



TPS735-Q1 500mA、低静止電流、低ノイズ、高 PSRR、 低ドロップアウト・リニア・レギュレータ

1 特長

- 車載アプリケーションに対応
- 下記内容で AEC-Q100 認定済み
 - デバイス温度グレード 1: 動作時周囲温度範囲 $-40^{\circ}\text{C} \sim 125^{\circ}\text{C}$
 - デバイス HBM ESD 分類レベル 2
 - デバイス CDM ESD 分類レベル C4B
- 入力電圧: $2.7\text{V} \sim 6.5\text{V}$
- EN を備えた 500mA 低ドロップアウト・レギュレータ
- 低い I_Q : $46\mu\text{A}$
- 複数の出力電圧バージョンを利用可能:
 - 固定出力: $1\text{V} \sim 4.3\text{V}$
 - 可変出力: $1.25\text{V} \sim 6\text{V}$
- 高 PSRR: 1kHz 時に 68dB
- 低ノイズ: $13.2\mu\text{V}_{\text{RMS}}$
- 高速起動: $45\mu\text{s}$
- 低 ESR、 $2\mu\text{F}$ の出力コンデンサで安定動作
- 非常に優れた負荷/ライン過渡応答
- 総合精度 2%
(負荷、ライン、温度、 $V_{\text{OUT}} > 2.2\text{V}$)
- 低ドロップアウト: 280mV (500mA 時)
- $3\text{mm} \times 3\text{mm}$ VSON-8 パッケージ

2 アプリケーション

- 車載インフォテインメント
- ナビゲーション・システム
- WiFi、WiMax モジュール
- テレマティクス・システム
- マイクロプロセッサ電源

3 概要

TPS735-Q1 ファミリの低ドロップアウト (LDO) 低消費電力リニア・レギュレータは、極めて低いグランド電流で優れた AC 性能を提供します。高い電源除去比 (PSRR)、低ノイズ、高速起動、優れたライン/負荷過渡応答を実現しながら、消費するグランド電流はわずか $46\mu\text{A}$ (標準値) です。

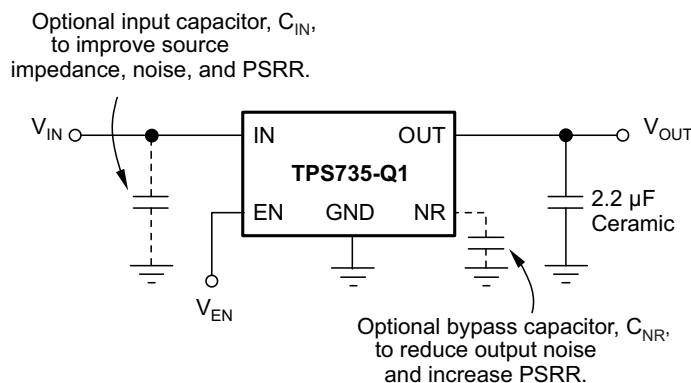
TPS735-Q1 ファミリはセラミック・コンデンサで安定動作し、先進の BiCMOS 製造プロセスの採用により、500mA 出力で標準 280mV のドロップアウト電圧を実現しています。高精度の電圧リファレンスと帰還ループにより、すべての負荷、ライン、プロセス、および温度変化に対して 2% ($V_{\text{OUT}} > 2.2\text{V}$) の総合精度を達成できます。 $T_A = -40^{\circ}\text{C} \sim 125^{\circ}\text{C}$ で仕様が規定されており、薄型の $3\text{mm} \times 3\text{mm}$ VSON パッケージで供給されます。

製品情報⁽¹⁾

型番	パッケージ	本体サイズ (公称)
TPS735-Q1	VSON (8)	$3.00\text{mm} \times 3.00\text{mm}$

(1) 利用可能なすべてのパッケージについては、このデータシートの末尾にある注文情報を参照してください。

代表的なアプリケーション



目次

1	特長	1	8	Application and Implementation	11
2	アプリケーション	1	8.1	Application Information	11
3	概要	1	8.2	Typical Application	11
4	改訂履歴	2	9	Power Supply Recommendations	14
5	Pin Configuration and Functions	3	10	Layout	14
6	Specifications	4	10.1	Layout Guidelines	14
6.1	Absolute Maximum Ratings	4	10.2	Layout Example	17
6.2	ESD Ratings	4	11	デバイスおよびドキュメントのサポート	18
6.3	Recommended Operating Conditions	4	11.1	デバイス・サポート	18
6.4	Thermal Information	4	11.2	ドキュメントのサポート	18
6.5	Electrical Characteristics	5	11.3	ドキュメントの更新通知を受け取る方法	18
6.6	Typical Characteristics	6	11.4	コミュニティ・リソース	18
7	Detailed Description	8	11.5	商標	18
7.1	Overview	8	11.6	静電気放電に関する注意事項	18
7.2	Functional Block Diagram	8	11.7	Glossary	18
7.3	Feature Description	9	12	メカニカル、パッケージ、および注文情報	19
7.4	Device Functional Modes	10			

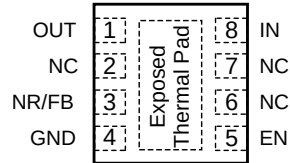
4 改訂履歴

Revision A (January 2015) から Revision B に変更	Page
• p.1 の図にタイトルを 追加	1
• Changed time scale from 10 ms to 10 μ s in <i>TPS73525-Q1 Turn-On Response ($V_{IN} = V_{EN}$)</i> figure	13
• Changed time scale from 10 ms to 10 μ s in <i>TPS73525-Q1 Turn-On Response Using EN</i> figure	13

2014年10月発行のものから更新	Page
• 製品プレビュー・ドキュメントを変更	1

5 Pin Configuration and Functions

DRB Package
8-Pin VSON With Exposed Thermal Pad
Top View



NC = No internal connection.

Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
EN	5	I	Driving the enable pin (EN) high turns on the regulator. Driving this pin low puts the regulator into shutdown mode. The EN pin can be connected to the IN pin if not used.
FB	3	I	This pin is only available for the adjustable version. The FB pin is the input to the control-loop error amplifier, and is used to set the output voltage of the device.
GND	4	—	Ground
IN	8	I	Input supply
NC	2, 6, 7	—	Not internally connected
NR	3	—	This pin is only available for the fixed voltage versions. Connecting an external capacitor to this pin bypasses noise generated by the internal band gap and allows the output noise to be reduced to very low levels. The maximum recommended capacitor is 0.01 μ F.
OUT	1	O	This pin is the output of the regulator. A small 2- μ F ceramic capacitor is required from this pin to ground to assure stability.
Exposed thermal pad		—	The pad must be tied to the GND pin.

6 Specifications

6.1 Absolute Maximum Ratings

At $-40^{\circ}\text{C} \leq T_J$ and $T_A \leq 125^{\circ}\text{C}$ (unless otherwise noted). All voltages are with respect to GND.⁽¹⁾

		MIN	MAX	UNIT
Voltage	V_{IN}	-0.3	7	V
	V_{EN}	-0.3	$V_{IN} + 0.3$	V
	V_{FB}	-0.3	1.6	V
	V_{OUT}	-0.3	$V_{IN} + 0.3$	V
Current	I_{OUT}	Internally limited		A
Continuous total power dissipation	Continuous, $P_{D(tot)}$	See the Power Dissipation section		
Operating junction temperature, T_J		-40	150	$^{\circ}\text{C}$
Storage temperature, T_{stg}		-55	150	$^{\circ}\text{C}$

- (1) Stresses beyond those listed as *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 as *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per AEC Q100-002 ⁽¹⁾	± 2000	V
		Charged device model (CDM), per AEC Q100-011	Corner pins (1, 4, 5, and 8)	
			Other pins	

- (1) AEC Q100-002 indicates HBM stressing is done in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V_{IN}	Input voltage	2.7	6.5	V
V_{OUT}	Output voltage	V_{FB}	6	V
I_{OUT}	Output current ⁽¹⁾	0	500	mA
T_A	Operating free-air temperature	-40	125	$^{\circ}\text{C}$

- (1) When operating at T_J near 125°C , $I_{OUT(min)}$ is 500 μA .

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾		TPS735-Q1	UNIT
		DRB (VSON)	
		8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	54.1	$^{\circ}\text{C/W}$
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	71.0	$^{\circ}\text{C/W}$
$R_{\theta JB}$	Junction-to-board thermal resistance	28.4	$^{\circ}\text{C/W}$
ψ_{JT}	Junction-to-top characterization parameter	2.3	$^{\circ}\text{C/W}$
ψ_{JB}	Junction-to-board characterization parameter	28.5	$^{\circ}\text{C/W}$
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	9.7	$^{\circ}\text{C/W}$

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

6.5 Electrical Characteristics

Over operating temperature range ($-40^{\circ}\text{C} \leq T_J$, $T_A \leq 125^{\circ}\text{C}$), $V_{IN} = V_{OUTnom} + 0.5\text{ V}$ or 2.7 V (whichever is greater), $I_{OUT} = 1\text{ mA}$, $V_{EN} = V_{IN}$, $C_{OUT} = 2.2\text{ }\mu\text{F}$, and $C_{NR} = 0.01\text{ }\mu\text{F}$, unless otherwise noted.

For the adjustable version (TPS73501-Q1), $V_{OUT} = 3\text{ V}$. Typical values are at $T_A = 25^{\circ}\text{C}$.

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{IN}	Input voltage ⁽¹⁾			2.7		6.5	V
V_{FB}	Internal reference (TPS73501-Q1)	$T_J = 25^{\circ}\text{C}$		1.196	1.208	1.220	V
V_{OUT}	Output voltage range (TPS73501-Q1)			V_{FB}		6	V
	DC output accuracy ⁽¹⁾	$1\text{ mA} \leq I_{OUT} \leq 500\text{ mA}$, $V_{OUT} + 0.5\text{ V} \leq V_{IN} < 6.5\text{ V}$	$V_{OUT} > 2.2\text{ V}$	-2%	$\pm 1\%$	2%	
			$V_{OUT} \leq 2.2\text{ V}$	-3%	$\pm 1\%$	3%	
$\Delta V_{OUT(\Delta V_{IN})}$	Line regulation ⁽¹⁾	$V_{OUTnom} + 0.5\text{ V} \leq V_{IN} \leq 6.5\text{ V}$			0.02		%/V
$\Delta V_{OUT(\Delta I_{OUT})}$	Load regulation	$500\text{ }\mu\text{A} \leq I_{OUT} \leq 500\text{ mA}$			0.005		%/mA
V_{DO}	Dropout voltage ⁽²⁾ ($V_{IN} = V_{OUTnom} - 0.1\text{ V}$)	$I_{OUT} = 500\text{ mA}$			280	500	mV
I_{LIM}	Output current limit	$V_{OUT} = 0.9 \times V_{OUTnom}$, $V_{IN} = V_{OUTnom} + 0.9\text{ V}$, $V_{IN} \geq 2.7\text{ V}$		800	1170	1900	mA
I_{GND}	Ground pin current	$10\text{ mA} \leq I_{OUT} \leq 500\text{ mA}$			45	65	μA
I_{SHDN}	Shutdown current	$V_{EN} \leq 0\text{ V}$			0.15	1	μA
I_{FB}	Feedback pin current (TPS73501-Q1)	$V_{OUTnom} = 1.2\text{ V}$		-0.5		0.5	μA
PSRR	Power-supply rejection ratio	$V_{IN} = 3.85\text{ V}$, $V_{OUT} = 2.85\text{ V}$, $C_{NR} = 0.01\text{ }\mu\text{F}$, $I_{OUT} = 100\text{ mA}$	$f = 100\text{ Hz}$		60		dB
			$f = 1\text{ kHz}$		68		dB
			$f = 10\text{ kHz}$		41		dB
			$f = 100\text{ kHz}$		21		dB
V_n	Output noise voltage	BW = 10 Hz to 100 kHz, $V_{OUT} = 2.8\text{ V}$	$C_{NR} = 0.01\text{ }\mu\text{F}$		$11 \times V_{OUT}$		μV_{RMS}
			$C_{NR} = \text{none}$		$95 \times V_{OUT}$		μV_{RMS}
t_{STR}	Startup time	$C_{NR} = \text{none}$			45		μs
		$C_{NR} = 0.001\text{ }\mu\text{F}$			45		μs
		$C_{NR} = 0.01\text{ }\mu\text{F}$			50		μs
		$C_{NR} = 0.047\text{ }\mu\text{F}$			50		μs
$V_{EN(HI)}$	Enable high (enabled)			1.2			V
$V_{EN(LO)}$	Enable low (shutdown)					0.4	V
$I_{EN(HI)}$	Enable pin current, enabled	$V_{EN} = V_{IN} = 6.5\text{ V}$			0.03	1	μA
T_{sd}	Thermal shutdown temperature	Shutdown, temperature increasing			165		$^{\circ}\text{C}$
		Reset, temperature decreasing			145		$^{\circ}\text{C}$
UVLO	Undervoltage lockout	V_{IN} rising		1.9	2.2	2.65	V
V_{hys}	Hysteresis	V_{IN} falling			70		mV

(1) Minimum $V_{IN} = V_{OUT} + V_{DO}$ or 2.7 V , whichever is greater.

(2) V_{DO} is not measured for this family of devices with $V_{OUTnom} < 2.8\text{ V}$ because the minimum $V_{IN} = 2.7\text{ V}$.

6.6 Typical Characteristics

Over operating temperature range ($-40^{\circ}\text{C} \leq T_J$, $T_A \leq 125^{\circ}\text{C}$), $V_{IN} = V_{OUTnom} + 0.5\text{ V}$ or 2.7 V (whichever is greater), $I_{OUT} = 1\text{ mA}$, $V_{EN} = V_{IN}$, $C_{OUT} = 2.2\text{ }\mu\text{F}$, and $C_{NR} = 0.01\text{ }\mu\text{F}$, unless otherwise noted. $T_A = 25^{\circ}\text{C}$, unless otherwise noted.

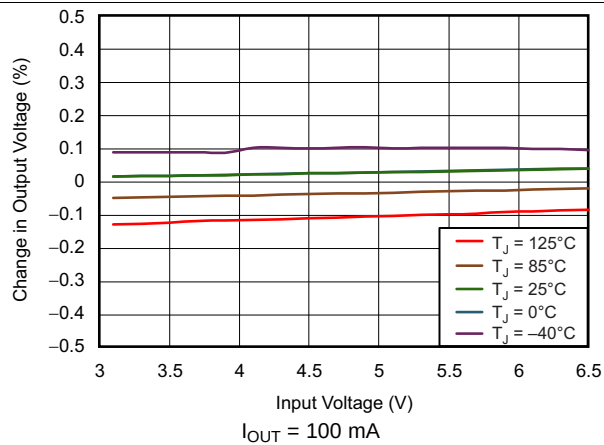


Figure 1. TPS73501-Q1 Line Regulation

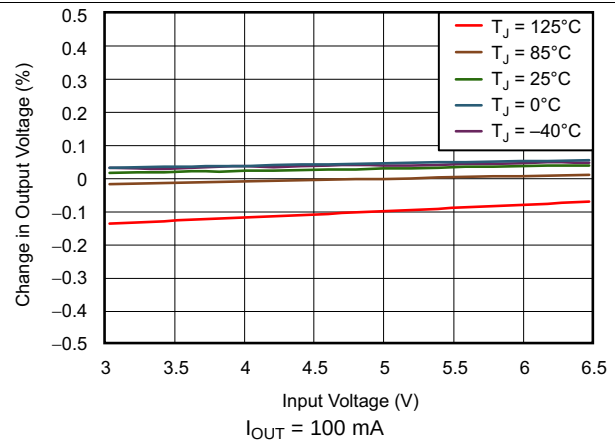


Figure 2. TPS73525-Q1 Line Regulation

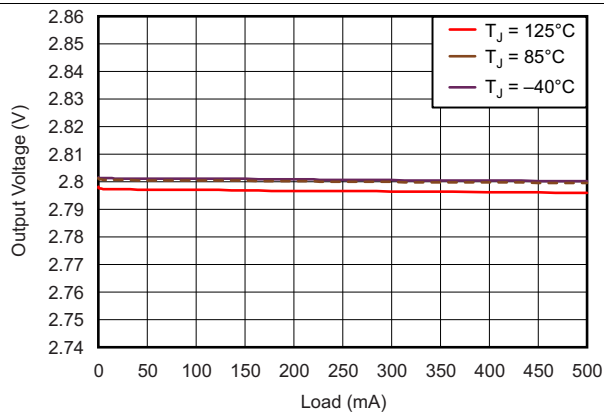


Figure 3. TPS73501-Q1 Load Regulation

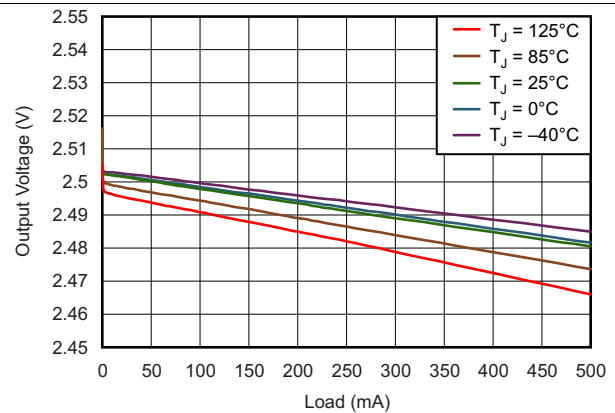


Figure 4. TPS73525-Q1 Load Regulation

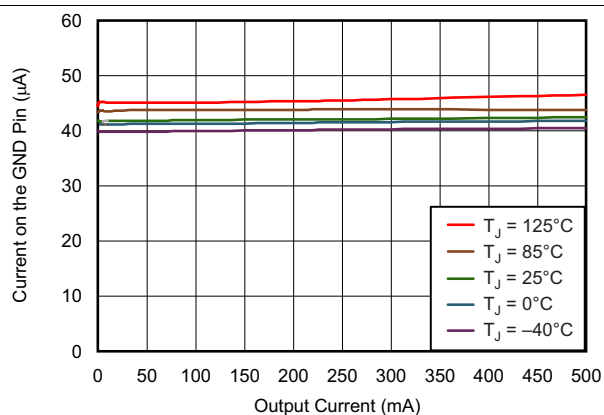


Figure 5. TPS73525-Q1 Ground Pin Current vs Output Current

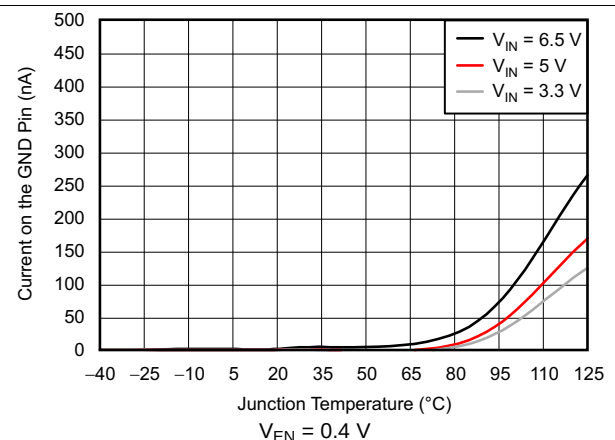


Figure 6. TPS73525-Q1 Ground Pin Current (Disable) vs Temperature

Typical Characteristics (continued)

Over operating temperature range ($-40^{\circ}\text{C} \leq T_J$, $T_A \leq 125^{\circ}\text{C}$), $V_{IN} = V_{OUTnom} + 0.5\text{ V}$ or 2.7 V (whichever is greater), $I_{OUT} = 1\text{ mA}$, $V_{EN} = V_{IN}$, $C_{OUT} = 2.2\text{ }\mu\text{F}$, and $C_{NR} = 0.01\text{ }\mu\text{F}$, unless otherwise noted. $T_A = 25^{\circ}\text{C}$, unless otherwise noted.

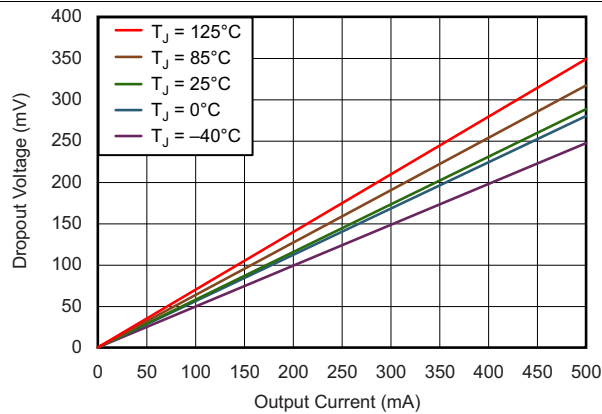


Figure 7. TPS73501-Q1 Dropout Voltage vs Output Current

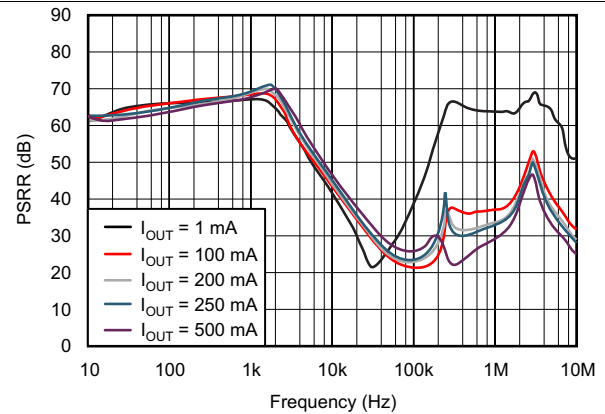


Figure 8. Power-Supply Ripple Rejection vs Frequency ($V_{IN} - V_{OUT} = 1\text{ V}$)

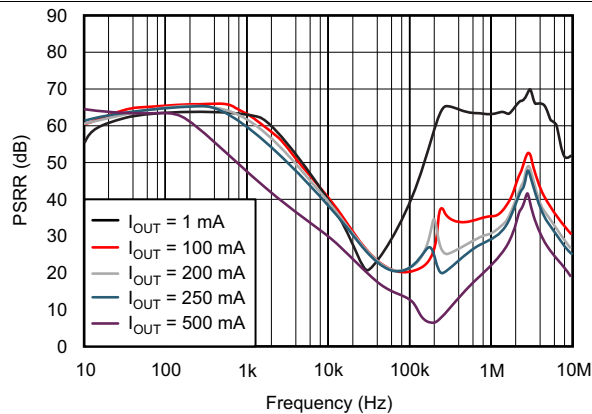


Figure 9. Power-Supply Ripple Rejection vs Frequency ($V_{IN} - V_{OUT} = 0.5\text{ V}$)

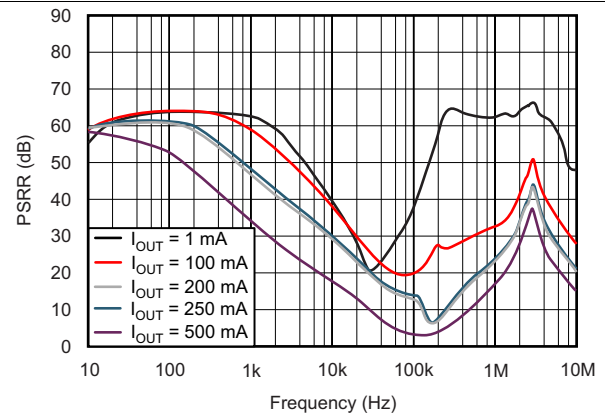


Figure 10. Power-Supply Ripple Rejection vs Frequency ($V_{IN} - V_{OUT} = 0.3\text{ V}$)

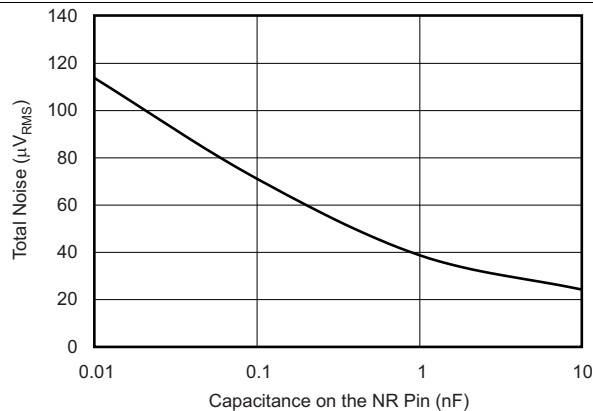


Figure 11. TPS73525-Q1 RMS Noise vs C_{NR}

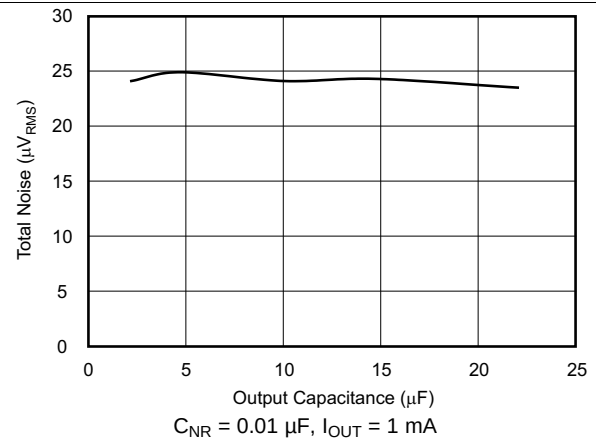


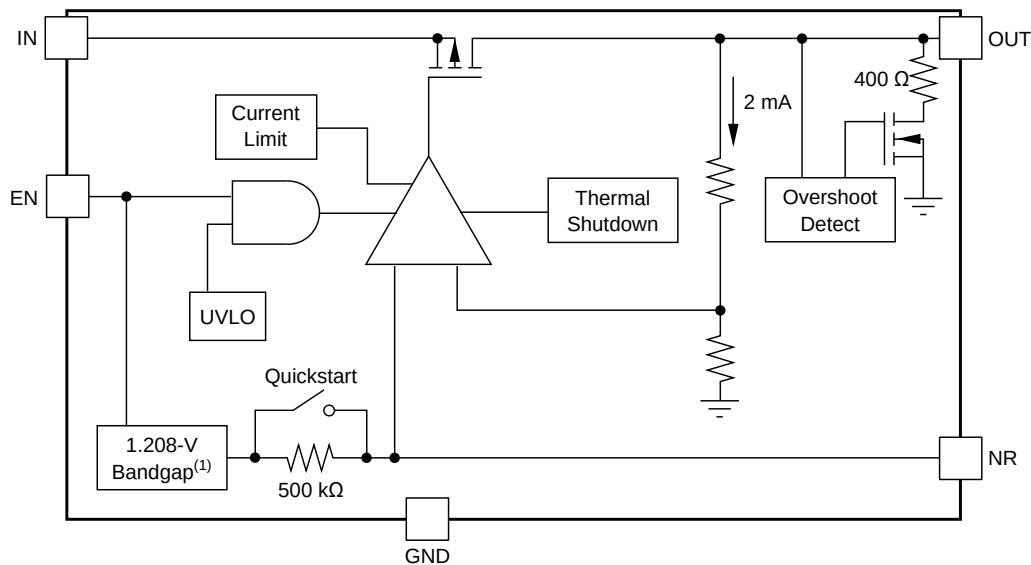
Figure 12. TPS73525-Q1 RMS Noise vs C_{OUT}

7 Detailed Description

7.1 Overview

The TPS735-Q1 family of low dropout (LDO) regulators combines the high performance required by many radio frequency (RF) and precision analog applications with ultra-low current consumption. High PSRR is provided by a high-gain, high-bandwidth error loop with good supply rejection and very low headroom ($V_{IN} - V_{OUT}$). Fixed voltage versions provide a noise reduction pin to bypass noise generated by the band-gap reference and to improve PSRR. A quick-start circuit fast-charges this capacitor at startup. The combination of high performance and low ground current also make the TPS735-Q1 family of devices an excellent choice for portable applications. All versions have thermal and overcurrent protection and are fully specified from $-40^{\circ}\text{C} \leq T_J, T_A \leq 125^{\circ}\text{C}$.

7.2 Functional Block Diagram



NOTE: Fixed voltage versions between 1 V to 1.2 V have a 1-V band-gap circuit instead of a 1.208-V band-gap circuit.

Figure 13. Fixed Voltage Versions

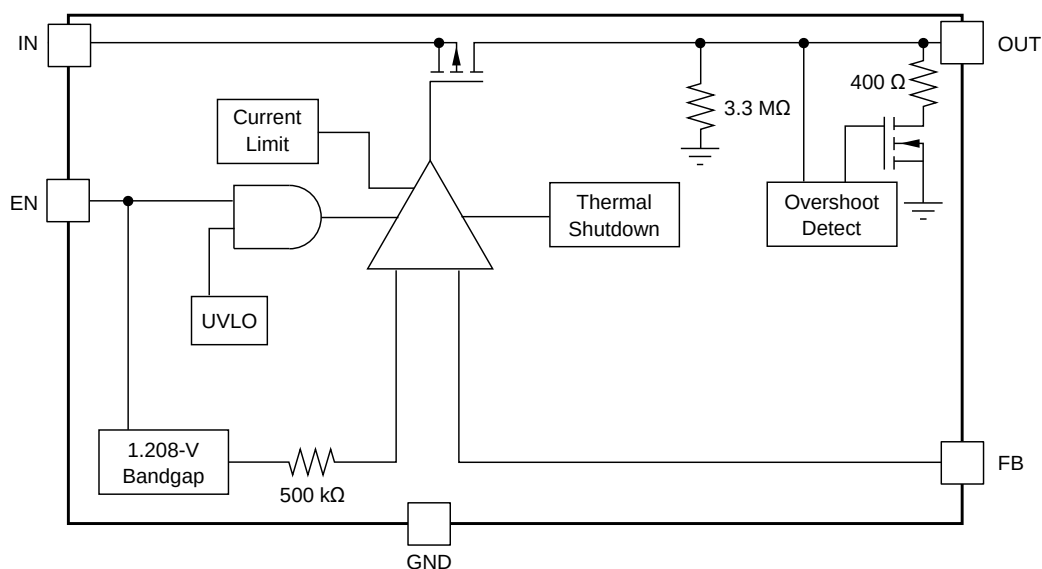


Figure 14. Adjustable Voltage Versions

7.3 Feature Description

7.3.1 Internal Current-Limit

The TPS735-Q1 internal current-limit helps protect the regulator during fault conditions. During current-limit, the output sources a fixed amount of current that is largely independent of the output voltage. For reliable operation, do not operate the device in current-limit for extended periods of time.

The PMOS pass element in the TPS735-Q1 family of devices has a built-in body diode that conducts current when the voltage at the OUT pin exceeds the voltage at the IN pin. This current is not limited, so if extended reverse voltage operation is anticipated, external limiting can be appropriate.

7.3.2 Shutdown

The enable pin (EN) is active high and is compatible with standard and low-voltage TTL-CMOS levels. When shutdown capability is not required, the EN pin can be connected to the IN pin.

7.3.3 Dropout Voltage

The TPS735-Q1 family of devices uses a PMOS pass transistor to achieve low dropout. When $(V_{IN} - V_{OUT})$ is less than the dropout voltage (V_{DO}), the PMOS pass device is in the linear region of operation and the input-to-output resistance ($R_{(IN/OUT)}$) of the PMOS pass element. V_{DO} scales with the output current because the PMOS device behaves like a resistor in dropout.

As with any linear regulator, PSRR and transient response are degraded when $(V_{IN} - V_{OUT})$ approaches dropout. This effect is shown in the [Typical Characteristics](#) section (see [Figure 8](#) through [Figure 10](#)).

7.3.4 Startup and Noise Reduction Capacitor

Fixed voltage versions of the TPS735-Q1 family of devices use a quick-start circuit to fast-charge the noise reduction capacitor, C_{NR} , if present (see the [Functional Block Diagram](#) section). This architecture allows the combination of very-low output noise and fast startup times. The NR pin is high impedance so a low-leakage C_{NR} capacitor must be used. Most ceramic capacitors are appropriate in this configuration. A high-quality, COG-type (NPO) dielectric ceramic capacitor is recommended for C_{NR} when used in environments where abrupt changes in temperature can occur.

Note that for fastest start-up, apply V_{IN} first, then drive the enable pin (EN) high. If the EN pin is tied to the IN pin, start-up is somewhat slower. Refer to the [Typical Application](#) section (see [Figure 17](#) and [Figure 18](#)). The quick-start switch is closed for approximately 135 μ s. To ensure that C_{NR} is charged during the quick-start time, use a capacitor with a value of no more than 0.01 μ F.

7.3.5 Transient Response

As with any regulator, increasing the size of the output capacitor reduces overshoot and undershoot magnitude but increases the transient response duration. In the adjustable version, adding C_{FB} between the OUT and FB pins improves stability and transient response performance. The transient response of the TPS735-Q1 family of devices is enhanced by an active pulldown that engages when the output overshoots by approximately 5% or more when the device is enabled. When enabled, the pull-down device behaves like a 400- Ω resistor to ground.

7.3.6 Undervoltage Lockout (UVLO)

The TPS735-Q1 family of devices uses an undervoltage lockout circuit to keep the output shut off until the internal circuitry is operating properly. The UVLO circuit has a deglitch feature so that the UVLO typically ignores undershoot transients on the input if the transients are less than 50 μ s in duration.

7.3.7 Minimum Load

The TPS735-Q1 family of devices is stable and well-behaved with no output load. To meet the specified accuracy, a minimum load of 500 μ A is required. Below 500 μ A and at junction temperatures near 125°C, the output can drift up enough to cause the output pulldown to turn on. The output pulldown limits voltage drift to 5% (typically) but ground current can increase by approximately 50 μ A. In most applications, the junction does not reach high temperatures at light loads because very little power is dissipated. Therefore, the specified ground current is valid at no load in most applications.

7.4 Device Functional Modes

7.4.1 Normal Operation

The device regulates to the nominal output voltage under the following conditions:

- The input voltage has previously exceeded the UVLO voltage and has not decreased below the UVLO threshold minus V_{hys} .
- The input voltage is greater than the nominal output voltage added to the dropout voltage.
- The enable voltage has previously exceeded the enable rising threshold voltage and has not decreased below the enable falling threshold.
- The output current is less than the current limit.
- The device junction temperature is less than the thermal shutdown temperature.

7.4.2 Dropout Operation

If the input voltage is lower than the nominal output voltage plus the specified dropout voltage, but all other conditions are met for normal operation, the device operates in dropout mode. In this condition, the output voltage is equal to the input voltage minus the dropout voltage. The transient performance of the device is significantly degraded because the pass device is in a triode state and the LDO behaves like a resistor. Line or load transients in dropout can result in large output voltage deviations.

7.4.3 Disabled

The device is disabled under the following conditions:

- The input voltage is less than the UVLO threshold minus V_{hys} , or has not yet exceeded the UVLO threshold.
- The enable voltage is less than the enable falling threshold voltage or has not yet exceeded the enable rising threshold.
- The device junction temperature is greater than the thermal shutdown temperature.

[Table 1](#) shows the conditions that lead to the different modes of operation.

Table 1. Device Functional Mode Comparison

OPERATING MODE	PARAMETER			
	V_{IN}	V_{EN}	I_{OUT}	T_{J}
Normal mode	$V_{\text{IN}} > V_{\text{OUTnom}} + V_{\text{DO}}$ and $V_{\text{IN}} > \text{UVLO}$	$V_{\text{EN}} > V_{\text{EN(HI)}}$	$I_{\text{OUT}} < I_{\text{LIM}}$	$T_{\text{J}} < 165^{\circ}\text{C}$
Dropout mode	$\text{UVLO} < V_{\text{IN}} < V_{\text{OUTnom}} + V_{\text{DO}}$	$V_{\text{EN}} > V_{\text{EN(HI)}}$	—	$T_{\text{J}} < 165^{\circ}\text{C}$
Disabled mode (any true condition disables the device)	$V_{\text{IN}} < \text{UVLO} - V_{\text{hys}}$	$V_{\text{EN}} < V_{\text{EN(LO)}}$	—	$T_{\text{J}} > 165^{\circ}\text{C}$

8 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.

8.1 Application Information

The TPS735-Q1 family of automotive-qualified LDO regulators provides a design with an ultra-low noise, high PSRR, low-dropout linear regulation with a very small ground current (46 μ A, typical).

The devices are stable with ceramic capacitors, and have a dropout voltage of 280 mV at the full output rating of 500 mA. The features of the TPS735-Q1 family of devices enables the LDO regulators to be suitable for a wide variety of applications, with minimal design complexity.

8.2 Typical Application

Figure 15 shows the basic circuit connections for fixed-voltage models. Figure 16 gives the connections for the adjustable output version (TPS73501-Q1). Use the equation in Figure 16 to calculate the value of R1 and R2 for any output voltage.

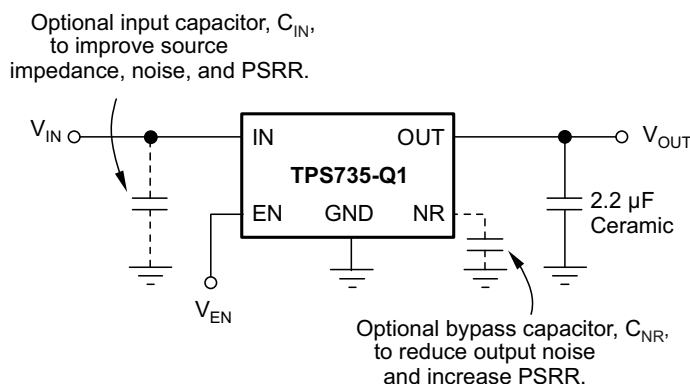


Figure 15. Typical Application Circuit for Fixed Voltage Versions

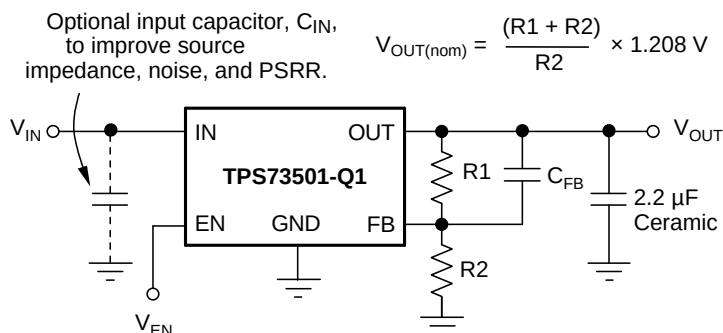


Figure 16. Typical Application Circuit for Adjustable Voltage Versions

Typical Application (continued)

8.2.1 Design Requirements

8.2.1.1 Input and Output Capacitor Requirements

Although an input capacitor is not required for stability, connecting a 0.1-μF to 1-μF low-equivalent series-resistance (ESR) capacitor across the input supply near the regulator is good analog design practice. This capacitor counteracts reactive input sources and improves transient response and ripple rejection. A higher-value capacitor can be necessary if large, fast, rise-time load transients are anticipated or if the device is located several inches from the power source. If source impedance is not sufficiently low, a 0.1-μF input capacitor can be necessary to ensure stability.

The TPS735-Q1 family of devices is designed to be stable with standard ceramic output capacitors of values 2 μF or larger. X5R- and X7R-type capacitors are best because they have minimal variation in value and ESR over temperature. Maximum ESR of the output capacitor is < 1 Ω and, therefore, the output capacitor type must either be ceramic or conductive polymer electrolytic.

8.2.1.2 Feedback Capacitor Requirements (TPS73501-Q1 only)

The feedback capacitor (C_{FB}), shown in [Figure 16](#), is required for stability. For a parallel combination of R1 and R2 equal to 250 kΩ, any value between 3 pF to 1 nF can be used. Fixed voltage versions have an internal 30-pF feedback capacitor that is quick-charged at start-up. Larger value capacitors also improve noise slightly. The TPS73501-Q1 device is stable in unity-gain configurations (the OUT pin is tied to the FB pin) without C_{FB} .

8.2.2 Detailed Design Procedure

8.2.2.1 Output Noise

In most LDO regulators, the band gap is the dominant noise source. If a noise-reduction capacitor (C_{NR}) is used with the TPS735-Q1 family of devices, the band gap does not contribute significantly to noise. Instead, noise is dominated by the output-resistor divider and the error-amplifier input. To minimize noise in a given application, use a 0.01-μF noise reduction capacitor. For the adjustable version, smaller value resistors in the output resistor divider reduce noise. A parallel combination that gives 2 μA of divider current has the same noise performance as a fixed voltage version with a C_{NR} . To further optimize noise, ESR of the output capacitor can be set to approximately 0.2 Ω. This configuration maximizes phase margin in the control loop, reducing the total output noise up to 10%. The maximum recommended capacitor is 0.01 μF.

[Equation 1](#) calculates the approximate integrated output noise from 10 Hz to 100 kHz with a C_{NR} value of 0.01 μF.

$$V_n (\mu V_{RMS}) = 11 (\mu V_{RMS} / V) \times V_{OUT} (V) \quad (1)$$

The TPS73501-Q1 adjustable version does not have the noise-reduction pin available, so ultra-low noise operation is not possible. Noise can be minimized according to the previously listed recommendations.

Typical Application (continued)

8.2.3 Application Curves

At $V_{IN} = V_{OUTnom} + 0.5\text{ V}$ or 2.7 V (whichever is greater), $I_{OUT} = 1\text{ mA}$, $V_{EN} = V_{IN}$, $C_{OUT} = 2.2\text{ }\mu\text{F}$, $C_{NR} = 0.01\text{ }\mu\text{F}$, and $T_A = 25^\circ\text{C}$, unless otherwise noted.

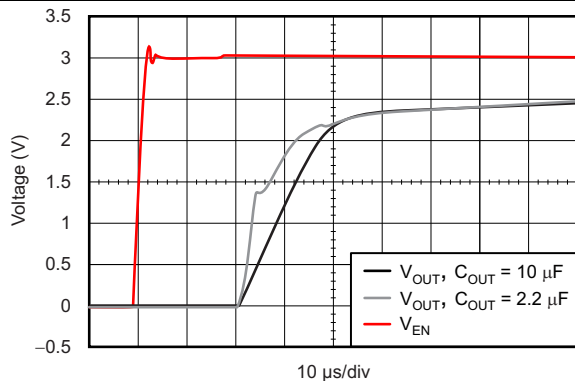


Figure 17. TPS73525-Q1 Turn-On Response ($V_{IN} = V_{EN}$)

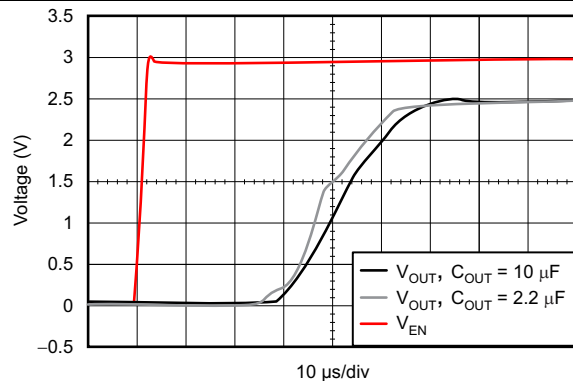


Figure 18. TPS73525-Q1 Turn-On Response Using EN

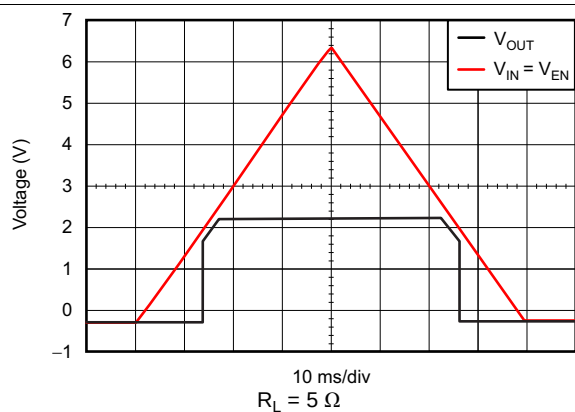


Figure 19. TPS73525-Q1 Power-Up and Power-Down ($V_{IN} = V_{EN}$)

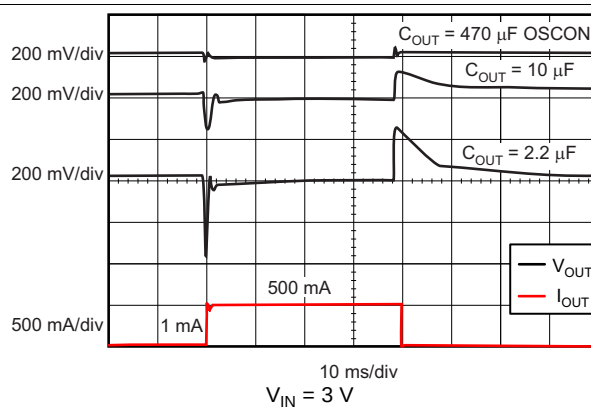


Figure 20. TPS73525-Q1 Load Transient Response

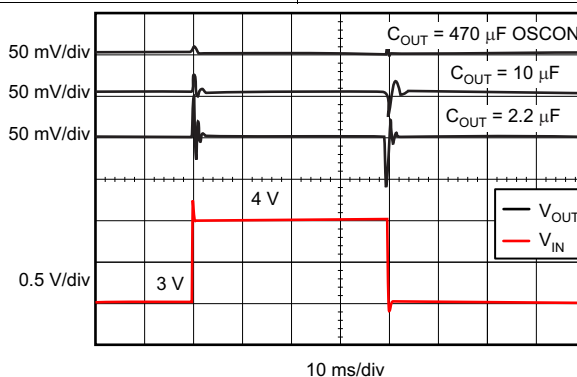


Figure 21. TPS73525-Q1 Line Transient Response

9 Power Supply Recommendations

The device is designed to operate from an input voltage supply range between 2.7 V and 6.5 V. The input voltage range must provide adequate headroom in order for the device to have a regulated output. This input supply must be well regulated. If the input supply is noisy, additional input capacitors with low ESR can help improve output noise.

10 Layout

10.1 Layout Guidelines

For best overall performance, place all circuit components on the same side of the circuit board and as near as practical to the respective LDO pin connections. Place ground return connections to the input and output capacitor, and to the LDO ground pin as close to each other as possible, connected by a wide, component-side, copper surface. The use of vias and long traces to create LDO component connections is strongly discouraged and negatively affects system performance. This grounding and layout scheme minimizes inductive parasitics, and thereby reduces load-current transients, minimizes noise, and increases circuit stability. A ground reference plane is also recommended and is either embedded in the printed circuit board (PCB) itself or located on the bottom side of the PCB opposite the components. This reference plane serves to assure accuracy of the output voltage, shields the LDO from noise, and behaves similar to a thermal plane to spread (or sink) heat from the LDO device when connected to the PowerPAD™. In most applications, this ground plane is necessary to meet thermal requirements.

10.1.1 Board Layout Recommendations to Improve PSRR and Noise Performance

To improve ac performance (such as PSRR, output noise, and transient response), designing the board with separate ground planes for V_{IN} and V_{OUT} is recommended, with each ground plane connected only at the GND pin of the device. In addition, the ground connection for the bypass capacitor must connect directly to the GND pin of the device.

10.1.2 Thermal Protection

Thermal protection disables the output when the junction temperature rises to approximately 165°C, allowing the device to cool. When the junction temperature cools to approximately 145°C, the output circuitry is again enabled. Depending on power dissipation, thermal resistance, and ambient temperature, the thermal protection circuit can cycle on and off. This cycling limits the dissipation of the regulator, protecting it from damage as a result of overheating.

Any tendency to activate the thermal protection circuit indicates excessive power dissipation or an inadequate heatsink. For reliable operation, limit junction temperature to 125°C maximum. To estimate the thermal margin in a complete design (including heatsink), increase the ambient temperature until the thermal protection is triggered; use worst-case loads and signal conditions. For good reliability, trigger thermal protection at least 40°C above the maximum expected ambient condition of a particular application. This configuration produces a worst-case junction temperature of 125°C at the highest expected ambient temperature and worst-case load.

The internal protection circuitry of the TPS735-Q1 family of devices is designed to protect against overload conditions. This protection circuitry is not intended to replace proper heatsinking. Continuously running the TPS735-Q1 family of devices into thermal shutdown degrades device reliability.

10.1.3 Package Mounting

Solder pad footprint recommendations for the TPS735-Q1 family of devices are available from the Texas Instruments web site at www.ti.com.

10.1.4 Power Dissipation

The ability to remove heat from the die is different for each package type, presenting different considerations in the PCB layout. The PCB area around the device that is free of other components moves the heat from the device to the ambient air. Performance data for JEDEC low- and high-K boards are given in the [Thermal Information](#) table. Using heavier copper increases the effectiveness in removing heat from the device. The addition of plated through-holes to heat-dissipating layers also improves the heatsink effectiveness.

Layout Guidelines (continued)

Power dissipation depends on input voltage and load conditions. Power dissipation is equal to the product of the output current and the voltage drop across the output pass element, as shown in [Equation 2](#).

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} \quad (2)$$

NOTE

When the device is used in a condition of high input and low output voltages, P_D can exceed the junction temperature rating even when the ambient temperature is at room temperature.

[Equation 3](#) is an example calculation for the power dissipation (P_D) of the DRB package.

$$P_D = (6.5 \text{ V} - 1.2 \text{ V}) \times 500 \text{ mA} = 2.65 \text{ W} \quad (3)$$

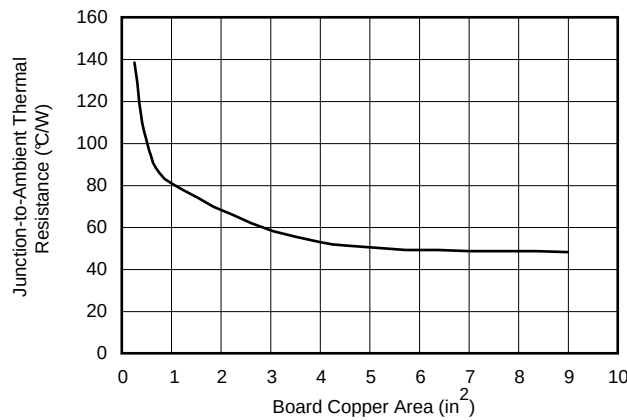
Power dissipation can be minimized and greater efficiency can be achieved by using the lowest possible input voltage necessary to achieve the required output performance.

On the DRB package, the primary conduction path for heat is through the exposed thermal pad to the PCB. The pad can be connected to ground or left floating; however, the pad must be attached to an appropriate amount of copper PCB area to ensure the device does not overheat. The maximum allowable junction-to-ambient thermal resistance depends on the maximum ambient temperature, maximum device junction temperature, and power dissipation of the device. Use [Equation 4](#) to calculate the maximum junction-to-ambient thermal resistance.

$$R_{\theta JA} = \frac{(125^{\circ}\text{C} - T_A)}{P_D} \quad (4)$$

Layout Guidelines (continued)

Knowing the maximum $R_{\theta JA}$, the minimum amount of PCB copper area needed for appropriate heatsinking can be estimated using [Figure 22](#).



NOTE: The $R_{\theta JA}$ value at a board size of 9 in² (that is, 3 in × 3 in) is a JEDEC standard.

Figure 22. $R_{\theta JA}$ vs Board Size

[Figure 22](#) shows the variation of $R_{\theta JA}$ as a function of copper area in the board that is connected to the thermal pad. [Figure 22](#) is intended only as a guideline to demonstrate the effects of heat spreading in the ground plane and is not to be used to calculate actual thermal performance.

NOTE

When the device is mounted on an application PCB, TI strongly recommends using Ψ_{JT} and Ψ_{JB} , as explained in the [Estimating Junction Temperature](#) section.

10.1.5 Estimating Junction Temperature

Using the thermal metrics Ψ_{JT} and Ψ_{JB} , as shown in the [Thermal Information](#) table, the junction temperature can be estimated with the corresponding formulas (given in [Equation 5](#)).

$$\Psi_{JT} : T_J = T_T + \Psi_{JT} \times P_D$$

$$\Psi_{JB} : T_J = T_B + \Psi_{JB} \times P_D$$

where:

- P_D is the power dissipation calculated with [Equation 2](#),
- T_T is the temperature at the center-top of the device package, and
- T_B is the PCB temperature measured 1 mm away from the device package on the PCB surface (as shown in [Figure 23](#)).

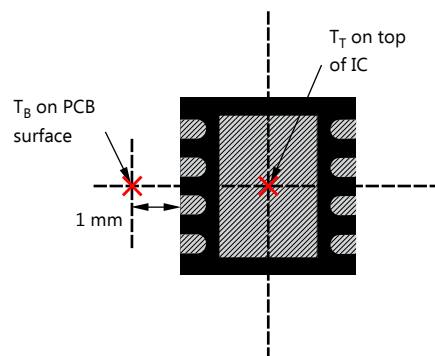


Figure 23. Measuring Points for T_T and T_B

Layout Guidelines (continued)

NOTE

Both T_T and T_B can be measured on actual application boards using an infrared thermometer.

For more information about measuring T_T and T_B , see the application note, *Using New Thermal Metrics*, [SBVA025](#).

According to [Figure 24](#), the thermal metrics (Ψ_{JT} and Ψ_{JB}) have very little dependency on copper area. Using Ψ_{JT} or Ψ_{JB} with [Equation 5](#) is a good way to estimate T_J by simply measuring T_T or T_B on an application board.

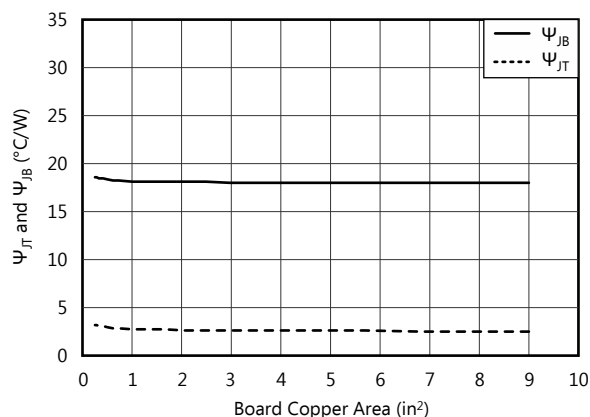
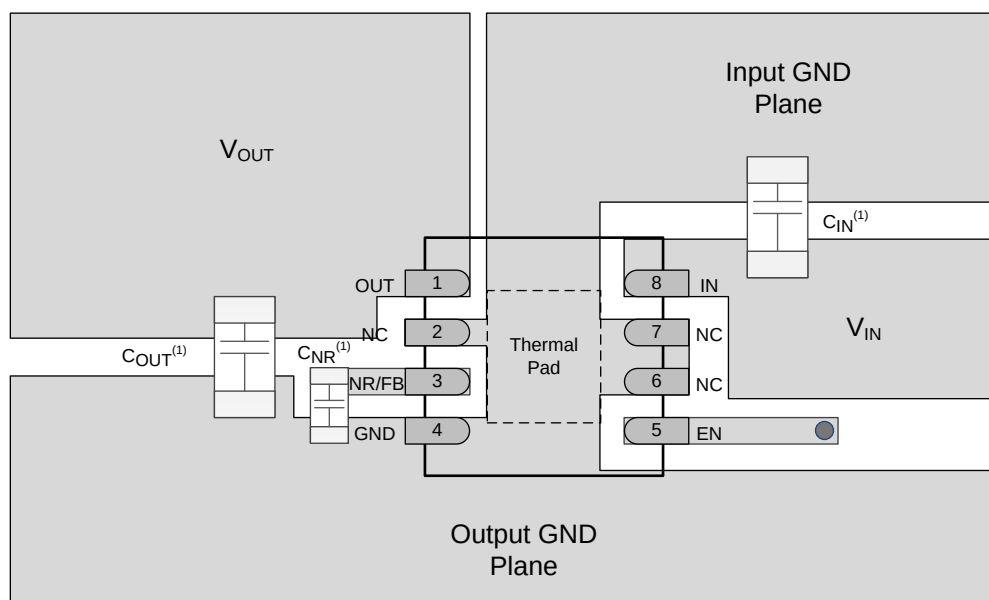


Figure 24. Ψ_{JT} and Ψ_{JB} vs Board Size

10.2 Layout Example



(1) C_{IN} and C_{OUT} are 0603 capacitors and C_{NR} is a 0402 capacitor. The footprint is shown to scale with package size.

Figure 25. TPS735-Q1 Fixed Version Layout Reference Diagram

11 デバイスおよびドキュメントのサポート

11.1 デバイス・サポート

11.1.1 デバイスの項目表記

表 2. デバイスの項目表記⁽¹⁾

製品名	V _{OUT}
TPS735xx(x) yyy z	xx(x) は公称出力電圧です。出力電圧の分解能が 100mV の場合、注文番号に 2 桁が使用されます。それ以外の場合は 3 桁が使用されます (例: 33 = 3.3V、125 = 1.25V)。 YYYはパッケージ指定子です。 Zはテープ・アンド・リール数量です (R = 3,000、T = 250)。 01は可変出力バージョンです。

(1) 最新のパッケージおよび発注情報については、このデータシートの末尾にあるパッケージ・オプションについての付録を参照するか、TIのWebサイト (www.ti.com) をご覧ください。

11.2 ドキュメントのサポート

11.2.1 関連資料

関連資料については、以下を参照してください。

- テキサス・インスツルメンツ、『[半導体および IC パッケージの熱評価基準](#)』アプリケーション・レポート
- テキサス・インスツルメンツ、『[TPS735xxEVM-276](#)』ユーザー・ガイド
- テキサス・インスツルメンツ、『[新しい熱評価基準の解説](#)』アプリケーション・レポート

11.3 ドキュメントの更新通知を受け取る方法

ドキュメントの更新についての通知を受け取るには、ti.com のデバイス製品フォルダを開いてください。右上の「アラートを受け取る」をクリックして登録すると、変更されたすべての製品情報に関するダイジェストを毎週受け取れます。変更の詳細については、修正されたドキュメントに含まれている改訂履歴をご覧ください。

11.4 コミュニティ・リソース

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.

11.5 商標

E2E is a trademark of Texas Instruments.

PowerPAD is a trademark of Texas Instruments, Inc.

All other trademarks are the property of their respective owners.

11.6 静電気放電に関する注意事項



すべての集積回路は、適切なESD保護方法を用いて、取扱いと保存を行うようにして下さい。

静電気放電はわずかな性能の低下から完全なデバイスの故障に至るまで、様々な損傷を与えます。高精度の集積回路は、損傷に対して敏感であり、極めてわずかなパラメータの変化により、デバイスに規定された仕様に適合しなくなる場合があります。

11.7 Glossary

[SLYZ022](#) — TI Glossary.

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

12 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。この情報は、そのファミリのデバイスについて利用可能な最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

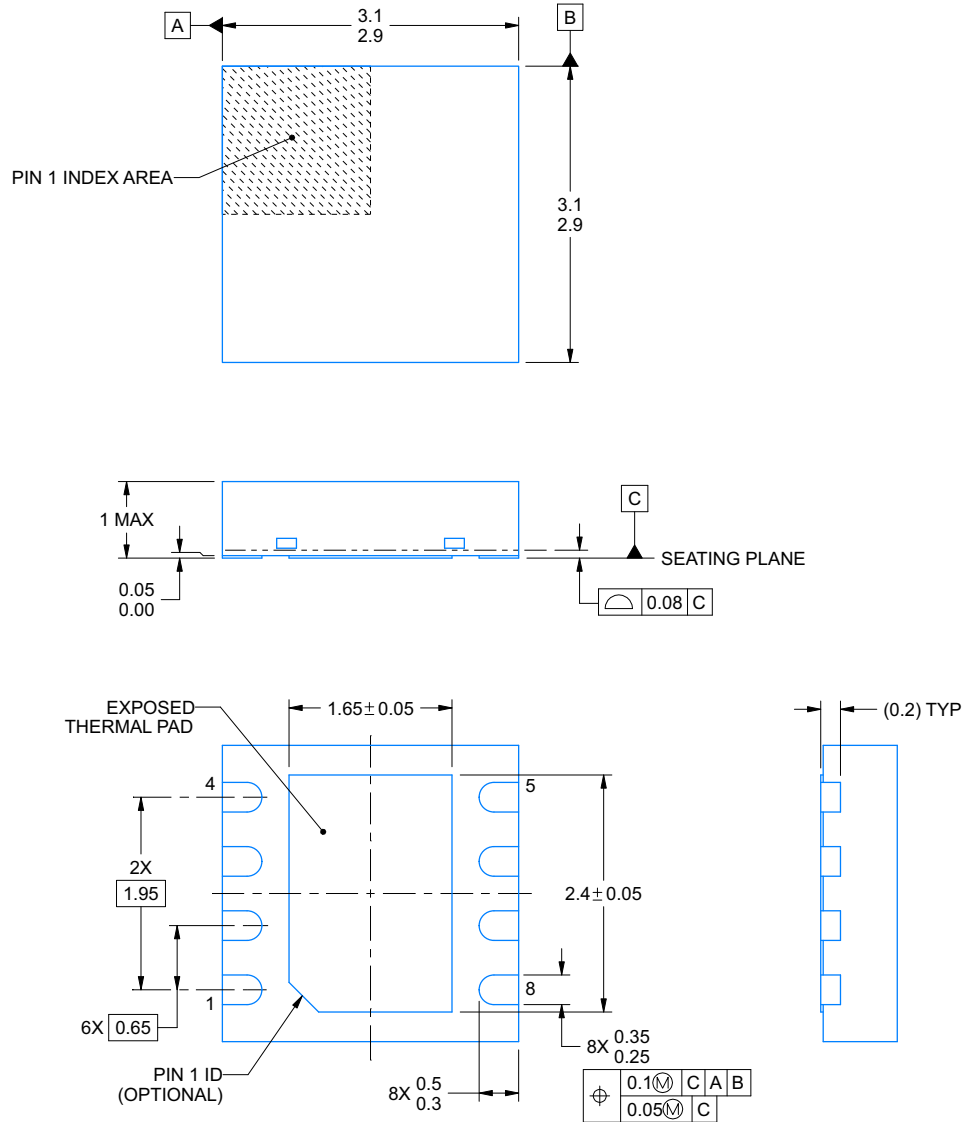


DRB0008B

PACKAGE OUTLINE

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



4218876/A 12/2017

NOTES:

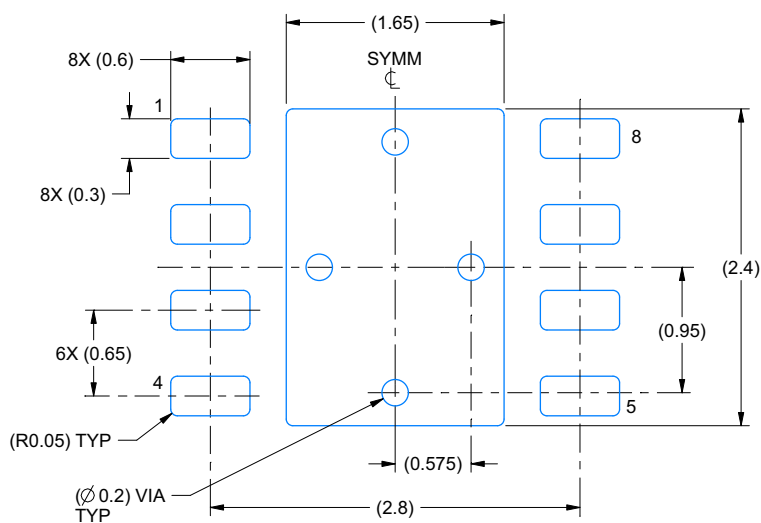
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE BOARD LAYOUT

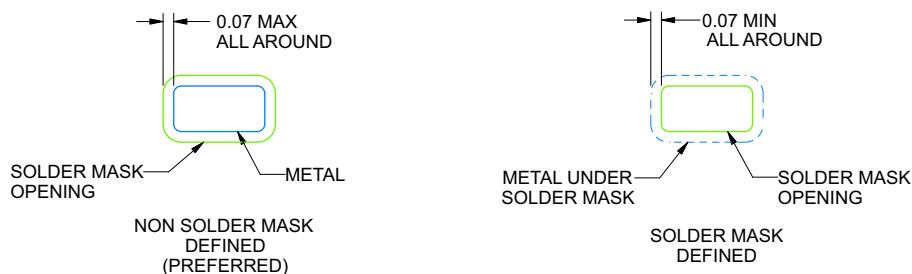
DRB0008B

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE
SCALE:20X



SOLDER MASK DETAILS

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NOTES: (continued)

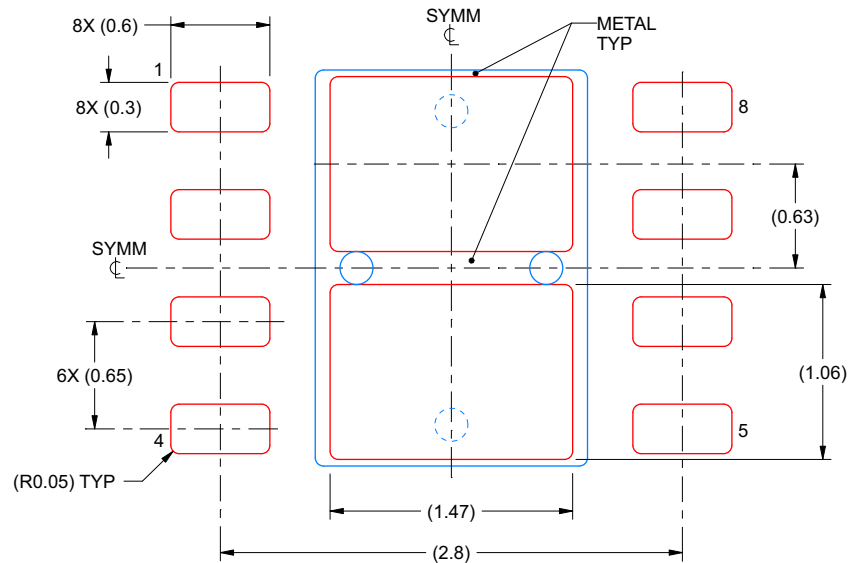
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/sluea271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

EXAMPLE STENCIL DESIGN

DRB0008B

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD
81% PRINTED SOLDER COVERAGE BY AREA
SCALE:25X

4218876/A 12/2017

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TPS73501QDRBRQ1	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	501DRB
TPS73501QDRBRQ1.B	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	501DRB
TPS73512QDRBRQ1	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	512DRB
TPS73512QDRBRQ1.B	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	512DRB
TPS73515QDRBRQ1	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	515DRB
TPS73515QDRBRQ1.B	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	515DRB
TPS73518QDRBRQ1	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	518DRB
TPS73518QDRBRQ1.B	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	518DRB
TPS73525QDRBRQ1	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	525DRB
TPS73525QDRBRQ1.B	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	525DRB
TPS73527QDRBRQ1	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	527DRB
TPS73527QDRBRQ1.B	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	527DRB
TPS73530QDRBRQ1	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	530DRB
TPS73530QDRBRQ1.B	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	530DRB
TPS73533QDRBRQ1	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	533DRB
TPS73533QDRBRQ1.B	Active	Production	SON (DRB) 8	3000 LARGE T&R	Yes	NIPDAU	Level-3-260C-168 HR	-40 to 125	533DRB

⁽¹⁾ **Status:** For more details on status, see our [product life cycle](#).

⁽²⁾ **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

⁽³⁾ **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

⁽⁴⁾ **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

⁽⁵⁾ **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) Part marking: There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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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 TPS735-Q1 :

- Catalog : [TPS735](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

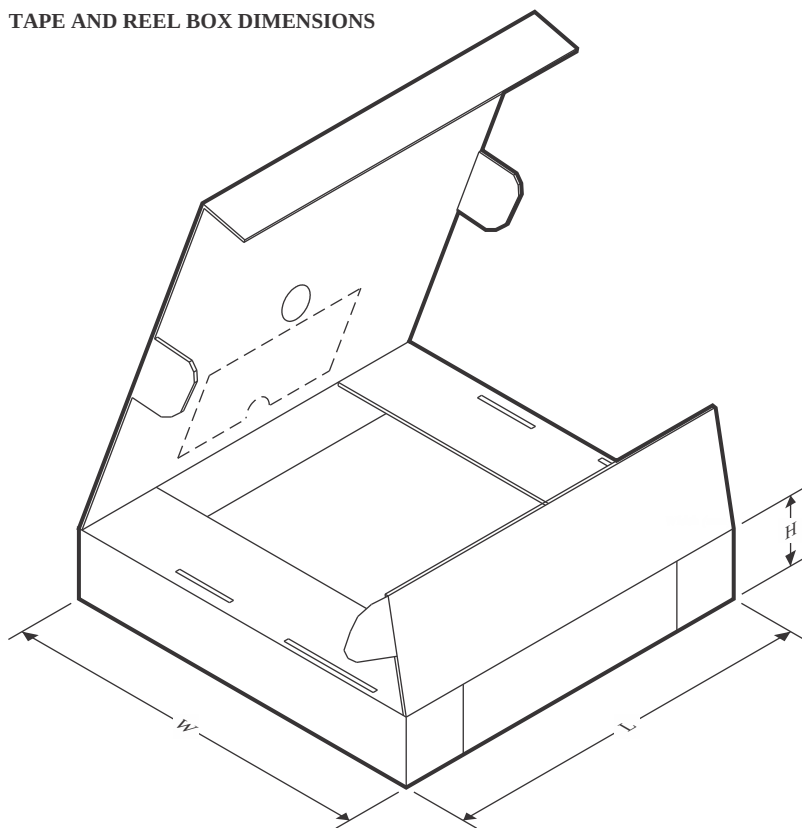
TAPE AND REEL INFORMATION



*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
TPS73501QDRBRQ1	SON	DRB	8	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
TPS73512QDRBRQ1	SON	DRB	8	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
TPS73515QDRBRQ1	SON	DRB	8	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
TPS73518QDRBRQ1	SON	DRB	8	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
TPS73525QDRBRQ1	SON	DRB	8	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
TPS73527QDRBRQ1	SON	DRB	8	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
TPS73530QDRBRQ1	SON	DRB	8	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
TPS73533QDRBRQ1	SON	DRB	8	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TPS73501QDRBRQ1	SON	DRB	8	3000	353.0	353.0	32.0
TPS73512QDRBRQ1	SON	DRB	8	3000	353.0	353.0	32.0
TPS73515QDRBRQ1	SON	DRB	8	3000	353.0	353.0	32.0
TPS73518QDRBRQ1	SON	DRB	8	3000	353.0	353.0	32.0
TPS73525QDRBRQ1	SON	DRB	8	3000	353.0	353.0	32.0
TPS73527QDRBRQ1	SON	DRB	8	3000	353.0	353.0	32.0
TPS73530QDRBRQ1	SON	DRB	8	3000	353.0	353.0	32.0
TPS73533QDRBRQ1	SON	DRB	8	3000	353.0	353.0	32.0

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