



TPS22951 Current-Limited 1-Ω Smart-Load Switch

1 Features

- 1-Ω P-Channel MOSFET
- 300-mA Continuous Source Current
- Thermal and Short-Circuit Protection
- 600-mA Current Limit
- Operating Range: $V_{CC} = 2.8\text{ V to }5.3\text{ V}$
- 41-μs Typical Rise Time
- 10-μA Maximum Standby Supply Current
- Ambient Temperature Range: $-40^{\circ}\text{C to }+85^{\circ}\text{C}$
- ESD Performance Tested Per JESD 22
 - 4000-V Human-Body Model (HBM)
 - 400-V Machine Model (MM)
 - 1000-V Charged-Device Model (CDM)

2 Applications

- Smart Phones
- Notebooks
- Digital Cameras
- Peripheral Ports

3 Description

The TPS22951 smart-load switch is intended for applications where heavy capacitive loads and short circuits are likely to be encountered. This device incorporates a 1-Ω P-channel MOSFET power switch for power distribution. The switch is controlled by a logic enable (EN) input and an accessory detect (DET) pin. The switch is active when EN is high and DET is low. The switch is disabled if EN is low or DET is high. A low power state is achieved by driving EN low.

When the output load exceeds the current-limit threshold or a short is present, the device limits the output current to a safe level by increasing the on resistance of the power switch. When continuous heavy overloads and short circuits increase the power dissipation in the switch, causing the junction temperature to rise, a thermal-protection circuit shuts off the switch to prevent damage. The device recovers from a thermal shutdown once the device has cooled sufficiently, but the switch remains OFF until EN is toggled. This smart-load switch is designed to set current limit at 600 mA maximum.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TPS22951	DSBGA (6)	1.20 mm x 0.80 mm

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

Simplified Schematic

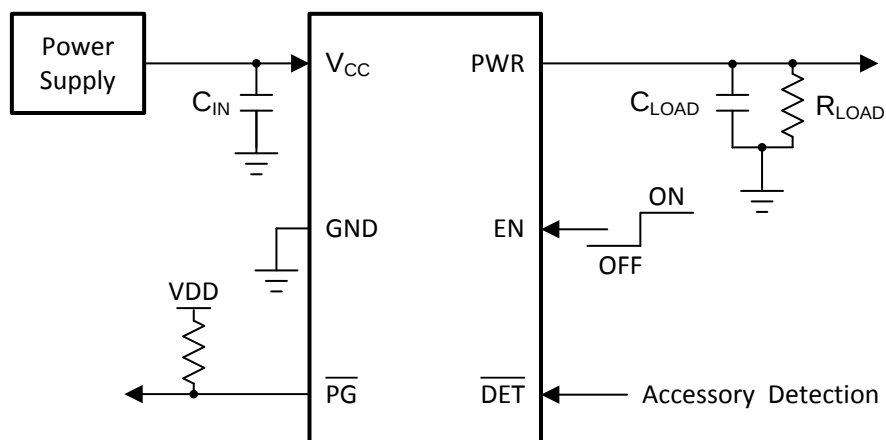


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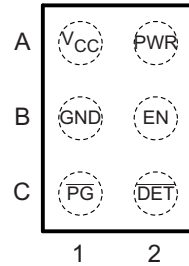
4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

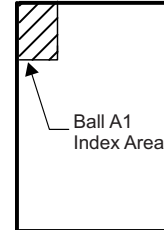
Changes from Revision C (March 2015) to Revision D	Page
• Changed all instances of "POK" to "PG" in the data sheet	1
Changes from Revision B (November 2012) to Revision C	Page
• Added <i>Pin Configuration and Functions</i> section, <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i> , <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section	1
Changes from Revision A (March 2009) to Revision B	Page
• Updated Top-Side Marking in the <i>Ordering Information</i> table.....	3

5 Pin Configurations and Functions

**YFP Package
6-Pin DSBGA
Top-Through View**



**YFP Package
6-Pin DSBGA
Top View**



Pin Functions

Pin		I/O	DESCRIPTION
NO.	NAME		
A1	V _{CC}	I	Supply voltage
A2	PWR	O	Power switch output
B1	GND	—	Ground
B2	EN	I	Enable input ⁽¹⁾
C1	$\overline{\text{PG}}$	O	Power Good switch status open-drain output, active low
C2	$\overline{\text{DET}}$	I	Accessory detect, active low

(1) $\overline{\text{DET}}$ must be low for a minimum of 2 μs before EN is pulled high (see the [Timing Requirements](#) section).

6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
V_{CC} ⁽²⁾	Supply voltage	−0.3	6	V
$V_{O(PWR)}$ ⁽²⁾	Output voltage	−0.3	$V_{CC} + 0.3$	V
$V_{I(EN)}, V_{I(DET)}$	Input voltage	−0.3	6	V
$V_{O(PG)}$	Voltage	−0.3	6	V
$I_{O(PWR)}$	Continuous output current	Internally limited		
	Continuous total power dissipation	See the Thermal Information section		
	Lead temperature soldering 1.6 mm (1/16 in) from case for 10 s	−0.3	6	V
T_J	Operating virtual junction temperature	−40	85	°C
T_{stg}	Storage temperature	−65	150	°C

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

6.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$ Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	4000	V
	Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾	1000	
	Machine model (MM)	400	

- (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

		MIN	MAX	UNIT
V_{CC}	Supply voltage	2.2	5.3	V
$V_{I(EN)}, V_{I(DET)}$	Input voltage	0	V_{CC}	V
$I_{O(PWR)}$	Continuous output current	0	−600	mA
T_J	Operating virtual junction temperature	−40	85	°C

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾		TPS22951	UNIT
		YFP (DSBGA)	
		6 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	125.1	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	1.4	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	26	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	0.3	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	26	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	°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

over operating $-40^{\circ}\text{C} \leq T_J \leq +85^{\circ}\text{C}$ range (unless otherwise noted)

PARAMETER		TEST CONDITIONS ⁽¹⁾	MIN	TYP	MAX	UNIT
POWER SWITCH						
$r_{DS(on)}$	Static drain-source ON-state resistance, 3-V operation	$V_{CC} = 3\text{ V}$, $I_O = 0.3\text{ A}$			1	Ω
	Leakage current	PWR connected to GND, $V_{I(EN)} = 0\text{ V}$		1		μA
EN AND DET						
V_{IH}	High-level input voltage	$2.8\text{ V} \leq V_{CC} \leq 5.3\text{ V}$	1.35			V
V_{IL}	Low-level input voltage	$2.8\text{ V} \leq V_{CC} \leq 5.3\text{ V}$		0.45		V
I_I	Input current	$V_{I(EN)}$ or $V_{I(DET)} = 0\text{ V}$ or 5.3 V		1		μA
CURRENT LIMIT						
I_{OS}	Short-circuit output current	$V_{CC} = 2.8\text{ V}$ or 5.3 V , PWR connected to GND, Device enabled into short circuit	–0.3		–0.6	A
SUPPLY CURRENT						
	Supply current, enabled	No load on PWR, $V_{CC} = 5.3\text{ V}$, $V_{I(EN)} = V_{CC}$, $V_{I(DET)} = V_{CC}$ or 0 V			100	μA
	Supply current, disabled	No load on PWR, $V_{CC} = 5.3\text{ V}$, $V_{I(EN)} = 0\text{ V}$, $V_{I(DET)} = V_{CC}$ or 0 V			10	μA
PG						
$V_{OL(PG)}$	Power Good output low voltage	$I_{(PG)} = 1\text{ mA}$			0.4	V
	OFF-state current	$V_{(PG)} = 5.3\text{ V}$			1	μA
THERMAL SHUTDOWN						
	Thermal shutdown threshold ⁽²⁾		135			$^{\circ}\text{C}$
	Recovery from thermal shutdown ⁽²⁾		125			$^{\circ}\text{C}$
	Hysteresis ⁽²⁾			25		$^{\circ}\text{C}$

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

(2) Not tested in production, specified by design

6.6 Timing Requirements

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

	MIN	MAX	UNIT
t_{SU} Setup time, $\overline{DET}$ low before EN high	2		μs

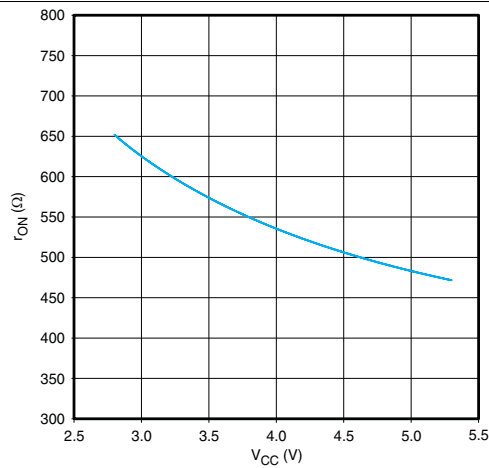
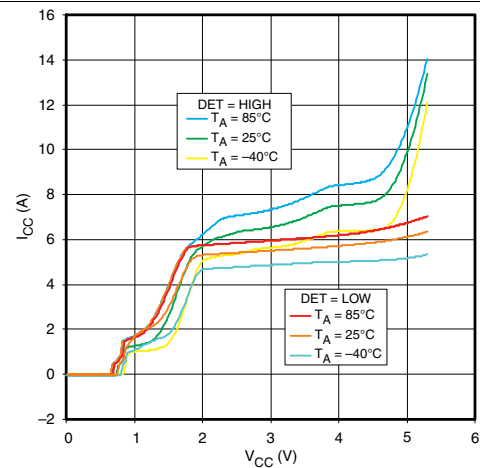
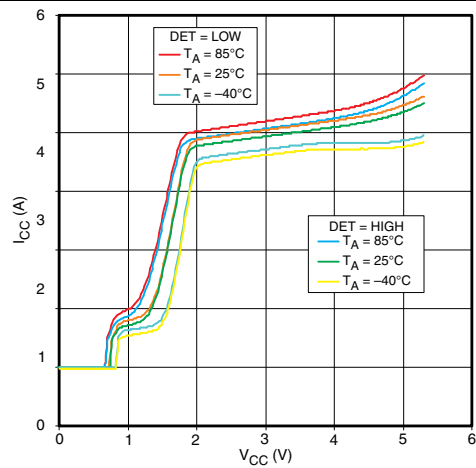
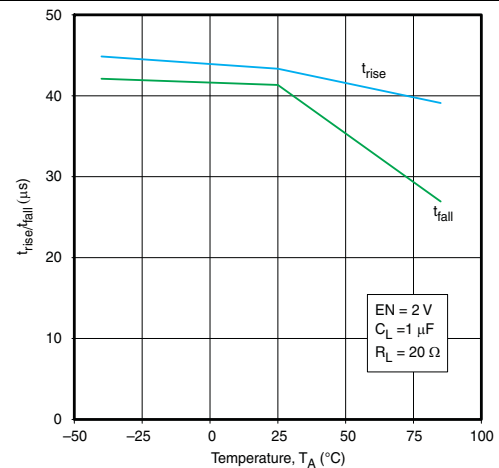
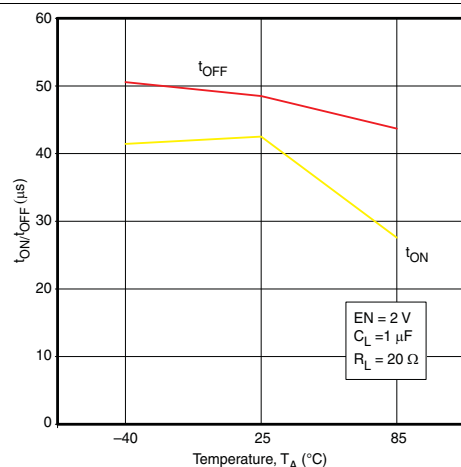
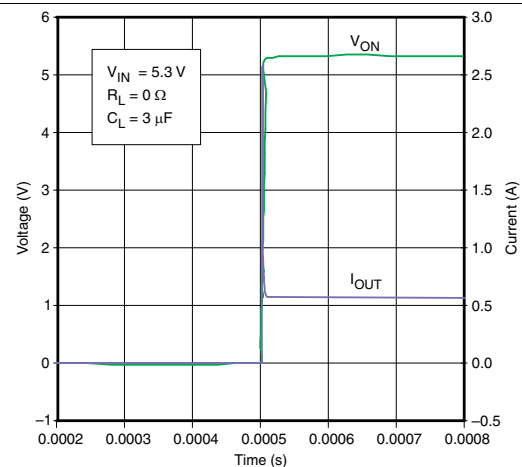
6.7 Switching Characteristics

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

PARAMETER		TEST CONDITIONS			MIN	TYP	MAX	UNIT
POWER SWITCH								
$t_r^{(1)}$	Rise time, output	$V_{CC} = 5.3\text{ V}$	$C_L = 1\text{ }\mu\text{F},$ $R_L = 20\text{ }\Omega$	$T_J = 25^{\circ}\text{C}$	41		μS	
		$V_{CC} = 2.8\text{ V}$			6			
$t_f^{(1)}$	Fall time, output	$V_{CC} = 5.3\text{ V}$	$C_L = 1\text{ }\mu\text{F},$ $R_L = 20\text{ }\Omega$	$T_J = 25^{\circ}\text{C}$	43		μS	
		$V_{CC} = 2.8\text{ V}$			43			
EN AND DET								
$t_{on}^{(1)}$	Turnon time (EN to PWR)	$V_{CC} = 5.3\text{ V}$	$C_L = 1\text{ }\mu\text{F}, R_L = 20\text{ }\Omega$		42		μS	
	Turnon time (EN to $\overline{\text{PG}}$)		$C_P = 15\text{ pF}, R_P = 10\text{ k}\Omega$		9.5			
$t_{off}^{(1)}$	Turnoff time (EN to PWR)	$V_{CC} = 5.3\text{ V}$	$C_L = 1\text{ }\mu\text{F}, R_L = 20\text{ }\Omega$		48		μS	
	Turnoff time (EN to $\overline{\text{PG}}$)		$C_P = 15\text{ pF}, R_P = 10\text{ k}\Omega$		47			

(1) Not tested in production, specified by design

6.8 Typical Characteristics


Figure 1. ON-State Resistance vs VCC

Figure 2. ICC vs VCC, EN = VCC

Figure 3. ICC vs VCC, EN = GND

Figure 4. trise/tfall vs Temperature, VCC = 5.3 V

Figure 5. tON/tOFF vs Temperature, VCC = 5.3 V

Figure 6. Device Enabled into Short-Circuit

Typical Characteristics (continued)

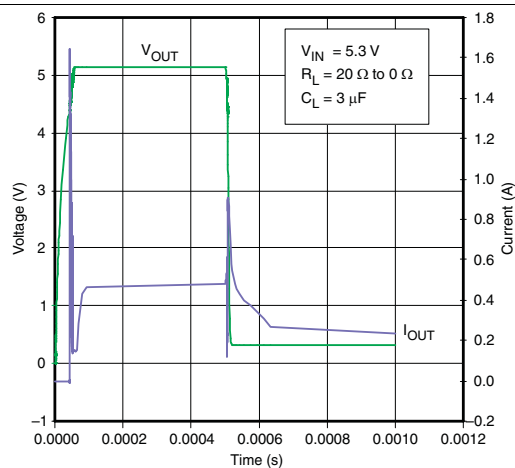


Figure 7. Full-Load to Short-Circuit Transient Response

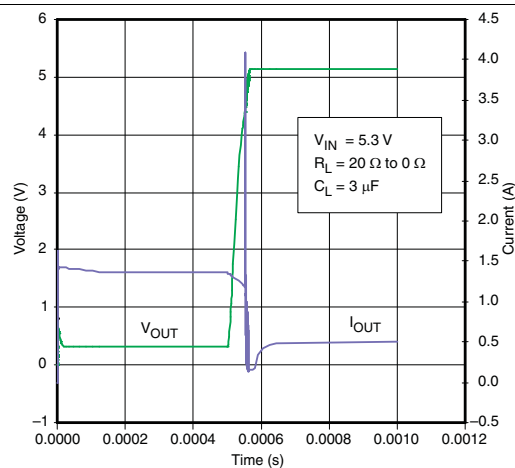


Figure 8. Short-Circuit to Full-Load Recovery Response

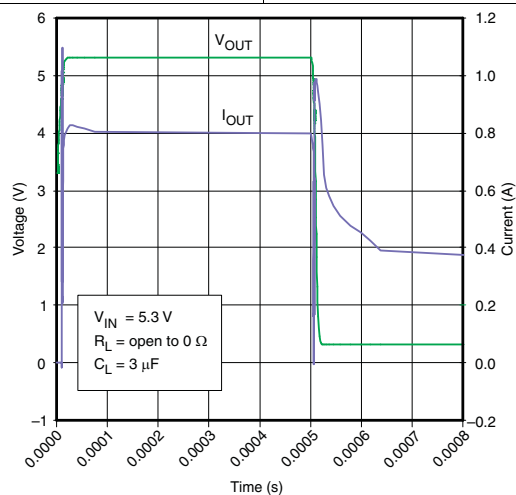


Figure 9. No-Load to Short-Circuit Transient Response

7 Parameter Measurement Information

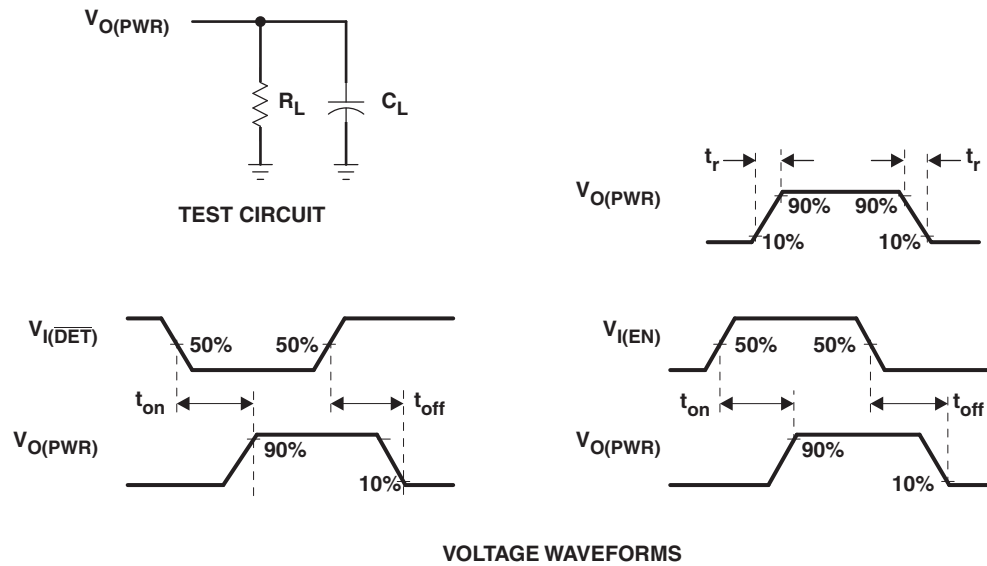


Figure 10. Test Circuit and Voltage Waveforms

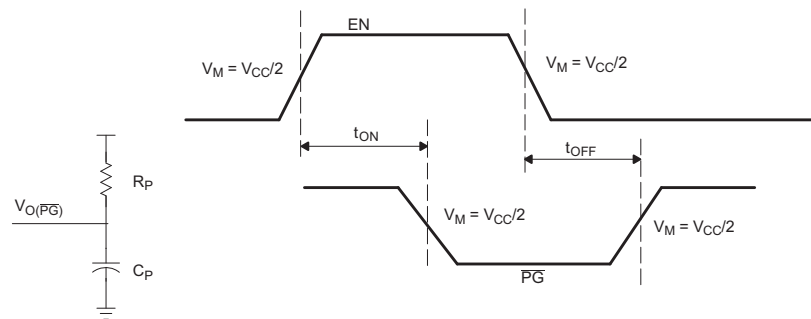


Figure 11. EN to $\overline{\text{PG}}$ Test Point

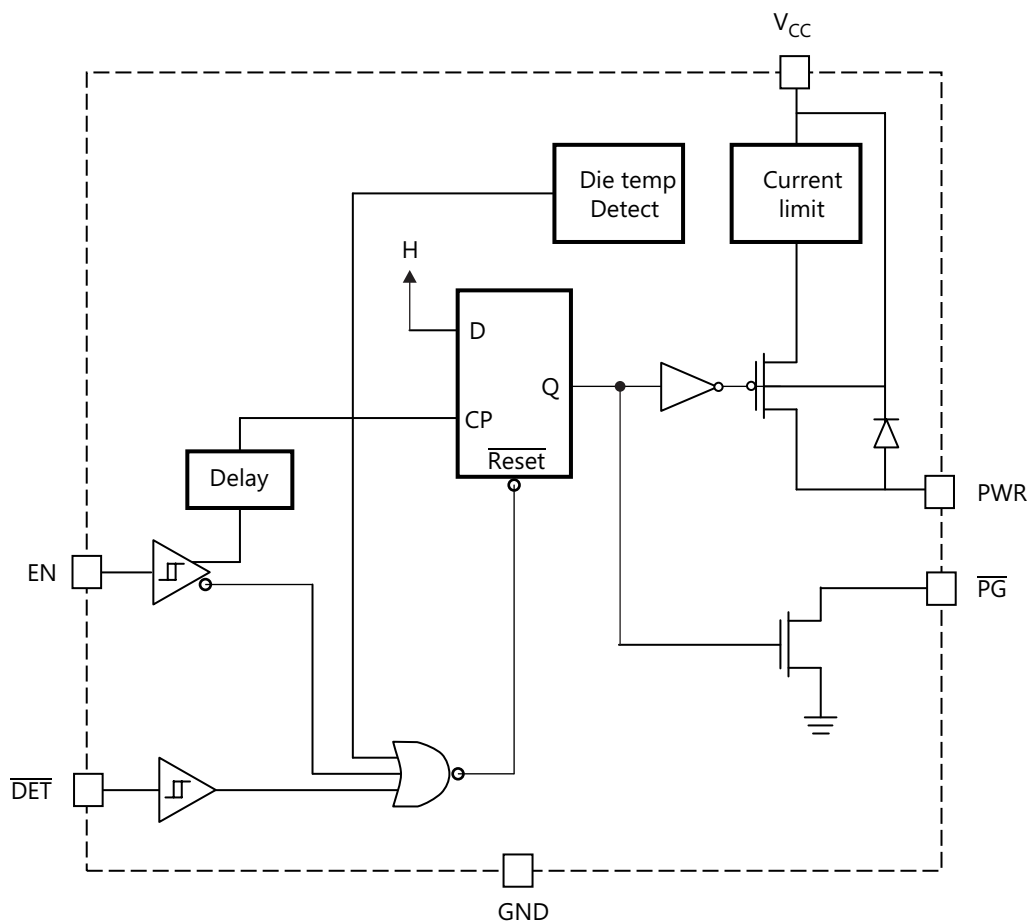
8 Detailed Description

8.1 Overview

The TPS22951 smart-load switch is intended for applications where heavy capacitive loads and short circuits are likely to be encountered. This device incorporates a 1- Ω P-channel MOSFET power switch for power distribution. The switch is controlled by a logic enable (EN) input and an accessory detect ($\overline{\text{DET}}$) pin. The switch is active when EN is high and $\overline{\text{DET}}$ is low. The switch is disabled if EN is low or $\overline{\text{DET}}$ is high. A low power state is achieved by driving EN low.

When the output load exceeds the current-limit threshold or a short is present, the device limits the output current to a safe level by increasing the on resistance of the power switch. When continuous heavy overloads and short circuits increase the power dissipation in the switch, causing the junction temperature to rise, a thermal-protection circuit shuts off the switch to prevent damage. The device recovers from a thermal shutdown once the device has cooled sufficiently, but the switch remains OFF until EN is toggled. This smart-load switch is designed to set current limit at 600 mA maximum.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Current Limit

The TPS22951 includes a current-limiting feature. The current limit can help protect the system from high currents in the case of large capacitive loads and short circuits. When the load current exceeds the current limit threshold, the device limits the output current by increasing the on-resistance of the switch.

8.3.2 Power Good Indication

The TPS22951 includes an open-drain Power Good indication. This signal can be used to provide an indication to another component in the system. The signal behaves according to [Table 1](#).

To use the signal, the PG pin must be connected to a pullup resistor. The PG pin has an absolute maximum rating of 6 V and must not be pulled up to any voltage beyond 6 V. The pullup resistor must be in the range of 10 kΩ to limit the current flowing into the PG pin when the switch is on and the PG signal is low.

8.3.3 EN and DET inputs

The switch is controlled by the EN and DET pins. To enable the switch, the EN pin must be high and the DET pin must be low.

8.3.4 Thermal Shutdown

The TPS22951 includes a thermal shutdown circuit. If the device reaches the thermal shutdown threshold, the switch is automatically be disabled. The switch retries after the device temperature has decreased and the EN pin is toggled from H to L to H.

8.4 Device Functional Modes

[Table 1](#) lists the functional modes of the TPS22951.

Table 1. Function Table

EN	$\overline{\text{DET}}$	CURRENT LIMIT	THERMAL LIMIT	POWER SWITCH (V _{CC} TO PWR)	$\overline{\text{PG}}$ (OPEN-DRAIN)
0	X	Not exceeded	Not exceeded	OFF	Z
X	1	Not exceeded	Not exceeded	OFF	Z
1	0	Not exceeded	Not exceeded	ON	L
1	0	Exceeded	Not exceeded	ON – current-limited	L
X	X	X	Exceeded ⁽¹⁾	OFF	Z

(1) To recover from a thermal event, the die temperature must first drop below the specified limit. EN must then be toggled to latch in the proper state of the flip-flop.

9 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.

9.1 Application Information

The input to output 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_{CC} condition of the device. Refer to [Figure 1](#) r_{ON} vs V_{CC} to determine the r_{ON} of the device based upon the V_{CC} condition. Use [Equation 1](#) to calculate the input to output voltage drop:

$$\Delta V = I_{LOAD} \times R_{ON}$$

where

- ΔV = voltage drop from V_{CC} to PWR
- I_{LOAD} = load current
- R_{ON} = ON-Resistance of the device for a specific V_{CC}

(1)

9.2 Typical Application

This application demonstrates how the TPS22951 can be used to protect against a short-circuit event. In this application, the PWR node is accidentally shorted to ground.

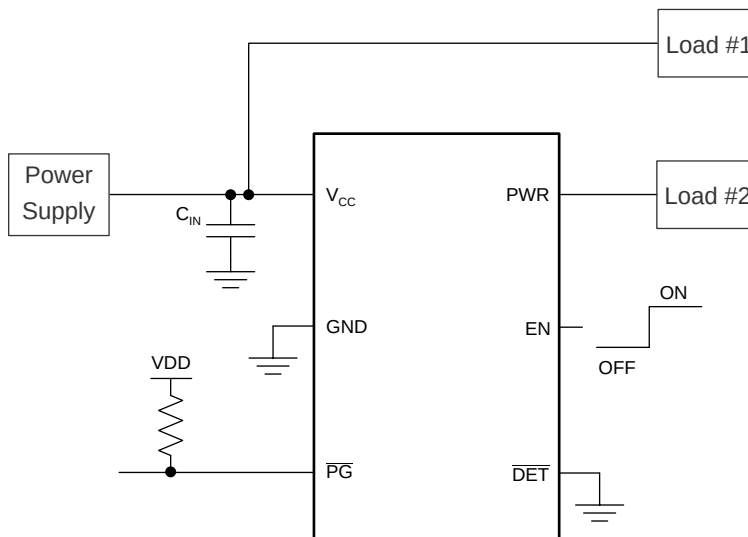


Figure 12. Typical Application Circuit

9.2.1 Design Requirements

For this design example, use the input parameters given in [Table 2](#):

Table 2. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Power Supply Maximum DC Output Current	2 A
Load 1 Current Consumption	1 A

9.2.2 Detailed Design Procedure

The power supply provides power to multiple loads. In the event that Load 2 is shorted to ground, the power supply must continue providing power to Load 1. The power supply can provide 2-A continuous current. Load 1 consumes 1-A continuous current. The TPS22951 is used to ensure that Load 2 consumes less than 1-A continuous current. This ensures that the power supply can provide power to Load 1 even in the case that Load 2 is shorted to ground.

9.2.3 Application Curve

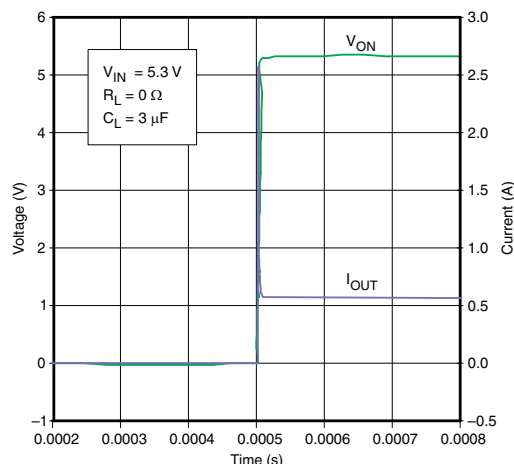


Figure 13. Device Enabled into Short-Circuit

10 Power Supply Recommendations

The device is designed to operate from a V_{CC} range of 2.8 to 5.3 V. The V_{CC} power supply must be well regulated and placed as close to the V_{CC} terminal as possible. The power supply must be able to withstand all transient load current steps. In most situations, using a small input capacitor is sufficient to prevent the supply voltage from dipping when the switch is turned on. In cases where the power supply is slow to respond to a large transient current or large load current step, additional bulk capacitance may be required on the input.

11 Layout

11.1 Layout Guidelines

- The V_{CC} and PWR traces must be wide enough to carry the necessary load current (up to 600 mA).
- To handle transient load currents, a capacitor may be placed close to the V_{CC} pin.
- To make use of the PG signal, it must be connected to a pullup resistor. The pullup source may be the V_{CC} node. It is also possible to use a different source for the pullup resistor.

11.2 Layout Example

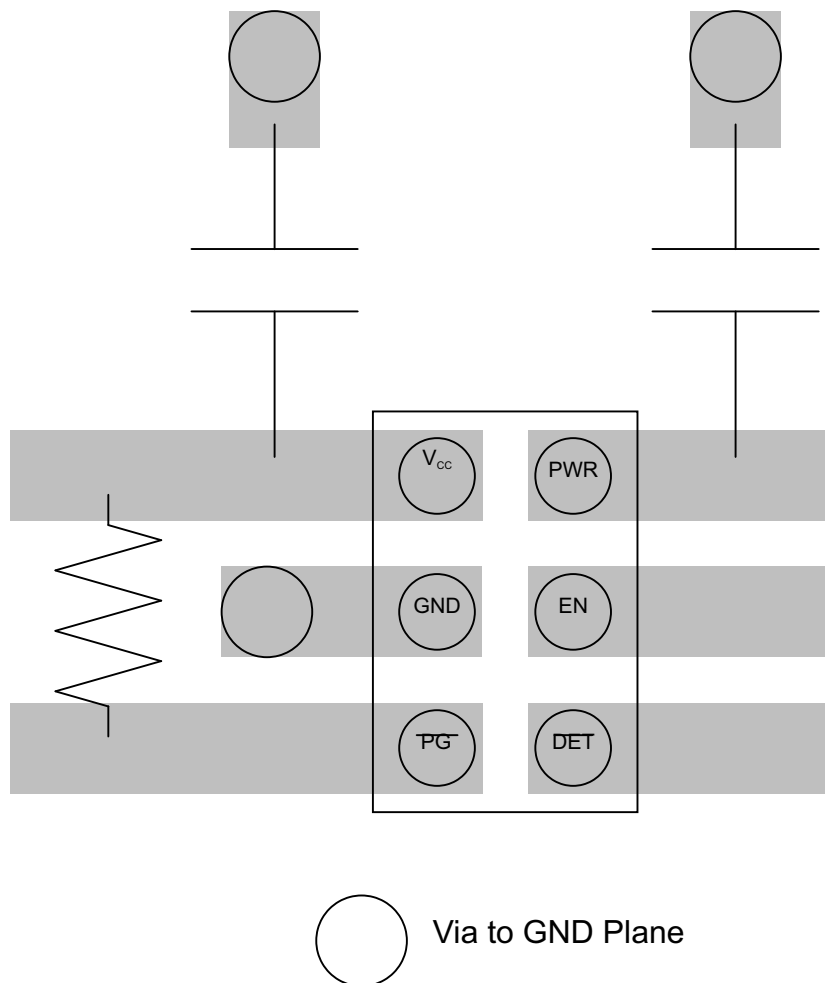


Figure 14. Layout Example

11.3 Thermal Considerations

The maximum IC junction temperature must be restricted to 85°C under normal operating conditions. To calculate the maximum allowable dissipation, $P_{D(max)}$ for a given ambient temperature, use [Equation 2](#) and [Equation 3](#).

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{R_{\theta JA}}$$

where

- $P_{D(max)}$ = maximum allowable power dissipation
- $T_{J(max)}$ = maximum allowable junction temperature (85°C for the TPS22951)

Thermal Considerations (continued)

- T_A = ambient temperature of the device
- $R_{\theta JA}$ = junction to air thermal impedance. See thermal metrics table. This parameter is highly dependent upon board layout. (2)

$$P_D = I^2 \times R \quad (3)$$

12 Device and Documentation Support

12.1 Documentation Support

12.1.1 Related Documentation

For related documentation see the following:

- [Basics of Load Switches](#)
- [Load Switch Thermal Considerations](#)

12.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](#). In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

12.3 Community Resources

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

TI E2E™ Online Community *TI's Engineer-to-Engineer (E2E) Community*. Created to foster collaboration among engineers. At [e2e.ti.com](#), you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.4 Trademarks

E2E is a trademark of Texas Instruments.

All other trademarks are the property of their respective owners.

12.5 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

12.6 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
TPS22951YFPR	ACTIVE	DSBGA	YFP	6	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	-40 to 85	(2W ~ 2W7)	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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

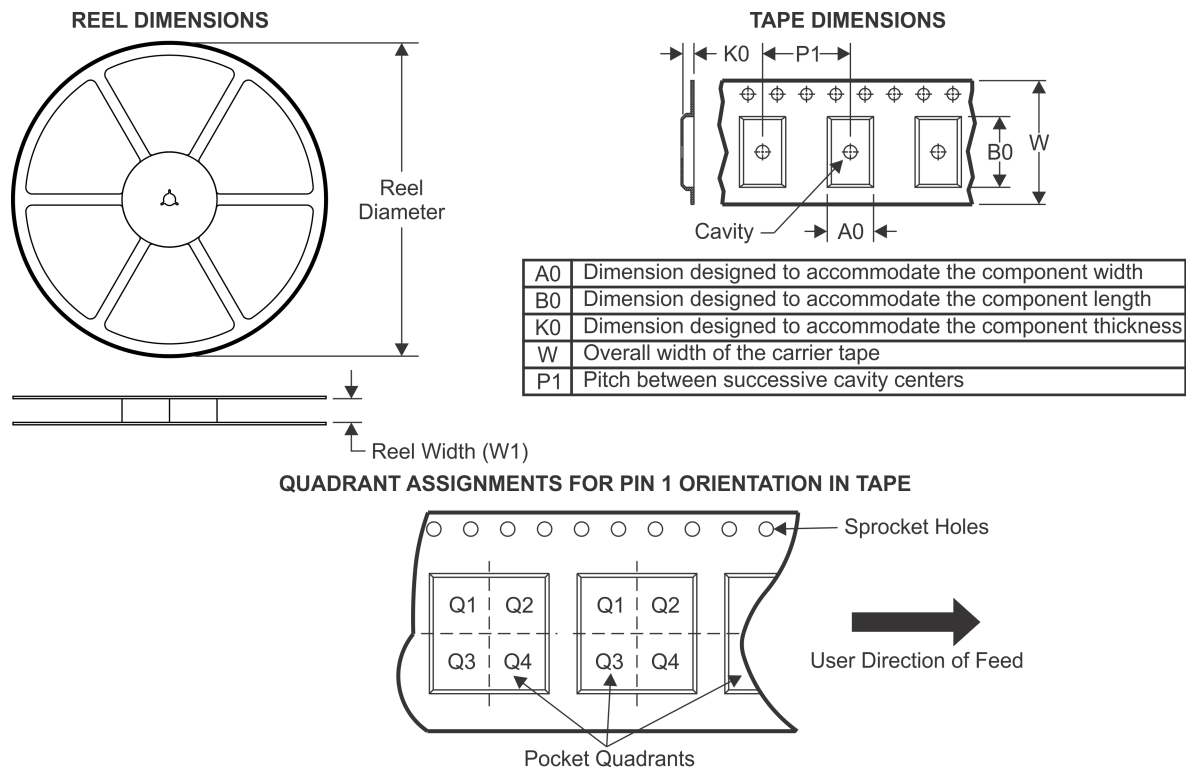
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(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.

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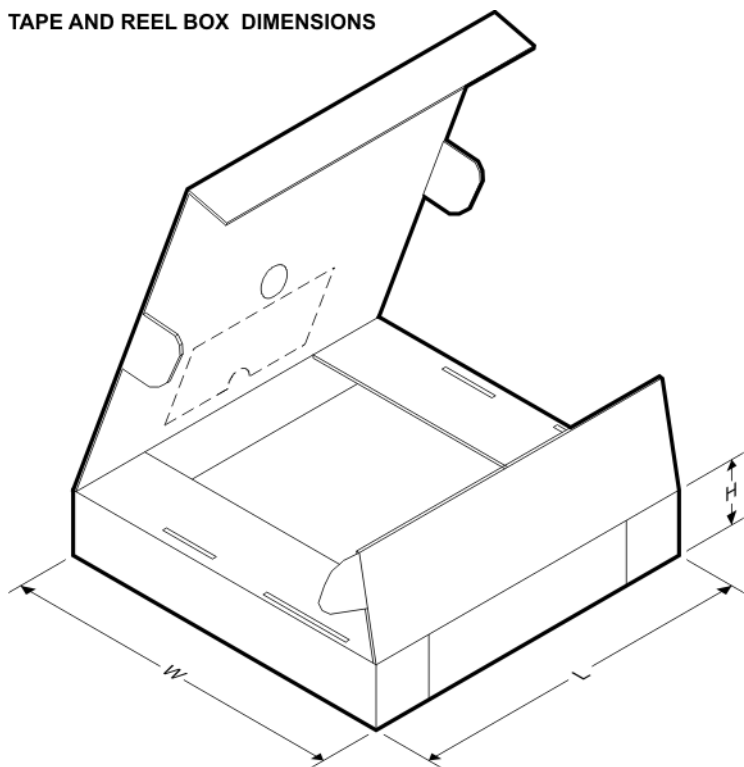
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TAPE AND REEL INFORMATION


*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
TPS22951YFPR	DSBGA	YFP	6	3000	180.0	8.4	0.9	1.3	0.6	4.0	8.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

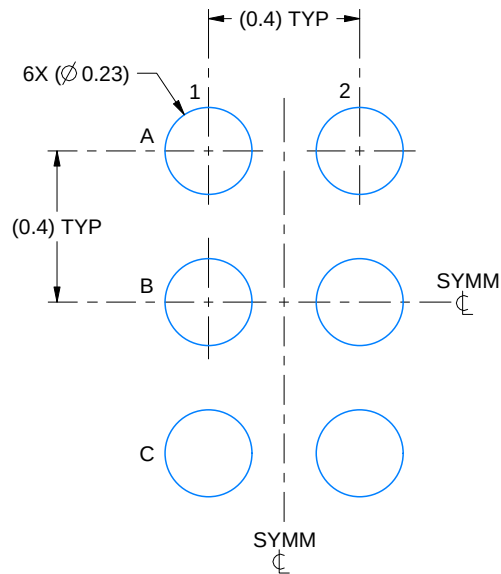
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS22951YFPR	DSBGA	YFP	6	3000	220.0	220.0	34.0

EXAMPLE BOARD LAYOUT

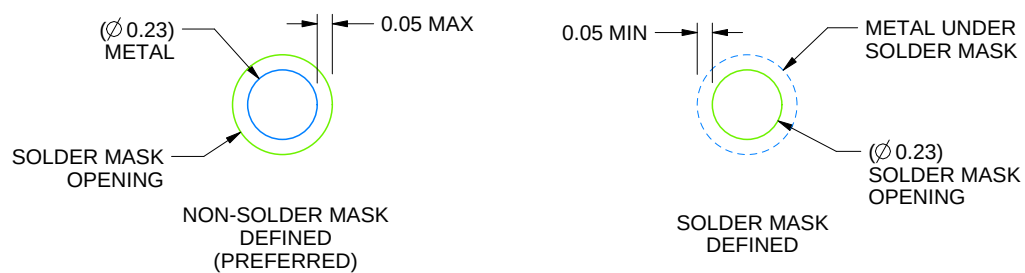
YFP0006

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY



LAND PATTERN EXAMPLE
SCALE:50X



SOLDER MASK DETAILS
NOT TO SCALE

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NOTES: (continued)

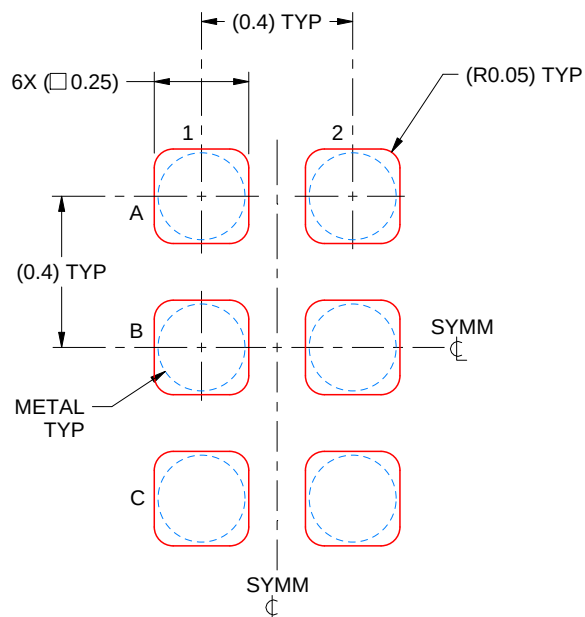
- Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. For more information, see Texas Instruments literature number SNVA009 (www.ti.com/lit/snva009).

EXAMPLE STENCIL DESIGN

YFP0006

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL
SCALE:50X

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NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

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