current | $V_{ON}$ = 0 V (TPS22943/4/5) or $V_{ON}$ = $V_{IN}$ (TPS22941/2) | $V_{IN}$ = 3.6 V, $V_{OUT}$ open | Full | | | 1 | µA |
| $I_{OUT(LEAKAGE)}$ | OFF-State switch current | $V_{ON}$ = 0 V (TPS22943/4/5) or $V_{ON}$ = $V_{IN}$ (TPS22941/2) | $V_{IN}$ = 3.6 V, $V_{OUT}$ short to GND | Full | | | 1 | µA |
| $r_{ON}$ | ON-state resistance | $I_{OUT}$ = 20 mA | $V_{IN}$ = 5.5 V | 25°C | | 0.4 | 0.5 | Ω |
| | | | | Full | | | 0.6 | |
| | | | $V_{IN}$ = 3.3 V | 25°C | | 0.5 | 0.6 | |
| | | | | Full | | | 0.7 | |
| | | | $V_{IN}$ = 2.5 V | 25°C | | 0.6 | 0.7 | |
| | | | | Full | | | 0.8 | |
| | | | $V_{IN}$ = 1.8 V | 25°C | | 0.8 | 0.9 | |
| | | | | Full | | | 1.1 | |
| | | | $V_{IN}$ = 1.62 V | 25°C | | 0.9 | 1.1 | |
| | | | | Full | | | 1.2 | |
| $I_{ON}$ | ON input leakage current | $V_{ON}$ = $V_{IN}$ or GND | | Full | | | 1 | µA |
| $I_{LIM}$ | Current limit | $V_{IN}$ = 3.3 V, $V_{OUT}$ = 3 V | TPS22941/3 | Full | 40 | 65 | 80 | mA |
| | | | TPS22942/4/5 | | 100 | 150 | 200 | |
| $T_{SD}$ | Thermal shutdown | Shutdown threshold | | Full | | 140 | | °C |
| | | Return from shutdown | | | | 130 | | |
| | | Hysteresis | | | | 10 | | |

(1) Typical values are at $V_{IN}$ = 3.3 V and $T_A$ = 25°C.

## Electrical Characteristics (continued)

$V_{IN}$ = 1.62 V to 5.5 V, $T_A$ = –40°C to 85°C (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$ | MIN | TYP(1) | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| UVLO | Undervoltage shutdown | $V_{IN}$ increasing | Full | 1.32 | 1.42 | 1.52 | V |
| | Undervoltage shutdown hysteresis | | Full | | 45 | | mV |
| **Control Output (OC)** | | | | | | | |
| Vol | OC output logic low voltage | $V_{IN}$ = 5 V, $I_{SINK}$ = 10 mA | Full | | 0.1 | 0.2 | V |
| | | $V_{IN}$ = 1.8 V, $I_{SINK}$ = 10 mA | | | 0.1 | 0.3 | |
| Ioz | OC output high leakage current voltage | $V_{IN}$ = 5 V, Switch ON | Full | | | 0.5 | µA |
| **Control Input (ON)** | | | | | | | |
| Vih | ON high-level input voltage | $V_{IN}$ = 1.8 V | Full | 1.1 | | | V |
| | | $V_{IN}$ = 2.5 V | Full | 1.3 | | | V |
| | | $V_{IN}$ = 3.3 V | Full | 1.4 | | | V |
| | | $V_{IN}$ = 5.5 V | Full | 1.7 | | | V |
| Vil | ON low-level input voltage | $V_{IN}$ = 1.8 V | Full | | | 0.5 | V |
| | | $V_{IN}$ = 2.5 V | Full | | | 0.7 | V |
| | | $V_{IN}$ = 3.3 V | Full | | | 0.8 | V |
| | | $V_{IN}$ = 5.5 V | Full | | | 0.9 | V |
| Ii | ON high-level input leakage current | $V_{IN}$ = 1.8 V to 5 V, Switch ON | Full | | | 1 | µA |

## 7.6 Switching Characteristics

$V_{IN}$ = 3.3 V, $R_L$ = 500 Ω, $C_L$ = 0.1 µF, $T_A$ = 25°C (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $t_{ON}$ | Turn-ON time | $R_L$ = 500 Ω, | $C_L$ = 0.1 µF | | 60 | | µs |
| $t_{OFF}$ | Turn-OFF time | $R_L$ = 500 Ω, | $C_L$ = 0.1 µF | | 30 | | µs |
| $t_r$ | $V_{OUT}$ rise time | $R_L$ = 500 Ω, | $C_L$ = 0.1 µF | | 10 | | µs |
| $t_f$ | $V_{OUT}$ fall time | $R_L$ = 500 Ω, | $C_L$ = 0.1 µF | | 90 | | µs |
| $t_{BLANK}$ | Over current blanking time | TPS22941/2/5 | | 5 | 10 | 20 | ms |
| $t_{RSTART}$ | Auto-restart time | TPS22941/2/5 | | 40 | 80 | 160 | ms |
| | Short-circuit response time | $V_{IN}$ = $V_{ON}$ = 3.3 V, moderate overcurrent condition | | | 9 | | µs |
| | | $V_{IN}$ = $V_{ON}$ = 3.3 V, hard short | | | 4 | | µs |

## 7.7 Typical Characteristics

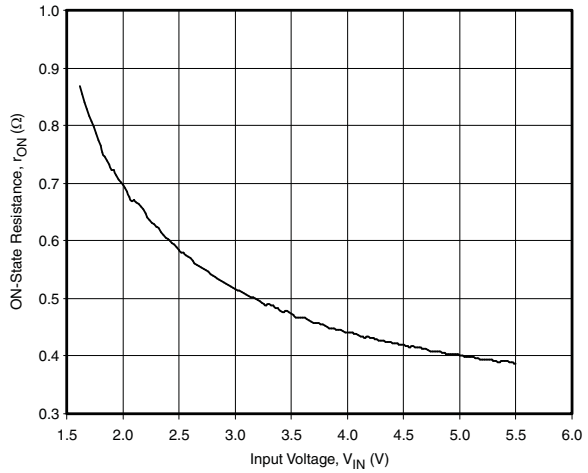



**Figure 1. $r_{ON}$ vs $V_{IN}$**

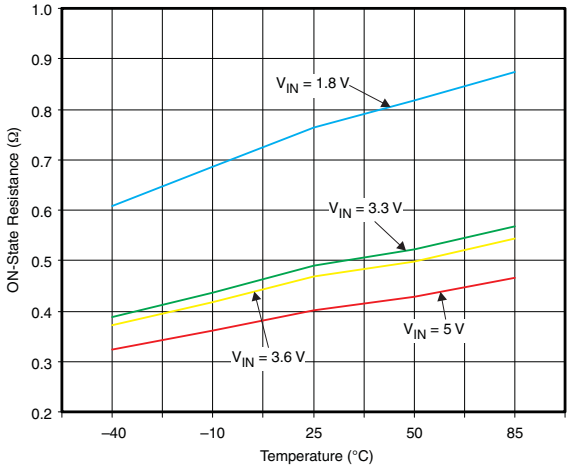



**Figure 2. $r_{ON}$ vs Temperature**

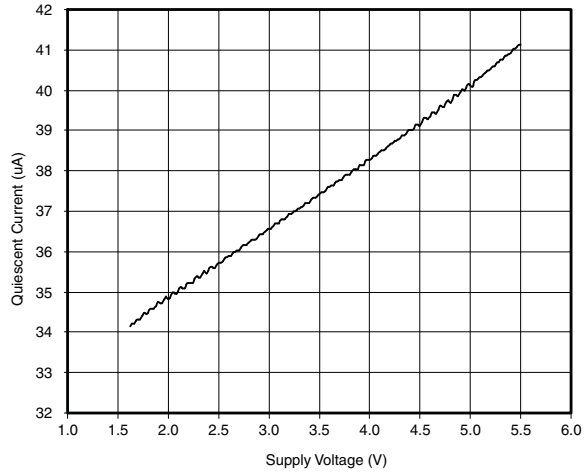



**Figure 3. Quiescent Current vs $V_{IN}$**

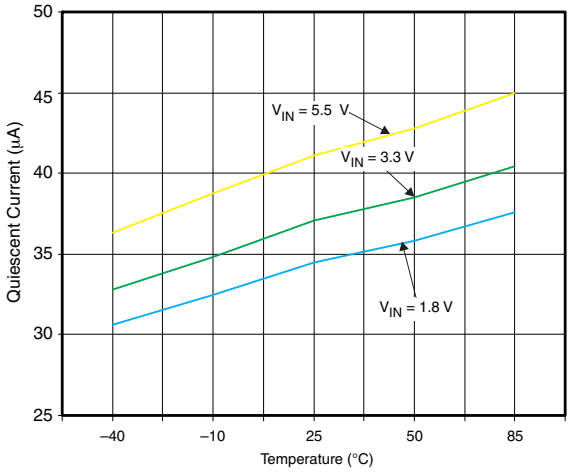



**Figure 4. Quiescent Current vs Temperature**

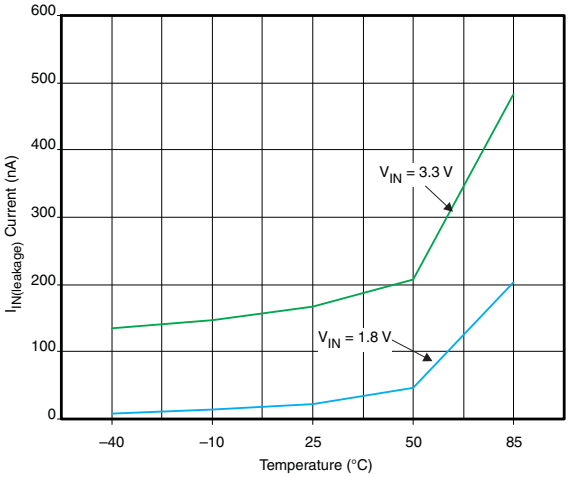



**Figure 5. $I_{IN(Leakage)}$ vs Temperature**

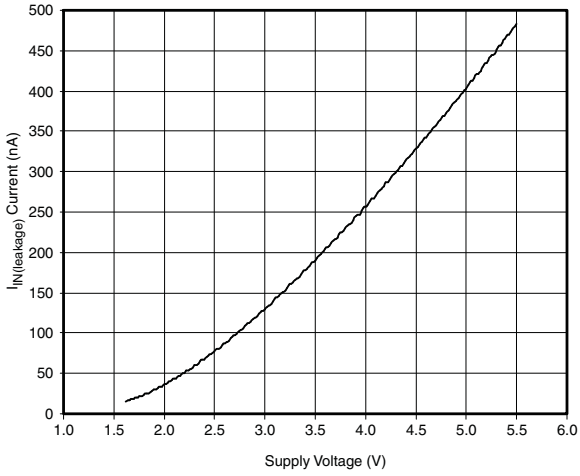



**Figure 6. $I_{IN(Leakage)}$ vs $V_{IN}$**

## Typical Characteristics (continued)

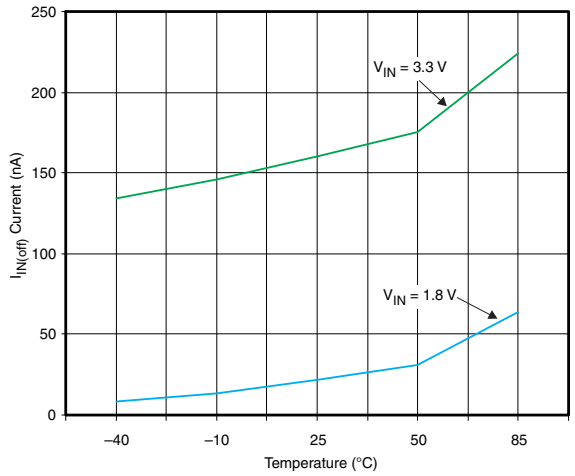



**Figure 7. $I_{IN(off)}$ vs Temperature**

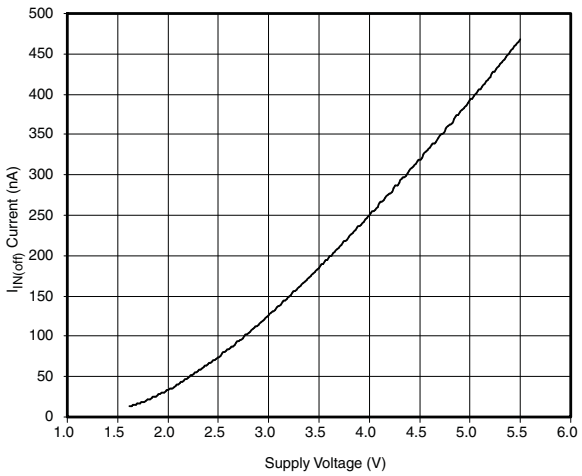



**Figure 8. $I_{IN(off)}$ vs $V_{IN}$**

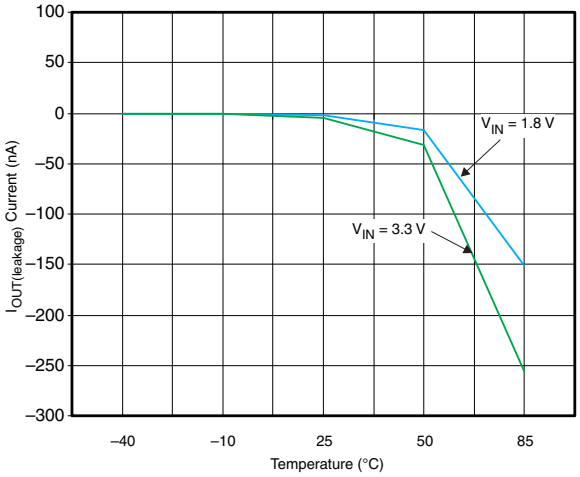



**Figure 9. $I_{OUT(leakage)}$ vs Temperature**

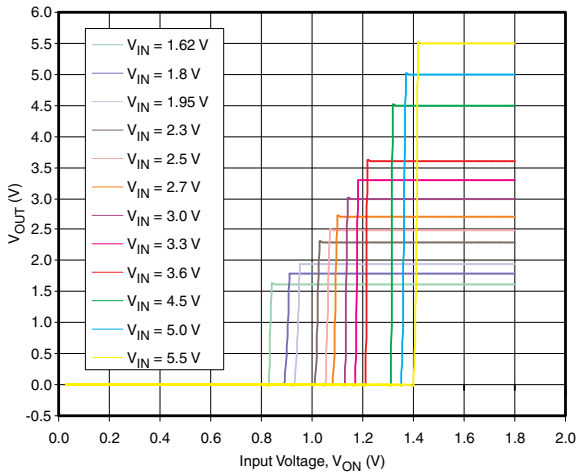



**Figure 10. $V_{OUT}$ vs ON Threshold**

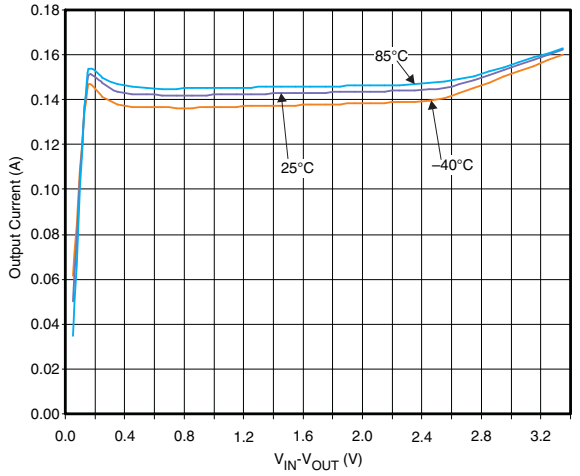



**Figure 11. $I_{LIM}$ vs Output Voltage (TPS22942, TPS22944, TPS22945)**

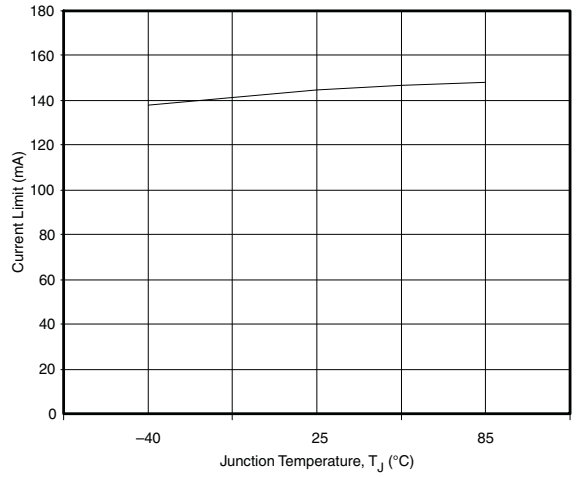



**Figure 12. $I_{LIM}$ vs Temperature (TPS22942, TPS22944, TPS22945)**

## Typical Characteristics (continued)

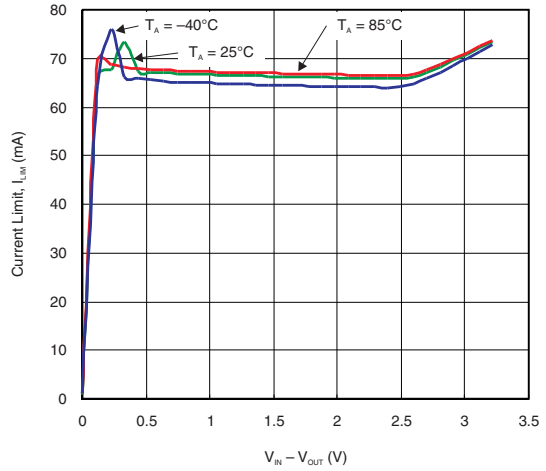



**Figure 13. $I_{LIM}$ vs ($V_{IN}$-$V_{OUT}$) (TPS22941, TPS22943)**

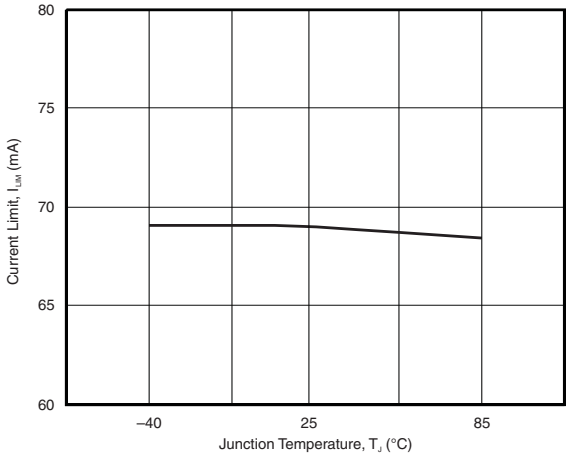
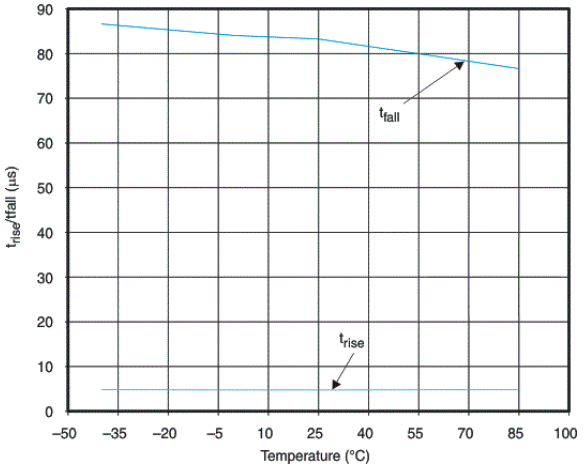
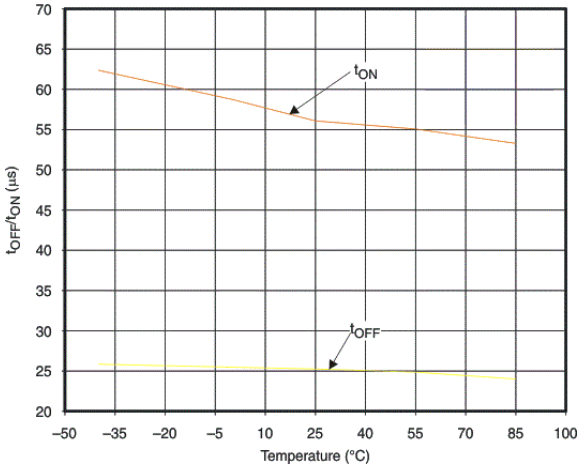



**Figure 14. $I_{LIM}$ vs Temperature (TPS22941, TPS22943)**




$C_L$ = 0.1 µF $R_L$ = 350 Ω $V_{IN}$ = 3.3 V

**Figure 15. $t_{rise}$/$t_{fall}$ vs Temperature**




$C_L$ = 0.1 µF $R_L$ = 350 Ω $V_{IN}$ = 3.3 V

**Figure 16. $t_{ON}$/$t_{OFF}$ vs Temperature**

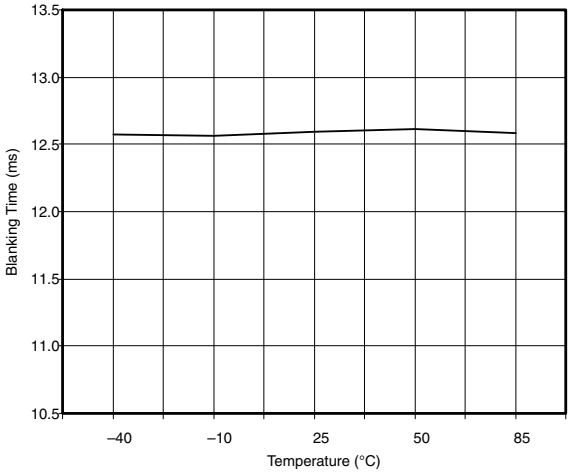



**Figure 17. $t_{BLANK}$ vs Temperature ($V_{IN}$ = 3.3 V)**

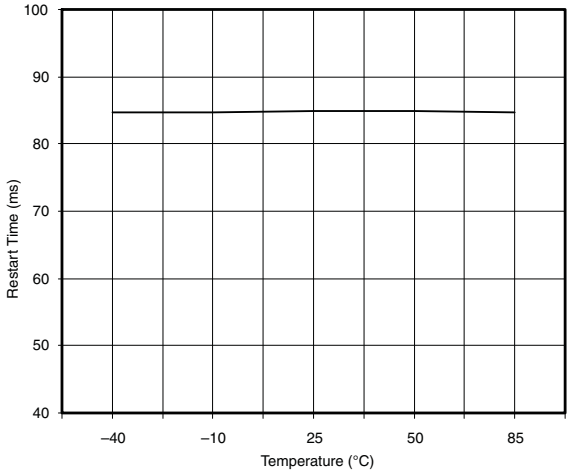



**Figure 18. $t_{RESTART}$ vs Temperature ($V_{IN}$ = 3.3 V)**

# 8 Detailed Description

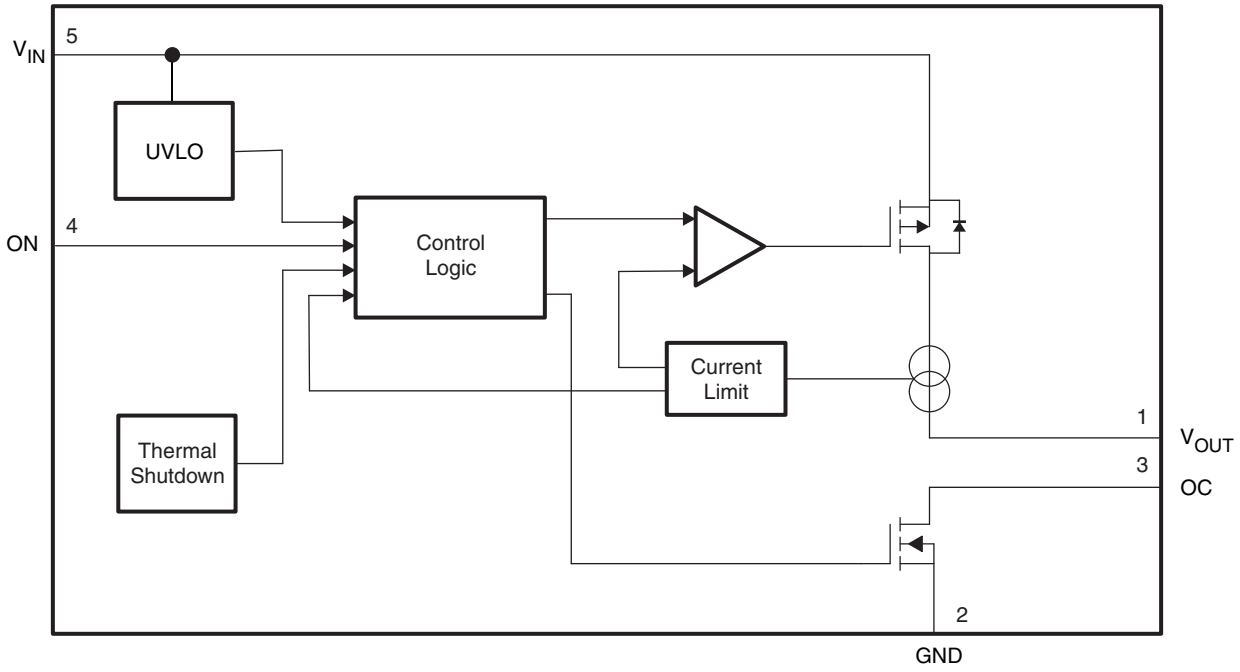
## 8.1 Overview

The TPS22941/2/3/4/5 load switches are 5.5V, current limited load switches in a SC-70 package. The devices contain a 0.4-Ω current-limited P-channel MOSFET that can operate over an input voltage range of 1.62 V to 5.5 V.

When the switch current reaches the maximum limit, the TPS22941/2/3/4/5 operates in a constant-current mode to prohibit excessive currents from causing damage. TPS22941/3 has a current limit of 40 mA and TPS22942/4/5 has a current limit of 100 mA.

For the TPS22941/2/5, if the constant current condition still persists after 10ms, these parts shut off the switch and pull the fault signal pin (OC) low. The TPS22941/2/5 have an auto-restart feature that turns the switch on again after 80 ms if the ON pin is still active. A current limit condition on the TPS22943 and on the TPS22944 immediately pull the fault signal pin low (OC pin) and the part remains in the constant-current mode until the switch current falls below the current limit.

## 8.2 Functional Block Diagram




## 8.3 Feature Description

### 8.3.1 Fault Reporting

When an overcurrent, input undervoltage, or overtemperature condition is detected, OC is set active low to signal the fault mode. OC is an open-drain MOSFET and requires a pullup resistor between $V_{IN}$ and OC. During shutdown, the pulldown on OC is disabled, reducing current draw from the supply.

### 8.3.2 Current Limiting

When the switch current reaches the maximum limit, the TPS22921/2/3/4/5 operates in a constant-current mode to prohibit excessive currents from causing damage. TPS22921/3 has a current limit of 40 mA and TPS22922/4/5 has a current limit of 100 mA. A current limit condition immediately pulls the fault signal pin low (OC pin), and the part remains in the constant-current mode until the switch current falls below the current limit.

## Feature Description (continued)

### 8.3.3 Thermal Shutdown

Thermal shutdown protects the part from internally or externally generated excessive temperatures. During an overtemperature condition the switch is turned off. The switch automatically turns on again if the temperature of the die drops below the threshold temperature.

## 8.4 Device Functional Modes

When the ON pin is actively pulled high and no fault conditions are present, the switch will be turned on, connecting VIN to VOUT. When the ON pin is actively pulled low regardless of the fault condition, the switch will be turned off.

In the event that the current limit is exceeded, the device will operate in a constant-current mode and pull the OC pin low until the fault condition is removed. If the condition persists after the current limit blanking time, the device will automatically turn off.

During thermal shutdown conditions, the switch will automatically turn off and will turn back on again if the temperature of the die drops below the threshold temperature.

# 9 Application and Implementation

This section will highlight some of the design considerations when implementing this device in various applications.

## 9.1 Application Information

### 9.1.1 On/Off Control

The ON pin controls the state of the switch. Activating ON continuously holds the switch in the on state as long as there is no fault. An undervoltage lockout or thermal shutdown event will override the ON pin control and turn off the switch. ON is active high and has a low threshold, making it capable of interfacing with low-voltage signals.

### 9.1.2 Undervoltage Lockout

The undervoltage lockout turns off the switch if the input voltage drops below the undervoltage lockout threshold. With the ON pin active, the input voltage rising above the undervoltage lockout threshold causes a controlled turn-on of the switch, which limits current overshoots.

### 9.1.3 Reverse Voltage

If the voltage at the $V_{OUT}$ pin is larger than the $V_{IN}$ pin, large currents may flow and can cause permanent damage to the device. TPS22941/2/3/4/5 is designed to control current flow only from $V_{IN}$ to $V_{OUT}$.

### 9.1.4 Input Capacitor

To limit the voltage drop on the input supply caused by transient in-rush currents when the switch turns on into a discharged load capacitor or a short-circuit, a capacitor needs to be placed between $V_{IN}$ and GND. A 1-µF ceramic capacitor, $C_{IN}$, placed close to the pins is usually sufficient. Higher values of $C_{IN}$ can be used to further reduce the voltage drop.

### 9.1.5 Output Capacitor

A 0.1-µF capacitor, $C_{OUT}$, should be placed between $V_{OUT}$ and GND. This capacitor will prevent parasitic board inductances from forcing $V_{OUT}$ below GND when the switch turns off. For the TPS22941/2/3/4/5, the total output capacitance needs to be kept below a maximum value, $C_{OUT(MAX)}$, to prevent the part from registering an over-current condition and turning-off the switch.

Due to the integrated body diode in the PMOS switch, a $C_{IN}$ greater than $C_{OUT}$ is highly recommended. A $C_{OUT}$ greater than $C_{IN}$ can cause $V_{OUT}$ to exceed $V_{IN}$ when the system supply is removed. This could result in current flow through the body diode from $V_{OUT}$ to $V_{IN}$.

## 9.2 Typical Application

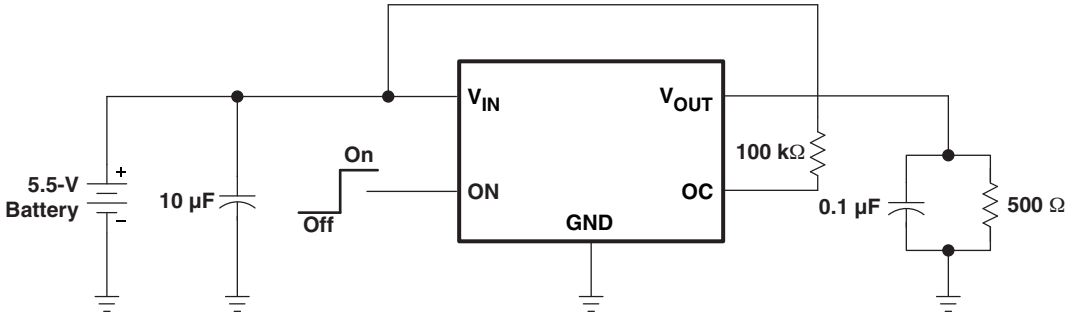



**Figure 19. Typical Application Circuit, Active-High Enabled Device (TPS22943, TPS22944 and TPS22945 Only)**

## Typical Application (continued)

### 9.2.1 Design Requirements

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

| DESIGN PARAMETER | EXAMPLE VALUE |
|---|---|
| $V_{IN}$ | 5.0 V |
| Load Current | 50mA |

### 9.2.2 Detailed Design Procedure

To begin the design process, the designer needs to know the following:

- VIN voltage
- Load current

#### *9.2.2.1 VIN to VOUT Voltage Drop*

The VIN to VOUT voltage drop in the device is determined by the $R_{ON}$ of the device and the load current. The $R_{ON}$ of the device depends upon the $V_{IN}$ condition of the device. Refer to the $R_{ON}$ specification of the device in the Electrical Characteristics table of this datasheet.

Once the $R_{ON}$ of the device is determined based upon the VIN conditions, use Equation 1 to calculate the VIN to VOUT voltage drop:

$$\Delta V = I_{LOAD} \times R_{ON} \quad (1)$$

where:

- $\Delta V$ = voltage drop from VIN to VOUT
- $I_{LOAD}$ = load current
- $R_{ON}$ = ON-resistance of the device for a specific $V_{IN}$

#### *9.2.2.2 Maximum Output Capacitance*

When designing this device, it is important to ensure the inrush current of the output capacitance does not cause the device to exceed the current limiting time beyond the blanking time. The maximum output capacitance can be determined from Equation 2 :

$$C_{OUT} = \frac{I_{LM(MAX)} \times t_{BLANK(MIN)}}{V_{IN}} \quad (2)$$

where:

- $C_{OUT}$ = output capacitance
- $I_{LIM(MAX)}$ = maximum current limit
- $t_{BLANK(MIN)}$ = minimum blanking time
- $V_{IN}$ = input voltage

### 9.2.2.3 Power Dissipation

During normal operation as a switch, the power dissipation is small and has little effect on the operating temperature of the part. The parts with the higher current limits will dissipate the most power and that will only be,

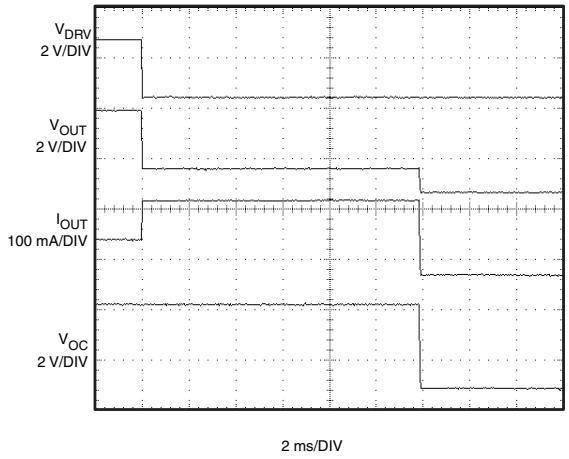
$$P_D = (I_{LIM})^2 \times r_{ON} \quad (3)$$

If the part goes into current limit the maximum power dissipation will occur when the output is shorted to ground. For TPS22941/2/5, the power dissipation scales by the auto-restart time ($t_{RESTART}$) and the overcurrent blanking time ($t_{BLANK}$) so that the maximum power dissipated is:

$$P_{D(MAX)} = \left(\frac{t_{BLANK}}{t_{RESTART} + t_{BLANK}}\right) \times V_{IN(MAX)} \times I_{LIM(MAX)} \quad (4)$$

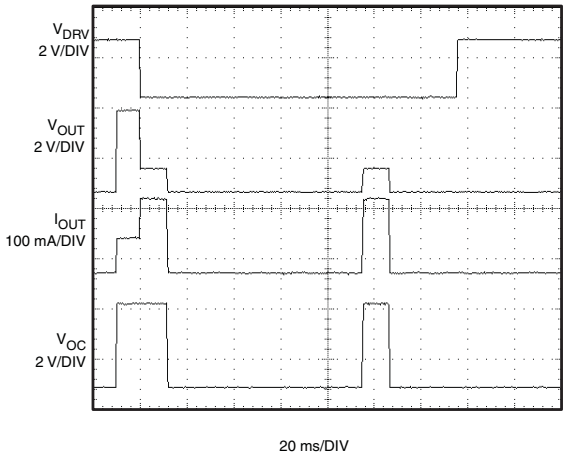
When using the TPS22943 and TPS22944, a short on the output causes the part to operate in a constant current state, dissipating a worst-case power as calculated above until the thermal shutdown activates. It then cycles in and out of thermal shutdown so long as the ON pin is active and the short is present.

### 9.2.2.4 Application Curves



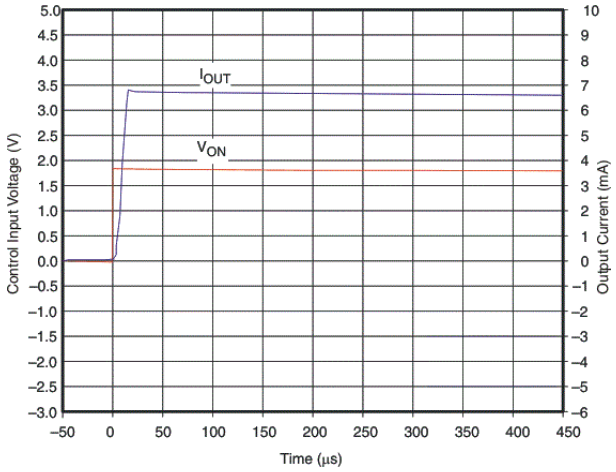

$V_{DRV}$ signal forces the device to go into over-current mode.

**Figure 20. $t_{BLANK}$ Response**



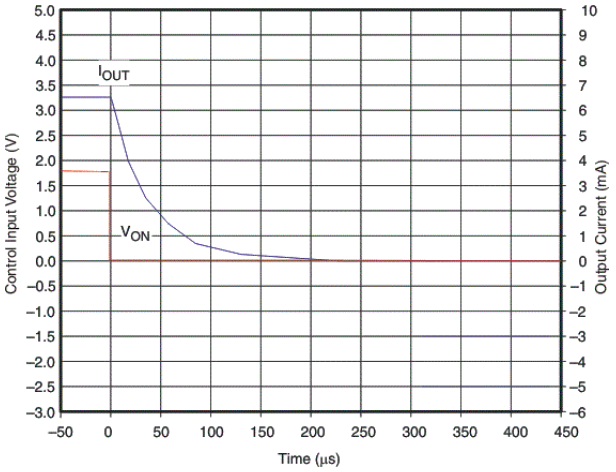

$V_{DRV}$ signal forces the device to go into over-current mode.

**Figure 21. $t_{RESTART}$ Response**



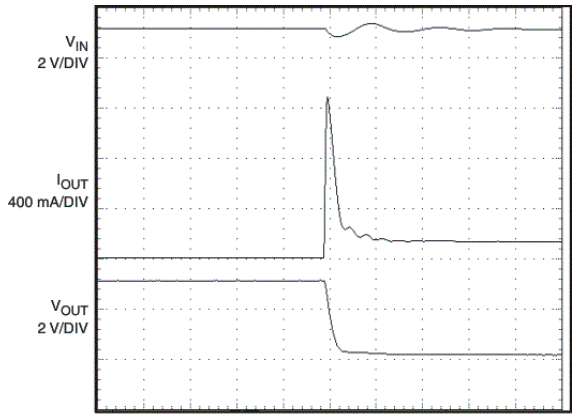

$C_L$ = 0.1 µF $R_L$ = 500 Ω $V_{IN}$ = 3.3 V

**Figure 22. $t_{ON}$ Response**



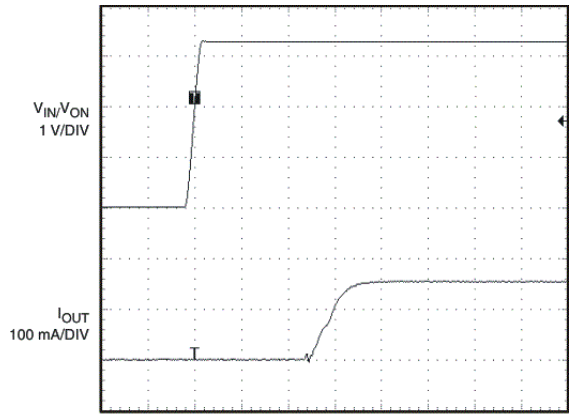

$C_L$ = 0.1 µF $R_L$ = 500 Ω $V_{IN}$ = 3.3 V

**Figure 23. $t_{ON}$ Response**



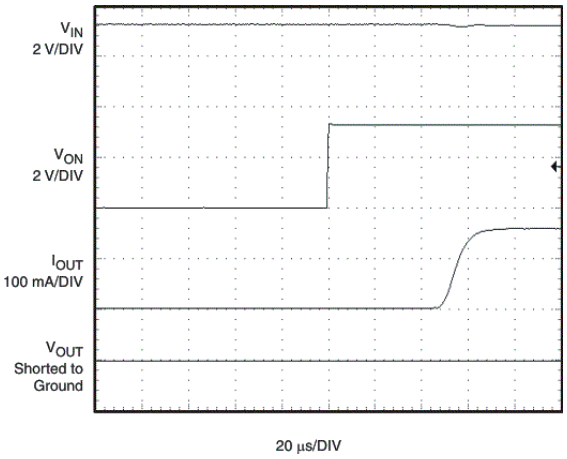

$C_{IN}$ = 10 µF $C_{OUT}$ = 1 µF

**Figure 24. Short-Circuit Response Time (Output Shorted to Ground)**




$C_{IN}$ = 10 µF $C_{OUT}$ = 1 µF

**Figure 25. Short-Circuit Response Time (Switch Powerup to Hard Short)**




$C_{IN}$ = 10 µF $C_{OUT}$ = 1 µF

**Figure 26. Current Limit Response Time**

# 10 Power Supply Recommendations

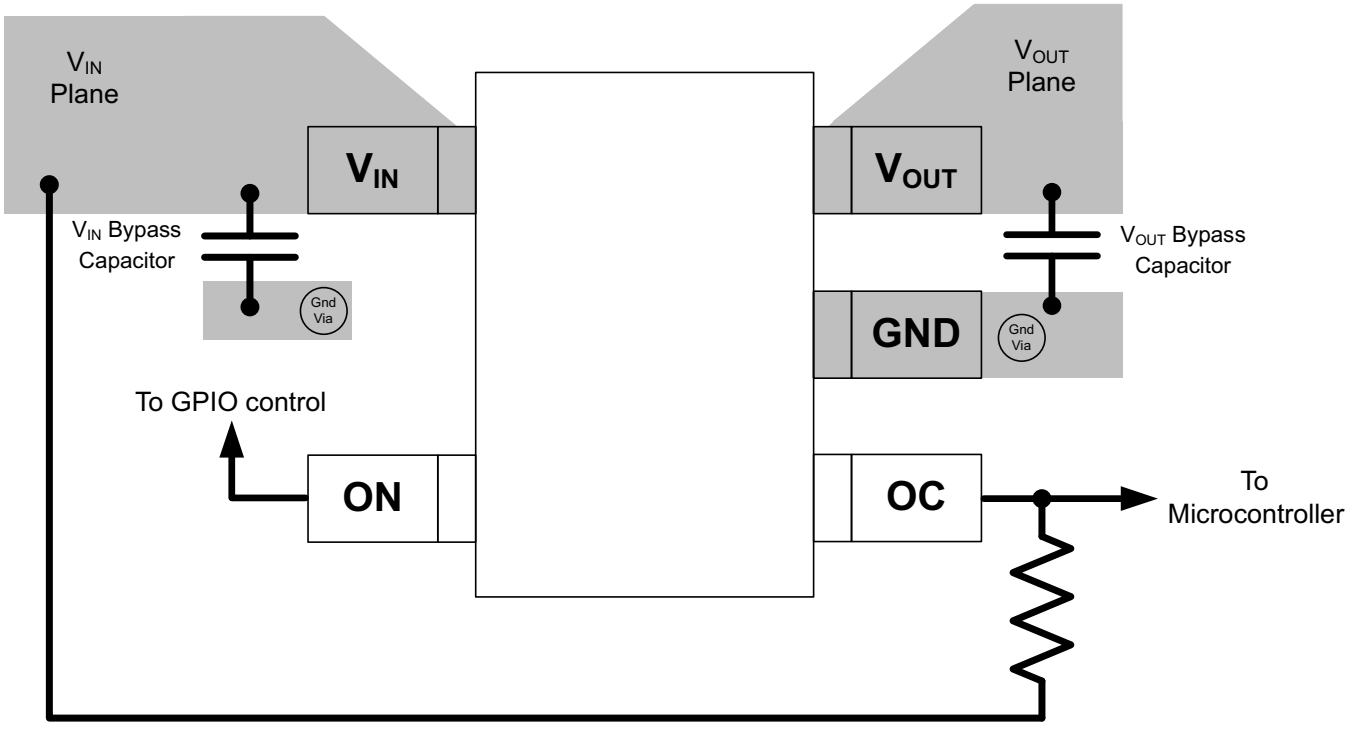
The device is designed to operate from a $V_{IN}$ range of 1.62-V to 5.5-V. This supply must be well regulated and placed as close to the device terminal as possible with the recommended 1µF bypass capacitor. If the supply is located more than a few inches from the device terminals, additional bulk capacitance may be required in addition to the ceramic bypass capacitors. If additional bulk capacitance is required, an electrolytic, tantalum, or ceramic capacitor of 10-µF may be sufficient.

# 11 Layout

## 11.1 Layout Guidelines

- For best performance, all traces should be as short as possible.
- To be most effective, the input and output capacitors should be placed close to the device to minimize the effects that parasitic trace inductances may have on normal and short-circuit operation.
- The $V_{IN}$ terminal should be bypassed to grond with low ESR ceramic bypass capacitors. The typical recommended bypass capacitance is 1-µF ceramic with X5R or X7R dielectric. This capacitor should be placed as close to the device terminals as possible.
- The $V_{OUT}$ terminal should be bypassed to grond with low ESR ceramic bypass capacitors. The typical recommended bypass capacitance is one-tenth of the VIN bypass capacitor of X5R or X7R dielectric. This capacitor should be placed as close to the device terminals as possible.
- Using wide traces for $V_{IN}$, $V_{OUT}$, and GND will help minimize parasitic electrical effects along with minimizing the case to ambient thermal impedance.

## 11.2 Layout Example



## 11.3 Thermal Considerations

The maximum junction temperature will be internally limited by the thermal shutdown ($T_{SD}$). To calculate the maximum allowable dissipation, $P_{D(MAX)}$ for a given ambient temperature, use Equation 5.

$$P_{D(MAX)} = \frac{T_{SD} - T_A}{\theta_{JA}} \quad (5)$$

where:

- $P_{D(MAX)}$ = maximum allowable power dissipation
- $T_{SD}$ = thermal shutdown threshold (140 °C typical)
- $T_A$ = ambient temperature of the device
- $\theta_{JA}$ = junction to air thermal impedance. See the section. This parameter is highly dependent upon board layout.

# 12 Device and Documentation Support

## 12.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 1. Related Links**

| PARTS | PRODUCT FOLDER | SAMPLE & BUY | TECHNICAL DOCUMENTS | TOOLS & SOFTWARE | SUPPORT & COMMUNITY |
|---|---|---|---|---|---|
| TPS22941 | Click here | Click here | Click here | Click here | Click here |
| TPS22942 | Click here | Click here | Click here | Click here | Click here |
| TPS22943 | Click here | Click here | Click here | Click here | Click here |
| TPS22944 | Click here | Click here | Click here | Click here | Click here |
| TPS22945 | Click here | Click here | Click here | Click here | Click here |

## 12.2 Trademarks

All trademarks are the property of their respective owners.

## 12.3 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## 12.4 Glossary

SLYZ022 — *TI Glossary*.

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

# 13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TPS22941DCKR | ACTIVE | SC70 | DCK | 5 | 3000 | Green (RoHS & no Sb/Br) | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 4AN | Samples |
| TPS22942DCKR | ACTIVE | SC70 | DCK | 5 | 3000 | Green (RoHS & no Sb/Br) | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | (4BJ, 4BN) | Samples |
| TPS22942DCKRG4 | ACTIVE | SC70 | DCK | 5 | 3000 | Green (RoHS & no Sb/Br) | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | (4BJ, 4BN) | Samples |
| TPS22943DCKR | ACTIVE | SC70 | DCK | 5 | 3000 | Green (RoHS & no Sb/Br) | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 4CN | Samples |
| TPS22944DCKR | ACTIVE | SC70 | DCK | 5 | 3000 | Green (RoHS & no Sb/Br) | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 4DN | Samples |
| TPS22945DCKR | ACTIVE | SC70 | DCK | 5 | 3000 | Green (RoHS & no Sb/Br) | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | (4EJ, 4EN) | Samples |
| TPS22945DCKRG4 | ACTIVE | SC70 | DCK | 5 | 3000 | Green (RoHS & no Sb/Br) | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | (4EJ, 4EN) | 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.
**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

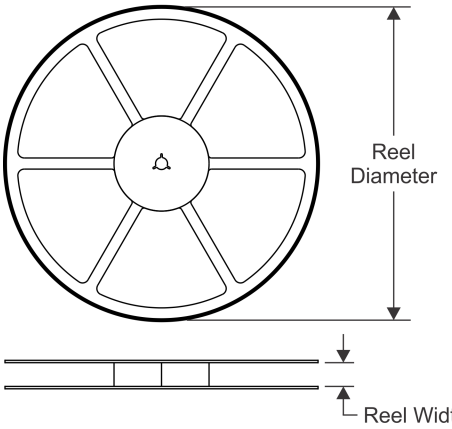
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

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

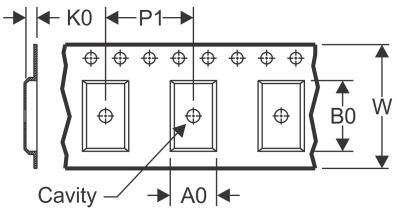
**(6)** Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

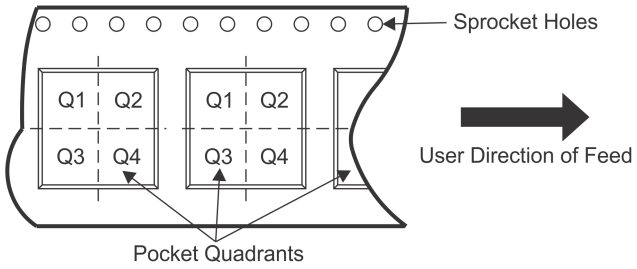



**TAPE DIMENSIONS**




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

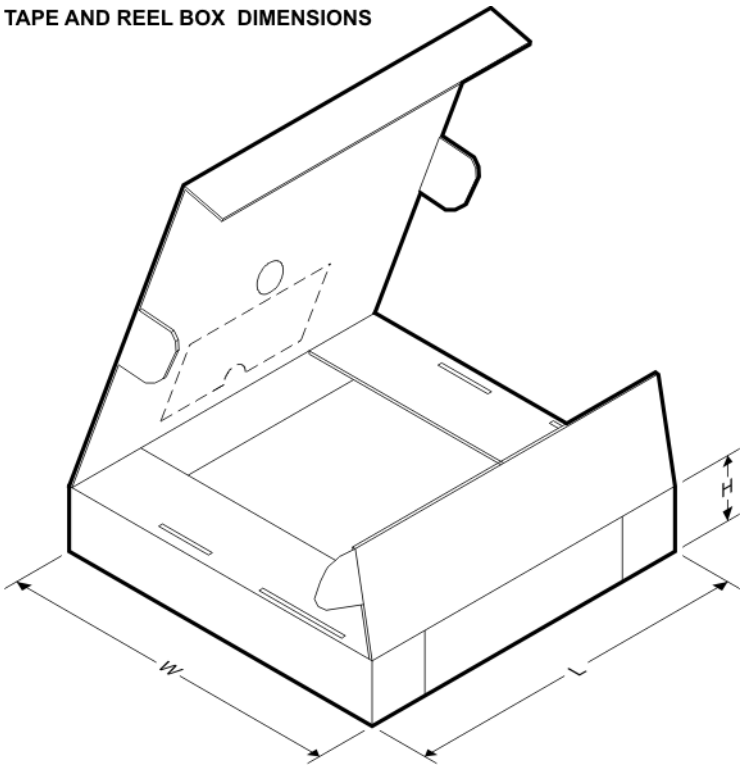
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TPS22941DCKR | SC70 | DCK | 5 | 3000 | 180.0 | 9.2 | 2.3 | 2.55 | 1.2 | 4.0 | 8.0 | Q3 |
| TPS22942DCKR | SC70 | DCK | 5 | 3000 | 180.0 | 9.2 | 2.3 | 2.55 | 1.2 | 4.0 | 8.0 | Q3 |
| TPS22942DCKR | SC70 | DCK | 5 | 3000 | 179.0 | 8.4 | 2.2 | 2.5 | 1.2 | 4.0 | 8.0 | Q3 |
| TPS22943DCKR | SC70 | DCK | 5 | 3000 | 180.0 | 9.2 | 2.3 | 2.55 | 1.2 | 4.0 | 8.0 | Q3 |
| TPS22944DCKR | SC70 | DCK | 5 | 3000 | 180.0 | 9.2 | 2.3 | 2.55 | 1.2 | 4.0 | 8.0 | Q3 |
| TPS22945DCKR | SC70 | DCK | 5 | 3000 | 179.0 | 8.4 | 2.2 | 2.5 | 1.2 | 4.0 | 8.0 | Q3 |
| TPS22945DCKR | SC70 | DCK | 5 | 3000 | 180.0 | 9.2 | 2.3 | 2.55 | 1.2 | 4.0 | 8.0 | Q3 |

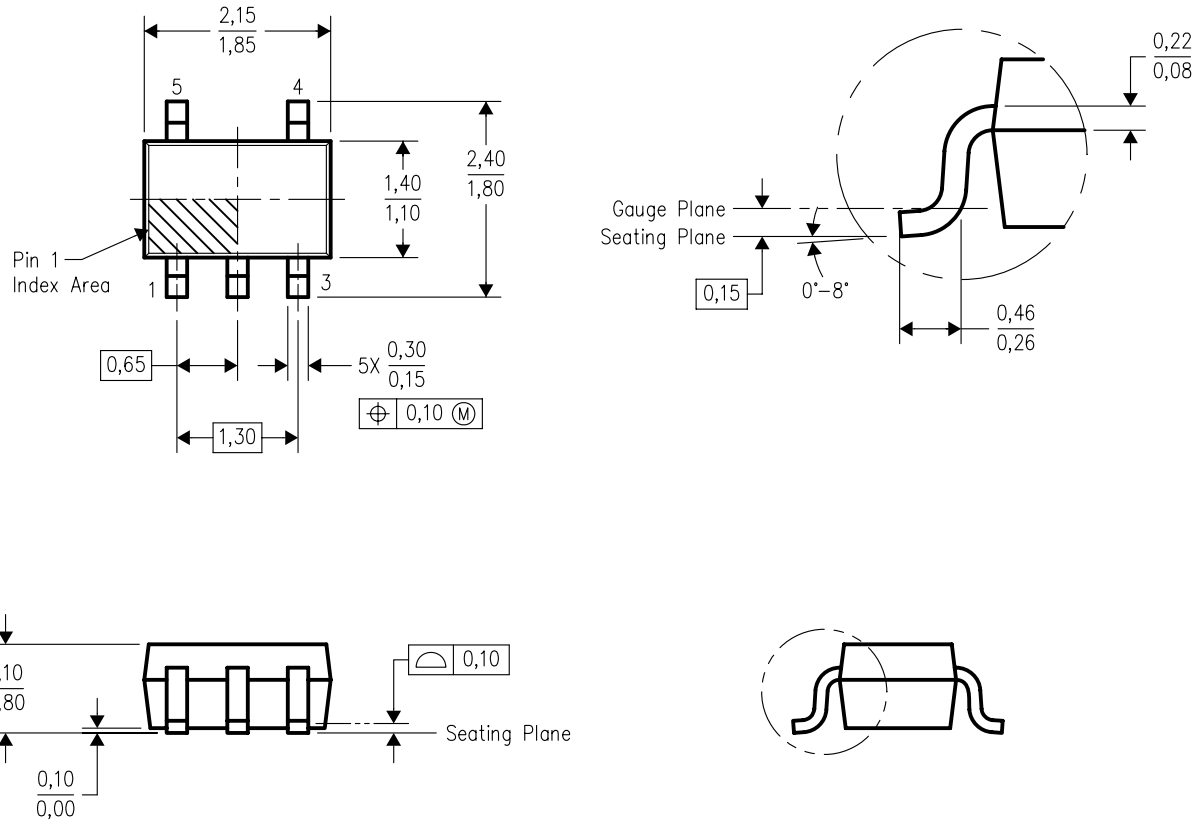
TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| TPS22941DCKR | SC70 | DCK | 5 | 3000 | 205.0 | 200.0 | 33.0 |
| TPS22942DCKR | SC70 | DCK | 5 | 3000 | 205.0 | 200.0 | 33.0 |
| TPS22942DCKR | SC70 | DCK | 5 | 3000 | 203.0 | 203.0 | 35.0 |
| TPS22943DCKR | SC70 | DCK | 5 | 3000 | 205.0 | 200.0 | 33.0 |
| TPS22944DCKR | SC70 | DCK | 5 | 3000 | 205.0 | 200.0 | 33.0 |
| TPS22945DCKR | SC70 | DCK | 5 | 3000 | 203.0 | 203.0 | 35.0 |
| TPS22945DCKR | SC70 | DCK | 5 | 3000 | 205.0 | 200.0 | 33.0 |

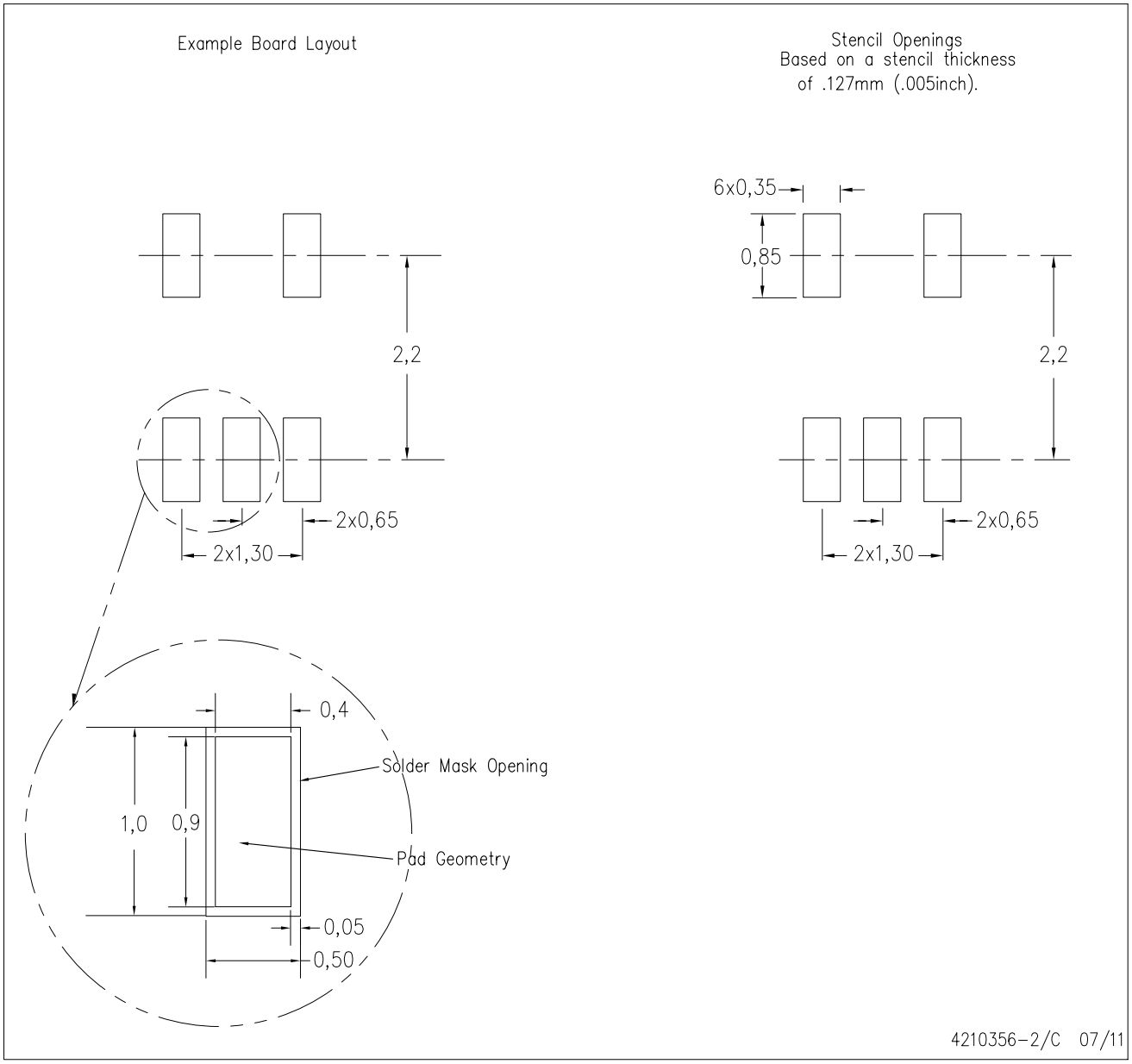
## DCK (R–PDSO–G5) PLASTIC SMALL–OUTLINE PACKAGE




4093553–3/G 01/2007

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Falls within JEDEC MO–203 variation AA.

DCK (R–PDSO–G5) PLASTIC SMALL OUTLINE




NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
D. Publication IPC–7351 is recommended for alternate designs.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC–7525 for other stencil recommendations.

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