



TPS769xx-Q1 Ultralow-Power 100-mA Low-Dropout Linear Regulators

1 Features

- Qualified for Automotive Applications
- 100-mA Low-Dropout Regulator
- Available in 1.2-V, 1.5-V, 1.8-V, 2.5-V, 2.7-V, 2.8-V, 3-V, 3.3-V and 5-V Fixed-Output and Adjustable Versions
- Only 17- μ A Quiescent Current at 100 mA
- 1- μ A Quiescent Current in Standby Mode
- Dropout Voltage Typically 71 mV at 100 mA
- Overcurrent Limitation
- -40°C to 125°C Operating Junction Temperature Range
- 5-Pin SOT-23 (DBV) Package

2 Applications

- ADAS Modules
- RF Modules
- Wireless Modules
- General Noise-Sensitive Applications

3 Description

The TPS769xx-Q1 family of low-dropout (LDO) voltage regulators offers the benefits of low-dropout voltage, ultralow-power operation, and miniaturized packaging. These regulators feature low-dropout voltages and ultralow quiescent current compared to conventional LDO regulators. Offered in a 5-pin small outline integrated-circuit SOT-23 package, the TPS769xx-Q1 series of devices are ideal for micropower operations and where board space is at a premium.

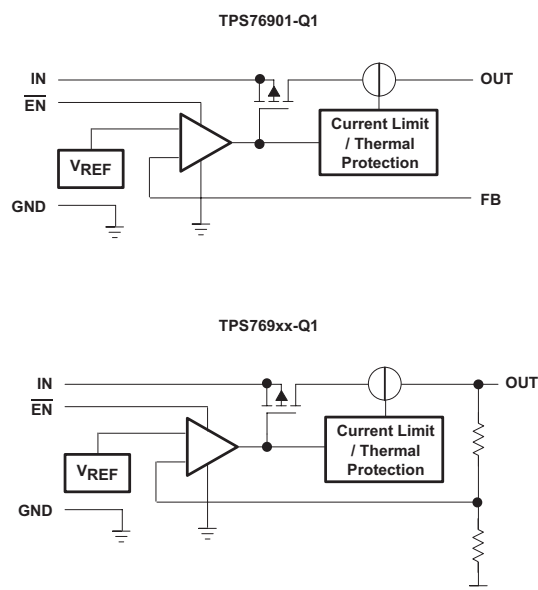
A combination of new circuit design and process innovation has enabled the usual PNP pass transistor to be replaced by a PMOS pass element. Because the PMOS pass element behaves as a low-value resistor, the dropout voltage is very low, typically 71 mV at 100 mA of load current (TPS76950-Q1), and is directly proportional to the load current. Because the PMOS pass element is a voltage-driven device, the quiescent current is ultralow (28 μ A maximum) and is stable over the entire range of output load current (0 mA to 100 mA). The ultralow-dropout voltage feature and ultralow-power operation result in a significant increase in system battery operating life, making this device suitable for use in automotive applications.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TPS769xx-Q1	SOT-23 (5)	2.90 mm $\times$ 1.60 mm

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

Functional Block Diagrams



Copyright © 2016, Texas Instruments Incorporated

TPS76933-Q1 Ground Current vs Free-Air Temperature

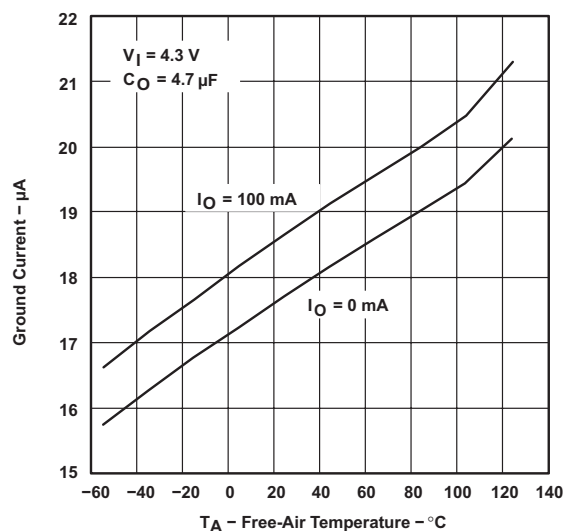


Table of Contents

1 Features	1	8.4 Device Functional Modes.....	10
2 Applications	1	9 Application and Implementation	11
3 Description	1	9.1 Application Information.....	11
4 Revision History	2	9.2 Typical Application	11
5 Description (continued)	3	10 Power Supply Recommendations	13
6 Pin Configuration and Functions	3	11 Layout	14
7 Specifications	3	11.1 Layout Guidelines	14
7.1 Absolute Maximum Ratings	3	11.2 Layout Example	14
7.2 ESD Ratings.....	3	11.3 Power Dissipation and Junction Temperature	14
7.3 Recommended Operating Conditions.....	4	12 Device and Documentation Support	15
7.4 Thermal Information	4	12.1 Related Links	15
7.5 Electrical Characteristics.....	4	12.2 Receiving Notification of Documentation Updates	15
7.6 Dissipation Ratings	6	12.3 Community Resources.....	15
7.7 Typical Characteristics	6	12.4 Trademarks	15
8 Detailed Description	10	12.5 Electrostatic Discharge Caution.....	15
8.1 Overview	10	12.6 Glossary	15
8.2 Functional Block Diagrams	10	13 Mechanical, Packaging, and Orderable Information	15
8.3 Feature Description.....	10		

4 Revision History

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

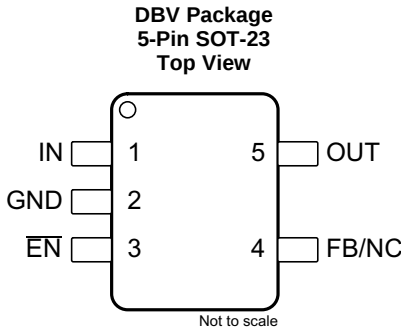
Changes from Revision C (June 2012) to Revision D	Page
• Added ESD Ratings table, Thermal Information table, Feature Description section, Device Functional Modes, Application and Implementation section, Power Supply Recommendations section, Layout section, Device and Documentation Support section, and Mechanical, Packaging, and Orderable Information section.....	1
• Removed Ordering Information table, see POA at the end of the data sheet.....	1

Changes from Revision B (April 2008) to Revision C	Page
• Changed TPS769xx part names to TPS769xx-Q1 in text and images.	3
• Updated Figures 17 and 19 to include region of Instability below 0.2 Ω	9

5 Description (continued)

The TPS769xx-Q1 devices also feature a logic-enabled sleep mode to shut down the regulator, reducing quiescent current to 1 μ A (typical) at $T_J = 25^\circ\text{C}$. The TPS769xx-Q1 devices are offered in 1.2-V, 1.5-V, 1.8-V, 2.5-V, 2.7-V, 2.8-V, 3-V, 3.3-V, and 5-V fixed-voltage versions and in a variable version (programmable over the range of 1.2 V to 5.5 V).

6 Pin Configuration and Functions



Pin Functions

PIN		I/O	DESCRIPTION
NO.	NAME		
1	IN	I	Input supply voltage
2	GND	—	Ground
3	$\overline{\text{EN}}$	I	Enable input
4	FB/NC	I	Feedback voltage (TPS76901-Q1 only) No connection (Fixed options only)
5	OUT	O	Regulated output voltage

7 Specifications

7.1 Absolute Maximum Ratings

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

	MIN	MAX	UNIT
Input voltage ⁽²⁾	−0.3	13.5	V
Voltage range at $\overline{\text{EN}}$	−0.3	$V_I + 0.3$	V
Voltage on OUT, FB		7	V
Peak output current	Internally Limited		
Continuous total power dissipation	See Dissipation Ratings		
T_J Operating virtual junction temperature	−40	150	$^\circ\text{C}$
T_{stg} Storage temperature	−65	150	$^\circ\text{C}$

- (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
$V_{\text{(ESD)}}$ Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	± 2000
	Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾	$\pm \text{YYY}$

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V_I	Input voltage ⁽¹⁾	2.7	10	V
V_O	Output voltage	1.2	5.5	V
I_O	Continuous output current ⁽²⁾	0	100	mA
T_J	Operating junction temperature	–40	125	°C

- (1) To calculate the minimum input voltage for your maximum output current, use the following formula: $V_I(\min) = V_O(\max) + V_{DO}(\max \text{ load})$
 (2) Continuous output current and operating junction temperature are limited by internal protection circuitry, but it is not recommended that the device operate under conditions beyond those specified in this table for extended periods of time.

7.4 Thermal Information

THERMAL METRIC ⁽¹⁾		TPS769xx-Q1	UNIT
		DBV (SOT-23)	
		5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	204.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	117.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	34.4	°C/W
ψ_{JT}	Junction-to-top characterization parameter	11.8	°C/W
ψ_{JB}	Junction-to-board characterization parameter	33.5	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	—	°C/W

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

7.5 Electrical Characteristics

over recommended operating free-air temperature range, $V_I = V_O(\text{typ}) + 1 \text{ V}$, $I_O = 100 \text{ mA}$, $\overline{EN} = 0 \text{ V}$, $C_O = 4.7 \mu\text{F}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage (10 μ A to 100 mA load) ⁽¹⁾	TPS76901-Q1	1.2 V $\leq$ V _O $\leq$ 5.5 V, T _J = 25°C	V _O			V
		1.2 V $\leq$ V _O $\leq$ 5.5 V, T _J = –40°C to 125°C	0.97 V _O	1.03 V _O		
	TPS76912-Q1	T _J = 25°C, 2.7 V < V _{IN} < 10 V	1.224			
		T _J = –40°C to 125°C, 2.7 V < V _{IN} < 10 V	1.187	1.261		
	TPS76915-Q1	T _J = 25°C, 2.7 V < V _{IN} < 10 V	1.5			
		T _J = –40°C to 125°C, 2.7 V < V _{IN} < 10 V	1.455	1.545		
	TPS76918-Q1	T _J = 25°C, 2.8 V < V _{IN} < 10 V	1.8			
		T _J = –40°C to 125°C, 2.8 V < V _{IN} < 10 V	1.746	1.854		
	TPS76925-Q1	T _J = 25°C, 3.5 V < V _{IN} < 10 V	2.5			
		T _J = –40°C to 125°C, 3.5 V < V _{IN} < 10 V	2.425	2.575		
	TPS76927-Q1	T _J = 25°C, 3.7 V < V _{IN} < 10 V	2.7			
		T _J = –40°C to 125°C, 3.7 V < V _{IN} < 10 V	2.619	2.781		
	TPS76928-Q1	T _J = 25°C, 3.8 V < V _{IN} < 10 V	2.8			
		T _J = –40°C to 125°C, 3.8 V < V _{IN} < 10 V	2.716	2.884		
	TPS76930-Q1	T _J = 25°C, 4 V < V _{IN} < 10 V	3			
		T _J = –40°C to 125°C, 4 V < V _{IN} < 10 V	2.91	3.09		
	TPS76933-Q1	T _J = 25°C, 4.3 V < V _{IN} < 10 V	3.3			
		T _J = –40°C to 125°C, 4.3 V < V _{IN} < 10 V	3.201	3.399		
	TPS76950-Q1	T _J = 25°C, 6 V < V _{IN} < 10 V	5			
		T _J = –40°C to 125°C, 6 V < V _{IN} < 10 V	4.85	5.15		

- (1) Minimum IN operating voltage is 2.7 V or $V_O(\text{typ}) + 1 \text{ V}$, whichever is greater. The maximum IN voltage is 10 V, minimum output current is 10 μA , and maximum output current is 100 mA.

Electrical Characteristics (continued)

over recommended operating free-air temperature range, $V_I = V_O$ (typ) + 1 V, $I_O = 100$ mA, $\overline{EN} = 0$ V, $C_O = 4.7$ μ F (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Quiescent current (GND current) ⁽¹⁾⁽²⁾		$\overline{\text{EN}} = 0 \text{ V}$, $0 \text{ mA} < I_O < 100 \text{ mA}$, $T_J = 25^\circ\text{C}$		17		μA
		$\overline{\text{EN}} = 0 \text{ V}$, $I_O = 100 \text{ mA}$, $T_J = -40^\circ\text{C}$ to 125°C			28	
Load regulation		$\overline{\text{EN}} = 0 \text{ V}$, $I_O = 0$ to 100 mA , $T_J = 25^\circ\text{C}$		12		mV
Output voltage line regulation ($\Delta V_O/V_O$) ⁽²⁾		$V_O + 1 \text{ V} < V_I \leq 10 \text{ V}$, $T_J = 25^\circ\text{C}$ ⁽¹⁾		0.04		%V
		$V_O + 1 \text{ V} < V_I \leq 10 \text{ V}$, $T_J = -40^\circ\text{C}$ to 125°C ⁽¹⁾			0.1	
Output noise voltage		$\text{BW} = 300 \text{ Hz}$ to 50 kHz , $C_O = 10 \text{ }\mu\text{F}$, $T_J = 25^\circ\text{C}$		190		μV_{rms}
Output current limit		$V_O = 0 \text{ V}$ ⁽¹⁾		350	750	mA
Standby current		$\overline{\text{EN}} = V_I$, $2.7 < V_I < 10 \text{ V}$		1		μA
		$T_J = -40^\circ\text{C}$ to 125°C			2	
FB input current		FB = 1.224 V (TPS76901-Q1)	-1		1	μA
High level enable input voltage		$2.7 \text{ V} < V_I < 10 \text{ V}$	1.7			V
Low level enable input voltage		$2.7 \text{ V} < V_I < 10 \text{ V}$			0.9	V
Power supply ripple rejection		$f = 1 \text{ kHz}$, $C_O = 10 \text{ }\mu\text{F}$, $T_J = 25^\circ\text{C}$		60		dB
Input current ($\overline{\text{EN}}$)		$\overline{\text{EN}} = 0 \text{ V}$	-1	0	1	μA
		$\overline{\text{EN}} = V_I$	-1		1	
Dropout voltage ⁽³⁾	TPS76928-Q1	$I_O = 50 \text{ mA}$, $T_J = 25^\circ\text{C}$		60		mV
		$I_O = 50 \text{ mA}$, $T_J = -40^\circ\text{C}$ to 125°C			125	
		$I_O = 100 \text{ mA}$, $T_J = 25^\circ\text{C}$		122		
		$I_O = 100 \text{ mA}$, $T_J = -40^\circ\text{C}$ to 125°C			245	
	TPS76930-Q1	$I_O = 50 \text{ mA}$, $T_J = 25^\circ\text{C}$		57		
		$I_O = 50 \text{ mA}$, $T_J = -40^\circ\text{C}$ to 125°C			115	
		$I_O = 100 \text{ mA}$, $T_J = 25^\circ\text{C}$		115		
		$I_O = 100 \text{ mA}$, $T_J = -40^\circ\text{C}$ to 125°C			230	
	TPS76933-Q1	$I_O = 50 \text{ mA}$, $T_J = 25^\circ\text{C}$		48		
		$I_O = 50 \text{ mA}$, $T_J = -40^\circ\text{C}$ to 125°C			100	
		$I_O = 100 \text{ mA}$, $T_J = 25^\circ\text{C}$		98		
		$I_O = 100 \text{ mA}$, $T_J = -40^\circ\text{C}$ to 125°C			200	
	TPS76950-Q1	$I_O = 50 \text{ mA}$, $T_J = 25^\circ\text{C}$		35		
		$I_O = 50 \text{ mA}$, $T_J = -40^\circ\text{C}$ to 125°C			85	
		$I_O = 100 \text{ mA}$, $T_J = 25^\circ\text{C}$		71		
		$I_O = 100 \text{ mA}$, $T_J = -40^\circ\text{C}$ to 125°C			170	

(2) If $V_O \leq 1.8$ V then $V_{Imin} = 2.7$ V, $V_{Imax} = 10$ V:

$$\text{Line Reg. (mV)} = (\% / \text{V}) \times \frac{V_O(V_{Imax} - 2.7 \text{ V})}{100} \times 1000$$

If $V_O \geq 2.5$ V then $V_{Imin} = V_O + 1$ V, $V_{Imax} = 10$ V:

$$\text{Line Reg. (mV)} = (\% / \text{V}) \times \frac{V_O(V_{Imax} - (V_O + 1 \text{ V}))}{100} \times 1000$$

(3) The IN voltage equals V_O (typ) — 100 mV; the TPS76901-Q1 output voltage is set to 3.3 V nominal with an external resistor divider. TPS76912-Q1, TPS76915-Q1, TPS76918-Q1, TPS76925-Q1, and TPS76927-Q1 dropout voltage is limited by input voltage range limitations.

7.6 Dissipation Ratings

BOARD	PACKAGE	$R_{\theta JC}$	$R_{\theta JA}$	DERATING FACTOR ABOVE $T_A = 25^\circ\text{C}$	$T_A \leq 25^\circ\text{C}$ POWER RATING	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING
Low K ⁽¹⁾	DBV	65.8°C/W	259°C/W	3.9 mW/°C	386 mW	212 mW	154 mW
High K ⁽²⁾	DBV	65.8°C/W	180°C/W	5.6 mW/°C	555 mW	305 mW	222 mW

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

7.7 Typical Characteristics

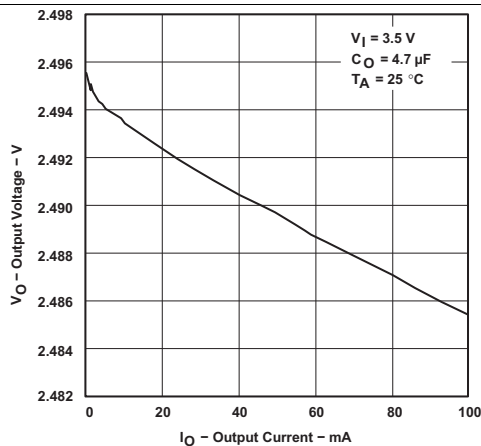


Figure 1. TPS76925-Q1 Output Voltage vs Output Current

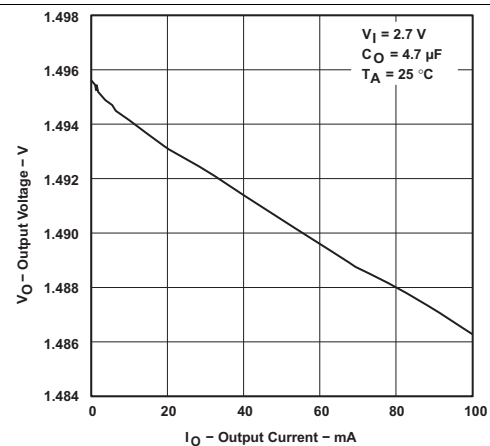


Figure 2. TPS76915-Q1 Output Voltage vs Output Current

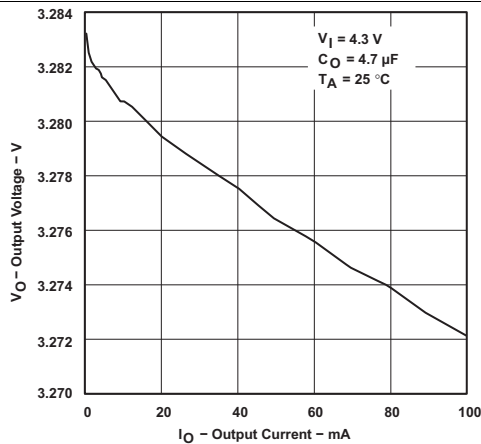


Figure 3. TPS76933-Q1 Output Voltage vs Output Current

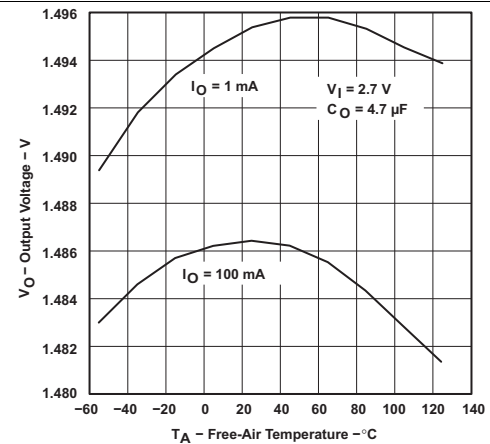


Figure 4. TPS76915-Q1 Output Voltage vs Free-Air Temperature

Typical Characteristics (continued)

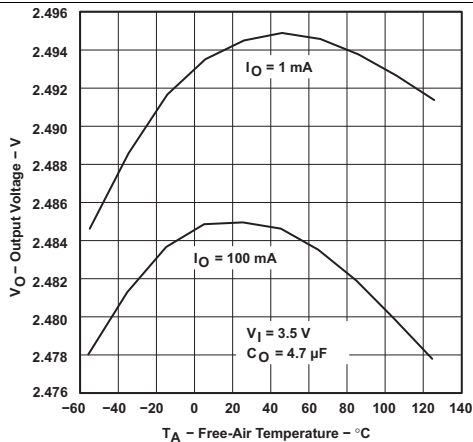


Figure 5. TPS76925-Q1 Output Voltage vs Free-Air Temperature

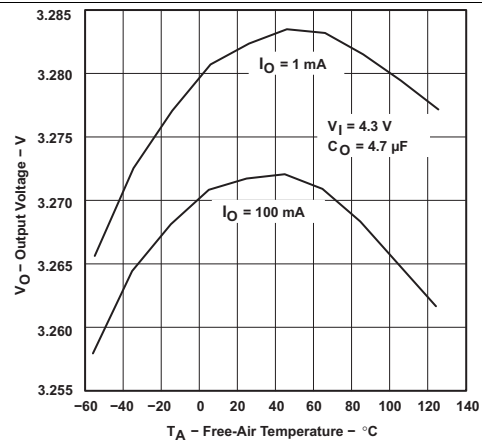


Figure 6. TPS76933-Q1 Output Voltage vs Free-Air Temperature

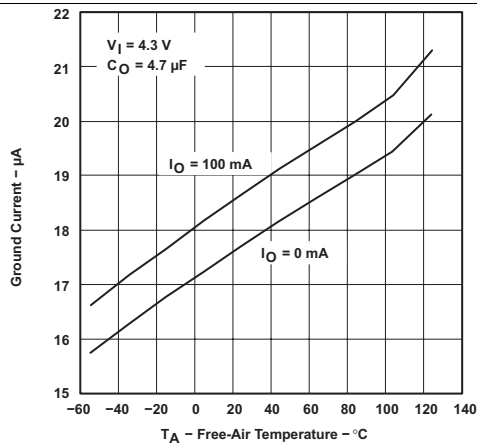


Figure 7. TPS76933-Q1 Ground Current vs Free-Air Temperature

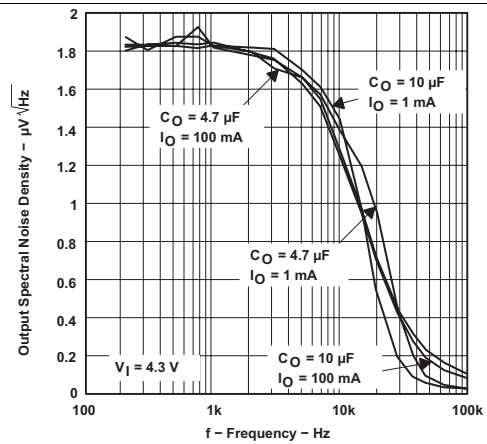


Figure 8. TPS76933-Q1 Output Spectral Noise Density vs Frequency

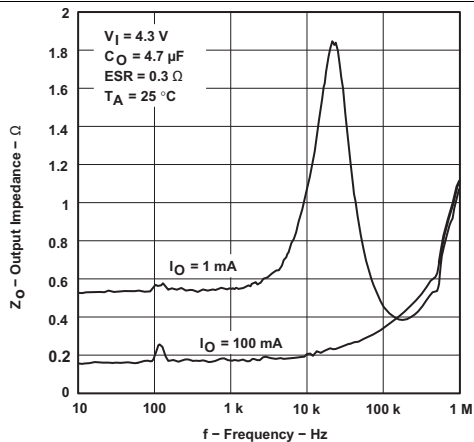


Figure 9. Output Impedance vs Frequency

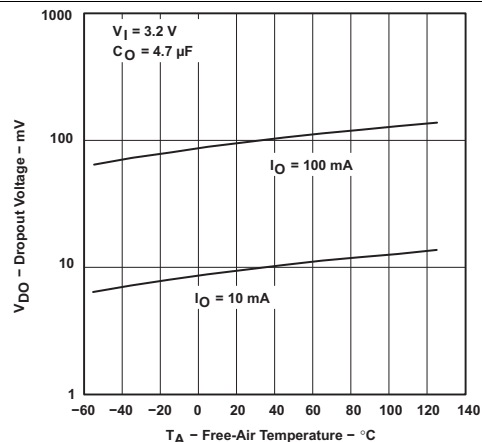


Figure 10. TPS76933-Q1 Dropout Voltage vs Free-Air Temperature

Typical Characteristics (continued)

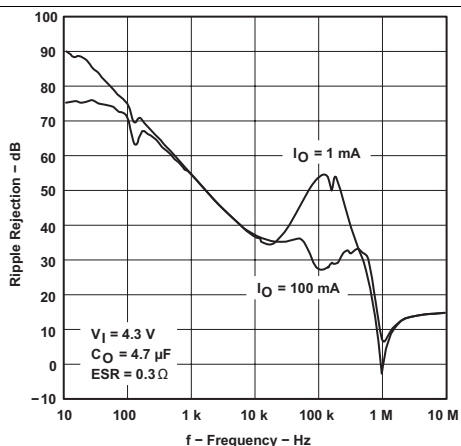


Figure 11. TPS76933-Q1 Ripple Rejection vs Frequency

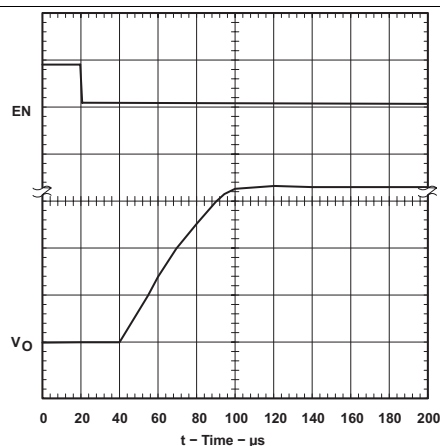


Figure 12. LDO Start-Up Time

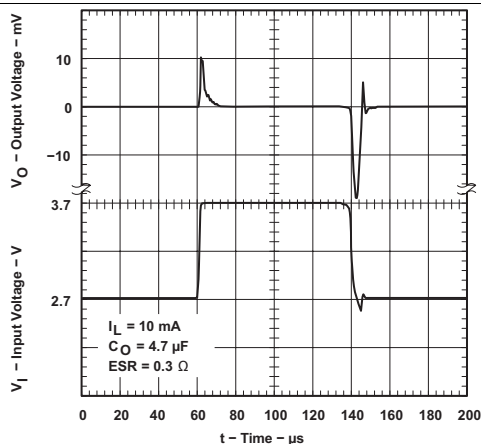


Figure 13. TPS76915-Q1 Line Transient Response

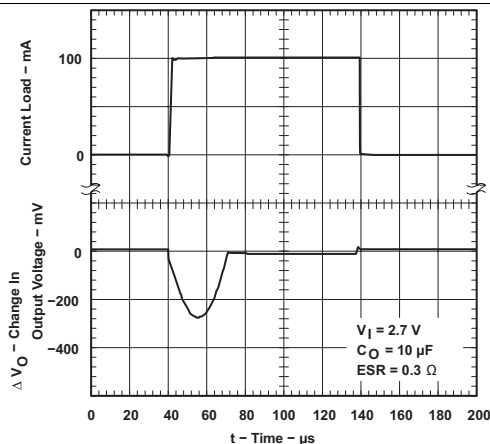


Figure 14. TPS76915-Q1 Load Transient Response

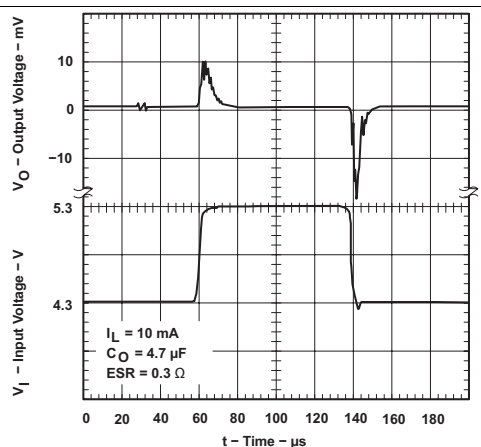


Figure 15. TPS76933-Q1 Line Transient Response

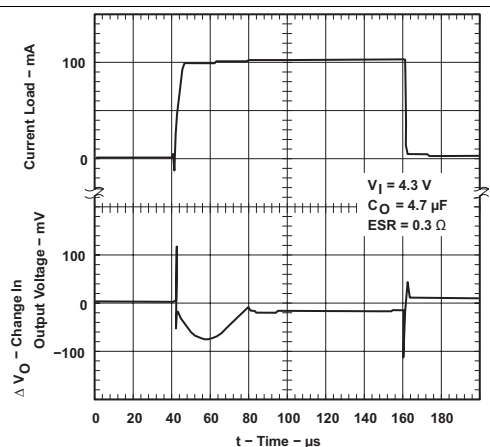


Figure 16. TPS76933-Q1 Load Transient Response

Typical Characteristics (continued)

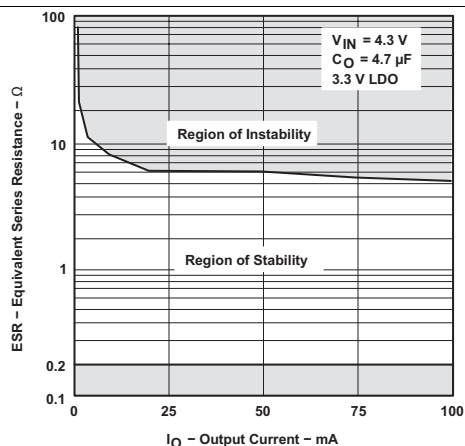


Figure 17. TPS76933-Q1 Typical Regions of Stability
Equivalent Series Resistance (ESR) vs Output Current

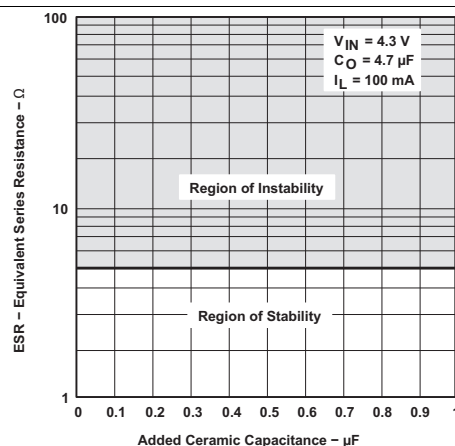


Figure 18. TPS76933-Q1 Typical Regions of Stability
Equivalent Series Resistance (ESR) vs Added Ceramic Capacitance

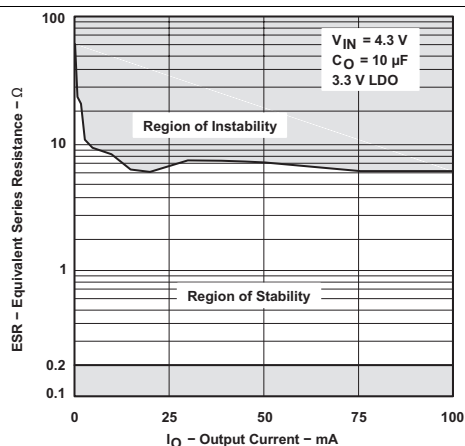


Figure 19. TPS76933-Q1 Typical Regions of Stability
Equivalent Series Resistance (ESR) vs Output Current

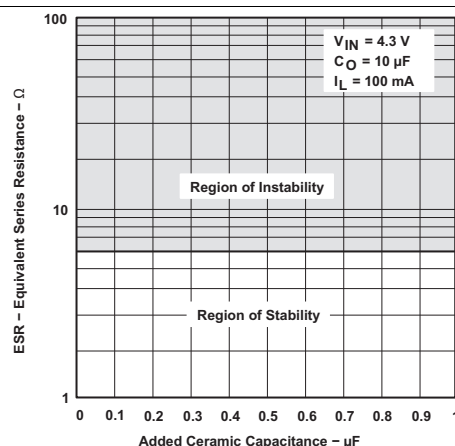


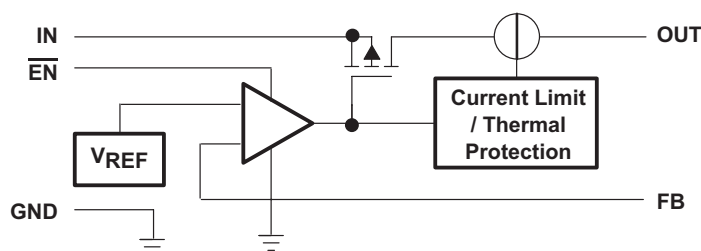
Figure 20. TPS76933-Q1 Typical Regions of Stability
Equivalent Series Resistance (ESR) vs Added Ceramic Capacitance

8 Detailed Description

8.1 Overview

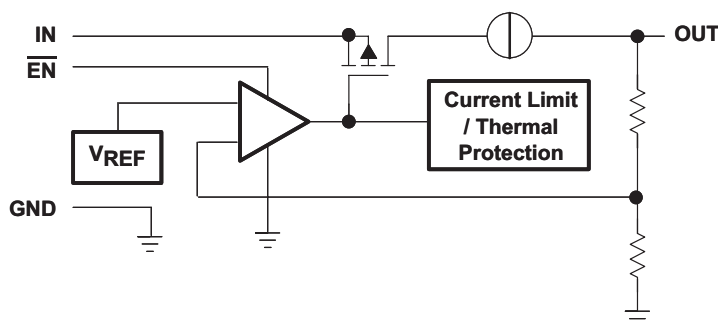
The TPS769xx-Q1 family of low-dropout (LDO) regulators are optimized for use in battery-operated equipment and automotive applications. They feature extremely low dropout voltages, low quiescent current (17 μA nominally), and enable inputs to reduce supply currents to 1 μA when the regulators are turned off.

8.2 Functional Block Diagrams



Copyright © 2016, Texas Instruments Incorporated

Figure 21. TPS76901-Q1 Functional Block Diagram



Copyright © 2016, Texas Instruments Incorporated

Figure 22. TPS769xx-Q1 Functional Block Diagram

8.3 Feature Description

8.3.1 Regulator Protection

The TPS769xx-Q1 PMOS-pass transistor has a built-in back diode that conducts reverse current when the input voltage drops below the output voltage (for example, during power down). Current is conducted from the output to the input and is not internally limited. If extended reverse voltage operation is anticipated, external limiting might be appropriate.

The TPS769xx-Q1 features internal current limiting and thermal protection. During normal operation, the TPS769xx-Q1 limits output current to approximately 350 mA. When current limiting engages, the output voltage scales back linearly until the overcurrent condition ends. While current limiting is designed to prevent gross device failure, care must be taken not to exceed the power dissipation ratings of the package. If the temperature of the device exceeds approximately 165°C, thermal-protection circuitry shuts it down. Once the device has cooled down to below approximately 140°C, regulator operation resumes.

8.4 Device Functional Modes

At 100-mA loads the device operates in low power mode and the quiescent current consumption is reduced to 28 μA (maximum).

9 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

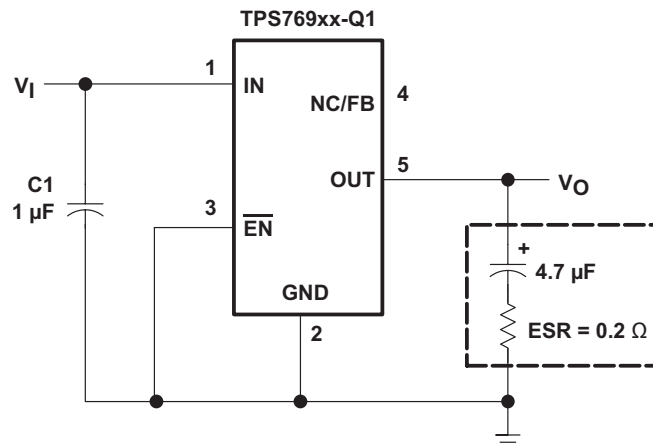
9.1 Application Information

The TPS769xx-Q1 uses a PMOS pass element to dramatically reduce both dropout voltage and supply current over more conventional PNP-pass-element LDO designs. The PMOS pass element is a voltage-controlled device and, unlike a PNP transistor, it does not require increased drive current as output current increases. Supply current in the TPS769xx-Q1 is essentially constant from no load to maximum load.

Current limiting and thermal protection prevent damage by excessive output current and/or power dissipation. The device switches into a constant-current mode at approximately 350 mA; further load reduces the output voltage instead of increasing the output current. The thermal protection shuts the regulator off if the junction temperature rises above approximately 165°C. Recovery is automatic when the junction temperature drops approximately 25°C below the high temperature trip point. The PMOS pass element includes a back gate diode that conducts reverse current when the input voltage level drops below the output voltage level.

A voltage of 1.7 V or greater on the $\overline{\text{EN}}$ input disables the TPS769xx-Q1 internal circuitry, reducing the supply current to 1 μA . A voltage of less than 0.9 V on the $\overline{\text{EN}}$ input enables the TPS769xx and enables normal operation to resume. The $\overline{\text{EN}}$ input does not include any deliberate hysteresis, and it exhibits an actual switching threshold of approximately 1.5 V.

9.2 Typical Application



Copyright © 2016, Texas Instruments Incorporated

TPS76912-Q1, TPS76915-Q1, TPS76918-Q1, TPS76925-Q1, TPS76927-Q1, TPS76928-Q1, TPS76930-Q1, TPS76933-Q1, TPS76950-Q1 (fixed-voltage options).

Figure 23. Typical Application Circuit

Typical Application (continued)

9.2.1 Design Requirements

Table 1 lists the design parameters for this example.

Table 1. Design Parameters

PARAMETER	EXAMPLE VALUE
Input voltage range	4 V to 10 V
Output voltage	2.5 V to 5 V
Output current rating	100 mA
Output capacitor	4.7 μ F to 10 μ F
Output capacitor ESR range	200 m Ω to 10 Ω

9.2.2 Detailed Design Procedure

9.2.2.1 External Capacitor Requirements

Although not required, TI recommends a 0.047- μ F or larger ceramic input bypass capacitor, connected between IN and GND and located close to the TPS769xx-Q1, to improve transient response and noise rejection. A higher-value electrolytic input capacitor may be necessary if large, fast-rise-time load transients are anticipated and the device is located several inches from the power source.

Like all low dropout regulators, the TPS769xx-Q1 requires an output capacitor connected between OUT and GND to stabilize the internal control loop. The minimum recommended capacitance is 4.7 μ F. The ESR (equivalent series resistance) of the capacitor must be between 0.2 Ω and 10 Ω to ensure stability. Capacitor values larger than 4.7 μ F are acceptable, and allow the use of smaller ESR values. Capacitances less than 4.7 μ F are not recommended because they require careful selection of ESR to ensure stability. Solid tantalum electrolytic, aluminum electrolytic, and multilayer ceramic capacitors are all suitable, provided they meet the requirements described above. Most of the commercially available 4.7- μ F surface-mount solid tantalum capacitors, including devices from Sprague, Kemet, and Nichicon, meet the ESR requirements stated above. Multilayer ceramic capacitors may have very small equivalent series resistances and may therefore require the addition of a low value series resistor to ensure stability.

Table 2. Capacitor Selection

PART NO.	MFR.	VALUE	MAX ESR	SIZE (H $\times$ L $\times$ W) ⁽¹⁾
T494B475K016AS	KEMET	4.7 μ F	1.5 Ω	1.9 $\times$ 3.5 $\times$ 2.8
195D106X0016X2T	SPRAGUE	10 μ F	1.5 Ω	1.3 $\times$ 7 $\times$ 2.7
695D106X003562T	SPRAGUE	10 μ F	1.3 Ω	2.5 $\times$ 7.6 $\times$ 2.5
TPSC475K035R0600	AVX	4.7 μ F	0.6 Ω	2.6 $\times$ 6 $\times$ 3.2

(1) Size is in mm. ESR is maximum resistance in Ω at 100 kHz and T_A = 25°C. Contact manufacturer for minimum ESR values.

9.2.2.2 Output Voltage Programming

The output voltage of the TPS76901-Q1 adjustable regulator is programmed using an external resistor divider as shown in Figure 24. The output voltage is calculated using Equation 1.

$$V_O = V_{ref} \times \left(1 + \frac{R_1}{R_2}\right)$$

where

- The internal reference voltage (V_{REF}) = 1.224 V (typical) (1)

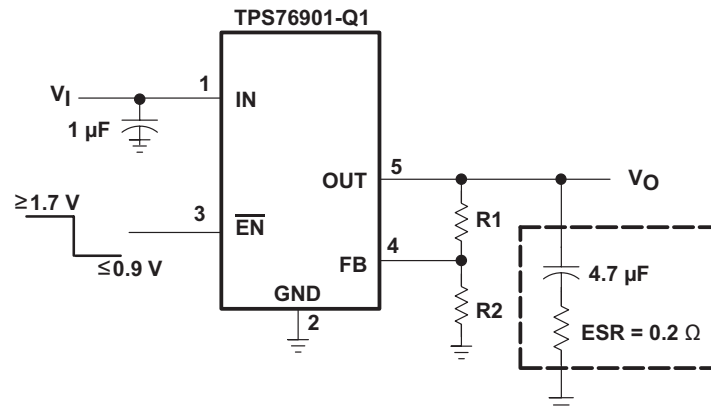
Resistors R1 and R2 must be chosen for approximately 7- μ A divider current. Lower value resistors can be used but offer no inherent advantage and waste more power. Higher values must be avoided as leakage currents at FB increase the output voltage error. The recommended design procedure is to choose R2 = 169 k Ω to set the divider current at 7 μ A and then calculate R1 using Equation 2.

$$R_1 = \left(\frac{V_O}{V_{ref}} - 1\right) \times R_2 \quad (2)$$

Table 3. Output Voltage Programming Guide

OUTPUT VOLTAGE (V)	DIVIDER RESISTANCE (k Ω) ⁽¹⁾	
	R1	R2
2.5	174	169
3.3	287	169
3.6	324	169
4	383	169
5	523	169

(1) 1% values shown.



Copyright © 2016, Texas Instruments Incorporated

Figure 24. TPS76901-Q1 Adjustable LDO Regulator Programming

9.2.3 Application Curves

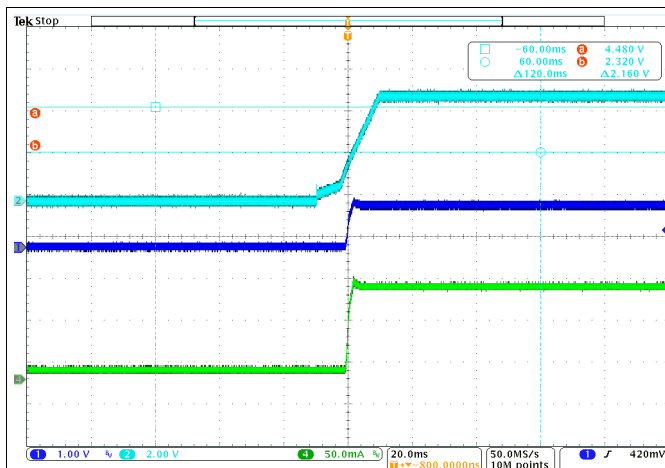


Figure 25. Power-Up Waveform
(CH1 VOUT, CH2 VIN, CH4 IOUT)

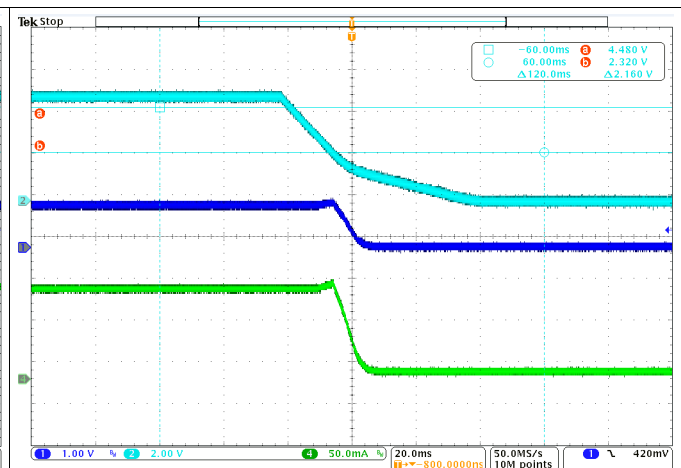


Figure 26. Power-Down Waveform
(CH1 VOUT, CH2 VIN, CH4 IOUT)

10 Power Supply Recommendations

Design of the device is for operation from an input voltage supply with a range between 2.7 V and 10 V. This input supply must be well regulated. If the input supply is located more than a few inches from the device, TI recommends adding an electrolytic capacitor with a value of 1 μ F and a ceramic bypass capacitor at the input.

11 Layout

11.1 Layout Guidelines

For the LDO power supply, especially these high voltage and large current ones, layout is an important step. If layout is not carefully designed, the regulator could not deliver enough output current because of the thermal limitation. To improve the thermal performance of the device, and maximize the current output at high ambient temperature, it is recommended to spread the GND as large as possible and put enough thermal vias on the thermal pad. [Figure 27](#) shows an example layout.

11.2 Layout Example

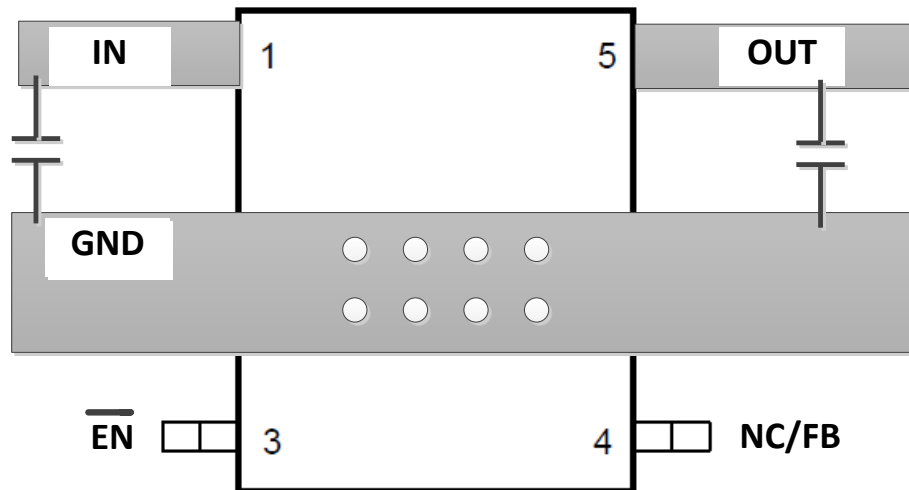


Figure 27. Layout Recommendation

11.3 Power Dissipation and Junction Temperature

Specified regulator operation is assured to a junction temperature of 125°C; the maximum junction temperature must be restricted to 125°C under normal operating conditions. This restriction limits the power dissipation the regulator can handle in any given application. To ensure the junction temperature is within acceptable limits, calculate the maximum allowable dissipation, $P_{D(max)}$, and the actual dissipation, P_D , which must be less than or equal to $P_{D(max)}$.

The maximum-power-dissipation limit is determined using [Equation 3](#).

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

where

- T_{Jmax} is the maximum allowable junction temperature
- $R_{\theta JA}$ is the thermal resistance junction-to-ambient for the package, see the dissipation rating table.
- T_A is the ambient temperature.

(3)

The regulator dissipation is calculated using [Equation 4](#).

$$P_D = (V_I - V_O) \times I_O$$

(4)

Power dissipation resulting from quiescent current is negligible. Excessive power dissipation triggers the thermal protection circuit.

12 Device and Documentation Support

12.1 Related Links

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

Table 4. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
TPS76901-Q1	Click here	Click here	Click here	Click here	Click here
TPS76912-Q1	Click here	Click here	Click here	Click here	Click here
TPS76915-Q1	Click here	Click here	Click here	Click here	Click here
TPS76918-Q1	Click here	Click here	Click here	Click here	Click here
TPS76925-Q1	Click here	Click here	Click here	Click here	Click here
TPS76927-Q1	Click here	Click here	Click here	Click here	Click here
TPS76928-Q1	Click here	Click here	Click here	Click here	Click here
TPS76930-Q1	Click here	Click here	Click here	Click here	Click here
TPS76933-Q1	Click here	Click here	Click here	Click here	Click here
TPS76950-Q1	Click here	Click here	Click here	Click here	Click here

12.2 Receiving Notification of Documentation Updates

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

12.3 Community Resources

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

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

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

12.4 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

12.5 Electrostatic Discharge Caution



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.

12.6 Glossary

SLYZ022 — *TI Glossary*.

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

13 Mechanical, Packaging, and Orderable Information

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

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TPS76901QDBVRG4Q1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCFQ	Samples
TPS76901QDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCFQ	Samples
TPS76912QDBVRG4Q1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCGQ	Samples
TPS76915QDBVRG4Q1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCHQ	Samples
TPS76918QDBVRG4Q1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCIQ	Samples
TPS76918QDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCIQ	Samples
TPS76925QDBVRG4Q1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCJQ	Samples
TPS76925QDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCJQ	Samples
TPS76927QDBVRG4Q1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCKQ	Samples
TPS76928QDBVRG4Q1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCLQ	Samples
TPS76930QDBVRG4Q1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCMQ	Samples
TPS76930QDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCMQ	Samples
TPS76933QDBVRG4Q1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCNQ	Samples
TPS76933QDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCNQ	Samples
TPS76950QDBVRG4Q1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCOQ	Samples
TPS76950QDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	PCOQ	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.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF TPS769-Q1 :

- Catalog: [TPS769](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

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
TPS76901QDBVRG4Q1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76901QDBVRQ1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76912QDBVRG4Q1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76915QDBVRG4Q1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76918QDBVRG4Q1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76918QDBVRQ1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76925QDBVRG4Q1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76925QDBVRQ1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76927QDBVRG4Q1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76928QDBVRG4Q1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76930QDBVRG4Q1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76930QDBVRQ1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76933QDBVRG4Q1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76933QDBVRQ1	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS76950QDBVRG4Q1	SOT-23	DBV	5	3000	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
TPS76950QDBVRQ1	SOT-23	DBV	5	3000	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

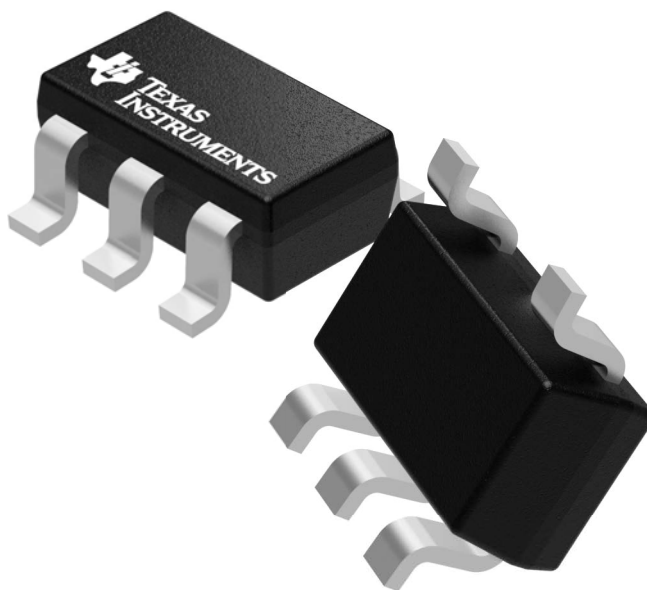
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS76901QDBVRG4Q1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76901QDBVRQ1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76912QDBVRG4Q1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76915QDBVRG4Q1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76918QDBVRG4Q1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76918QDBVRQ1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76925QDBVRG4Q1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76925QDBVRQ1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76927QDBVRG4Q1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76928QDBVRG4Q1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76930QDBVRG4Q1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76930QDBVRQ1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76933QDBVRG4Q1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76933QDBVRQ1	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS76950QDBVRG4Q1	SOT-23	DBV	5	3000	180.0	180.0	18.0
TPS76950QDBVRQ1	SOT-23	DBV	5	3000	180.0	180.0	18.0

GENERIC PACKAGE VIEW

DBV 5

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

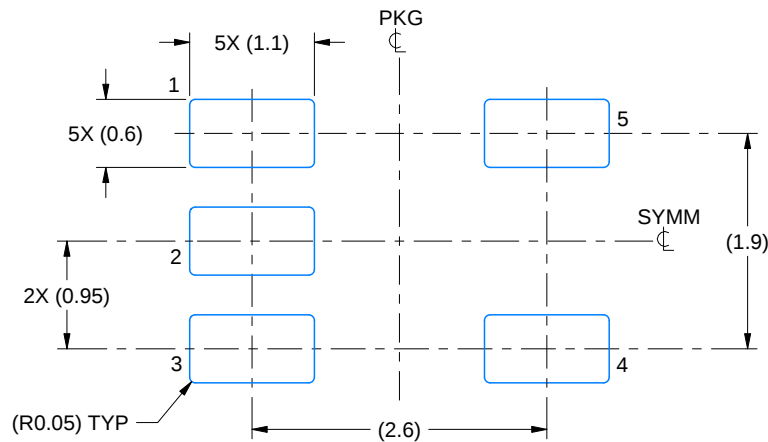
4073253/P

EXAMPLE BOARD LAYOUT

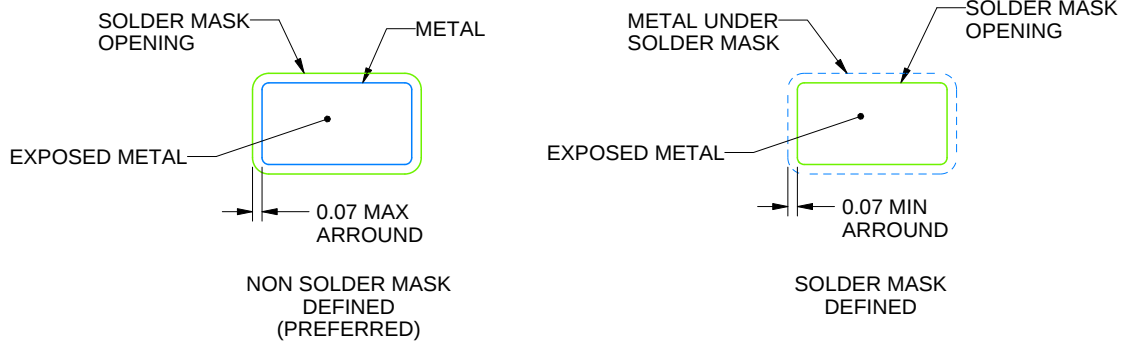
DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

4214839/C 04/2017

NOTES: (continued)

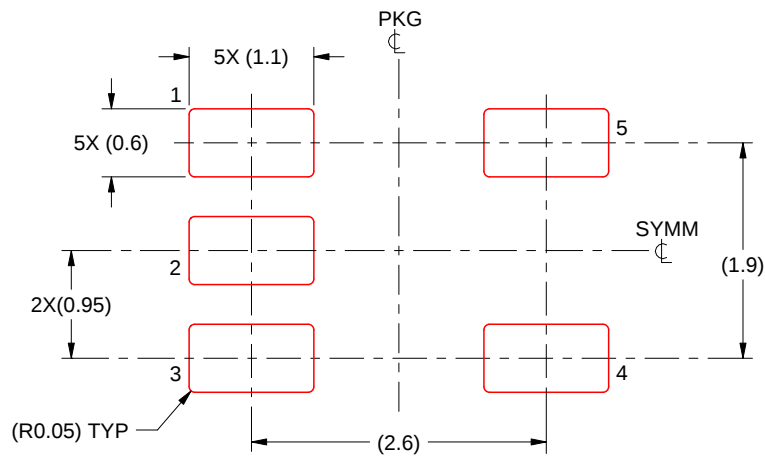
4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/C 04/2017

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
7. Board assembly site may have different recommendations for stencil design.

IMPORTANT NOTICE

Texas Instruments Incorporated (TI) reserves the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete.

TI's published terms of sale for semiconductor products (<http://www.ti.com/sc/docs/stdterms.htm>) apply to the sale of packaged integrated circuit products that TI has qualified and released to market. Additional terms may apply to the use or sale of other types of TI products and services.

Reproduction of significant portions of TI information in TI data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such reproduced documentation. Information of third parties may be subject to additional restrictions. Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyers and others who are developing systems that incorporate TI products (collectively, "Designers") understand and agree that Designers remain responsible for using their independent analysis, evaluation and judgment in designing their applications and that Designers have full and exclusive responsibility to assure the safety of Designers' applications and compliance of their applications (and of all TI products used in or for Designers' applications) with all applicable regulations, laws and other applicable requirements. Designer represents that, with respect to their applications, Designer has all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. Designer agrees that prior to using or distributing any applications that include TI products, Designer will thoroughly test such applications and the functionality of such TI products as used in such applications.

TI's provision of technical, application or other design advice, quality characterization, reliability data or other services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using TI Resources in any way, Designer (individually or, if Designer is acting on behalf of a company, Designer's company) agrees to use any particular TI Resource solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

Designer is authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS. TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY DESIGNER AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

Unless TI has explicitly designated an individual product as meeting the requirements of a particular industry standard (e.g., ISO/TS 16949 and ISO 26262), TI is not responsible for any failure to meet such industry standard requirements.

Where TI specifically promotes products as facilitating functional safety or as compliant with industry functional safety standards, such products are intended to help enable customers to design and create their own applications that meet applicable functional safety standards and requirements. Using products in an application does not by itself establish any safety features in the application. Designers must ensure compliance with safety-related requirements and standards applicable to their applications. Designer may not use any TI products in life-critical medical equipment unless authorized officers of the parties have executed a special contract specifically governing such use. Life-critical medical equipment is medical equipment where failure of such equipment would cause serious bodily injury or death (e.g., life support, pacemakers, defibrillators, heart pumps, neurostimulators, and implantables). Such equipment includes, without limitation, all medical devices identified by the U.S. Food and Drug Administration as Class III devices and equivalent classifications outside the U.S.

TI may expressly designate certain products as completing a particular qualification (e.g., Q100, Military Grade, or Enhanced Product). Designers agree that it has the necessary expertise to select the product with the appropriate qualification designation for their applications and that proper product selection is at Designers' own risk. Designers are solely responsible for compliance with all legal and regulatory requirements in connection with such selection.

Designer will fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of Designer's non-compliance with the terms and provisions of this Notice.