

# ULTRA-SMALL, LOW-INPUT-VOLTAGE, LOW $r_{ON}$ LOAD SWITCH

Check for Samples: [TPS22924B](#)

## FEATURES

- **Integrated Single Load Switch**
- **Input Voltage: 0.75 V to 3.6 V**
- **Ultra-Low ON Resistance**
  - $r_{ON} = 18.3 \text{ m}\Omega$  at  $V_{IN} = 3.6 \text{ V}$
  - $r_{ON} = 18.5 \text{ m}\Omega$  at  $V_{IN} = 2.5 \text{ V}$
  - $r_{ON} = 19.6 \text{ m}\Omega$  at  $V_{IN} = 1.8 \text{ V}$
  - $r_{ON} = 19.4 \text{ m}\Omega$  at  $V_{IN} = 1.2 \text{ V}$
  - $r_{ON} = 20.3 \text{ m}\Omega$  at  $V_{IN} = 1.0 \text{ V}$
  - $r_{ON} = 22.7 \text{ m}\Omega$  at  $V_{IN} = 0.75 \text{ V}$
- **Ultra Small CSP-6 package**  
0.9 mm x 1.4 mm, 0.5-mm Pitch
- **2-A Maximum Continuous Switch Current**
- **Low Shutdown Current**
- **Low Threshold Control Input**
- **Controlled Slew Rate to Avoid Inrush Currents**
- **Quick Output Discharge Transistor**
- **ESD Performance Tested Per JESD 22**
  - 5000-V Human-Body Model (A114-B, Class II)
  - 1000-V Charged-Device Model (C101)

## APPLICATIONS

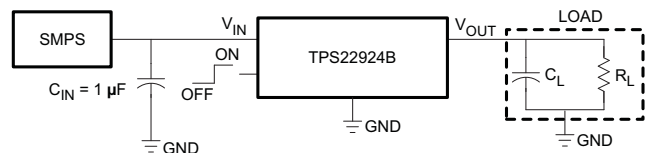
- **Battery Powered Equipment**
- **Portable Industrial Equipment**
- **Portable Medical Equipment**
- **Portable Media Players**
- **Point Of Sales Terminal**
- **GPS Devices**
- **Digital Cameras**
- **Notebooks / Tablet PCs / eReaders**
- **Smartphones**

## DESCRIPTION

The TPS22924B is a small, ultra-low  $r_{ON}$  load switch with controlled turn on. The device contains a N-channel MOSFET that can operate over an input voltage range of 0.75 V to 3.6 V. An integrated charge pump biases the NMOS switch to achieve a minimum switch ON resistance. The switch is controlled by an on/off input (ON), which is capable of interfacing directly with low-voltage control signals.

A 1250- $\Omega$  on-chip load resistor is added for output quick discharge when the switch is turned off. The rise time of the device is internally controlled to avoid inrush current. The TPS22924B features a rise time of 100  $\mu\text{s}$  at 3.6 V.

The TPS22924B is available in an ultra-small space-saving 6-pin CSP package and is characterized for operation over the free-air temperature range of  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

**Figure 1. TYPICAL APPLICATION**


NOTE: SMPS = Switched-mode power supply

**Table 1. FEATURE LIST**

	$r_{ON}$ (TYP) AT 3.6 V	SLEW RATE (TYP) AT 3.6 V	QUICK OUTPUT DISCHARGE <sup>(1)</sup>	MAXIMUM OUTPUT CURRENT	ENABLE
TPS22924B	18.3 m $\Omega$	100 $\mu\text{s}$	Yes	2 A	Active high

(1) This feature discharges the output of the switch to ground through a 1250- $\Omega$  resistor, preventing the output from floating. See the *Output Pulldown* section in Application Information.

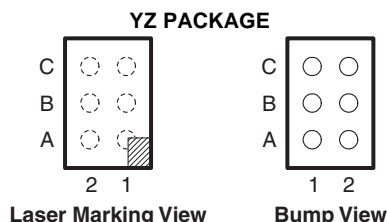


Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

**ORDERING INFORMATION<sup>(1)</sup>**

T <sub>A</sub>	PACKAGE <sup>(2)</sup>		ORDERABLE PART NUMBER	TOP-SIDE MARKING <sup>(3)</sup>
-40°C to 85°C	DSBGA – YZ (0.5-mm pitch)	Tape and reel	TPS22924BYZR	__5N__

- (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at [www.ti.com](http://www.ti.com).
- (2) Package drawings, thermal data, and symbolization are available at [www.ti.com/packaging](http://www.ti.com/packaging).
- (3) The actual top-side marking has three preceding characters to denote year, month, and sequence code, and one following character to designate the wafer fab/assembly site. Pin 1 identifier indicates solder-bump composition (1 = SnPb, • = Pb-free).



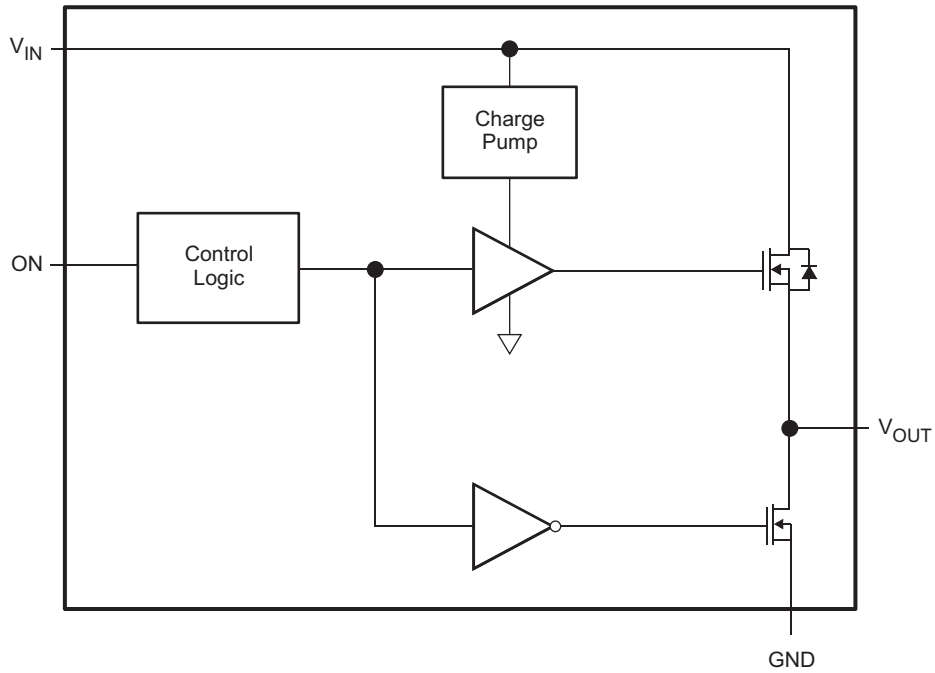
**TERMINALS ASSIGNMENTS (YZ PACKAGE)**

C	GND	ON
B	VOUT	VIN
A	VOUT	VIN
	1	2

**TERMINAL FUNCTIONS**

NO.	NAME	DESCRIPTION
C1	GND	Ground
C2	ON	Switch control input, active high. Do not leave floating
A1, B1	VOUT	Switch output
A2, B2	VIN	Switch input, bypass this input with a ceramic capacitor to ground

**BLOCK DIAGRAM**



**FUNCTION TABLE**

ON (Control Signal)	V <sub>IN</sub> to V <sub>OUT</sub>	V <sub>OUT</sub> to GND <sup>(1)</sup>
L	OFF	ON
H	ON	OFF

(1) See application section *Output Pulldown*.

**ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>**

		MIN	MAX	UNIT
V <sub>IN</sub>	Input voltage range	-0.3	4	V
V <sub>OUT</sub>	Output voltage range		V <sub>IN</sub> + 0.3	V
V <sub>ON</sub>	Input voltage range	-0.3	4	V
I <sub>MAX</sub>	Maximum continuous switch current, T <sub>A</sub> = -40°C to 85°C		2	A
I <sub>PLS</sub>	Maximum pulsed switch current, 100-μs pulse, 2% duty cycle, T <sub>A</sub> = -40°C to 85°C		4	A
T <sub>A</sub>	Operating free-air temperature range	-40	85	°C
T <sub>stg</sub>	Storage temperature range	-65	150	°C
ESD	Electrostatic discharge protection	Human-Body Model (HBM)		V
		Charged-Device Model (CDM)		

(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.

**DISSIPATION RATINGS**

BOARD	PACKAGE	R <sub>θJC</sub>	R <sub>θJA</sub>	DERATING FACTOR ABOVE T <sub>A</sub> = 25°C	T <sub>A</sub> < 25°C	T <sub>A</sub> = 70°C	T <sub>A</sub> = 85°C
High-K <sup>(1)</sup>	YZ	17.6°C/W	123.36°C/W	- 8.1063 mW/°C	810.63 mW	445.84 mW	324.25 mW

(1) The JEDEC high-K (2s2p) board used to derive this data was a 3- × 3-inch, multilayer board with 1-ounce internal power and ground planes and 2-ounce copper traces on top and bottom of the board.

**RECOMMENDED OPERATING CONDITIONS**

		MIN	MAX	UNIT
V <sub>IN</sub>	Input voltage	0.75	3.6	V
V <sub>OUT</sub>	Output voltage		V <sub>IN</sub>	V
V <sub>IH</sub>	High-level input voltage, ON	V <sub>IN</sub> = 2.5 V to 3.6 V		V
		V <sub>IN</sub> = 0.75 V to 2.5 V		
V <sub>IL</sub>	Low-level input voltage, ON	V <sub>IN</sub> = 2.5 V to 3.6 V		V
		V <sub>IN</sub> = 0.75 V to 2.49 V		
C <sub>IN</sub>	Input capacitance	1 <sup>(1)</sup>		μF

(1) See the *Input Capacitor* section in Application Information.

**ELECTRICAL CHARACTERISTICS**
 $V_{IN} = 0.75\text{ V to }3.6\text{ V}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	$T_A$	MIN	TYP <sup>(1)</sup>	MAX	UNIT
$I_{IN}$	Quiescent current	$I_{OUT} = 0, V_{IN} = V_{ON}$	Full	25°C	$V_{IN} = 3.6\text{ V}$		$\mu\text{A}$
					$V_{IN} = 2.5\text{ V}$		
					$V_{IN} = 1.8\text{ V}$		
					$V_{IN} = 1.2\text{ V}$		
					$V_{IN} = 1.0\text{ V}$		
					$V_{IN} = 0.75\text{ V}$		
$I_{IN(LEAK)}$	OFF-state supply current	$V_{ON} = \text{GND}, \text{OUT} = 0\text{V}$	Full			3.5	$\mu\text{A}$
$r_{ON}$	ON-state resistance	$I_{OUT} = -200\text{ mA}$	Full	25°C	$V_{IN} = 3.6\text{ V}$		$\text{m}\Omega$
					$V_{IN} = 2.5\text{ V}$		
					$V_{IN} = 1.8\text{ V}$		
					$V_{IN} = 1.2\text{ V}$		
					$V_{IN} = 1.0\text{ V}$		
					$V_{IN} = 0.75\text{ V}$		
					$V_{IN} = 3.6\text{ V}$		
					$V_{IN} = 2.5\text{ V}$		
$r_{PD}$	Output pulldown resistance <sup>(2)</sup>	$V_{IN} = 3.3\text{ V}, V_{ON} = 0, I_{OUT} = 3\text{ mA}$	25°C		1250	1500	$\Omega$
$I_{ON}$	ON-state input leakage current	$V_{ON} = 0.9\text{ V to }3.6\text{ V or GND}$	Full			0.1	$\mu\text{A}$

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

(2) See [Output Pulldown](#) in *Application Information*.

**SWITCHING CHARACTERISTICS**
 $V_{IN} = 3.6\text{ V}, T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{ON}$	Turn-ON time	$R_L = 10\ \Omega, C_L = 0.1\ \mu\text{F}, V_{IN} = 3.6\text{V}$		111		$\mu\text{s}$
$t_{OFF}$	Turn-OFF time	$R_L = 10\ \Omega, C_L = 0.1\ \mu\text{F}, V_{IN} = 3.6\text{V}$		3		$\mu\text{s}$
$t_r$	$V_{OUT}$ rise time	$R_L = 10\ \Omega, C_L = 0.1\ \mu\text{F}, V_{IN} = 3.6\text{V}$		96		$\mu\text{s}$
$t_f$	$V_{OUT}$ fall time	$R_L = 10\ \Omega, C_L = 0.1\ \mu\text{F}, V_{IN} = 3.6\text{V}$		2.5		$\mu\text{s}$

**SWITCHING CHARACTERISTICS**
 $V_{IN} = 0.9\text{ V}, T_A = 25^\circ\text{C}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{ON}$	Turn-ON time	$R_L = 10\ \Omega, C_L = 0.1\ \mu\text{F}, V_{IN} = 0.9\text{V}$		160		$\mu\text{s}$
$t_{OFF}$	Turn-OFF time	$R_L = 10\ \Omega, C_L = 0.1\ \mu\text{F}, V_{IN} = 0.9\text{V}$		20		$\mu\text{s}$
$t_r$	$V_{OUT}$ rise time	$R_L = 10\ \Omega, C_L = 0.1\ \mu\text{F}, V_{IN} = 0.9\text{V}$		81		$\mu\text{s}$
$t_f$	$V_{OUT}$ fall time	$R_L = 10\ \Omega, C_L = 0.1\ \mu\text{F}, V_{IN} = 0.9\text{V}$		5		$\mu\text{s}$

PARAMETER MEASUREMENT INFORMATION

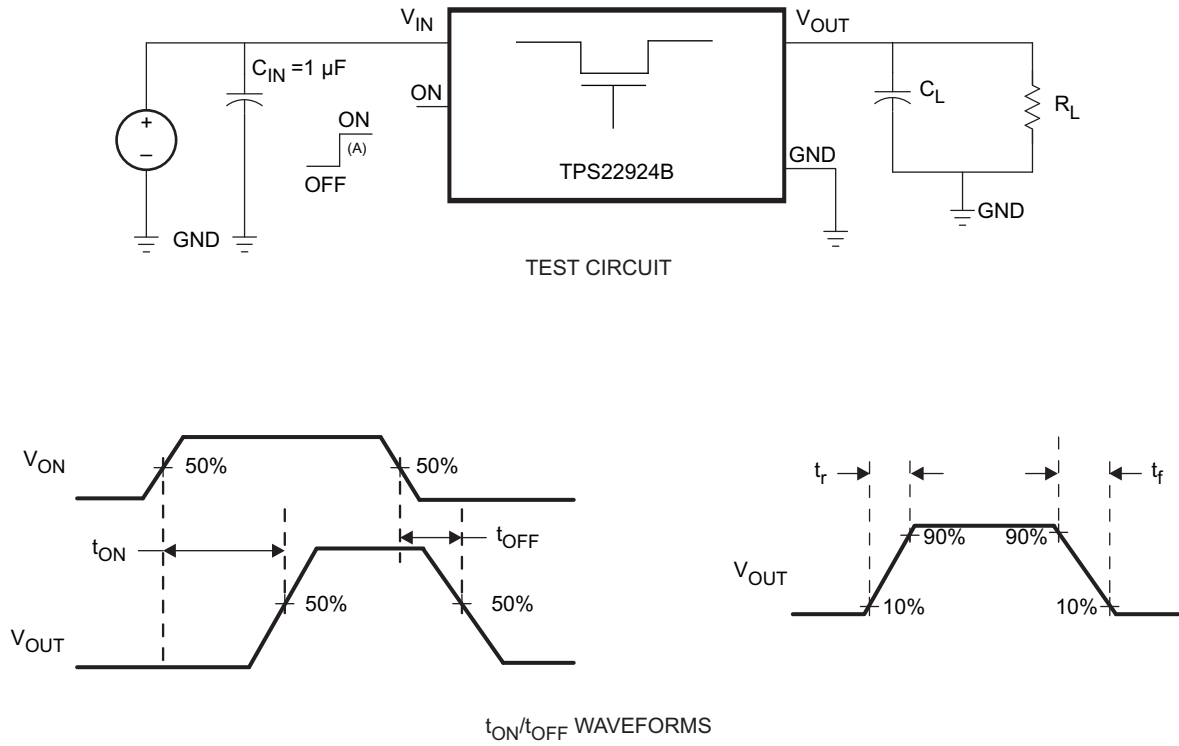
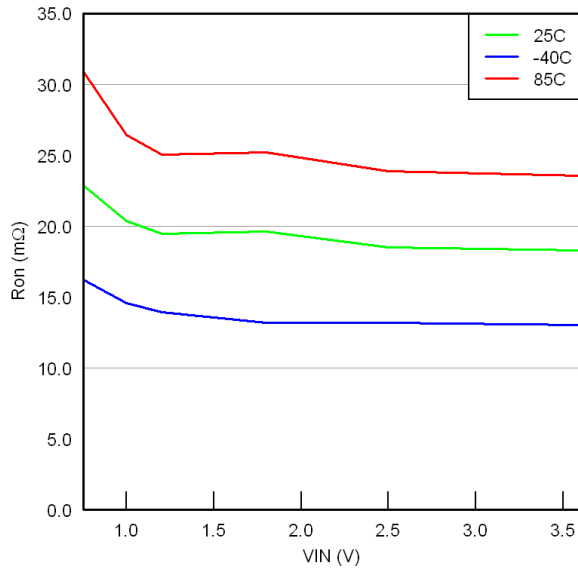


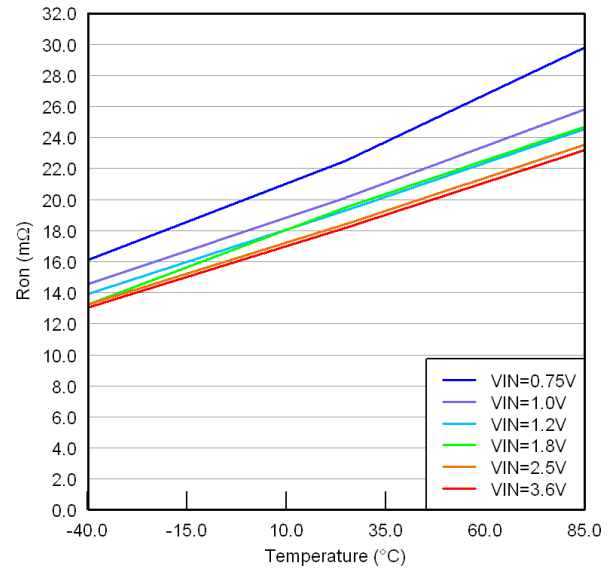
Figure 2. Test Circuit and  $t_{ON}/t_{OFF}$  Waveforms

TYPICAL CHARACTERISTICS

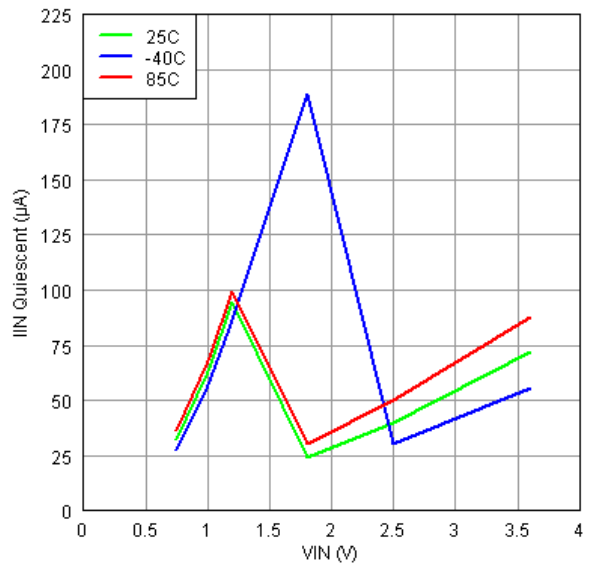
ON-STATE RESISTANCE  
vs  
INPUT VOLTAGE



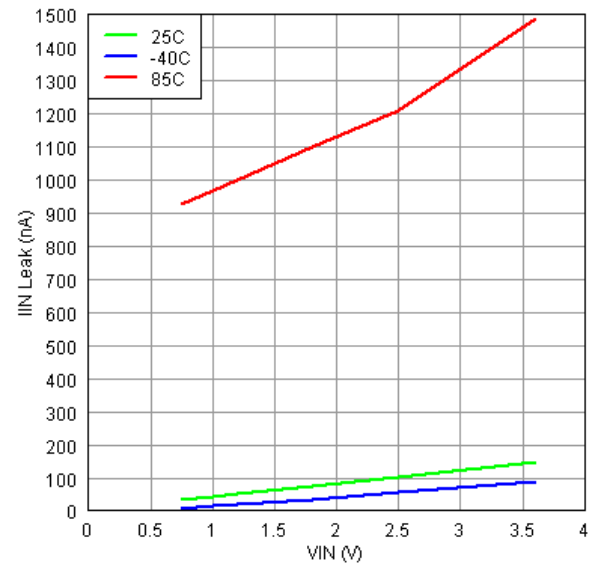
ON-STATE RESISTANCE  
vs  
TEMPERATURE



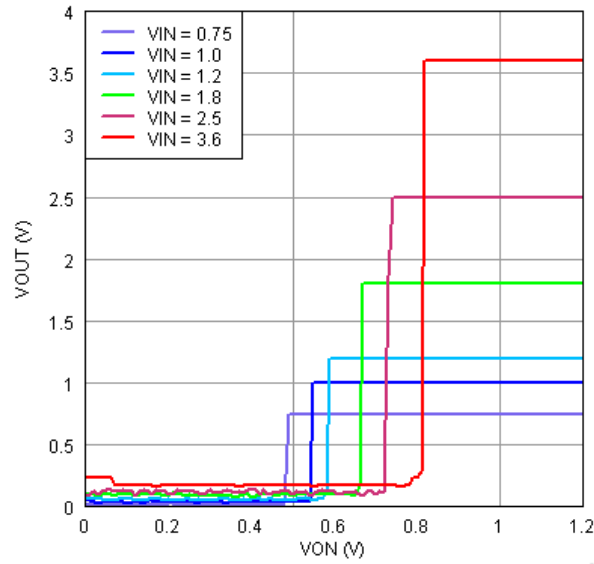
INPUT CURRENT, QUIESCENT  
vs  
INPUT VOLTAGE



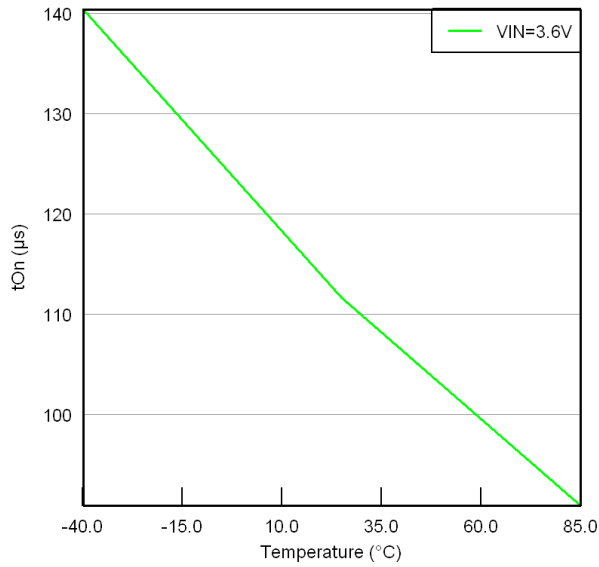
INPUT CURRENT, LEAK  
vs  
INPUT VOLTAGE



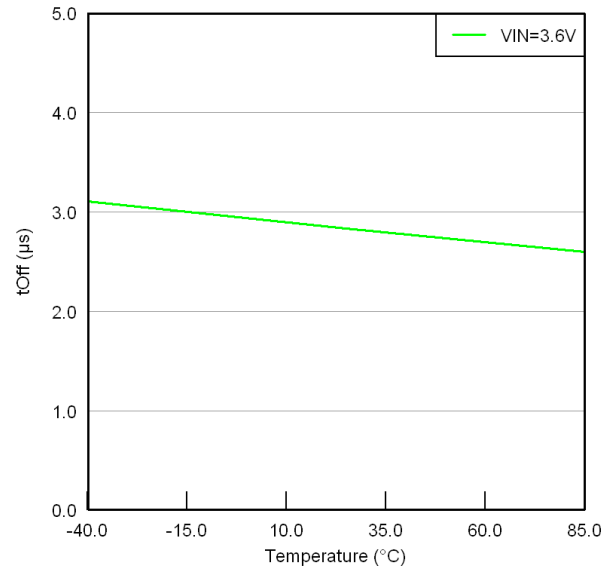
**TYPICAL CHARACTERISTICS (continued)**  
**ON INPUT THRESHOLD**



**TURN-ON TIME vs TEMPERATURE**  
 $V_{IN} = 3.6\text{ V}, C_L = 0.1\ \mu\text{F}, R_L = 10\ \Omega$



**TURN-OFF TIME vs TEMPERATURE**  
 $V_{IN} = 3.6\text{ V}, C_L = 0.1\ \mu\text{F}, R_L = 10\ \Omega$



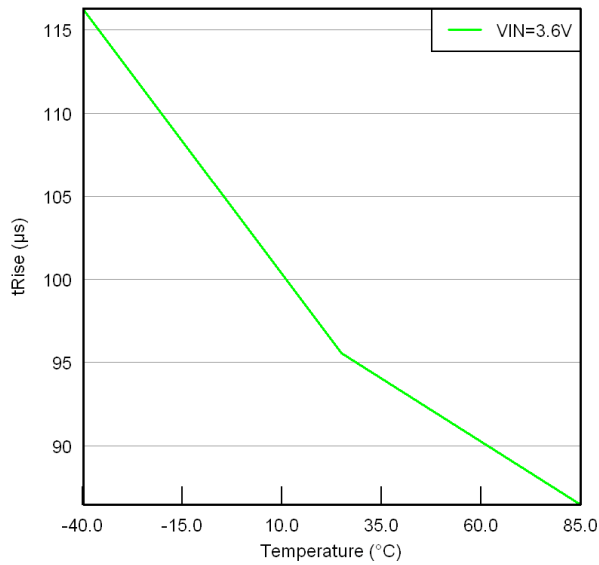


TYPICAL CHARACTERISTICS (continued)

RISE TIME

vs TEMPERATURE

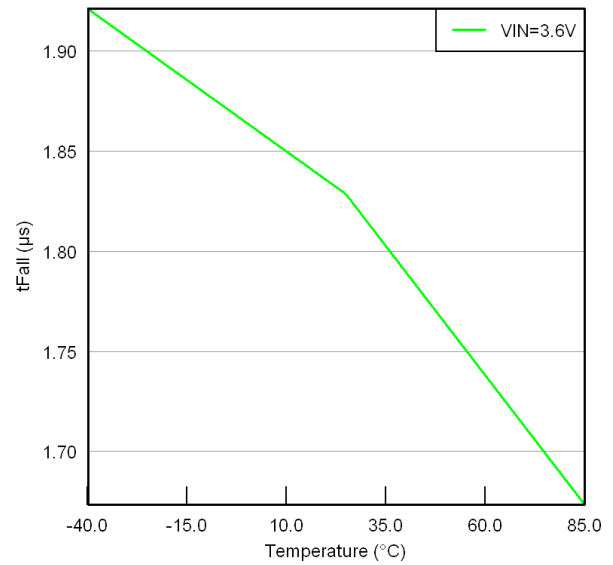
$V_{IN} = 3.6\text{ V}$ ,  $C_L = 0.1\ \mu\text{F}$ ,  $R_L = 10\ \Omega$



FALL TIME

vs TEMPERATURE

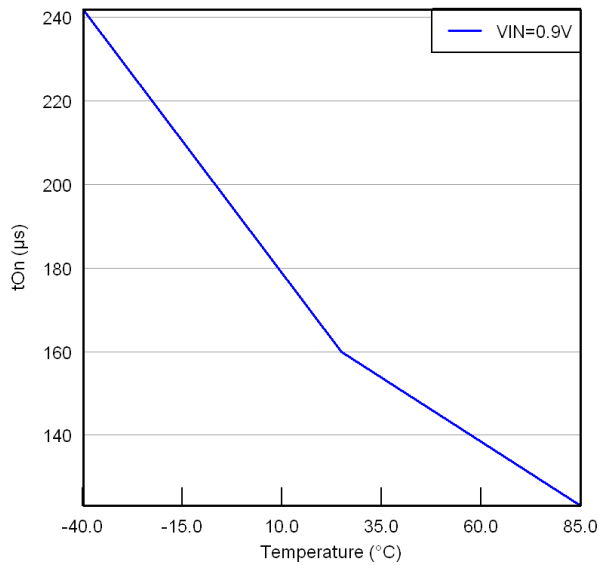
$V_{IN} = 3.6\text{ V}$ ,  $C_L = 0.1\ \mu\text{F}$ ,  $R_L = 10\ \Omega$



TURN-ON TIME

vs TEMPERATURE

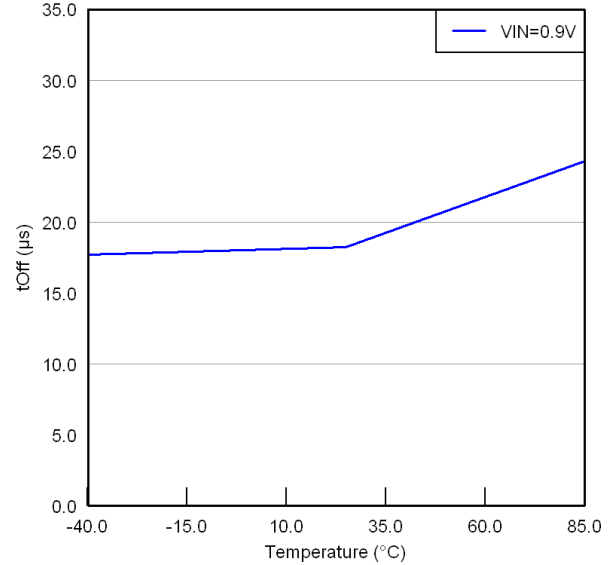
$V_{IN} = 0.9\text{ V}$ ,  $C_L = 0.1\ \mu\text{F}$ ,  $R_L = 10\ \Omega$



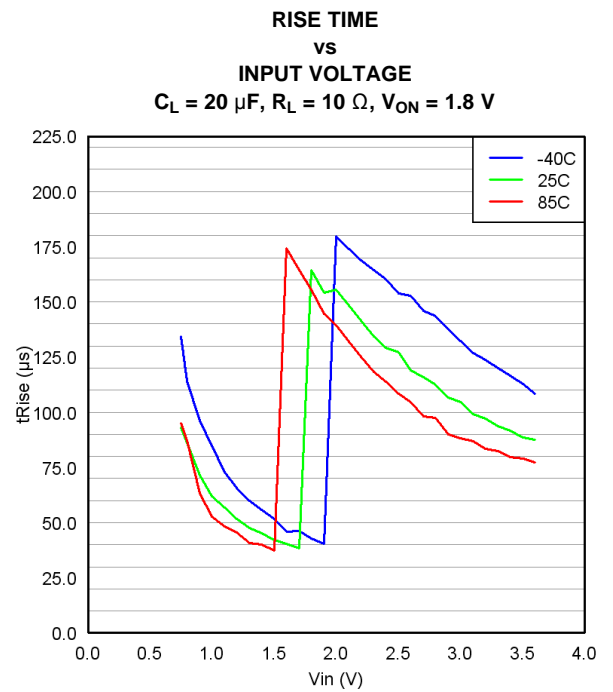
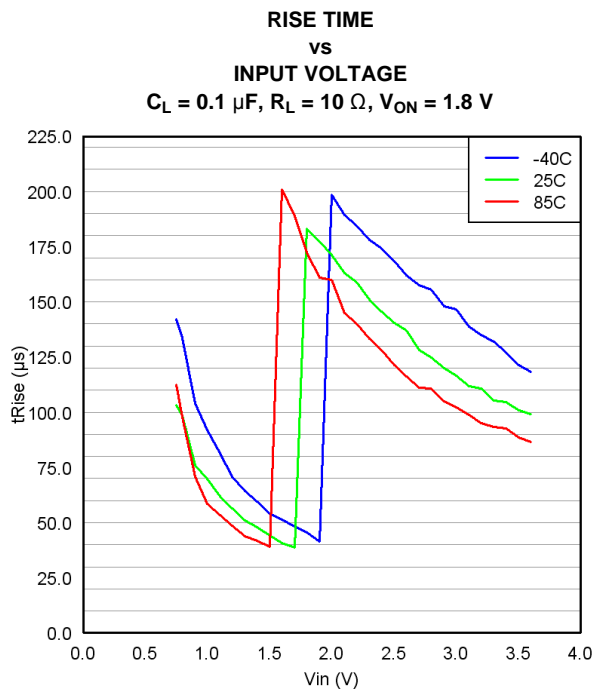
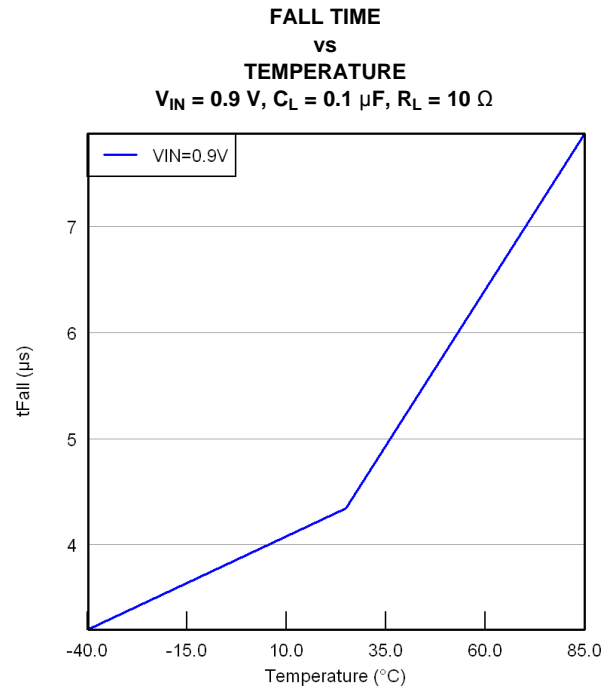
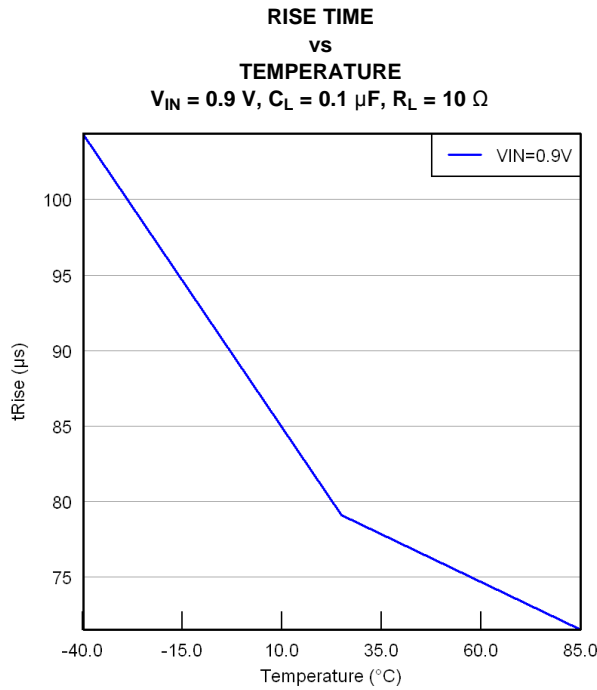
TURN-OFF TIME

vs TEMPERATURE

$V_{IN} = 0.9\text{ V}$ ,  $C_L = 0.1\ \mu\text{F}$ ,  $R_L = 10\ \Omega$



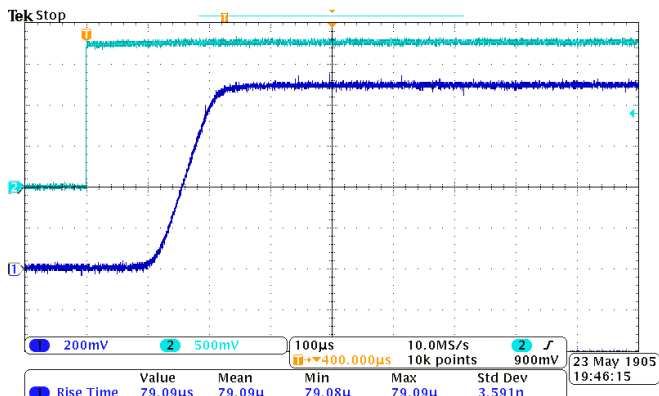
**TYPICAL CHARACTERISTICS (continued)**



TYPICAL CHARACTERISTICS (continued)

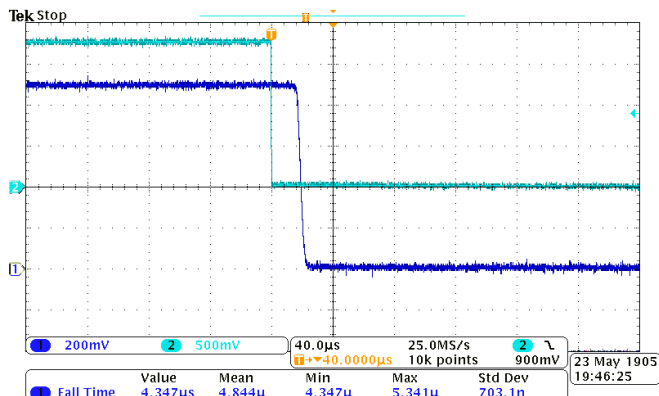
TURN-ON RESPONSE

$C_{IN} = 1 \mu F, C_L = 0.1 \mu F, R_L = 10 \Omega, V_{IN} = 0.9 V, T_A = 25^\circ C$



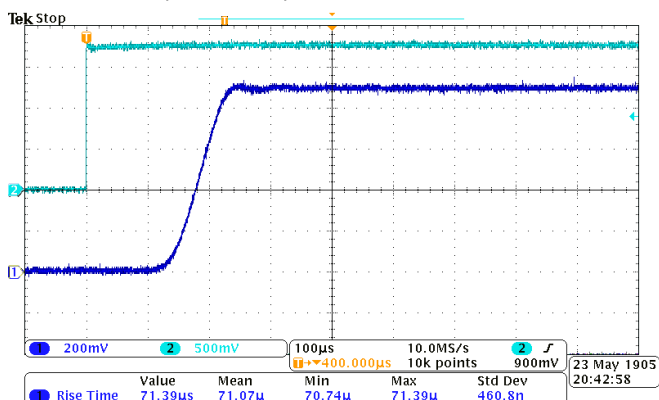
TURN-OFF RESPONSE

$C_{IN} = 1 \mu F, C_L = 0.1 \mu F, R_L = 10 \Omega, V_{IN} = 0.9 V, T_A = 25^\circ C$



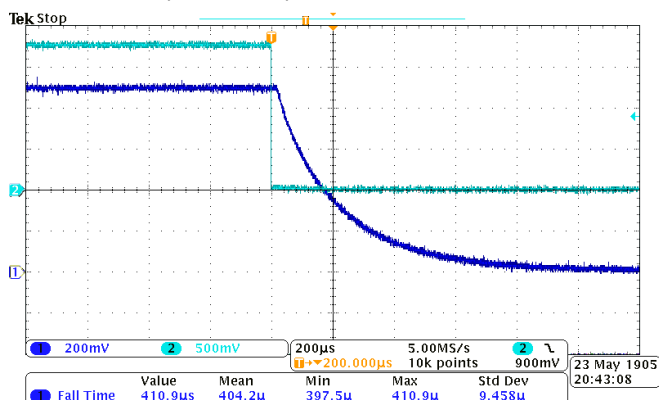
TURN-ON RESPONSE

$C_{IN} = 47 \mu F, C_L = 20 \mu F, R_L = 10 \Omega, V_{IN} = 0.9 V, T_A = 25^\circ C$



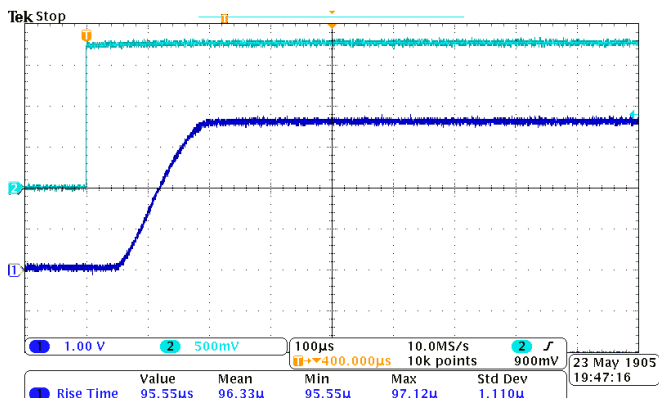
TURN-OFF RESPONSE

$C_{IN} = 47 \mu F, C_L = 20 \mu F, R_L = 10 \Omega, V_{IN} = 0.9 V, T_A = 25^\circ C$



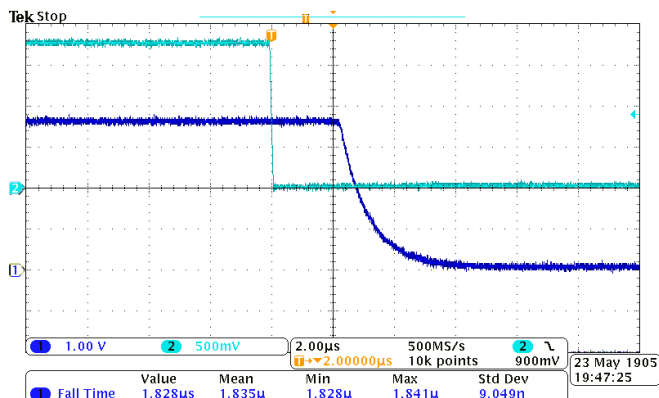
TURN-ON RESPONSE

$C_{IN} = 1 \mu F, C_L = 0.1 \mu F, R_L = 10 \Omega, V_{IN} = 3.6 V, T_A = 25^\circ C$



TURN-OFF RESPONSE

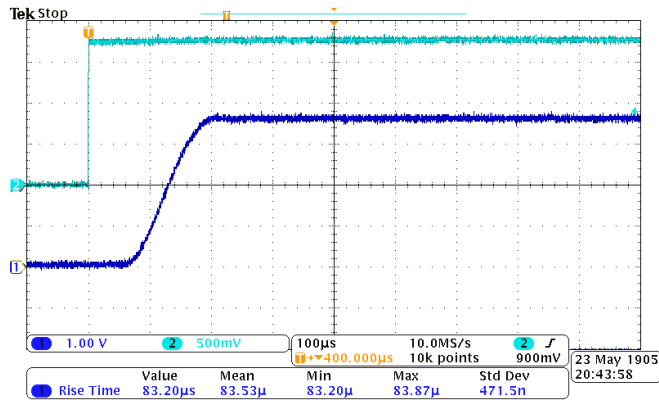
$C_{IN} = 1 \mu F, C_L = 0.1 \mu F, R_L = 10 \Omega, V_{IN} = 3.6 V, T_A = 25^\circ C$



**TYPICAL CHARACTERISTICS (continued)**

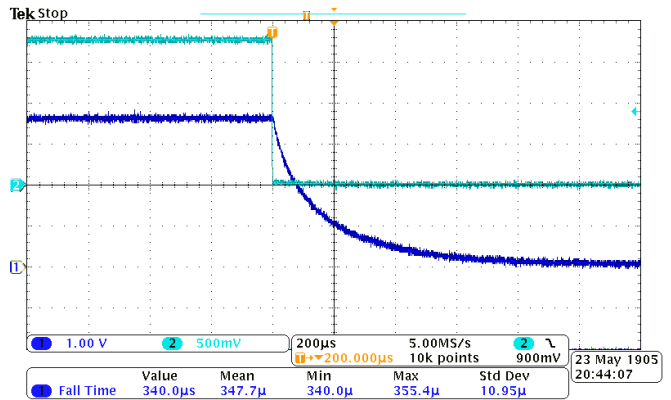
**TURN-ON RESPONSE**

$C_{IN} = 47 \mu F$ ,  $C_L = 20 \mu F$ ,  $R_L = 10 \Omega$ ,  $V_{IN} = 3.6 V$ ,  $T_A = 25^\circ C$



**TURN-OFF RESPONSE**

$C_{IN} = 47 \mu F$ ,  $C_L = 20 \mu F$ ,  $R_L = 10 \Omega$ ,  $V_{IN} = 3.6 V$ ,  $T_A = 25^\circ C$



## APPLICATION INFORMATION

### ON/OFF Control

The ON pin controls the state of the switch. Asserting ON high enables the switch. ON is active high and has a low threshold, making it capable of interfacing with low-voltage signals. The ON pin is compatible with standard GPIO logic threshold. It can be used with any microcontroller with 1.2-V, 1.8-V, 2.5-V or 3.3-V GPIOs.

### Input Capacitor

To limit the voltage drop on the input supply caused by transient inrush currents when the switch turns on into a discharged load capacitor or short-circuit, a capacitor needs to be placed between  $V_{IN}$  and GND. A 1- $\mu$ F 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.

### Output Capacitor

Due to the integral body diode in the NMOS switch, a  $C_{IN}$  greater than  $C_L$  is highly recommended. A  $C_L$  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  $V_{IN}$ . A  $C_{IN}$  to  $C_L$  ratio of 10 to 1 is recommended for minimizing  $V_{IN}$  dip caused by inrush currents during startup.

### Output Pulldown

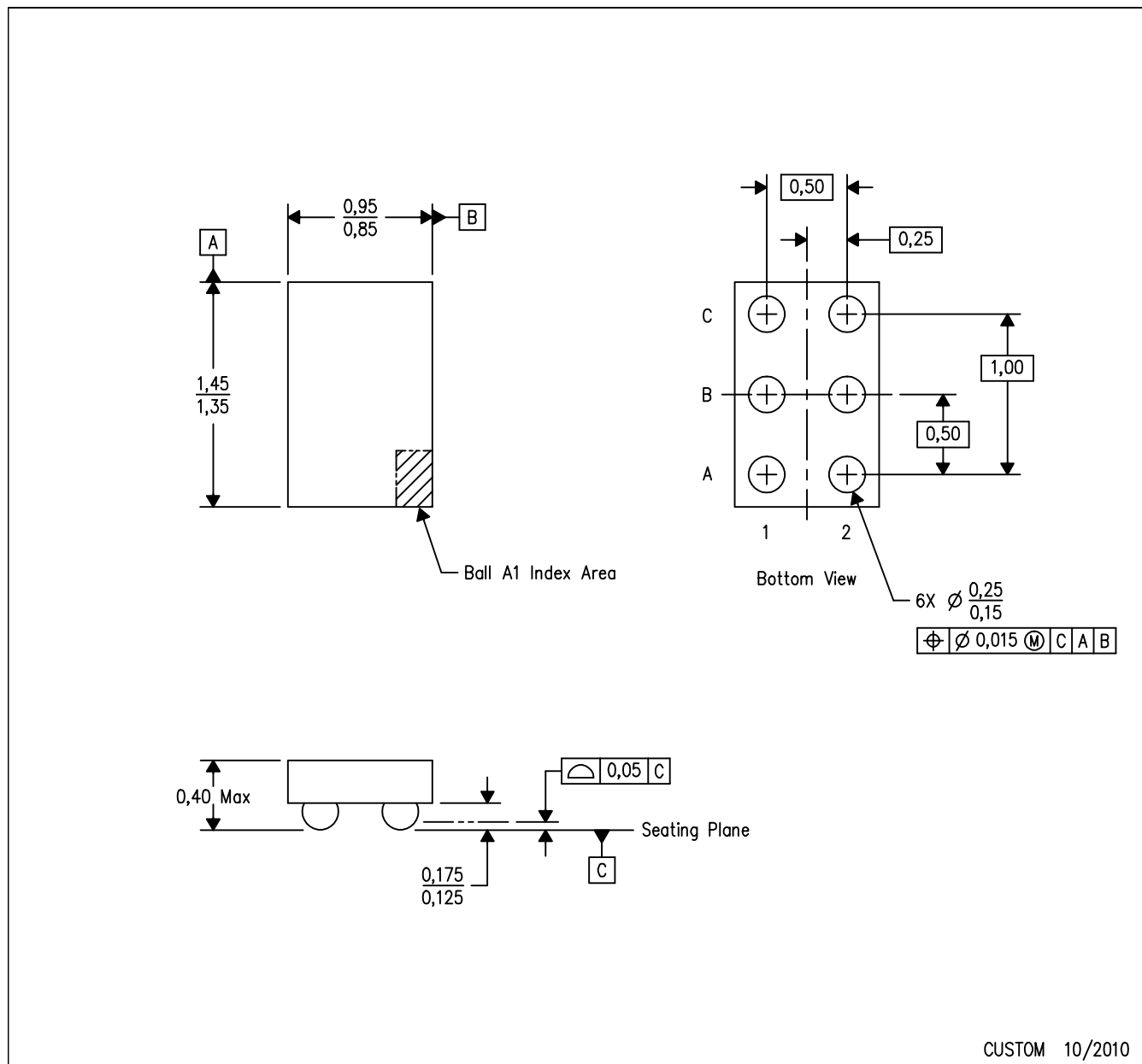
The output pulldown is active when the user is turning off the main pass FET. The pulldown discharges the output rail to approximately 10% of the rail, then the output pulldown is automatically disconnected to optimize the shutdown current.

### Board Layout

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. Using wide traces for  $V_{IN}$ ,  $V_{OUT}$ , and GND helps minimize the parasitic electrical effects along with minimizing the case to ambient thermal impedance.

YZ (R-XBGA-N6)

(CUSTOM) DIE-SIZE BALL GRID ARRAY



- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. NanoFree™ package configuration.
  - D. This package is lead-free.

NanoFree is a trademark of Texas Instruments.



[www.BDTIC.com/TI](http://www.BDTIC.com/TI)

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/ Ball Finish	MSL Peak Temp <sup>(3)</sup>	Samples (Requires Login)
TPS22924BYZR	ACTIVE	WCSP	YZ	6	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	
TPS22924BYZT	ACTIVE	WCSP	YZ	6	250	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	

<sup>(1)</sup> 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.

<sup>(2)</sup> 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)

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

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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

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
TPS22924BYZR	WCSP	YZ	6	3000	178.0	9.2	1.02	1.52	0.63	4.0	8.0	Q1



**TAPE AND REEL BOX DIMENSIONS**

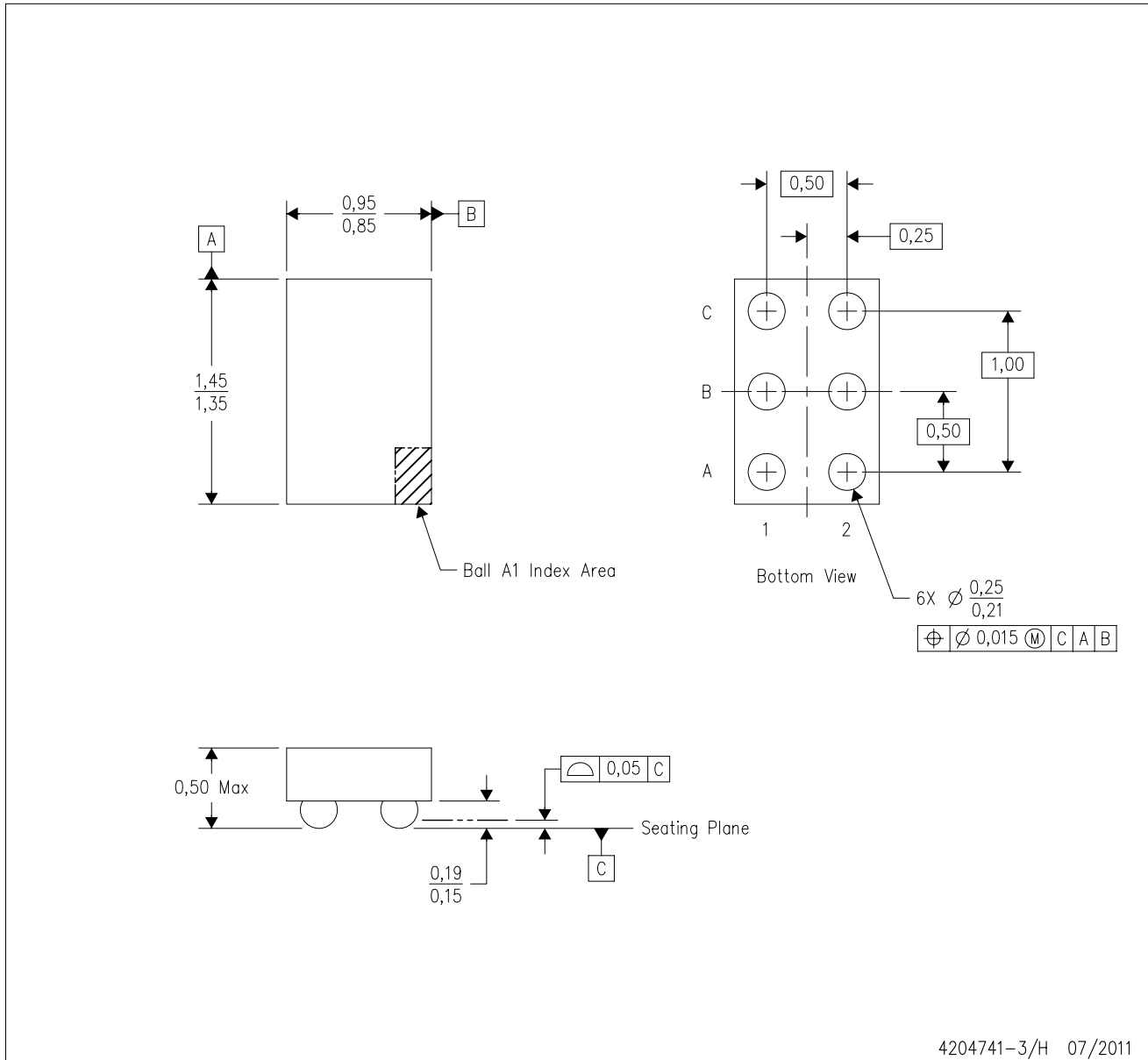


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS22924BYZR	WCSP	YZ	6	3000	220.0	220.0	35.0

YZP (R-XBGA-N6)

DIE-SIZE BALL GRID ARRAY



- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. NanoFree™ package configuration.
  - D. This package is a Pb-free solder ball design. Refer to the 6 YEP package (drawing 4204725) for tin-lead (SnPb).

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