

## TPS22971 3.6-V, 3-A, 6.7-mΩ On-Resistance Load Switch with Adjustable Fast Turn-ON and Power Good

### 1 Features

- Input voltage range ( $V_{IN}$ ): 0.65 V to 3.6 V
- On-resistance
  - $R_{DS(on)} = 6.7\text{ m}\Omega$  (typical) at  $V_{IN} \geq 1.8\text{ V}$
  - $R_{DS(on)} = 7.2\text{ m}\Omega$  (typical) at  $V_{IN} = 1.05\text{ V}$
  - $R_{DS(on)} = 8.9\text{ m}\Omega$  (typical) at  $V_{IN} = 0.65\text{ V}$
- Maximum continuous switch current ( $I_{MAX}$ ): 3 A
- ON state ( $I_Q$ ): 30  $\mu\text{A}$  (typical) at 3.6  $V_{IN}$
- OFF state ( $I_{SD}$ ): 1  $\mu\text{A}$  (typical) at 3.6  $V_{IN}$
- Adjustable slew rate through CT pin
  - Fast turn-ON  $\leq 65\text{ }\mu\text{s}$  at  $V_{IN} = 1\text{ V}$
- Power good (PG) indicator after switch turn ON
- Low threshold enable (ON) of 0.9 V ( $V_{IH}$ ) supports use of low voltage control logic
- Thermal shutdown ( $T_{SD}$ )
- Quick output discharge (QOD): 150- $\Omega$  (typical)

### 2 Applications

- [PC & notebooks](#)
- [Tablets](#)
- [Computer on modules](#)
- [Optical modules](#)
- [Data storage](#)

### 3 Description

The TPS22971 is a space-saving single-channel load switch with controlled and adjustable turn-on slew rate and an integrated power good indicator. The device contains an n-channel mosfet that can operate over a low input voltage range of 0.65 v to 3.6 V and can support a maximum continuous current of 3 A. A low on-resistance of 6.7-m $\Omega$  minimizes the power loss and voltage drop across the load switch. The switch is controlled by an on and off input (ON), which is capable of interfacing directly with low-voltage control signals.

By default, the TPS22971 has a fast turn-on time to minimize system startup and wait time. The adjustable slew rate can also be reduced to limit inrush current. A power good (PG) signal internally monitors the gate threshold and indicates when the switch is fully on. When the switch is disabled, a 150- $\Omega$  on-chip resistor quickly discharges the output to ground and keeps it from floating.

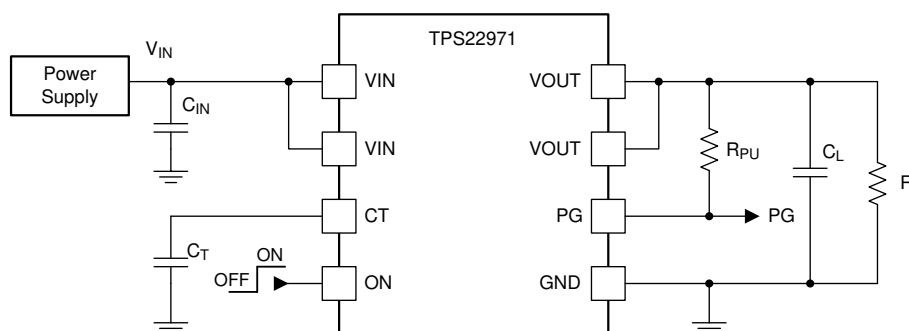
The TPS22971 is available in an ultra-small, space saving 8-pin WCSP package and is characterized for operation over the free-air temperature range of  $-40^{\circ}\text{C}$  to  $105^{\circ}\text{C}$  and integrates thermal shutdown to turn off in case of overheating.

#### Device Information<sup>(1)</sup>

| PART NUMBER | PACKAGE   | BODY SIZE (NOM)   |
|-------------|-----------|-------------------|
| TPS22971    | DSBGA (8) | 1.90 mm x 0.90 mm |

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

#### Typical Application



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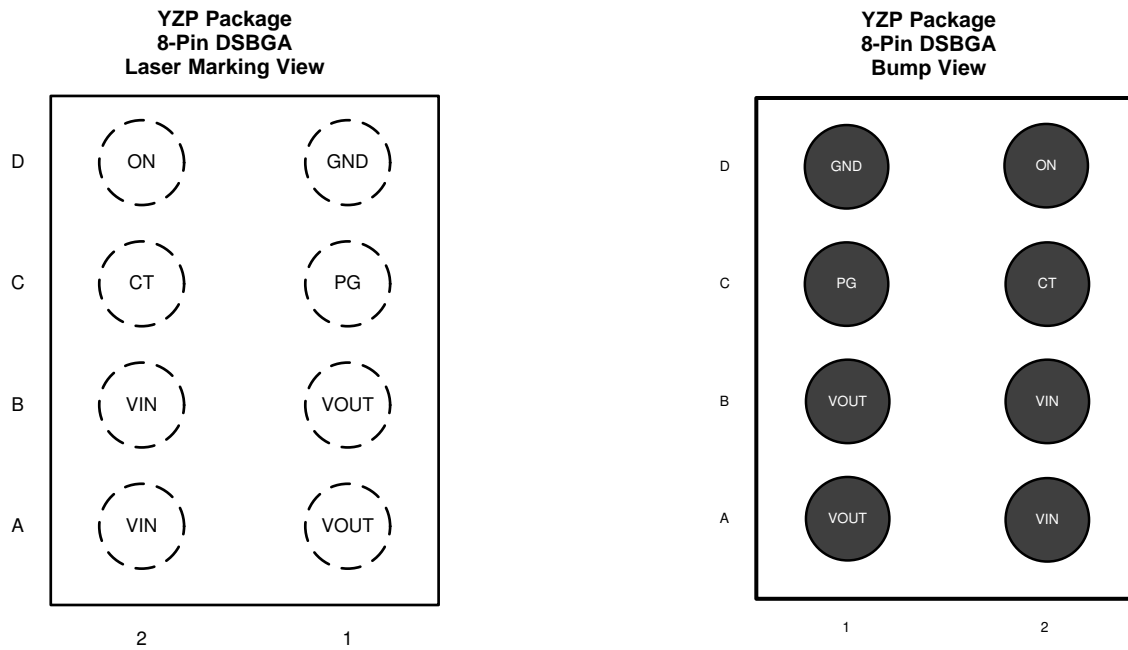
## 4 Revision History

| Changes from Revision B (December 2017) to Revision C  | Page |
|--|------|
| • Changed test conditions from " $V_{IN} = 1.0\text{ V}$ " to " $V_{IN} = 1.05\text{ V}$ " and " $0^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ " to " $-40^{\circ}\text{C} \leq T_A \leq 85^{\circ}\text{C}$ " for fast turn-on time specification in <a href="#">Switching Characteristics</a> table ..... | 6    |
| • Added load resistance and load capacitance test conditions for fast turn-on time specification in <a href="#">Switching Characteristics</a> table .....  | 6    |

| Changes from Original (April 2017) to Revision A                              | Page |
|---|------|
| • Changed device status from "Advance Information" to "Production Data" ..... | 1    |

| Changes from Revision A (July 2017) to Revision B                                   | Page |
|---|------|
| • Deleted YZPT from Part Number in the <i>Device Information</i> table .....        | 1    |
| • Changed 1.1 $\mu\text{A}$ to 1 $\mu\text{A}$ in the <i>Features</i> section ..... | 1    |
| • Deleted Duplicate Package Drawing .....   | 1    |

## 5 Pin Configuration and Functions



### Pin Functions

| PIN  |        | I/O | DESCRIPTION  |
|------|--------|-----|--|
| NAME | NO.    |     |  |
| CT   | C2     | O   | VOUT slew rate control. Adding capacitance from this pin to ground lowers the output slew rate |
| GND  | D1     | GND | Ground   |
| ON   | D2     | I   | Switch enable control input. Do not leave floating   |
| PG   | C1     | O   | Power Good Indication. Open drain releases when the switch is fully on                         |
| VOUT | A1, B1 | O   | Switch output  |
| VIN  | A2, B2 | I   | Switch input   |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|                  |  | MIN                | MAX | UNIT |
|------------------|--|--------------------|-----|------|
| V <sub>IN</sub>  | Input voltage  | -0.3               | 4   | V    |
| V <sub>OUT</sub> | Output voltage   | -0.3               | 4   | V    |
| V <sub>ON</sub>  | ON voltage   | -0.3               | 4   | V    |
| V <sub>PG</sub>  | PG voltage   | -0.3               | 4   | V    |
| I <sub>MAX</sub> | Maximum continuous switch current                            |                    | 3   | A    |
| I <sub>PLS</sub> | Maximum pulsed switch current, pulse < 300-μs, 2% duty cycle |                    | 4   | A    |
| T <sub>J</sub>   | Maximum junction temperature                                 | Internally Limited |     |      |
| T <sub>stg</sub> | 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.

### 6.2 ESD Ratings

|                    |                         |  | VALUE | UNIT |
|--------------------|-------------------------|--|-------|------|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | ±2000 | V    |
|                    |                         | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> | ±1000 |      |

(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

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

|                  |                                 | MIN  | MAX             | UNIT |
|------------------|---------------------------------|------|-----------------|------|
| V <sub>IN</sub>  | Input voltage                   | 0.65 | 3.6             | V    |
| V <sub>OUT</sub> | Output voltage                  |      | V <sub>IN</sub> | V    |
| V <sub>IH</sub>  | High-level input voltage, ON    | 0.9  | 3.6             | V    |
| V <sub>IL</sub>  | Low-level input voltage, ON     | 0    | 0.45            | V    |
| T <sub>J</sub>   | Operating temperature           | -40  | 125             | °C   |
| T <sub>A</sub>   | Operating free-air temperature  | -40  | 105             | °C   |
| C <sub>T</sub>   | CT pin capacitor voltage rating | 7    |                 | V    |

### 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |  | TPS22971    | UNIT |
|-------------------------------|--|-------------|------|
|                               |  | YZP (DSBGA) |      |
|                               |  | 8 PINS      |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 130         | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance    | 54          | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 51          | °C/W |
| ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 1           | °C/W |
| ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 50          | °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

Unless otherwise noted,  $V_{IN} = 0.65\text{ V}$  to  $3.6\text{ V}$

| PARAMETER     |  | TEST CONDITIONS                           |   | $T_A$                                       | MIN | TYP  | MAX      | UNIT             |
|---------------|--|---|---|---|-----|------|----------|------------------|
| $I_Q$         | Quiescent current                          | $V_{OUT} = \text{Open}$ , Switch enabled  | $V_{IN} > 1.2\text{ V}$                       | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  | 30  | 65   |          | $\mu\text{A}$    |
|               |  |   |   | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ |     | 75   |          |                  |
|               |  |   | $V_{IN} \leq 1.2\text{ V}$                    | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  | 20  | 50   |          |                  |
|               |  |   |   | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ |     | 55   |          |                  |
| $I_{SD}$      | Shutdown current                           | $V_{OUT} = \text{GND}$ , Switch disabled  | $V_{IN} > 1.8\text{ V}$                       | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  | 1   | 7.5  |          | $\mu\text{A}$    |
|               |  |   |   | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ |     | 18   |          |                  |
|               |  |   | $V_{IN} \leq 1.8\text{ V}$                    | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  | 0.9 | 5.5  |          |                  |
|               |  |   |   | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ |     | 9.5  |          |                  |
| $R_{ON}$      | ON-resistance                              | $I_{OUT} = -200\text{ mA}$                | $V_{IN} \geq 1.8\text{ V}$                    | $25^\circ\text{C}$                          | 6.7 | 10   |          | $\text{m}\Omega$ |
|               |  |   |   | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  |     | 12   |          |                  |
|               |  |   |   | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ |     | 12   |          |                  |
|               |  |   | $V_{IN} = 1.2\text{ V}$                       | $25^\circ\text{C}$                          | 6.9 | 10   |          |                  |
|               |  |   |   | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  |     | 12   |          |                  |
|               |  |   |   | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ |     | 13   |          |                  |
|               |  |   | $V_{IN} = 1.05\text{ V}$                      | $25^\circ\text{C}$                          | 7.2 | 10.5 |          |                  |
|               |  |   |   | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  |     | 13   |          |                  |
|               |  |   |   | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ |     | 14   |          |                  |
|               |  |   | $V_{IN} = 0.65\text{ V}$                      | $25^\circ\text{C}$                          | 8.9 | 14   |          |                  |
|               |  |   |   | $-40^\circ\text{C}$ to $+85^\circ\text{C}$  |     | 18   |          |                  |
|               |  |   |   | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ |     | 19   |          |                  |
| $R_{PD}$      | Output pull down resistance <sup>(1)</sup> | $I_{OUT} = 3\text{ mA}$ , Switch disabled | $V_{IN} = 3.6\text{ V}$                       | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ | 150 |      | $\Omega$ |                  |
|               |  |   | $V_{IN} = 0.65\text{ V}$                      | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ | 710 |      | $\Omega$ |                  |
| $I_{ON}$      | ON input leakage current                   | $V_{ON} = 0\text{ V}$ to $3.6\text{ V}$   |   | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ |     |      | 0.1      | $\mu\text{A}$    |
| $I_{PG,LK}$   | Leakage current into PG pin                | $V_{PG} = 0\text{ V}$ to $3.6\text{ V}$   | $V_{ON} \leq V_{IL}$                          | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ |     | 0.1  | 8.5      | $\mu\text{A}$    |
| $V_{PG,OL}$   | PG output low voltage                      | $V_{PG} = 0\text{ V}$ to $3.6\text{ V}$   | $V_{ON} \geq V_{IH}$ , $I_{PG} = 1\text{ mA}$ | $-40^\circ\text{C}$ to $+105^\circ\text{C}$ |     |      | 0.2      | V                |
| $T_{SD}$      | Thermal shutdown                           | $T_J$ rising                              |   |   |     | 170  |          | $^\circ\text{C}$ |
| $T_{SD, HYS}$ | Thermal shutdown hysteresis                | $T_J$ falling                             |   |   |     | 30   |          | $^\circ\text{C}$ |

(1) See the [Quick Output Discharge \(QOD\)](#) section.

## 6.6 Switching Characteristics

All typical values are at 25°C unless otherwise noted

| PARAMETER                      |                   | TEST CONDITIONS  | MIN | TYP  | MAX | UNIT |
|--------------------------------|-------------------|--|-----|------|-----|------|
| <b>V<sub>IN</sub> = 3.6 V</b>  |                   |  |     |      |     |      |
| t <sub>ON</sub>                | Turn-On time      | C <sub>T</sub> = 0 pF  |     | 54   |     | μs   |
|                                |                   | C <sub>T</sub> = 1000 pF   |     | 198  |     |      |
|                                |                   | C <sub>T</sub> = 10000 pF  |     | 1520 |     |      |
| t <sub>R</sub>                 | VOUT Rise time    | C <sub>T</sub> = 0 pF  |     | 35   |     |      |
|                                |                   | C <sub>T</sub> = 1000 pF   |     | 150  |     |      |
|                                |                   | C <sub>T</sub> = 10000 pF  |     | 1230 |     |      |
| t <sub>PG,ON</sub>             | PG Turn-On time   | C <sub>T</sub> = 0 pF  |     | 134  |     |      |
|                                |                   | C <sub>T</sub> = 1000 pF   |     | 314  |     |      |
|                                |                   | C <sub>T</sub> = 10000 pF  |     | 1990 |     |      |
| t <sub>PG,OFF</sub>            | PG Turn-Off time  |  |     | 1.9  |     |      |
| t <sub>OFF</sub>               | Turn-Off time     |  |     | 3.5  |     |      |
| t <sub>F</sub>                 | VOUT Fall time    | C <sub>L</sub> = 0.1 μF, R <sub>L</sub> = 10 Ω   |     | 2.1  |     |      |
| <b>V<sub>IN</sub> = 1.8 V</b>  |                   |  |     |      |     |      |
| t <sub>ON</sub>                | Turn-On time      | C <sub>T</sub> = 0 pF  |     | 41   |     | μs   |
|                                |                   | C <sub>T</sub> = 1000 pF   |     | 126  |     |      |
|                                |                   | C <sub>T</sub> = 10000 pF  |     | 857  |     |      |
| t <sub>R</sub>                 | VOUT Rise time    | C <sub>T</sub> = 0 pF  |     | 21   |     |      |
|                                |                   | C <sub>T</sub> = 1000 pF   |     | 82   |     |      |
|                                |                   | C <sub>T</sub> = 10000 pF  |     | 628  |     |      |
| t <sub>PG,ON</sub>             | PG Turn-On time   | C <sub>T</sub> = 0 pF  |     | 105  |     |      |
|                                |                   | C <sub>T</sub> = 1000 pF   |     | 220  |     |      |
|                                |                   | C <sub>T</sub> = 10000pF   |     | 1230 |     |      |
| t <sub>PG,OFF</sub>            | PG Turn-Off time  |  |     | 0.8  |     |      |
| t <sub>OFF</sub>               | Turn-Off time     |  |     | 4.8  |     |      |
| t <sub>F</sub>                 | VOUT Fall time    | C <sub>L</sub> = 0.1 μF, R <sub>L</sub> = 10 Ω   |     | 2.1  |     |      |
| <b>V<sub>IN</sub> = 0.65 V</b> |                   |  |     |      |     |      |
| t <sub>ON</sub>                | Turn-On time      | C <sub>T</sub> = 0 pF  |     | 54   |     | μs   |
|                                |                   | C <sub>T</sub> = 1000 pF   |     | 127  |     |      |
|                                |                   | C <sub>T</sub> = 10000 pF  |     | 720  |     |      |
| t <sub>R</sub>                 | VOUT Rise time    | C <sub>T</sub> = 0 pF  |     | 21   |     |      |
|                                |                   | C <sub>T</sub> = 1000 pF   |     | 61   |     |      |
|                                |                   | C <sub>T</sub> = 10000 pF  |     | 386  |     |      |
| t <sub>PG,ON</sub>             | PG Turn-On time   | C <sub>T</sub> = 0 pF  |     | 165  |     |      |
|                                |                   | C <sub>T</sub> = 1000 pF   |     | 290  |     |      |
|                                |                   | C <sub>T</sub> = 10000 pF  |     | 1290 |     |      |
| t <sub>PG,OFF</sub>            | PG Turn-Off time  |  |     | 0.5  |     |      |
| t <sub>OFF</sub>               | Turn-Off time     |  |     | 55   |     |      |
| t <sub>F</sub>                 | VOUT Fall time    | C <sub>L</sub> = 0.1 μF, R <sub>L</sub> = 10 Ω   |     | 8    |     |      |
| <b>V<sub>IN</sub> = 1.05 V</b> |                   |  |     |      |     |      |
| t <sub>ON</sub>                | Fast Turn-On time | C <sub>T</sub> = 0 pF, C <sub>L</sub> = 0.1 μF, R <sub>L</sub> = 10 Ω ,<br>-40°C ≤ T <sub>A</sub> ≤ 85°C |     | 30   | 65  | μs   |

### 6.7 Typical DC Characteristics

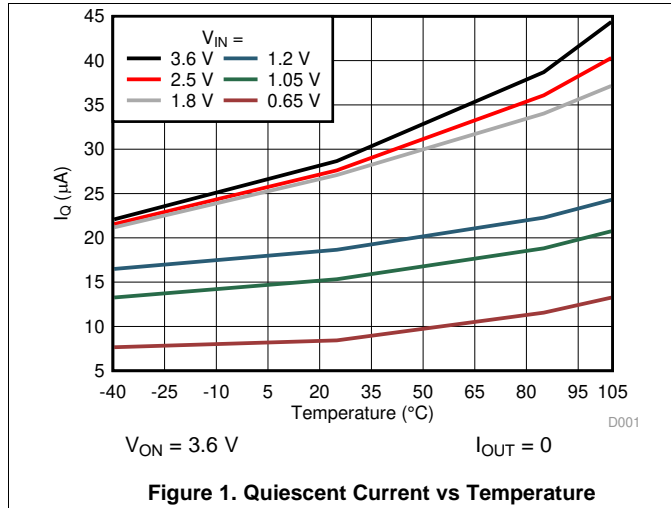


Figure 1. Quiescent Current vs Temperature

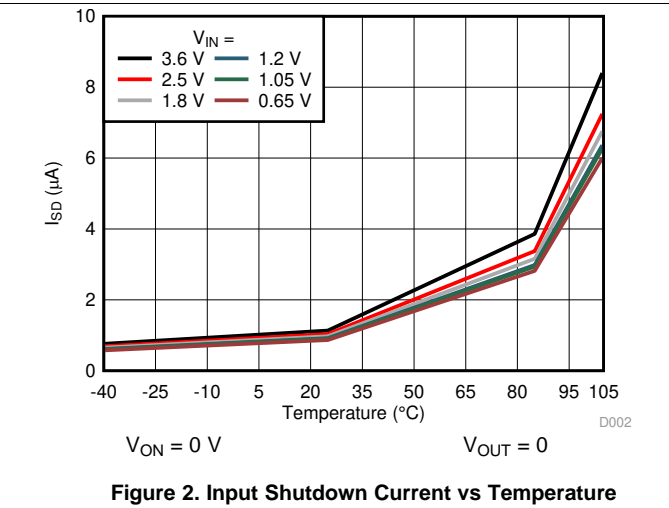


Figure 2. Input Shutdown Current vs Temperature

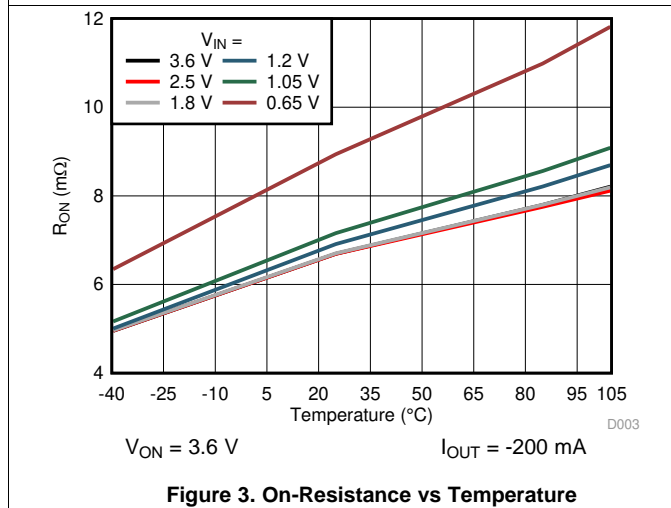


Figure 3. On-Resistance vs Temperature

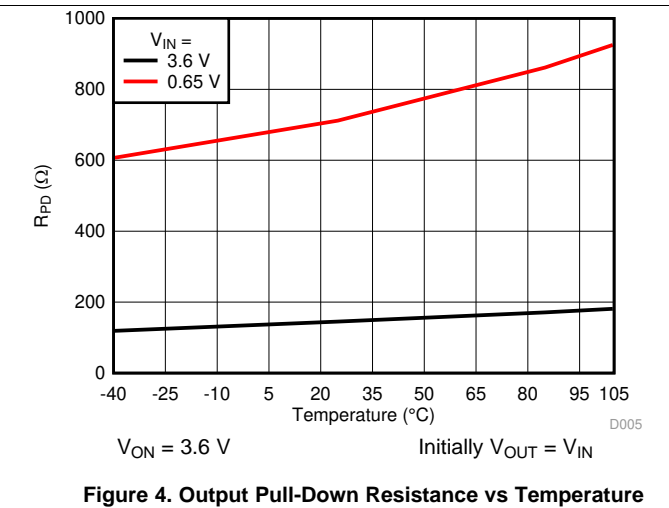


Figure 4. Output Pull-Down Resistance vs Temperature

### 6.8 Typical AC Characteristics

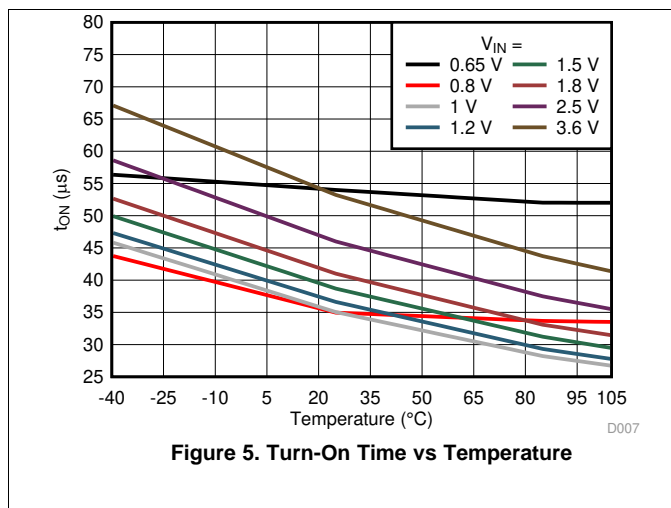


Figure 5. Turn-On Time vs Temperature

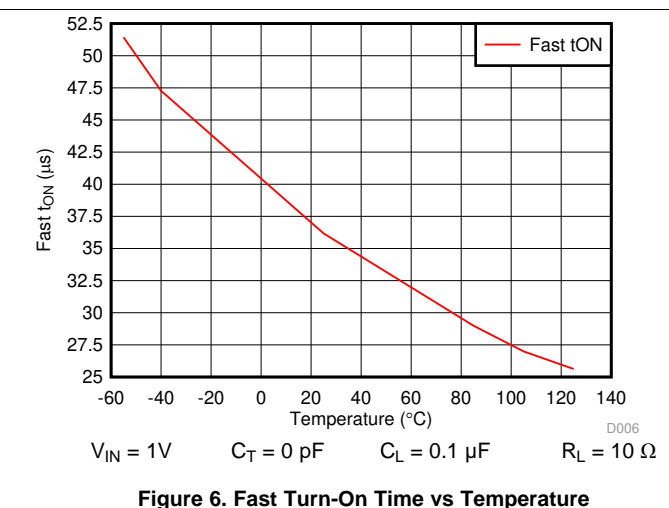


Figure 6. Fast Turn-On Time vs Temperature

Typical AC Characteristics (continued)

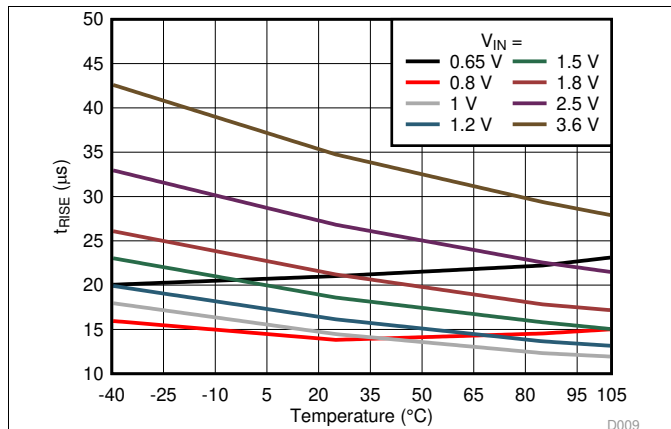


Figure 7. Rise Time vs Temperature

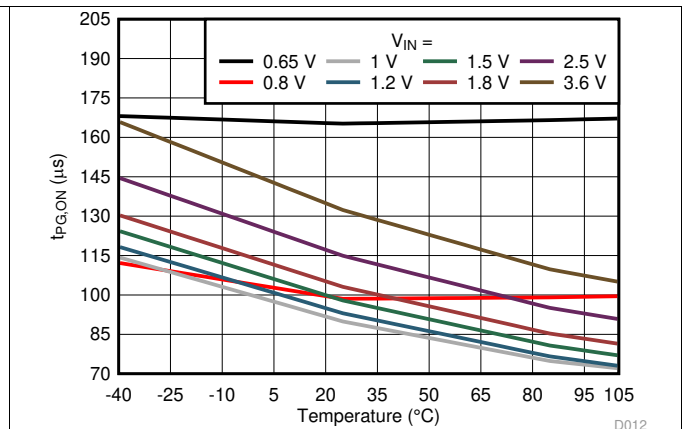


Figure 8. PG Turn-On Time vs Temperature

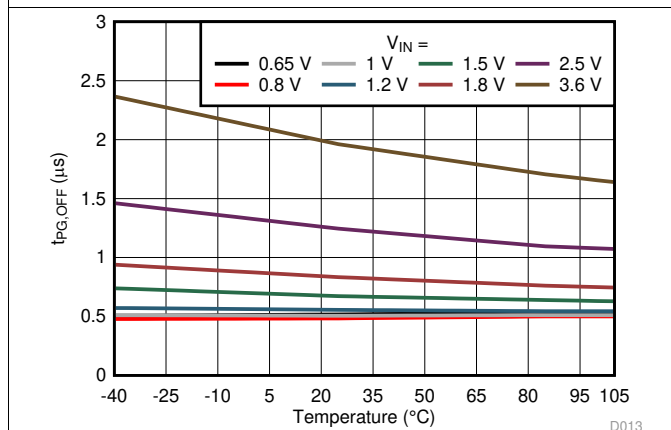


Figure 9. PG Turn-Off Time vs Temperature

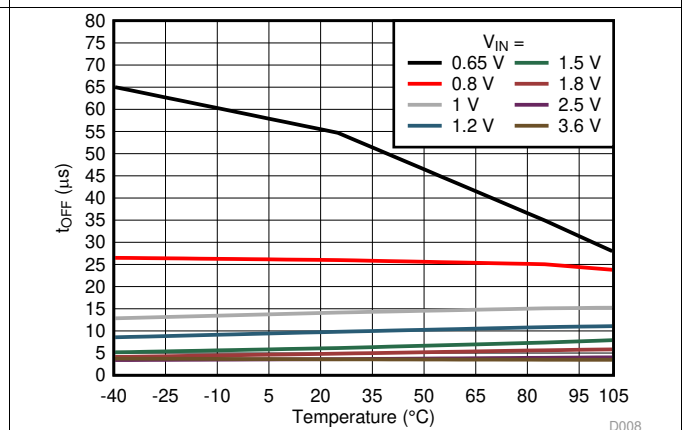
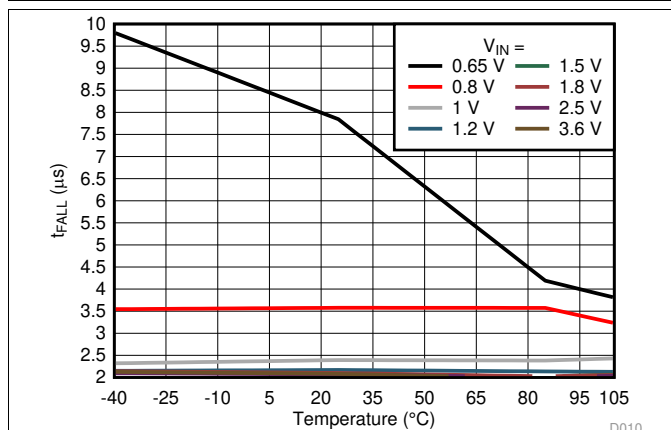
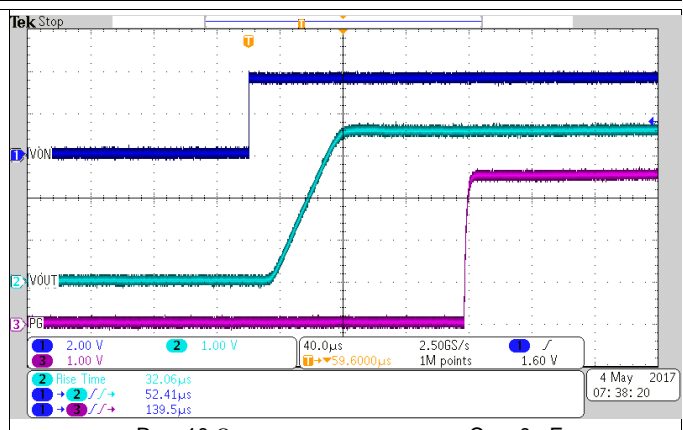


Figure 10. Turn-Off Time vs Temperature



$R_L = 10 \Omega$   $C_L = 0.1 \mu F$

Figure 11. Fall Time vs Temperature

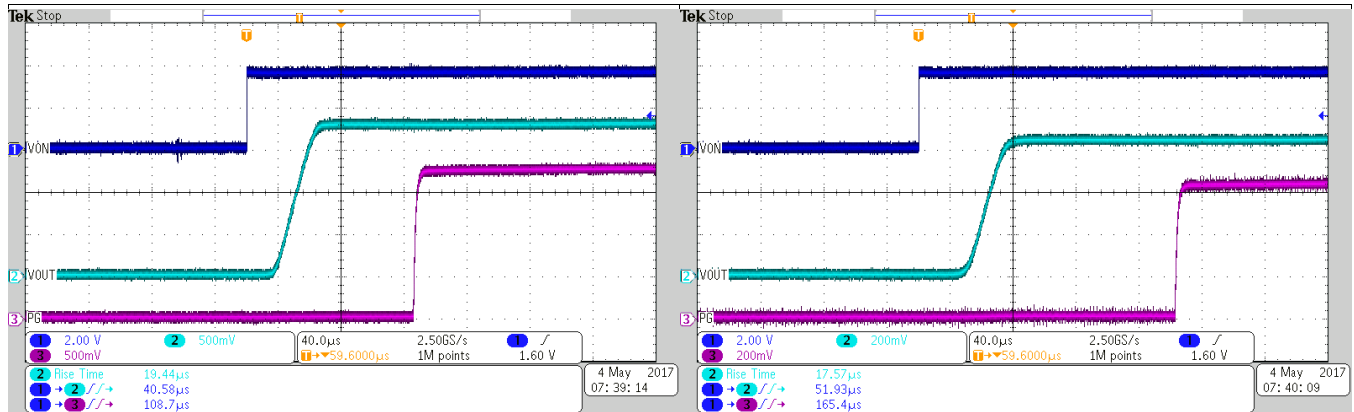


$R_L = 10 \Omega$   $C_T = 0 \text{ pF}$   
 $T_A = 25^\circ\text{C}$   $C_L = 0.1 \mu F$

Figure 12. Turn-On Response at 3.6  $V_{IN}$



Typical AC Characteristics (continued)

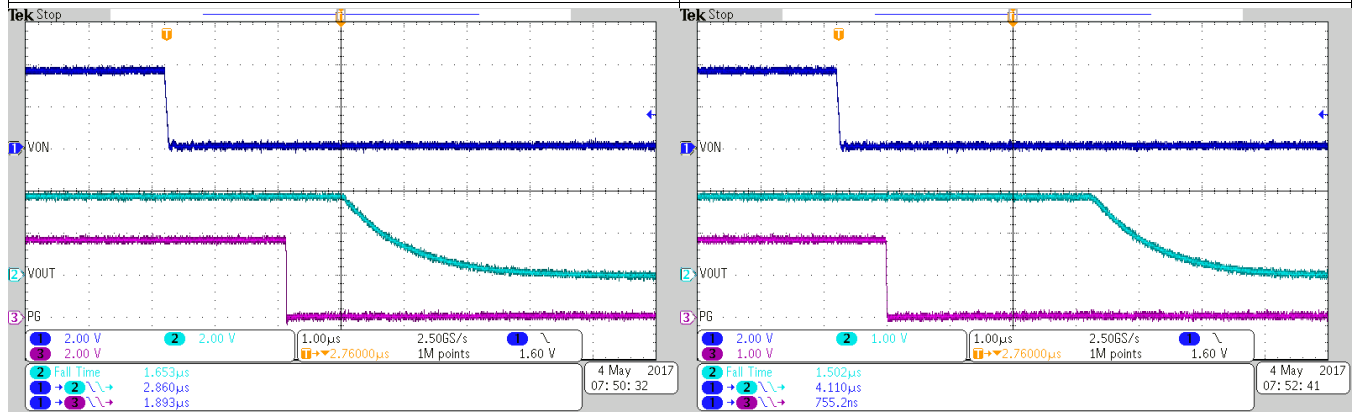


$R_L = 10 \Omega$   
 $T_A = 25^\circ\text{C}$   
 $C_T = 0 \text{ pF}$   
 $C_L = 0.1 \mu\text{F}$

Figure 13. Turn-On Response at 1.8  $V_{IN}$

$R_L = 10 \Omega$   
 $T_A = 25^\circ\text{C}$   
 $C_T = 0 \text{ pF}$   
 $C_L = 0.1 \mu\text{F}$

Figure 14. Turn-On Response at 0.65  $V_{IN}$

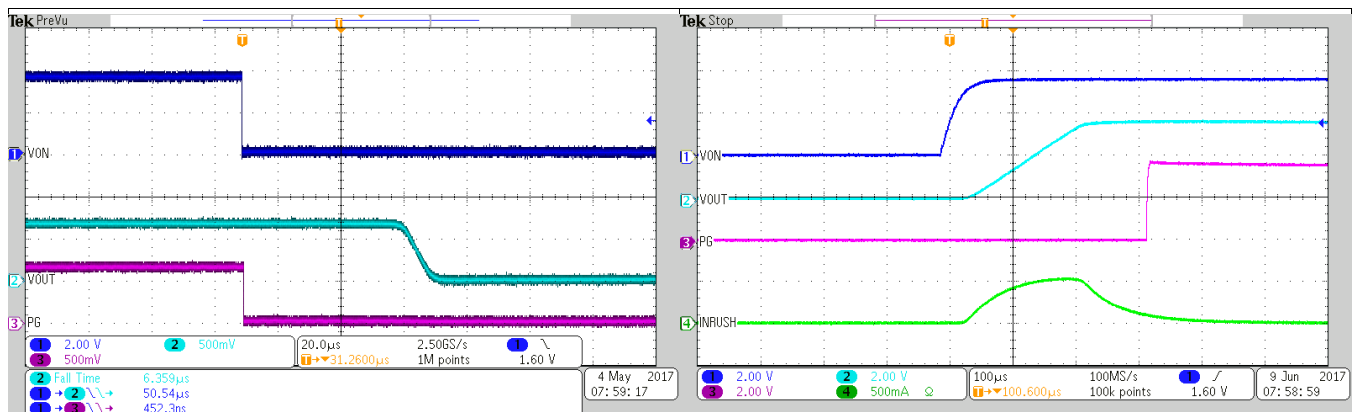


$R_L = 10 \Omega$   
 $T_A = 25^\circ\text{C}$   
 $C_T = 0 \text{ pF}$   
 $C_L = 0.1 \mu\text{F}$

Figure 15. Turn-Off Response at 3.6  $V_{IN}$

$R_L = 10 \Omega$   
 $T_A = 25^\circ\text{C}$   
 $C_T = 0 \text{ pF}$   
 $C_L = 0.1 \mu\text{F}$

Figure 16. Turn-Off Response at 1.8  $V_{IN}$



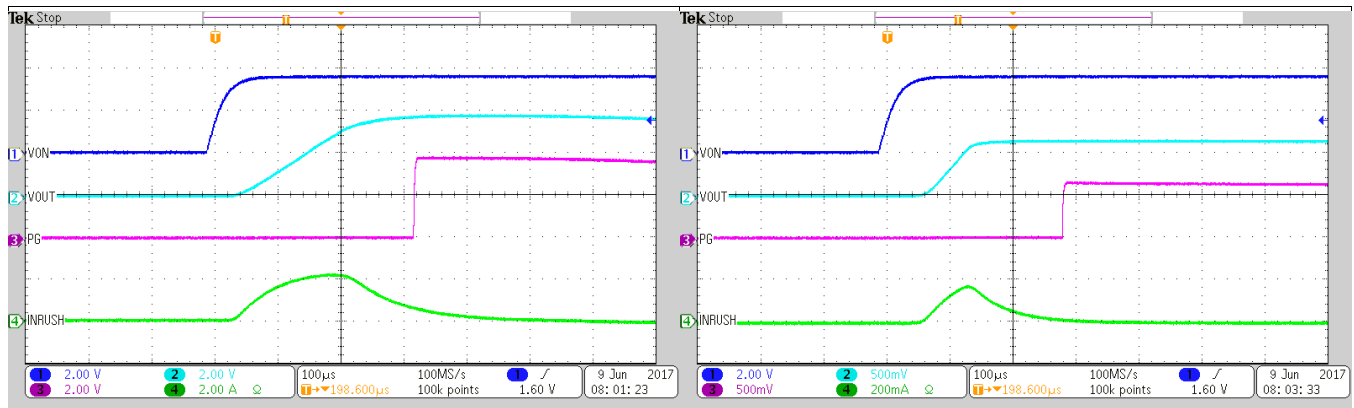
$R_L = 10 \Omega$   
 $T_A = 25^\circ\text{C}$   
 $C_{IN} = 0 \text{ pF}$   
 $C_L = 0.1 \mu\text{F}$

Figure 17. Turn-Off Response at 0.65  $V_{IN}$

$C_T = 1000 \text{ pF}$   
 $R_L = \text{OPEN}$   
 $C_L = 33 \mu\text{F}$   
 $T_A = 25^\circ\text{C}$

Figure 18. Low Inrush Current at 3.6  $V_{IN}$

Typical AC Characteristics (continued)

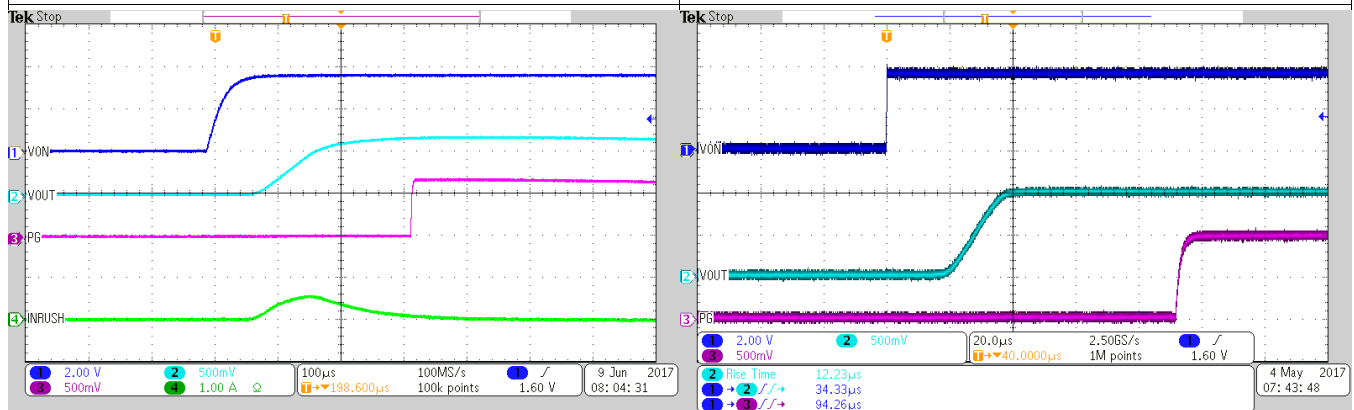


$C_T = 1000 \text{ pF}$   
 $R_L = \text{OPEN}$   
 $C_L = 133 \text{ }\mu\text{F}$   
 $T_A = 25^\circ\text{C}$

Figure 19. High Inrush Current at 3.6 V<sub>IN</sub>

$C_T = 1000 \text{ pF}$   
 $R_L = \text{OPEN}$   
 $C_L = 33 \text{ }\mu\text{F}$   
 $T_A = 25^\circ\text{C}$

Figure 20. Low Inrush Current at 0.65 V<sub>IN</sub>

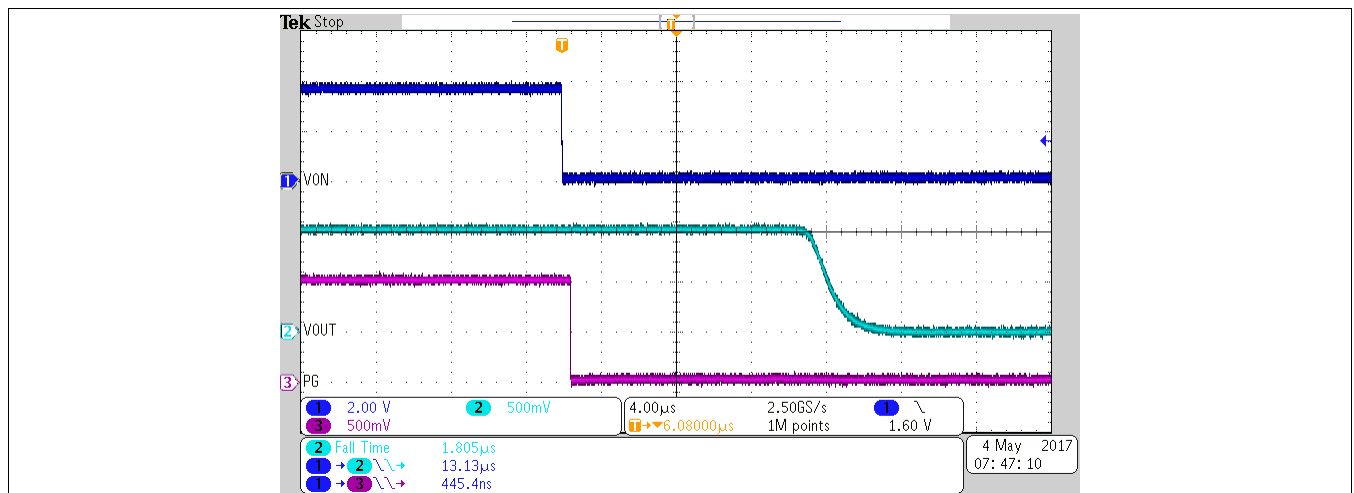


$C_T = 1000 \text{ pF}$   
 $R_L = \text{OPEN}$   
 $C_L = 133 \text{ }\mu\text{F}$   
 $T_A = 25^\circ\text{C}$

Figure 21. High Inrush Current at 0.65 V<sub>IN</sub>

$C_T = 0 \text{ pF}$   
 $R_L = 10 \text{ }\Omega$   
 $C_L = 0.1 \text{ }\mu\text{F}$   
 $T_A = 25^\circ\text{C}$

Figure 22. Fast Turn-On Response



$C_{IN} = 0 \text{ pF}$   
 $R_L = 10 \text{ }\Omega$

$C_L = 0.1 \text{ }\mu\text{F}$   
 $T_A = 25^\circ\text{C}$

Figure 23. Fast Turn-Off Response

## 7 Parameter Measurement Information

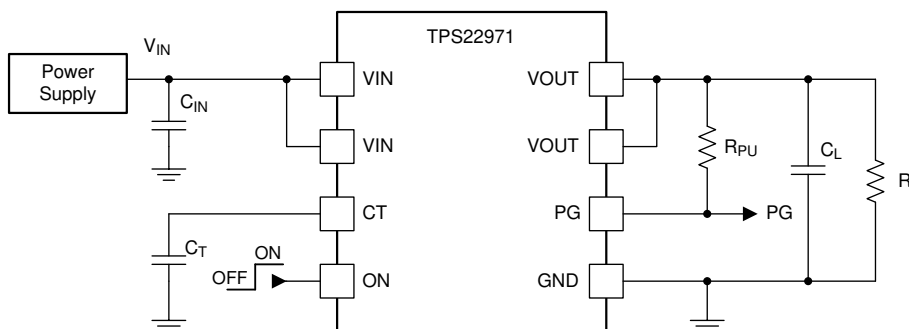


Figure 24. TPS22971 Test Circuit

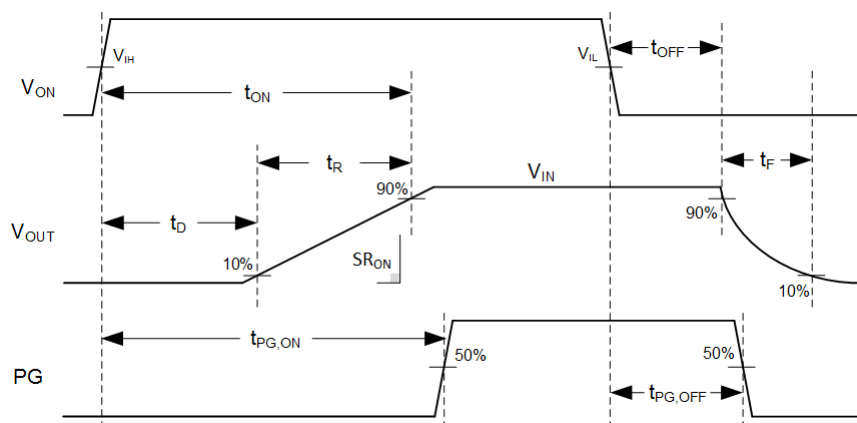


Figure 25. AC Timing Waveforms

## 8 Detailed Description

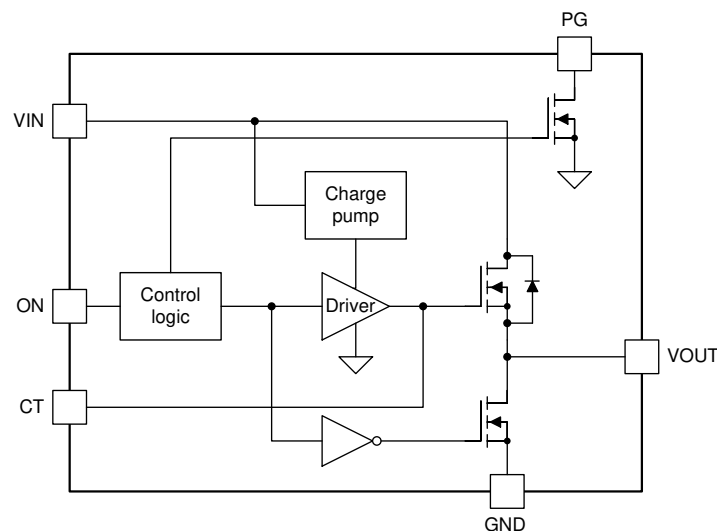
### 8.1 Overview

The TPS22971 is a single channel, 3-A load switch in a small, space-saving WCSP-8 package. This device implements a low resistance N-channel MOSFET with a controlled rise time for applications that need to limit the inrush current.

The controlled rise time for the device greatly reduces inrush current caused by large bulk load capacitances, thereby reducing or eliminating power supply droop. The adjustable slew rate through CT provides the design flexibility to trade off the inrush current and power up timing requirements. Integrated PG indicator notifies the system about the status of the load switch to facilitate seamless power sequencing.

This device is also designed to have very low leakage current during off state, which prevents downstream circuits from pulling high standby current from the supply. Integrated control logic, driver, power supply, and output discharge FET eliminates the need for additional external components, which reduces solution size and bill of materials (BOM) count.

### 8.2 Functional Block Diagram



### 8.3 Feature Description

#### 8.3.1 On and Off Control

The ON pin controls the state of the switch. Asserting ON high enables the switch. ON has a low threshold, making it capable of interfacing with low-voltage signals. The ON pin is compatible with standard GPIO logic. It can be used with any microcontroller with 1.2-V, 1.8-V, 2.5-V or 3.3-V GPIOs. This pin does not have an internal bias and must not be left floating for proper functionality.

#### 8.3.2 Controlled Turn-On

The TPS22971 has controlled Turn-On for inrush current control. A capacitor to GND on the CT pin adjusts the slew rate. For a given input voltage and desired slew rate, Equation 1 can be used to find the required CT value. For calculated CT values less than 220 pF, use 0 pF instead when solving for  $t_{ON}$  and  $t_{PG,ON}$ .

$$CT(VIN, SR) = \frac{\left(\frac{VIN}{SR} - (3.1 \times VIN) - 14.2\right) \times 800}{((32.5 \times VIN) + 12.5)}$$

where

- CT is the capacitor on the CT pin (in pF)

### Feature Description (continued)

- $V_{IN}$  is the input voltage (in V)
  - $SR$  is the desired slew rate (in V/ $\mu$ s)
- (1)

The CT value determined in [Equation 1](#) can be used to find the total Turn-On time,  $t_{ON}$ , in [Equation 2](#) or [Equation 3](#) depending on  $V_{IN}$ .

$$t_{ON}(V_{IN} \geq 0.95 \text{ V}, CT) = \left( (15 + (33 \times V_{IN})) \times \frac{CT}{1000} \right) + ((3.9 \times V_{IN}) + 35)$$
(2)

$$t_{ON}(V_{IN} < 0.95 \text{ V}, CT) = \left( (45 + (33 \times V_{IN})) \times \frac{CT}{1000} \right) + ((3.9 \times V_{IN}) + 55)$$

where

- $t_{ON}$  is the Turn-On time (in  $\mu$ s)
  - $CT$  is the capacitor on the CT pin (in pF)
  - $V_{IN}$  is the input voltage (in V)
- (3)

#### 8.3.3 Power Good (PG)

The TPS22971 has a power good (PG) output signal to indicate the gate of the pass FET is driven high and the switch is fully on (full load ready). The signal is an active high and open drain output which can be connected to a voltage source through an external pull up resistor,  $R_{PU}$ . This voltage source can be  $V_{OUT}$  from the TPS22971 or another external voltage. [Equation 4](#) and [Equation 5](#) show the approximate equation for the relationship between CT setting,  $V_{IN}$  and PG Turn-On time ( $t_{PG,ON}$ ):

$$t_{PG,ON}(V_{IN} \geq 0.95 \text{ V}, CT) = \left( (40 + (36 \times V_{IN})) \times \frac{CT}{1000} \right) + ((10.7 \times V_{IN}) + 85)$$
(4)

$$t_{PG,ON}(V_{IN} < 0.95 \text{ V}, CT) = \left( (80 + (36 \times V_{IN})) \times \frac{CT}{1000} \right) + ((10.7 \times V_{IN}) + 155)$$

where

- $t_{PG,ON}$  is the PG Turn-On time (in  $\mu$ s)
  - $V_{IN}$  is the input voltage (in V)
  - $C_T$  is the capacitance value on the CT pin (in pF)
- (5)

#### 8.3.4 Quick Output Discharge (QOD)

The TPS22971 includes a QOD feature. When the switch is disabled, a discharge resistor is connected between  $V_{OUT}$  and GND. This resistor has a typical value of 150  $\Omega$  and prevents the output from floating while the switch is disabled. The QOD pull-down resistance can vary with input voltage and temperature, see [Figure 4](#).

## 8.4 Device Functional Modes

Table 1 lists the functional modes for the TPS22971.

**Table 1. Function Table**

| TPS22971              |                                     |                         |           |
|-----------------------|-------------------------------------|-------------------------|-----------|
| ON-Pin                | V <sub>IN</sub> to V <sub>OUT</sub> | V <sub>OUT</sub> to GND | PG to GND |
| Below V <sub>IL</sub> | OFF                                 | ON                      | ON        |
| Above V <sub>IH</sub> | ON                                  | OFF                     | OFF       |

## 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

#### 9.1.1 Thermal Consideration

It is recommended to limit the junction temperature ( $T_J$ ) to below 125°C. To calculate the maximum allowable dissipation,  $P_{D(max)}$  for a given output current and ambient temperature, use [Equation 6](#) as a guideline:

$$P_{D(max)} = \frac{T_{J(max)} - T_A}{\theta_{JA}}$$

where

- $P_{D(max)}$  is maximum allowable power dissipation
- $T_{J(max)}$  is maximum allowable junction temperature
- $T_A$  is ambient temperature of the device
- $\theta_{JA}$  is junction to air thermal impedance. See the [Thermal Information](#) section. This parameter is highly dependent upon board layout

(6)

#### 9.1.2 PG Pull Up Resistor

The PG output is an open drain signal which connects to a voltage source through a pull up resistor  $R_{PU}$ . The PG signal can be used to drive the enable pins of downstream devices, EN. PG is active high, and its voltage is given by [Equation 7](#).

$$V_{PG} = V_{OUT} - (I_{PG,LK} + I_{EN,LK}) \times R_{PU}$$

where

- $V_{OUT}$  is the voltage where PG is tied to
- $I_{PG,LK}$  is the leakage current into PG pin
- $I_{EN,LK}$  is the leakage current into the EN pin driven by PG
- $R_{PU}$  is the pull up resistance

(7)

$V_{PG}$  needs to be higher than  $V_{IH,MIN}$  of the EN pin to be treated as logic high. The maximum  $R_{PU}$  is determined by [Equation 8](#).

$$R_{PU,MAX} = \frac{V_{OUT} - V_{IH,MIN}}{I_{PG,LK} + I_{EN,LK}}$$

(8)

When PG is disabled, with 1 mA current into PG pin ( $I_{PG} = 1$  mA),  $V_{PG,OL}$  is less than 0.2 V and treated as logic low as long as  $V_{IL,MAX}$  of the EN pin is greater than 0.2 V. The minimum  $R_{PU}$  is determined by [Equation 9](#).

$$R_{PU,MIN} = \frac{V_{OUT}}{I_{PG} + I_{EN,LK}}$$

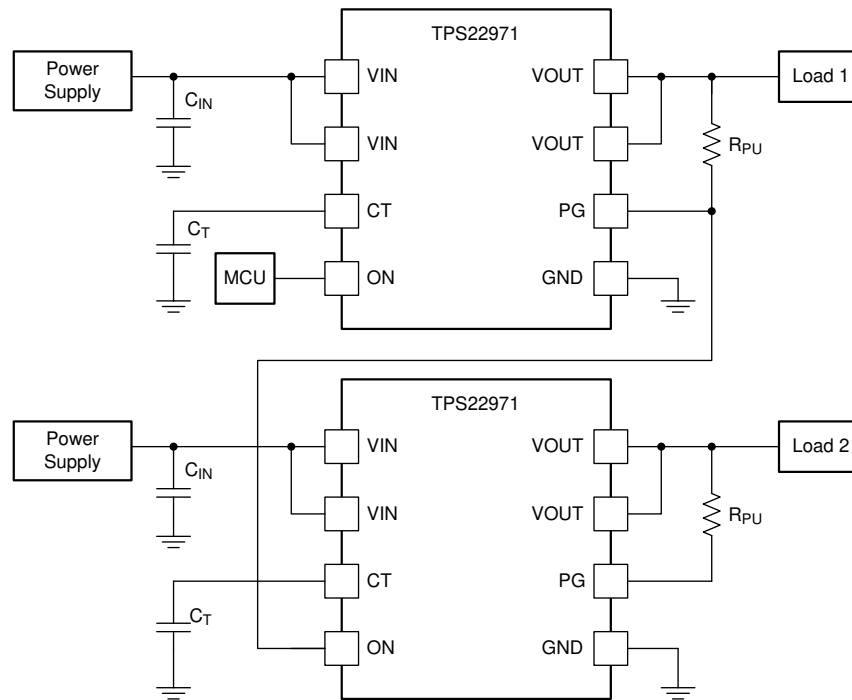
(9)

$R_{PU}$  can be chosen within the range defined by  $R_{PU,MIN}$  and  $R_{PU,MAX}$ .  $R_{PU} = 10$  k $\Omega$  is used for characterization.

#### 9.1.3 Power Sequencing

The TPS22971 has an integrated power good indicator which can be used for power sequencing. As shown in [Figure 26](#), the switch to the second load is controlled by the PG signal from the first switch. This ensures that the power to load 2 is only enabled after the same power to load 1 is enabled after the first switch has turned on.

**Application Information (continued)**



**Figure 26. Power Sequencing**



## 9.2 Typical Application

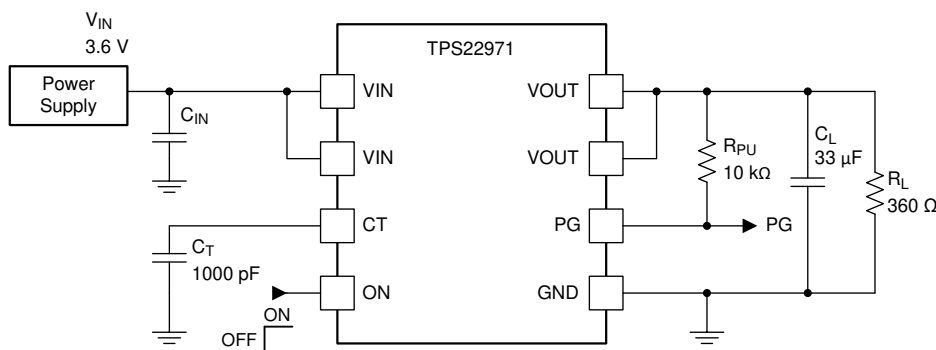


Figure 27. Typical Application

### 9.2.1 Design Requirements

For this design example, below, use the input parameters shown in Table 2.

Table 2. Design Parameters

| DESIGN PARAMETER           | VALUE      |
|----------------------------|------------|
| $V_{IN}$                   | 3.6 V      |
| $I_{LOAD}$                 | 10 mA      |
| Load capacitance ( $C_L$ ) | 33 $\mu$ F |
| Maximum voltage drop       | 1%         |
| Maximum inrush current     | 630 mA     |

### 9.2.2 Detailed Design Procedure

#### 9.2.2.1 Maximum Voltage Drop and On-Resistance

At 3.6-V input voltage, with a maximum voltage drop tolerance of 1%, the TPS22971 has a typical  $R_{ON}$  of 6.7 m $\Omega$ . The rail is supplying 10 mA of current; the voltage drop for a rail is calculated based on Equation 10.

$$V_{DROD} = R_{ON} \times I_{LOAD} \quad (10)$$

$$V_{DROD} = 0.067 \text{ mV} \quad (11)$$

The maximum voltage drop is 1% which is 36 mV. The voltage drop caused by the load current across the on resistance is 0.067 mV.

#### 9.2.2.2 Managing Inrush Current

When the switch is enabled, the output capacitors must be charged up from 0 V to  $V_{IN}$ . This charge arrives in the form of inrush current. Given a load capacitance ( $C_L$ ) of 33  $\mu$ F, an input voltage ( $V_{IN}$ ) of 3.6V and a maximum inrush ( $I_{INRUSH}$ ) of 630 mA, use Equation 12 and Equation 13 to solve for Slew Rate (SR).

$$SR = \frac{I_{INRUSH}}{C_L} \quad (12)$$

$$SR = 0.0191 \text{ V} / \mu\text{s} \quad (13)$$

Now that the desired slew rate has been calculated, use SR and  $V_{IN}$  in in Equation 14 to calculate a CT capacitance value.

$$CT(V_{IN}, SR) = 1007 \text{ pF} \quad (14)$$

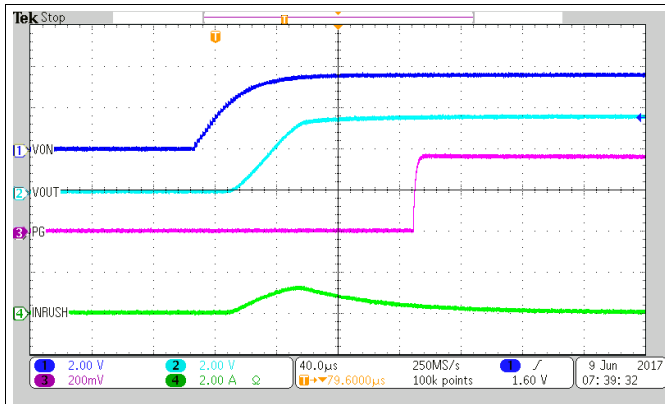
A capacitance value of 1007pF is a non-standard value therefore a 1000 pF CT capacitance is used moving forward.

The calculated CT value can be used with Equation 2 and Equation 4 to determine  $t_{ON}$  and  $t_{PG,ON}$ , respectively as shown in Equation 15 and Equation 16.

$$t_{ON}(V_{IN}, C_T) = 182.8 \mu s \tag{15}$$

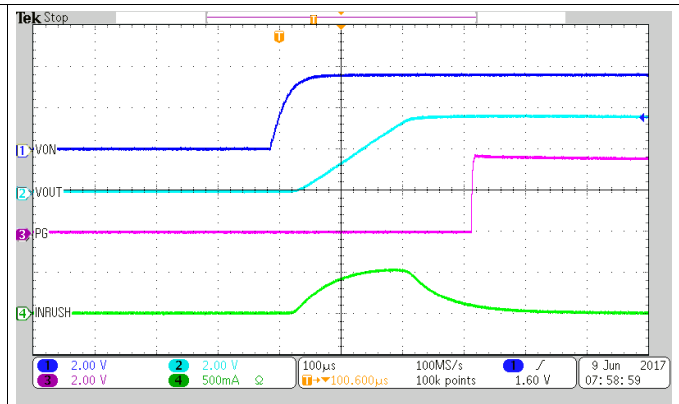
$$t_{PG,ON}(V_{IN}, C_T) = 293.1 \mu s \tag{16}$$

### 9.2.3 Application Curves



$V_{IN} = 3.6 V$        $V_{ON} = 3.6 V$        $C_{IN} = 1 \mu F$   
 $R_L = OPEN$        $T_A = 25^\circ C$        $C_L = 33 \mu F$

Figure 28. TPS22971 Inrush Current With  $C_T = 0 pF$



$V_{IN} = 3.6 V$        $V_{ON} = 3.6 V$        $C_{IN} = 1 \mu F$   
 $R_L = OPEN$        $T_A = 25^\circ C$        $C_L = 33 \mu F$

Figure 29. TPS22971 Inrush Current With  $C_T = 1000 pF$

## 10 Power Supply Recommendations

The device is designed to operate from a  $V_{IN}$  range of 0.65 V to 3.6 V. The  $V_{IN}$  power supply must be well regulated and placed as close to the device terminal as possible. The power supply must be able to withstand all transient load current steps. In most situations, using an input capacitance of 1  $\mu\text{F}$  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.

The requirements for larger input capacitance can be mitigated by adding additional capacitance to the CT pin. This causes the load switch to turn on more slowly. Not only does this reduce transient inrush current, but it also gives the power supply more time to respond to the load current step.

## 11 Layout

### 11.1 Layout Guidelines

All traces must be as short as possible for best performance. Using wide traces for  $V_{IN}$ ,  $V_{OUT}$ , and GND helps minimize the parasitic electrical effects along with minimizing the thermal impedance. The CT trace must be as short as possible to reduce parasitic capacitance.

### 11.2 Layout Example

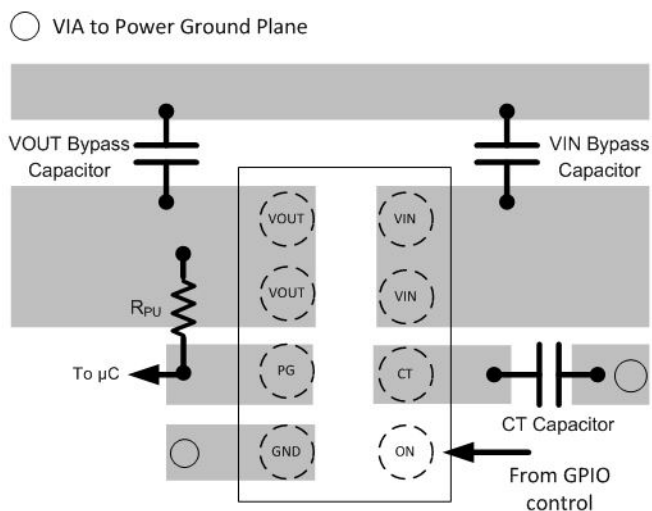


Figure 30. Package Layout Examples

## 12 Device and Documentation Support

### 12.1 Documentation Support

#### 12.1.1 Related Documentation

For related documentation see the following:

[TPS22971 Load Switch Evaluation Module User's Guide](#)

### 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

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

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### 12.4 Trademarks

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### 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<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples        |
|------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|----------------|
| TPS22971YZPR     | ACTIVE        | DSBGA        | YZP                | 8    | 3000           | RoHS & Green    | SAC396                               | Level-1-260C-UNLIM   | -40 to 85    | 1CKI                    | <b>Samples</b> |
| TPS22971YZPT     | ACTIVE        | DSBGA        | YZP                | 8    | 250            | RoHS & Green    | SAC396                               | Level-1-260C-UNLIM   | -40 to 85    | 1CKI                    | <b>Samples</b> |

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

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**TAPE AND REEL INFORMATION**

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


\*All dimensions are nominal

| Device       | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS22971YZPR | DSBGA        | YZP             | 8    | 3000 | 180.0              | 8.4                | 1.02    | 2.02    | 0.63    | 2.0     | 8.0    | Q1            |
| TPS22971YZPT | DSBGA        | YZP             | 8    | 250  | 180.0              | 8.4                | 1.02    | 2.02    | 0.63    | 2.0     | 8.0    | Q1            |

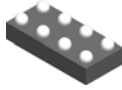
**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

| Device       | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPS22971YZPR | DSBGA        | YZP             | 8    | 3000 | 182.0       | 182.0      | 20.0        |
| TPS22971YZPT | DSBGA        | YZP             | 8    | 250  | 182.0       | 182.0      | 20.0        |



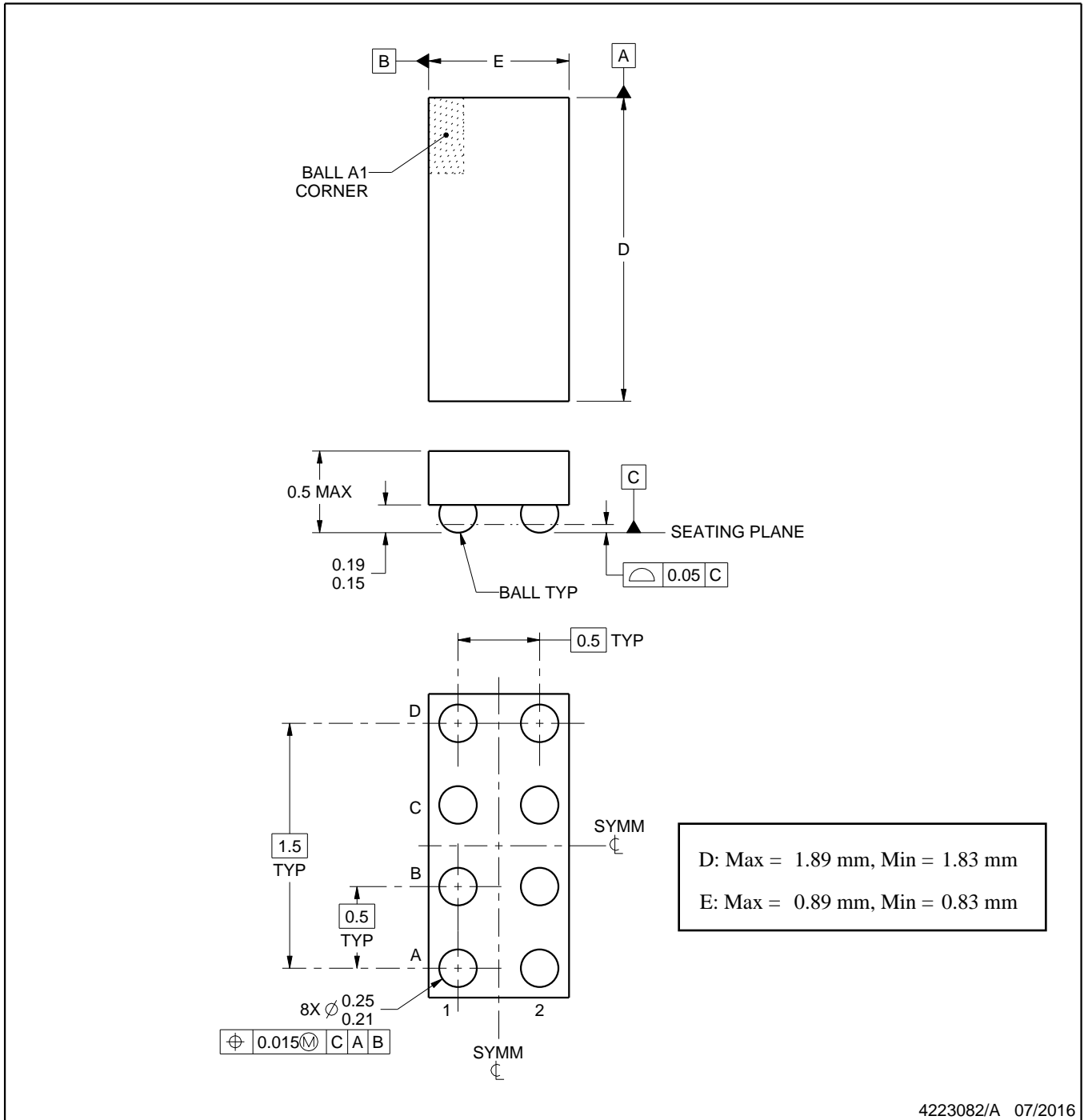
YZP0008



PACKAGE OUTLINE

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY



4223082/A 07/2016

NOTES:

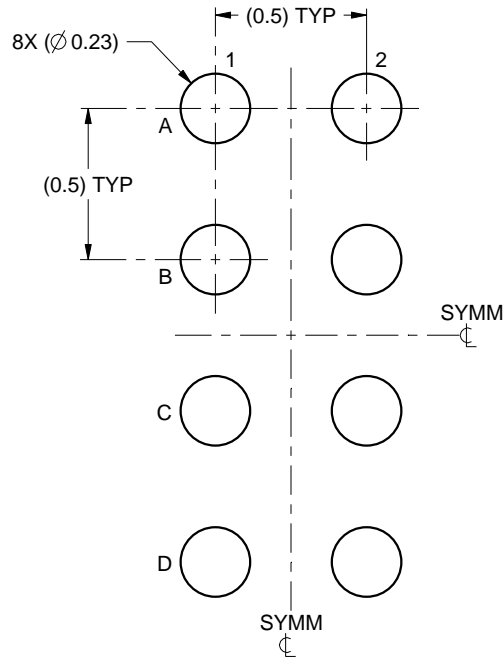
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

# EXAMPLE BOARD LAYOUT

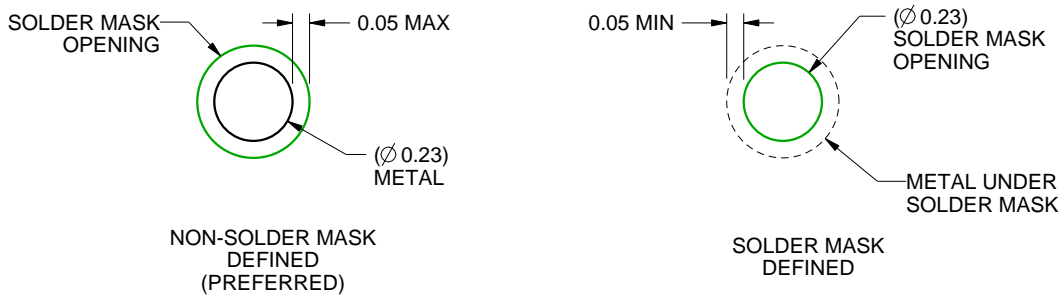
YZP0008

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY



LAND PATTERN EXAMPLE  
SCALE:40X



SOLDER MASK DETAILS  
NOT TO SCALE

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NOTES: (continued)

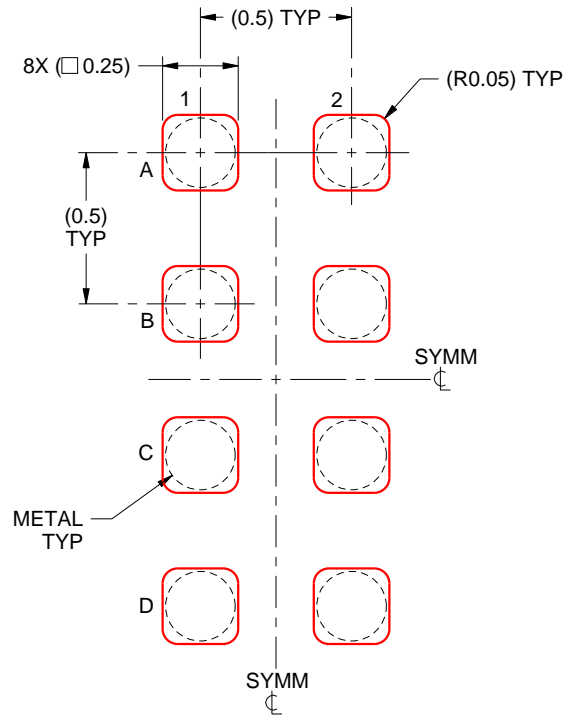
- Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. For more information, see Texas Instruments literature number SNVA009 ([www.ti.com/lit/snva009](http://www.ti.com/lit/snva009)).

# EXAMPLE STENCIL DESIGN

YZP0008

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY



SOLDER PASTE EXAMPLE  
BASED ON 0.1 mm THICK STENCIL  
SCALE:40X

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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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