TPS22965 5.7-V, 6-A, 16-mΩ On-Resistance Load Switch

1 Features

- Integrated Single Channel Load Switch
- Input Voltage Range: 0.8 V to 5.7 V
- Ultra-Low On Resistance (R_{ON})
  - R_{ON} = 16 mΩ at V_{IN} = 5 V (V_{BIAS} = 5 V)
  - R_{ON} = 16 mΩ at V_{IN} = 3.6 V (V_{BIAS} = 5 V)
  - R_{ON} = 16 mΩ at V_{IN} = 1.8 V (V_{BIAS} = 5 V)
- 6-A Maximum Continuous Switch Current
- Low Quiescent Current (50 µA)
- Low Control Input Threshold Enables Use of 1.2-V, 1.8-V, 2.5-V and 3.3-V Logic
- Configurable Rise Time
- Quick Output Discharge (QOD)
- SON 8-pin Package With Thermal Pad
- ESD Performance Tested per JESD 22
  - 2000 V HBM and 1000 V CDM

2 Applications

- Ultrabook™
- Notebooks/Netbooks
- Tablet PC
- Consumer Electronics
- Set-top Boxes/Residential Gateways
- Telecom Systems
- Solid State Drives (SSD)

3 Description

The TPS22965 is a single channel load switch that provides configurable rise time to minimize inrush current. The device contains an N-channel MOSFET that can operate over an input voltage range of 0.8 V to 5.7 V and can support a maximum continuous current of 6 A. The switch is controlled by an on/off input (ON), which is capable of interfacing directly with low-voltage control signals. In the TPS22965, a 225-Ω on-chip load resistor is added for quick output discharge when switch is turned off.

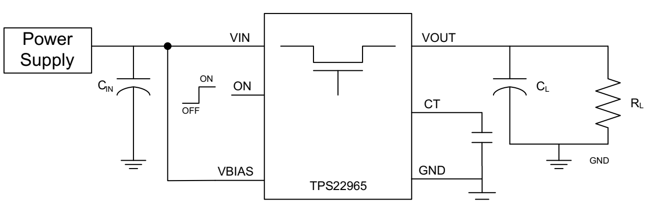
The TPS22965 is available in a small, space-saving 2.00 mm x 2.00 mm 8-pin SON package (DSG) with integrated thermal pad allowing for high power dissipation. The device is characterized for operation over the free-air temperature range of –40°C to 105°C.

Device Information(1)

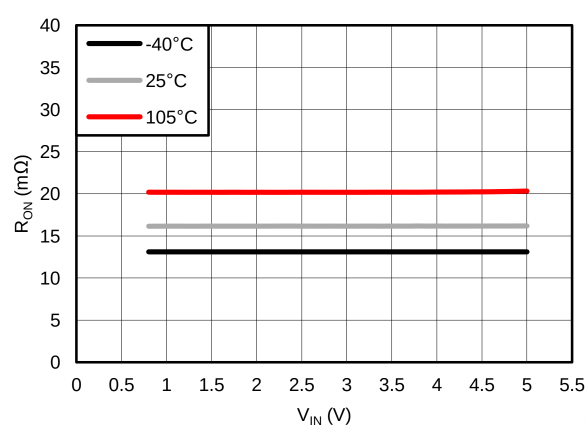
PART NUMBER	PACKAGE	BODY SIZE (NOM)
TPS22965	DSG (8)	2.00 mm x 2.00 mm

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

4 Simplified Schematic



R_{ON} vs V_{IN} (V_{BIAS} = 5V, I_{VOUT} = –200mA)



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5 Revision History

Changes from Revision B (June 2014) to Revision C — **Page**

- Extended Recommended Operating free-air temperature range maximum to 105°C. 1
- Added temperature operations to Electrical Characteristics, V_{BIAS} = 5.0 V. 5
- Added temperature operations to Electrical Characteristics, V_{BIAS} = 2.5V. 6

Changes from Revision A (August 2013) to Revision B — **Page**

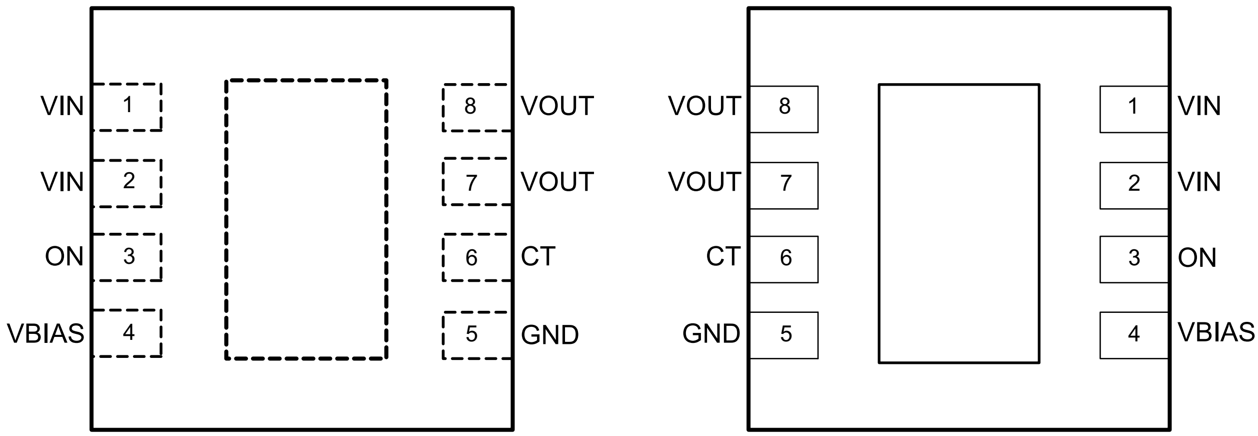
- Changed this data sheet into the new template layout. 1
- Device Information table. 1
- Added Handling Ratings table. 4
- Changed MAX value of "V_{IN}" from 5.5 V to 5.7 V. 4
- Changed MAX value of "V_{BIAS}" from 5.5 V to 5.7 V. 4
- Changed MAX value of "V_{ON}" from 5.5 V to 5.7 V. 4
- Added Thermal Information table. 4
- Added Detailed Description Section. 14
- Added Application and Implementation section. 16
- Added Power Supply Recommendations section. 19
- Added Layout section. 19

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

- Updated VON MAX value to fix typo that restricted operating range. Changed MAX value from "VIN" to "5.5" to align with rest of document. 4

6 Pin Configuration and Functions

DSG PACKAGE



TOP VIEW

BOTTOM VIEW

Pin Functions

PIN		I/O	DESCRIPTION
NAME	**DSG**		
CT	6	O	Switch slew rate control. Can be left floating. See *Application Information* section for more information.
GND	5	–	Device ground.
ON	3	I	Active high switch control input. Do not leave floating.
Thermal Pad	–	–	Thermal pad (exposed center pad) to alleviate thermal stress. Tie to GND. See *Layout Example* section for layout guidelines.
VBIAS	4	I	Bias voltage. Power supply to the device. Recommended voltage range for this pin is 2.5V to 5.7V. See *Application and Implementation* section for more information.
VIN	1, 2	I	Switch input. Input bypass capacitor recommended for minimizing V_{IN} dip. Must be connected to Pin 1 and Pin 2. See *Application and Implementation* section for more information.
VOUT	7, 8	O	Switch output.

7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1) (2)

		MIN	MAX	UNIT
V_{IN}	Input voltage range	–0.3	6	V
V_{OUT}	Output voltage range	–0.3	6	V
V_{BIAS}	Bias voltage range	–0.3	6	V
V_{ON}	Input voltage range	–0.3	6	V
I_{MAX}	Maximum continuous switch current		6	A
I_{PLS}	Maximum pulsed switch current, pulse <300 µs, 2% duty cycle		8	A
T_J	Maximum junction temperature		125	°C
T_{stg}	Storage temperature range	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute–maximum–rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to network ground terminal.

7.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101[2]	±1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Manufacturing with less than 500-V HBM is possible with the necessary precautions.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process. Manufacturing with less than 250-V CDM is possible with the necessary precautions.

7.3 Recommended Operating Conditions

			MIN	MAX	UNIT
V_{IN}	Input voltage range		0.8	V_{BIAS}	V
V_{BIAS}	Bias voltage range		2.5	5.7	V
V_{ON}	ON voltage range		0	5.7	V
V_{OUT}	Output voltage range			V_{IN}	V
V_{IH}	High-level input voltage, ON	V_{BIAS} = 2.5 V to 5.7 V	1.1	5.7	V
V_{IL}	Low-level input voltage, ON	V_{BIAS} = 2.5 V to 5.7 V	0	0.5	V
C_{IN}	Input capacitor		1[1]		µF
T_A	Operating free-air temperature range[2]		–40	105	°C

(1) Refer to *Application Information* section.
(2) In applications where high power dissipation and/or poor package thermal resistance is present, the maximum ambient temperature may have to be derated. Maximum ambient temperature [$T_{A(max)}$] is dependent on the maximum operating junction temperature [$T_{J(max)}$], the maximum power dissipation of the device in the application [$P_{D(max)}$], and the junction-to-ambient thermal resistance of the part/package in the application (θ_{JA}), as given by the following equation: $T_{A\ (max)} = T_{J(max)} – (\theta_{JA} \times P_{D(max)})$

7.4 Thermal Information

THERMAL METRIC[1]		TPS22965	UNIT
		DSG (8 PINS)	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	65.3	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	74.2	
$R_{\theta JB}$	Junction-to-board thermal resistance	35.4	
ψ_{JT}	Junction-to-top characterization parameter	2.2	
ψ_{JB}	Junction-to-board characterization parameter	36.0	
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	12.8	

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

7.5 Electrical Characteristics, V_{BIAS} = 5.0 V

Unless otherwise noted, the specification in the following table applies where **V_{BIAS} = 5.0 V**. Typical values are for T_A = 25 °C.

PARAMETER		TEST CONDITIONS		T_A	MIN	TYP	MAX	UNIT
POWER SUPPLIES AND CURRENTS								
$I_{IN(VBIAS-ON)}$	V_{BIAS} quiescent current	I_{OUT} = 0 mA, V_{IN} = V_{ON} = V_{BIAS} = 5.0 V		–40°C to 105°C		50	75	µA
$I_{IN(VBIAS-OFF)}$	V_{BIAS} shutdown current	V_{ON} = GND, V_{OUT} = 0 V		–40°C to 105°C			2	µA
$I_{IN(VIN-OFF)}$	V_{IN} off-state supply current	V_{ON} = GND, V_{OUT} = 0 V	V_{IN} = 5.0 V	–40°C to 105°C		0.005	5	µA
			V_{IN} = 3.3 V	–40°C to 105°C		0.002	3	
			V_{IN} = 1.8 V	–40°C to 105°C		0.002	2	
			V_{IN} = 0.8 V	–40°C to 105°C		0.001	1	
I_{ON}	ON pin input leakage current	V_{ON} = 5.5 V		–40°C to 105°C			0.5	µA
RESISTANCE CHARACTERISTICS								
R_{ON}	ON-state resistance	I_{OUT} = –200 mA, V_{BIAS} = 5.0 V	V_{IN} = 5.0 V	25°C		16	21	mΩ
				–40°C to 85°C			23	
				–40°C to 105°C			25	
			V_{IN} = 3.3 V	25°C		16	21	mΩ
				–40°C to 85°C			23	
				–40°C to 105°C			25	
			V_{IN} = 1.8 V	25°C		16	21	mΩ
				–40°C to 85°C			23	
				–40°C to 105°C			25	
			V_{IN} = 1.5 V	25°C		16	21	mΩ
				–40°C to 85°C			23	
				–40°C to 105°C			25	
			V_{IN} = 1.2 V	25°C		16	21	mΩ
				–40°C to 85°C			23	
				–40°C to 105°C			25	
			V_{IN} = 0.8 V	25°C		16	21	mΩ
				–40°C to 85°C			23	
				–40°C to 105°C			25	
R_{PD}	Output pull-down resistance	V_{IN} = 5.0 V, V_{ON} = 0 V, I_{OUT} = 15 mA		–40°C to 105°C		225	300	Ω

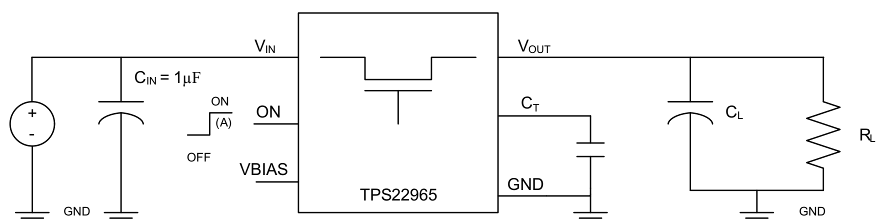
7.6 Electrical Characteristics, V_{BIAS} = 2.5 V

Unless otherwise noted, the specification in the following table applies where **V_{BIAS} = 2.5 V**. Typical values are for T_A = 25 °C.

PARAMETER		TEST CONDITIONS		T_A	MIN	TYP	MAX	UNIT
POWER SUPPLIES AND CURRENTS								
$I_{IN(VBIAS-ON)}$	V_{BIAS} quiescent current	I_{OUT} = 0 mA, V_{IN} = V_{ON} = V_{BIAS} = 2.5 V		–40°C to 105°C		20	30	µA
$I_{IN(VBIAS-OFF)}$	V_{BIAS} shutdown current	V_{ON} = GND, V_{OUT} = 0 V		–40°C to 105°C			2	µA
$I_{IN(VIN-OFF)}$	V_{IN} off-state supply current	V_{ON} = GND, V_{OUT} = 0 V	V_{IN} = 2.5 V	–40°C to 105°C		0.005	3	µA
			V_{IN} = 1.8 V	–40°C to 105°C		0.002	2	
			V_{IN} = 1.2 V	–40°C to 105°C		0.002	2	
			V_{IN} = 0.8 V	–40°C to 105°C		0.001	1	
I_{ON}	ON pin input leakage current	V_{ON} = 5.5 V		–40°C to 105°C			0.5	µA
RESISTANCE CHARACTERISTICS								
R_{ON}	ON-state resistance	I_{OUT} = –200 mA, V_{BIAS} = 2.5 V	V_{IN} = 2.5 V	25°C		20	24	mΩ
				–40°C to 85°C			27	
				–40°C to 105°C			28	
			V_{IN} = 1.8 V	25°C		19	23	mΩ
				–40°C to 85°C			26	
				–40°C to 105°C			28	
			V_{IN} = 1.5 V	25°C		18	23	mΩ
				–40°C to 85°C			25	
				–40°C to 105°C			27	
			V_{IN} = 1.2 V	25°C		18	23	mΩ
				–40°C to 85°C			25	
				–40°C to 105°C			27	
			V_{IN} = 0.8 V	25°C		17	22	mΩ
				–40°C to 85°C			25	
				–40°C to 105°C			27	
R_{PD}	Output pull-down resistance	V_{IN} = 2.5 V, V_{ON} = 0 V, I_{OUT} = 1 mA		–40°C to 105°C		275	325	Ω

7.7 Switching Characteristics

PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
$V_{IN} = V_{ON} = V_{BIAS}$ = 5 V, T_A = 25ºC (unless otherwise noted)						
t_{ON}	Turn-on time	R_L = 10 Ω, C_L = 0.1 µF, C_T = 1000 pF		1325		µs
t_{OFF}	Turn-off time			10		
t_R	V_{OUT} rise time			1625		
t_F	V_{OUT} fall time			3.5		
t_D	ON delay time			500		
V_{IN} = 0.8 V, $V_{ON} = V_{BIAS}$ = 5 V, T_A = 25ºC (unless otherwise noted)						
t_{ON}	Turn-on time	R_L = 10 Ω, C_L = 0.1 µF, C_T = 1000 pF		600		µs
t_{OFF}	Turn-off time			80		
t_R	V_{OUT} rise time			300		
t_F	V_{OUT} fall time			5.5		
t_D	ON delay time			460		
V_{IN} = 2.5V, V_{ON} = 5 V, V_{BIAS} = 2.5 V, T_A = 25ºC (unless otherwise noted)						
t_{ON}	Turn-on time	R_L = 10 Ω, C_L = 0.1 µF, C_T = 1000 pF		2200		µs
t_{OFF}	Turn-off time			9		
t_R	V_{OUT} rise time			2275		
t_F	V_{OUT} fall time			3.1		
t_D	ON delay time			1075		
V_{IN} = 0.8 V, V_{ON} = 5 V, V_{BIAS} = 2.5 V, T_A = 25ºC (unless otherwise noted)						
t_{ON}	Turn-on time	R_L = 10 Ω, C_L = 0.1 µF, C_T = 1000 pF		1450		µs
t_{OFF}	Turn-off time			60		
t_R	V_{OUT} rise time			875		
t_F	V_{OUT} fall time			5.5		
t_D	ON delay time			1010		



A. Rise and fall times of the control signal is 100 ns.

Figure 1. Test Circuit

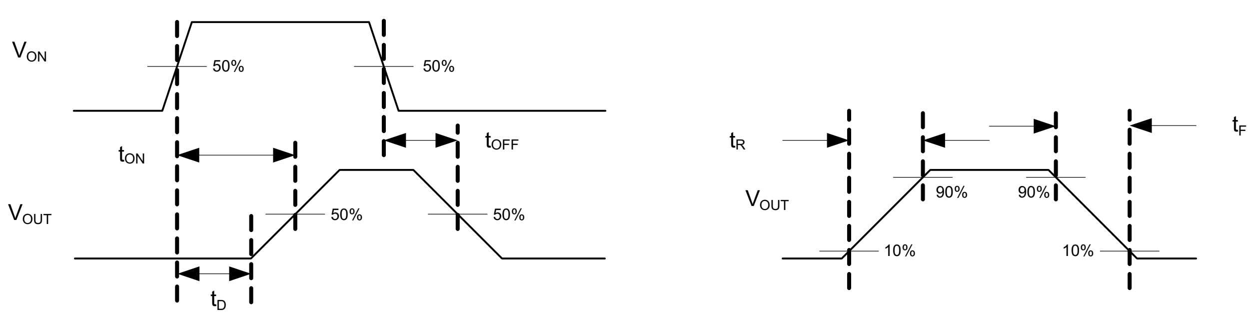
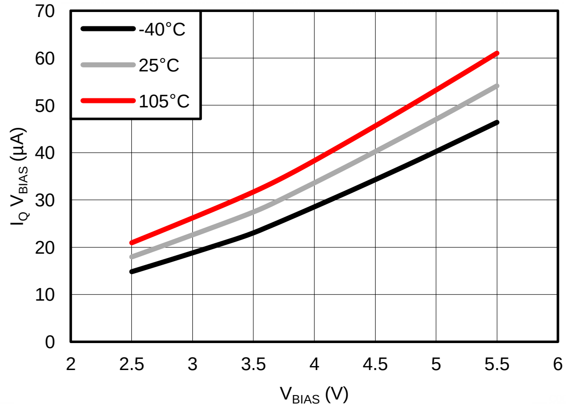


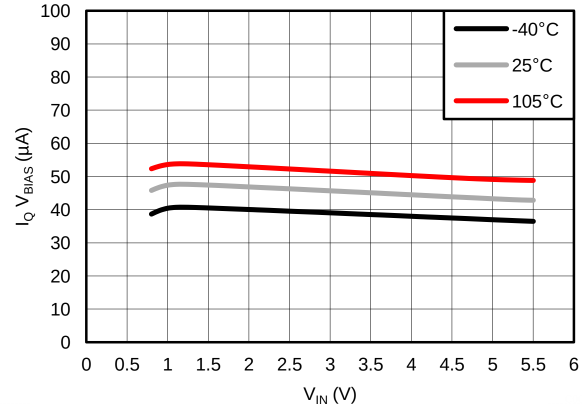
Figure 2. t_{ON}/t_{OFF} Waveforms

7.8 Typical DC Characteristics



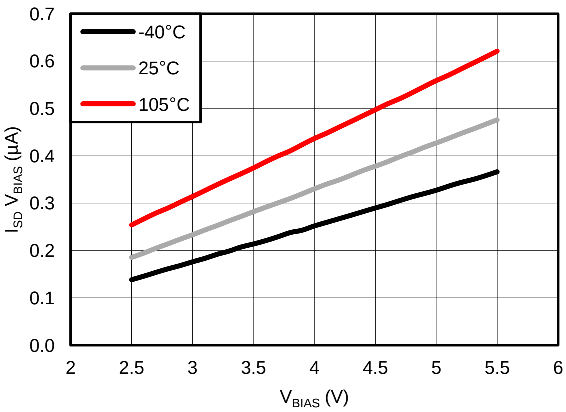
V_{IN} = 1.8V

Figure 3. I_Q V_{BIAS} vs. V_{BIAS}



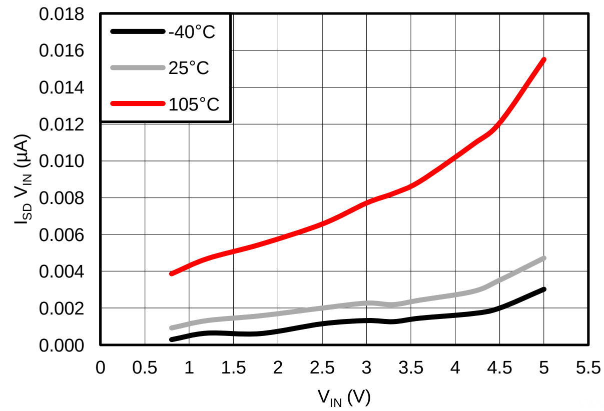
V_{BIAS} = 5V

Figure 4. I_Q V_{BIAS} vs. V_{IN}



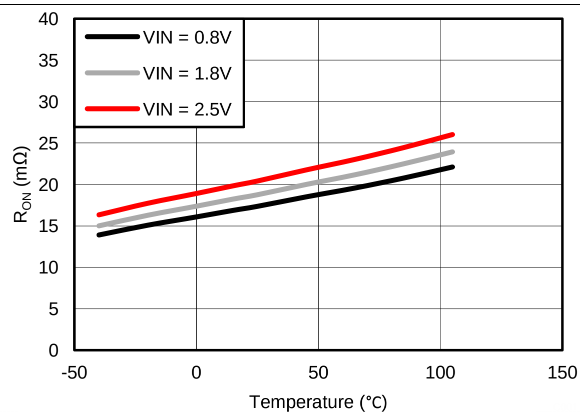
V_{IN} = 5V

Figure 5. I_{SD} V_{BIAS} vs. V_{BIAS}



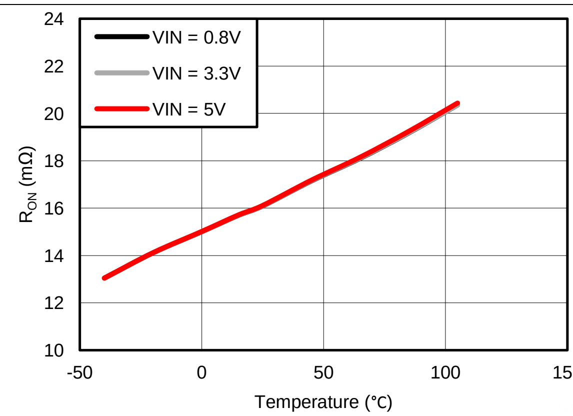
V_{BIAS} = 5V

Figure 6. I_{SD} V_{IN} vs. V_{IN}



V_{BIAS} = 2.5V I_{VOUT} = –200mA

Figure 7. R_{ON} vs. Ambient Temperature

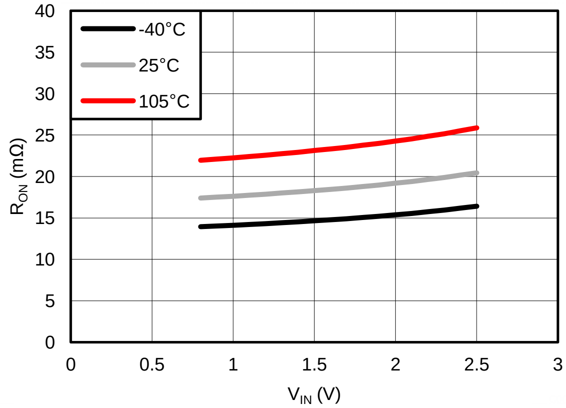


V_{BIAS} = 5V I_{VOUT} = –200mA

Note: All three RON curves have the same values and hence only one line is visible.

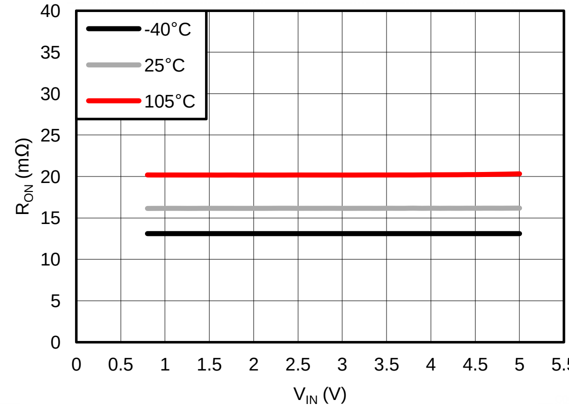
Figure 8. R_{ON} vs. Ambient Temperature

Typical DC Characteristics (continued)



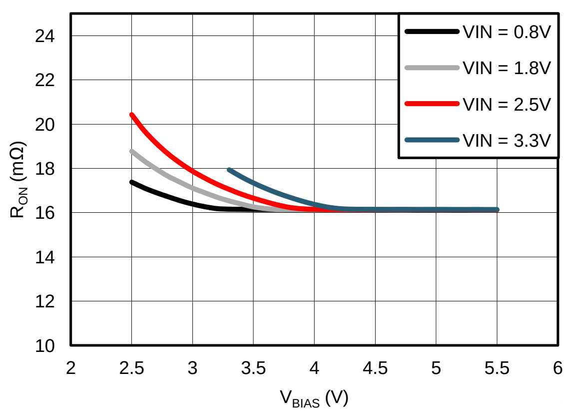
V_{BIAS} = 2.5V I_{VOUT} = –200mA

Figure 9. R_{ON} vs. V_{IN}



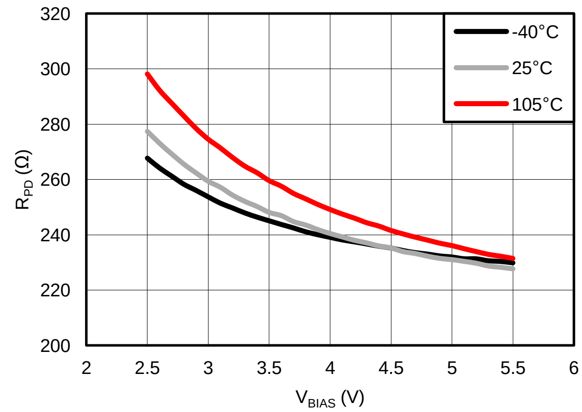
V_{BIAS} = 5V I_{VOUT} = –200mA

Figure 10. R_{ON} vs. V_{IN}



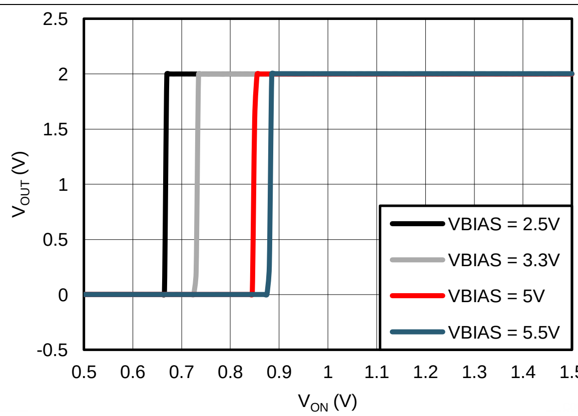
T_A = 25°C I_{VOUT} = –200mA

Figure 11. R_{ON} vs. V_{BIAS}



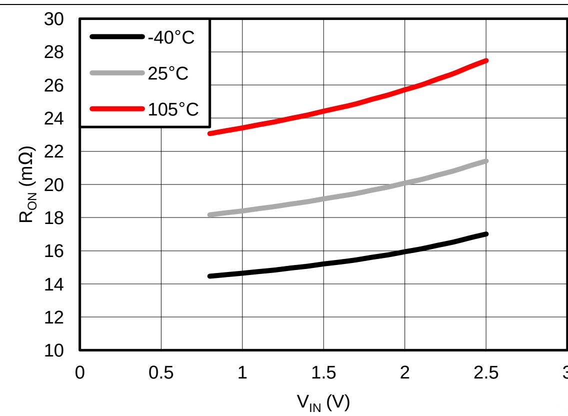
V_{IN} = 1.8V

Figure 12. R_{PD} vs. V_{BIAS}



V_{IN} = 2V T_A = 25°C

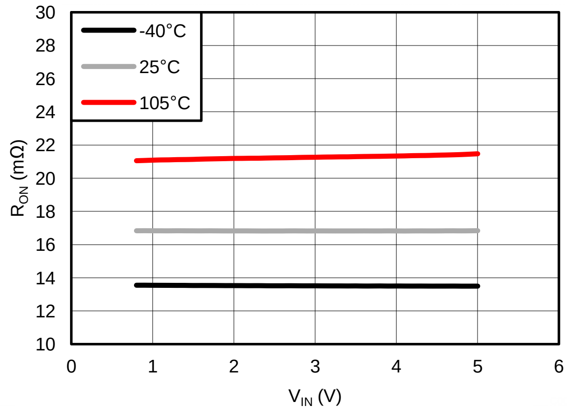
Figure 13. V_{OUT} vs V_{ON}



V_{BIAS} = 2.5V I_{VOUT} = –4A

Figure 14. R_{ON} vs V_{IN}

Typical DC Characteristics (continued)



V_{BIAS} = 5V I_{VOUT} = –4A

Figure 15. R_{ON} vs V_{IN}

7.9 Typical Switching Characteristics

T_A = 25 °C, C_T = 1 nF, C_{IN} = 1 µF, C_L = 0.1 µF, R_L = 10 Ω, CH1 = V_{OUT}, CH2 = V_{ON}

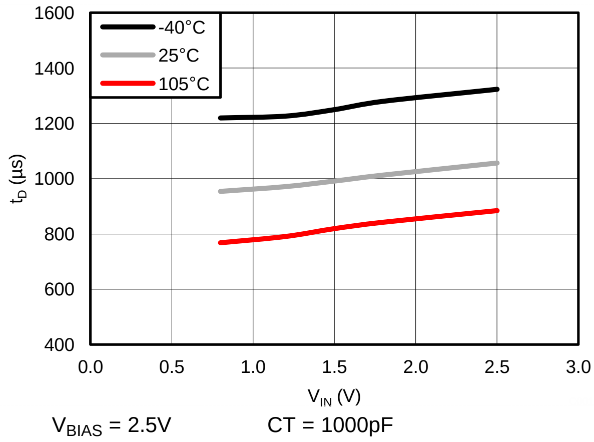


Figure 16. t_D vs. V_{IN}

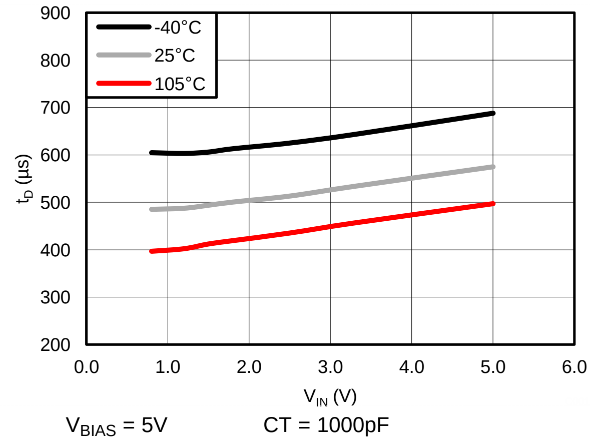


Figure 17. t_D vs. V_{IN}

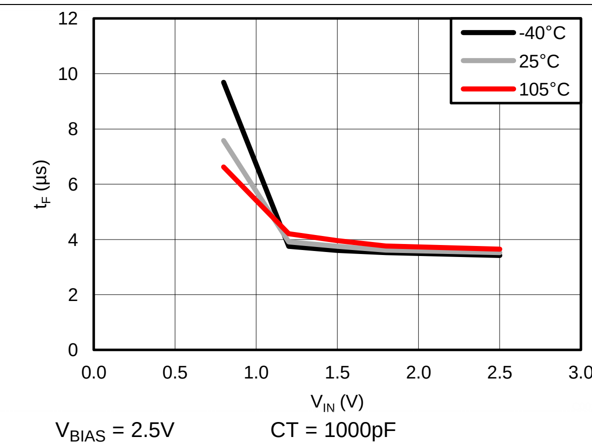


Figure 18. t_F vs. V_{IN}

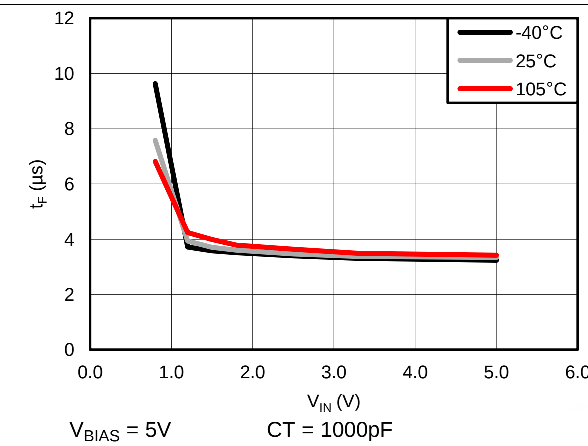


Figure 19. t_F vs. V_{IN}

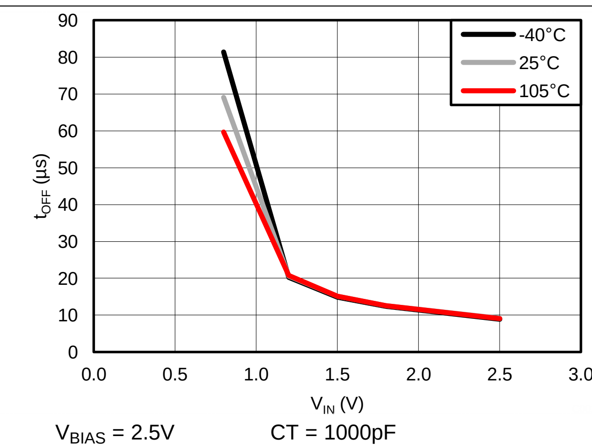


Figure 20. t_{OFF} vs. V_{IN}

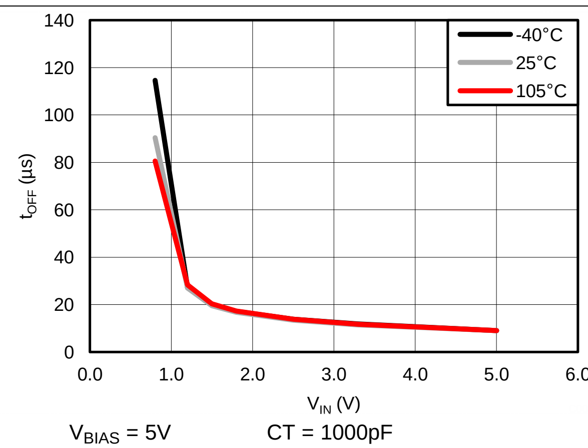
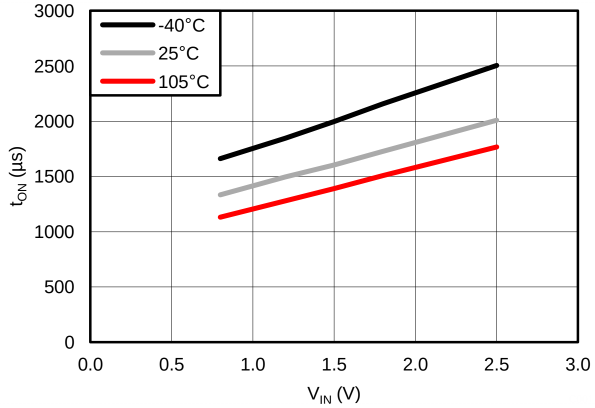


Figure 21. t_{OFF} vs. V_{IN}

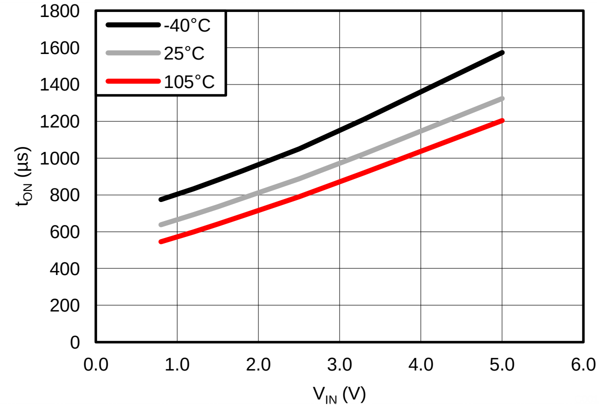
Typical Switching Characteristics (continued)

T_A = 25 °C, C_T = 1 nF, C_{IN} = 1 µF, C_L = 0.1 µF, R_L = 10 Ω, CH1 = V_{OUT}, CH2 = V_{ON}



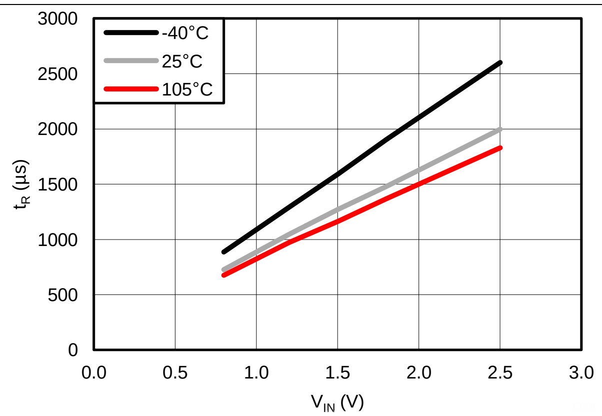
V_{BIAS} = 2.5V CT = 1000pF

Figure 22. t_{ON} vs. V_{IN}



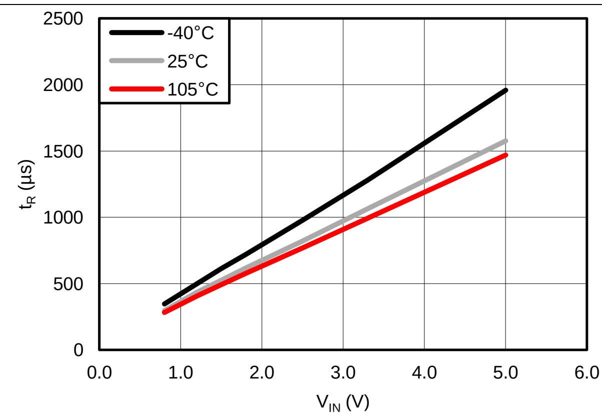
V_{BIAS} = 5V CT = 1000pF

Figure 23. t_{ON} vs. V_{IN}



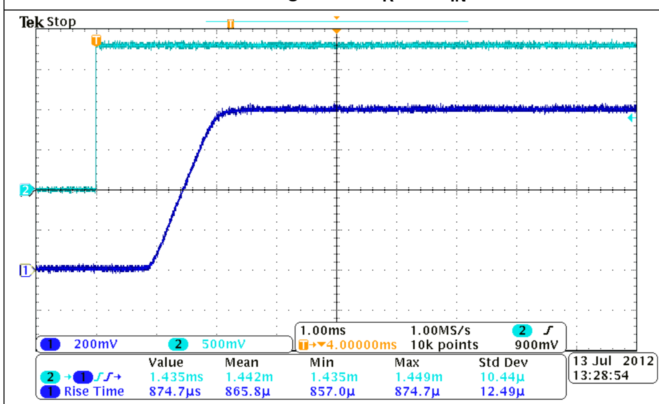
V_{BIAS} = 2.5V CT = 1000pF

Figure 24. t_R vs. V_{IN}



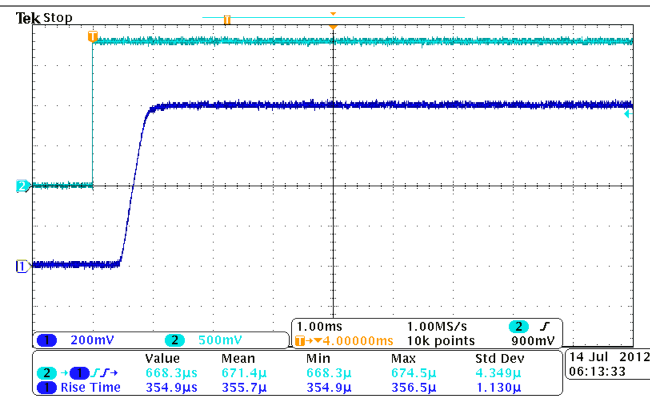
V_{BIAS} = 5V CT = 1000pF

Figure 25. t_R vs. V_{IN}



V_{IN} = 0.8 V V_{BIAS} = 2.5 V C_{IN} = 1 µF
C_L = 0.1 µF R_L = 10 Ω

Figure 26. Turn-on Response Time

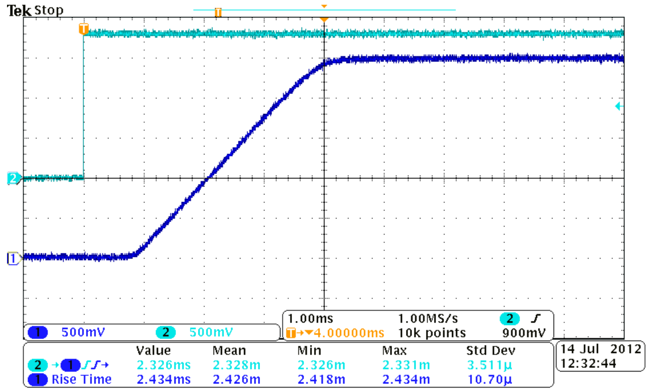


V_{IN} = 0.8 V V_{BIAS} = 5.0 V C_{IN} = 1 µF
C_L = 0.1 µF R_L = 10 Ω

Figure 27. Turn-on Response Time

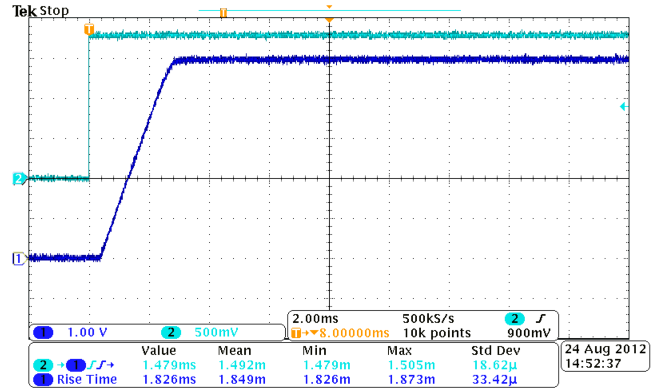
Typical Switching Characteristics (continued)

T_A = 25 °C, C_T = 1 nF, C_{IN} = 1 µF, C_L = 0.1 µF, R_L = 10 Ω, CH1 = V_{OUT}, CH2 = V_{ON}



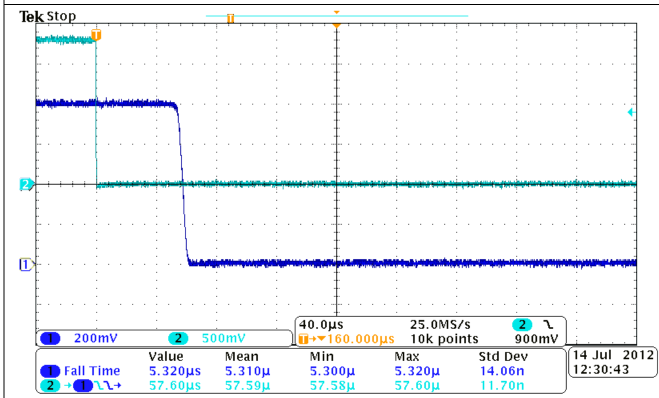
V_{IN} = 2.5 V V_{BIAS} = 2.5 V C_{IN} = 1 µF, C_L = 0.1 µF R_L = 10 Ω

Figure 28. Turn-on Response Time



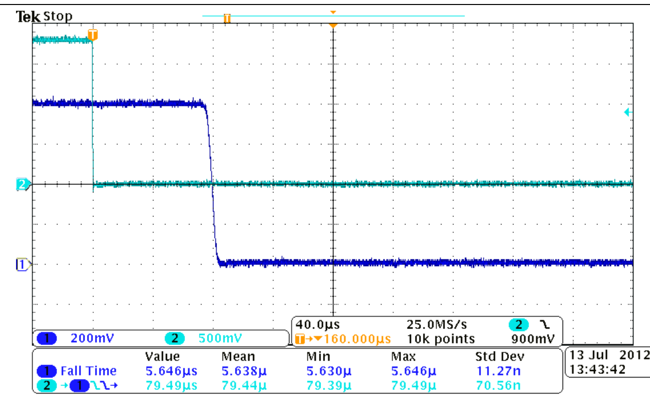
V_{IN} = 5.0 V V_{BIAS} = 5.0 V C_{IN} = 1 µF C_L = 0.1 µF R_L = 10 Ω

Figure 29. Turn-off Response Time



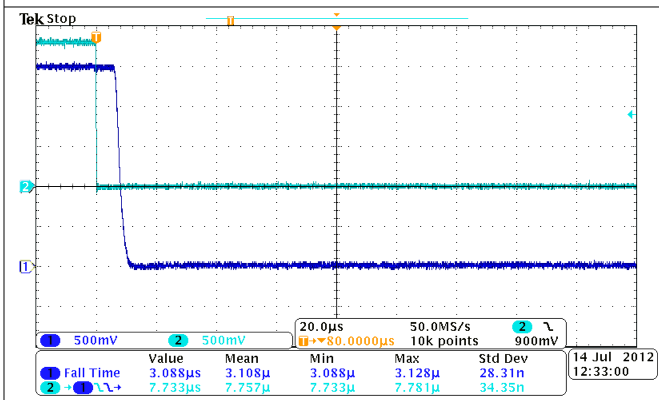
V_{IN} = 0.8 V V_{BIAS} = 2.5 V C_{IN} = 1 µF C_L = 0.1 µF R_L = 10 Ω

Figure 30. Turn-off Response Time



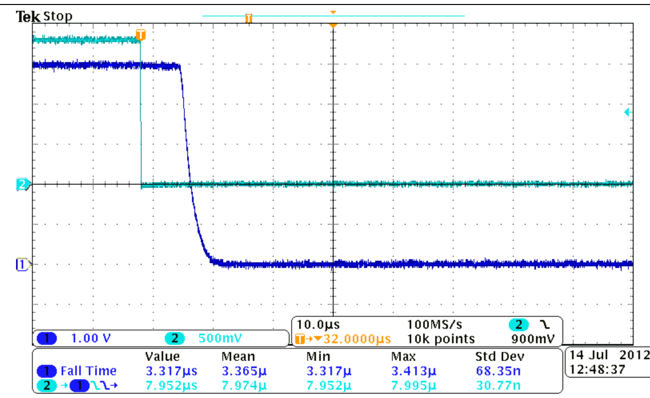
V_{IN} = 0.8 V V_{BIAS} = 5.0 V C_{IN} = 1 µF C_L = 0.1 µF R_L = 10 Ω

Figure 31. Turn-on Response Time



V_{IN} = 2.5 V V_{BIAS} = 2.5 V C_{IN} = 1 µF C_L = 0.1 µF R_L = 10 Ω

Figure 32. Turn-off Response Time



V_{IN} = 5.0 V V_{BIAS} = 5.0 V C_{IN} = 1 µF C_L = 0.1 µF R_L = 10 Ω)

Figure 33. Turn-off Response Time

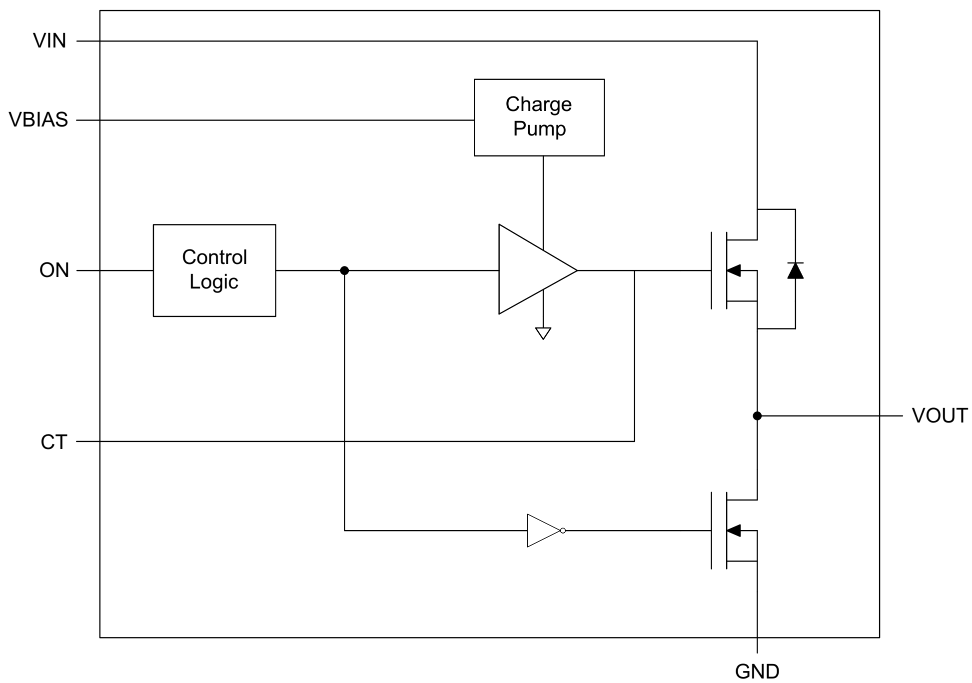
8 Detailed Description

8.1 Overview

The device is a single channel, 6-A load switch in an 8-terminal SON package. To reduce the voltage drop in high current rails, the device implements an ultra-low resistance N-channel MOSFET. The device has a programmable slew rate for applications that require specific rise-time.

The device has very low leakage current during off state. This 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 any external components, which reduces solution size and bill of materials (BOM) count.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Adjustable Rise Time

A capacitor to GND on the CT terminal sets the slew rate. The voltage on the CT terminal can be as high as 12 V. Therefore, the minimum voltage rating for the CT cap should be 25 V for optimal performance. An approximate formula for the relationship between CT and slew rate when V_{BIAS} is set to 5 V is shown in Equation 1 below. This equation accounts for 10% to 90% measurement on V_{OUT} and does **NOT** apply for CT = 0 pF. Use table below to determine rise times for when CT = 0 pF.

$$SR = 0.39 \times CT + 13.4 \quad (1)$$

Where,

SR = slew rate (in µs/V)
CT = the capacitance value on the CT terminal (in pF)
The units for the constant 13.4 are µs/V. The units for the constant 0.39 are µs/(V*pF).

Rise time can be calculated by multiplying the input voltage by the slew rate. The table below contains rise time values measured on a typical device. Rise times shown below are only valid for the power-up sequence where V_{IN} and V_{BIAS} are already in steady state condition before the ON terminal is asserted high.

Table 1. Rise Time vs CT Capacitor

CT (pF)	RISE TIME (µs) 10% - 90%, C_L = 0.1 µF, C_{IN} = 1 µF, R_L = 10 Ω, V_{BIAS} = 5 V TYPICAL VALUES at 25°C with a 25V X7R 10% CERAMIC CAPACITOR on CT						
	VIN = 5 V	VIN = 3.3 V	VIN = 1.8 V	VIN = 1.5 V	VIN = 1.2 V	VIN = 1.05 V	VIN = 0.8 V
0	127	93	62	55	51	46	42
220	475	314	188	162	141	125	103
470	939	637	359	304	255	218	188
1000	1869	1229	684	567	476	414	344
2200	4020	2614	1469	1211	1024	876	681
4700	8690	5746	3167	2703	2139	1877	1568
10000	18360	12550	6849	5836	4782	4089	3449

8.3.2 Quick Output Discharge

The TPS22965 includes a Quick Output Discharge (QOD) feature. When the switch is disabled, a discharge resistor is connected between VOUT and GND. This resistor has a typical value of 225-Ω and prevents the output from floating while the switch is disabled.

8.3.3 Low Power Consumption During Off State

The I_{SD} V_{IN} supply current is 0.01-µA typical at 1.8-VIN. Typically, the downstream loads would have a significantly higher off-state leakage current. The load switch allows system standby power consumption to be reduced.

8.4 Device Functional Modes

Table 2. Functional Table

ON	VIN to VOUT	VOUT to GND
L	Off	On
H	On	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 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 thresholds. It can be used with any microcontroller with 1.2 V or higher GPIO voltage. This pin cannot be left floating and must be driven either high or low for proper functionality.

9.1.2 Input Capacitor (Optional)

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 VIN and GND. A 1-µF ceramic capacitor, C_{IN}, placed close to the pins, is usually sufficient. Higher values of C_{IN} can be used to further reduce the voltage drop during high current applications. When switching heavy loads, it is recommended to have an input capacitor about 10 times higher than the output capacitor to avoid excessive voltage drop.

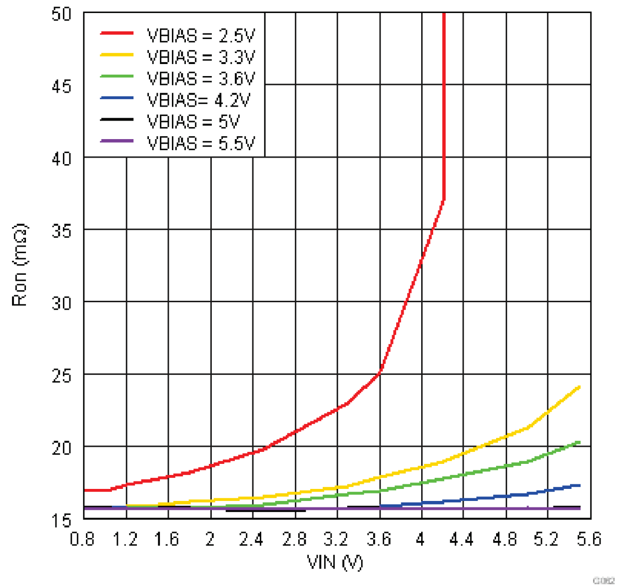
9.1.3 Output Capacitor (Optional)

Due to the integrated body diode in the NMOS switch, a $C_{I N}$ 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, however a 10 to 1 ratio for capacitance is not required for proper functionality of the device. A ratio smaller than 10 to 1 (such as 1 to 1) could cause slightly more V_{IN} dip upon turn-on due to inrush currents. This can be mitigated by increasing the capacitance on the CT pin for a longer rise time (see *Adjustable Rise Time* section below).

9.1.4 V_{IN} and V_{BIAS} Voltage Range

For optimal R_{ON} performance, make sure $V_{IN} \leq V_{BIAS}$. The device will still be functional if $V_{IN} > V_{BIAS}$ but it will exhibit R_{ON} greater than what is listed in the *Electrical Characteristics* table. See Figure 34 for an example of a typical device. Notice the increasing R_{ON} as V_{IN} exceeds V_{BIAS} voltage. Be sure to never exceed the maximum voltage rating for V_{IN} and V_{BIAS}.

Application Information (continued)



T_A = 25 °C I_{OUT} = –200 mA

Figure 34. R_{ON} vs. V_{IN}

9.2 Typical Application

This application demonstrates how the TPS22965 can be used to power downstream modules.

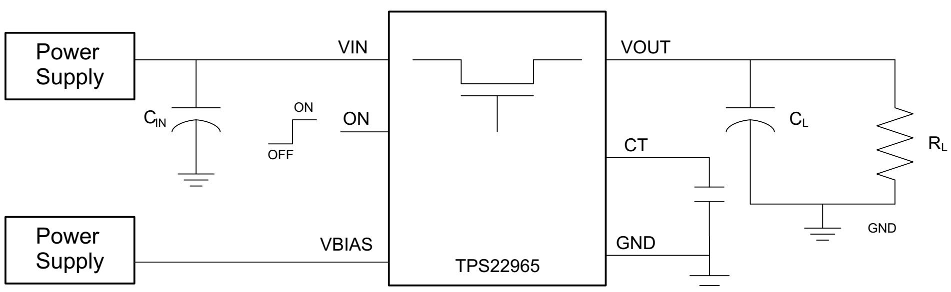


Figure 35. Powering a Downstream Module

9.2.1 Design Requirements

DESIGN PARAMETER	EXAMPLE VALUE
V_{IN}	3.3 V
V_{BIAS}	5 V
C_L	22 µF
Maximum Acceptable Inrush Current	400 mA

9.2.2 Detailed Design Procedure

9.2.2.1 Inrush Current

When the switch is enabled, the output capacitors must be charged up from 0-V to the set value (3.3-V in this example). This charge arrives in the form of inrush current. Inrush current can be calculated using the following equation:

$$\text{Inrush Current} = C \times dV/dt \quad (2)$$

Where:

C = output capacitance
dV = output voltage
dt = rise time

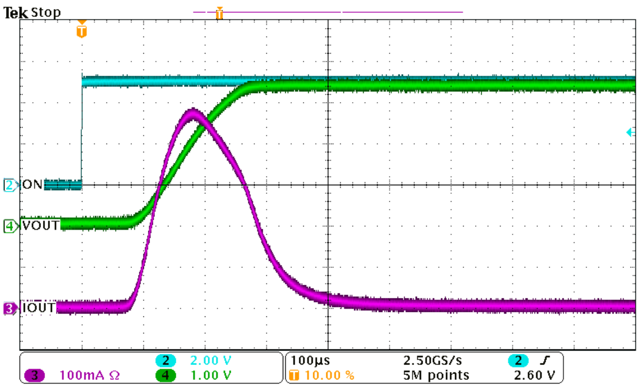
The TPS22965 offers adjustable rise time for VOUT. This feature allows the user to control the inrush current during turn-on. The appropriate rise time can be calculated using the design requirements and the inrush current equation.

$$400\text{ mA} = 22\ \mu\text{F} \times 3.3\text{ V}/dt \quad (3)$$

$$dt = 181.5\ \mu\text{s} \quad (4)$$

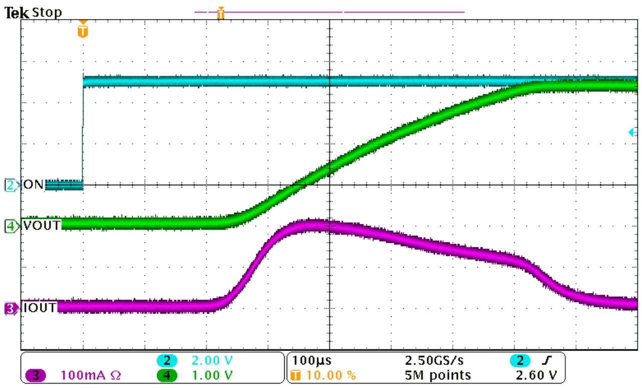
To ensure an inrush current of less than 400 mA, choose a CT value that will yield a rise time of more than 181.5 µs. See the oscilloscope captures below for an example of how the CT capacitor can be used to reduce inrush current.

9.2.3 Application Curves



V_{BIAS} = 5 V V_{IN} = 3.3 V C_L = 22 µF

Figure 36. Inrush Current with CT = 0pF



V_{BIAS} = 5 V V_{IN} = 3.3 V C_L = 22 µF

Figure 37. Inrush Current with CT = 220pF

10 Power Supply Recommendations

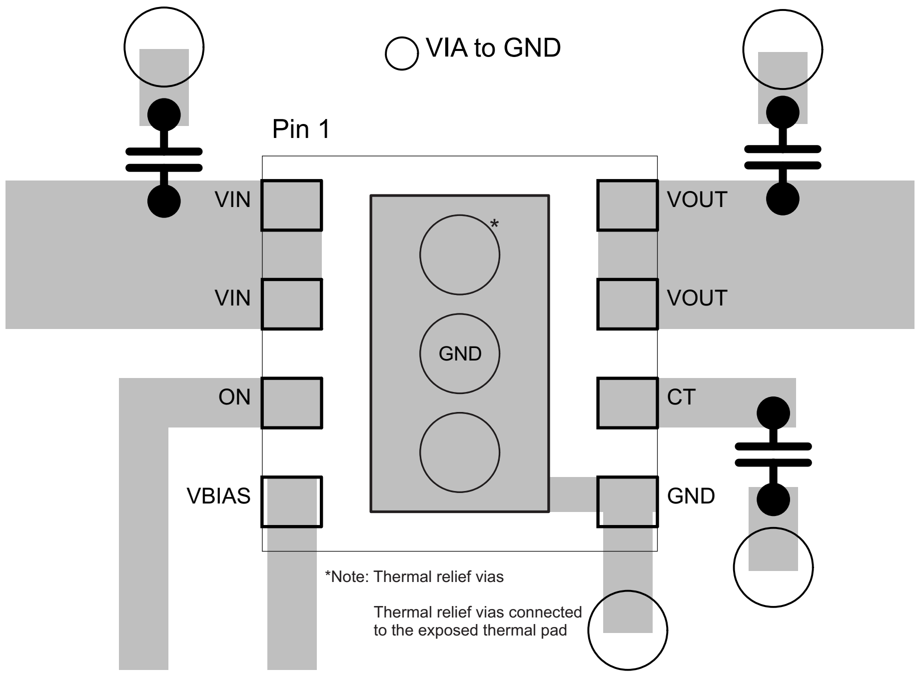
The device is designed to operate from a VBIAS range of 2.5 V to 5.7 V and a VIN range of 0.8 V to VBIAS.

11 Layout

11.1 Layout Guidelines

For best performance, all traces should be as short as possible. To be most effective, the input and output capacitors should be placed close to the device to minimize the effects that parasitic trace inductances may have on normal operation. Using wide traces for VIN, VOUT, and GND helps minimize the parasitic electrical effects along with minimizing the case to ambient thermal impedance. The CT trace should be as short as possible to avoid parasitic capacitance.

11.2 Layout Example



11.3 Thermal Considerations

The maximum IC junction temperature should be restricted to 125°C under normal operating conditions. To calculate the maximum allowable dissipation, $P_{D(max)}$ for a given output current and ambient temperature, use the following equation as a guideline:

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

Where:

$P_{D(max)}$ = maximum allowable power dissipation
$T_{J(max)}$ = maximum allowable junction temperature (125°C for the TPS22965)
T_A = ambient temperature of the device
Θ_{JA} = junction to air thermal impedance. See *Thermal Information* section. This parameter is highly dependent upon board layout.

Refer to the *Layout Example* , notice that the thermal vias are located under the exposed thermal pad of the device. This allows for thermal diffusion away from the device.

12 Device and Documentation Support

12.1 Trademarks

Ultrabook is a trademark of Intel.
All other trademarks are the property of their respective owners.

12.2 Electrostatic Discharge Caution

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

12.3 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
TPS22965DSGR	ACTIVE	WSON	DSG	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	ZSA0	Samples
TPS22965DSGT	ACTIVE	WSON	DSG	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 85	ZSA0	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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OTHER QUALIFIED VERSIONS OF TPS22965 :

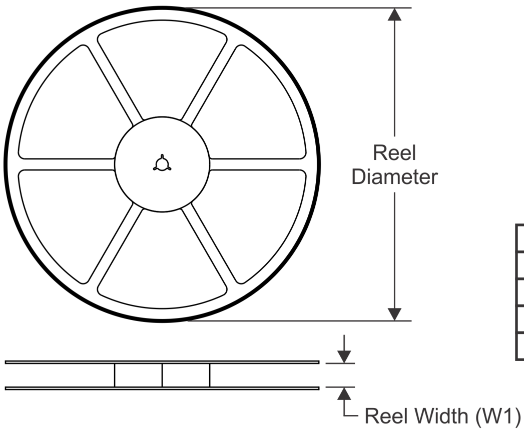
- Automotive: TPS22965-Q1

NOTE: Qualified Version Definitions:

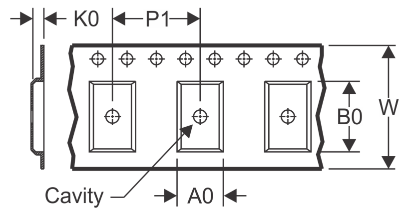
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION

REEL DIMENSIONS

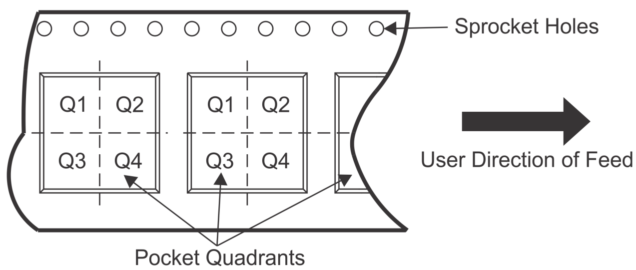


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

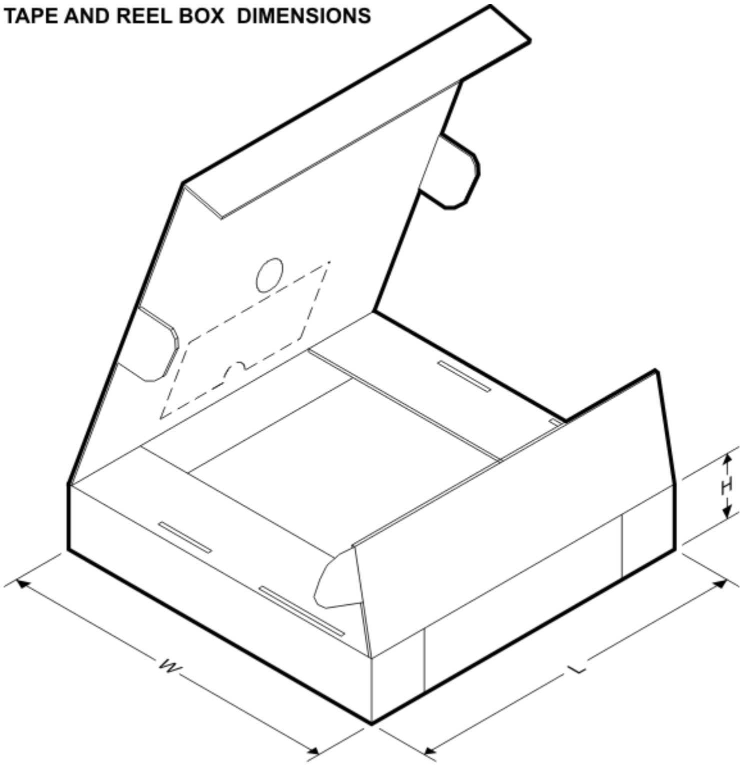
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS22965DSGR	WSON	DSG	8	3000	180.0	8.4	2.25	2.25	1.0	4.0	8.0	Q2
TPS22965DSGR	WSON	DSG	8	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
TPS22965DSGT	WSON	DSG	8	250	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2

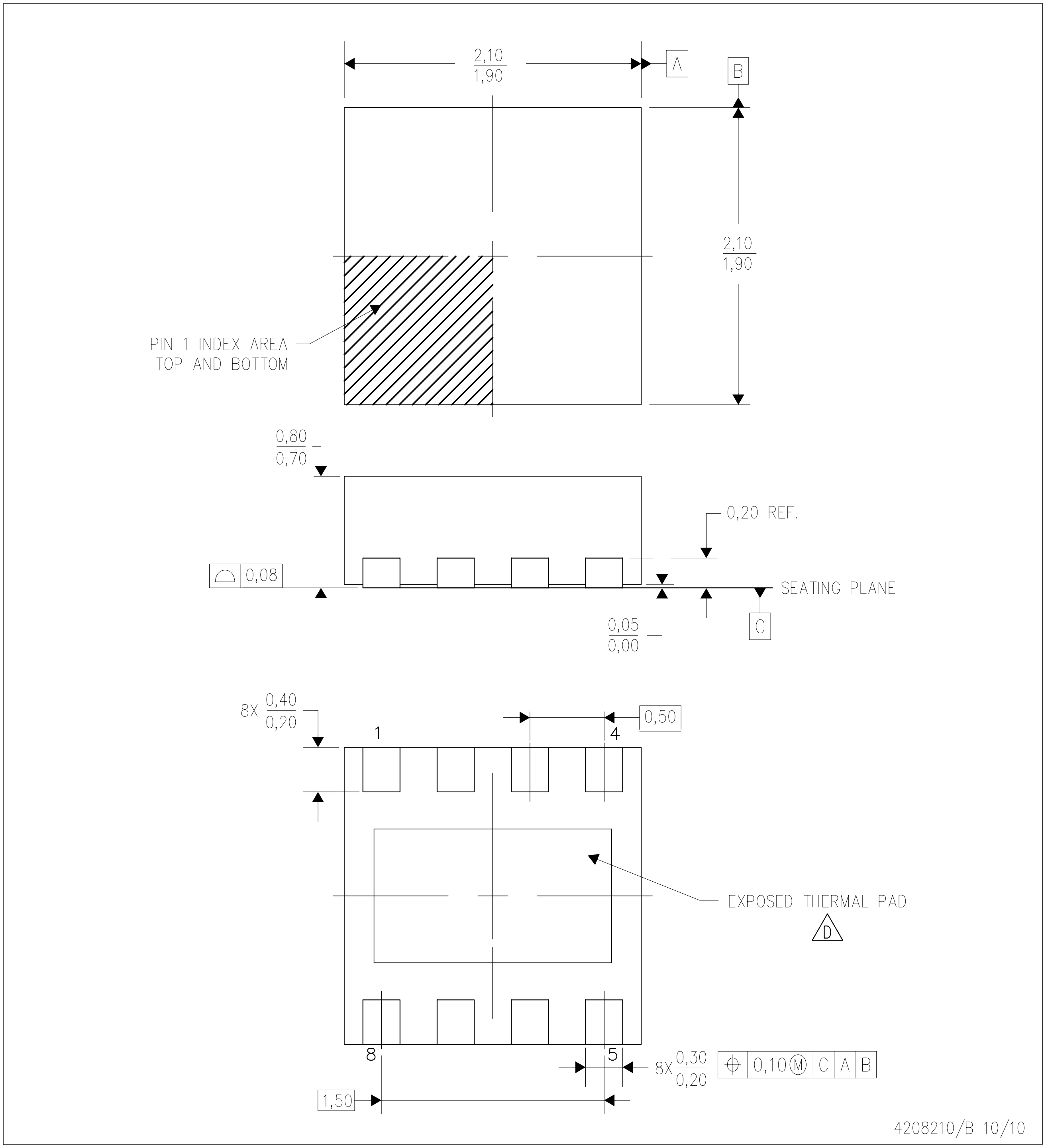
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS22965DSGR	WSON	DSG	8	3000	205.0	200.0	33.0
TPS22965DSGR	WSON	DSG	8	3000	210.0	185.0	35.0
TPS22965DSGT	WSON	DSG	8	250	210.0	185.0	35.0

DSG (S–PWSON–N8) PLASTIC SMALL OUTLINE NO–LEAD



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. Quad Flatpack, No–Leads (QFN) package configuration.
- D. The package thermal pad must be soldered to the board for thermal and mechanical performance. See the Product Data Sheet for details regarding the exposed thermal pad dimensions.
- E. Falls within JEDEC MO–229.

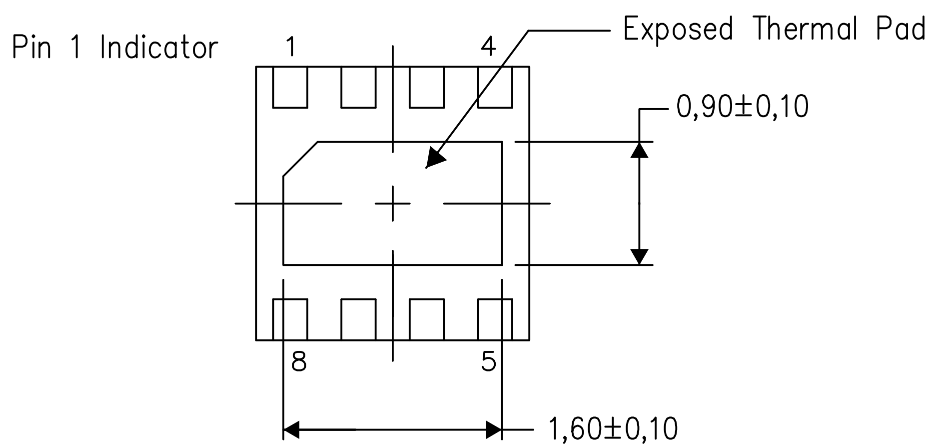
DSG (S–PWSON–N8) PLASTIC SMALL OUTLINE NO–LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No–Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



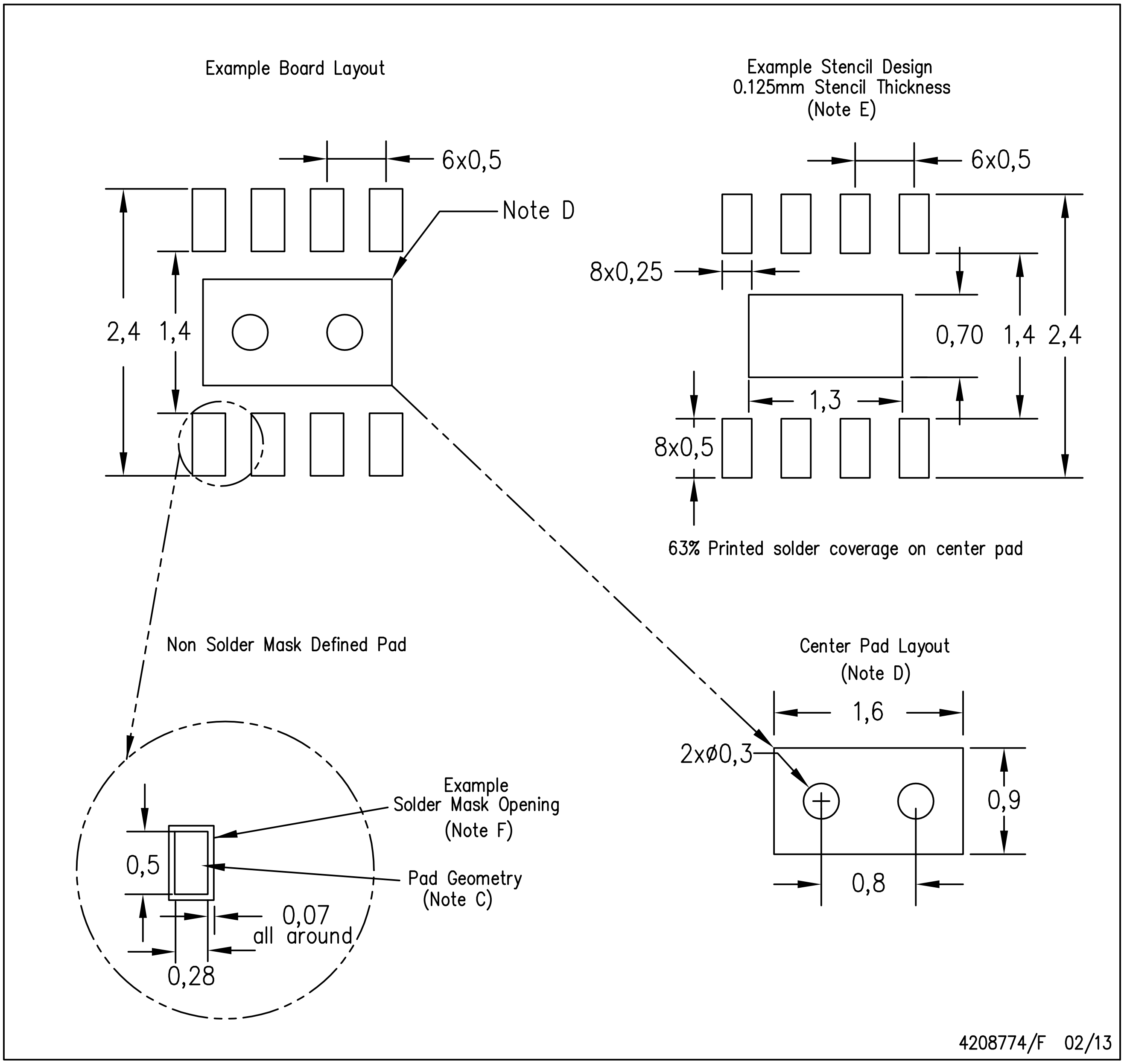
Bottom View

Exposed Thermal Pad Dimensions

4208347/G 08/13

NOTE: All linear dimensions are in millimeters

DSG (S–PWSON–N8) PLASTIC SMALL OUTLINE NO–LEAD



NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Publication IPC–7351 is recommended for alternate designs.
- D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http: //www.ti.com>.
- E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
- F. Customers should contact their board fabrication site for solder mask tolerances.

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