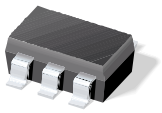


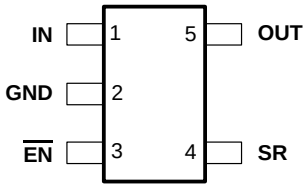
SLVS382A – JUNE 2001 – REVISED JULY 2001

150-mA LOW-NOISE LDO WITH IN-RUSH CURRENT CONTROL FOR USB APPLICATION

FEATURES

- **150-mA Low-Dropout Regulator**
- **Available in 2.5 V, 3.3 V**
- **Programmable Slew Rate Control**
- **Output Noise Typically 56 μV_{RMS}**
- **Only 17 μA Quiescent Current at 150 mA**
- **1 μA Quiescent Current in Standby Mode**
- **Dropout Voltage Typically 150 mV at 150 mA (TPS78833)**
- **Over Current Limitation**
- **–40°C to 125°C Operating Junction Temperature Range**
- **5-Pin SOT-23 (DBV) Package**

DBV PACKAGE
(TOP VIEW)



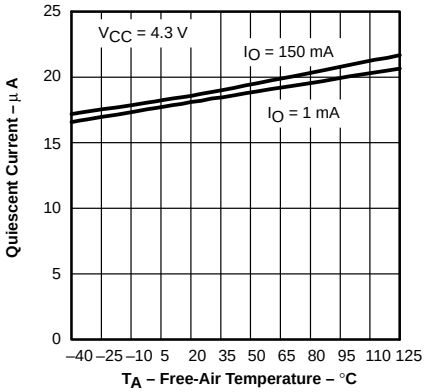
DESCRIPTION

The TPS78825 and TPS78833 are very small (SOT-23) package, low-noise LDOs that regulate the output voltage to 2.5 V and 3.3 V with input voltage ranging from 2.7 V to an absolute maximum of 13.5 V. These devices output 150 mA with a peak current of 350 mA (typ). The TPS788xx family uses the SR pin to program the output voltage slew rate to control the in-rush current. This is specifically used in the USB application where large load capacitance is present at start-up. The TPS788xx devices use only 17 μA of quiescent current and exhibit only 56 μV_{RMS} of output voltage noise using a 10 μF output capacitor.

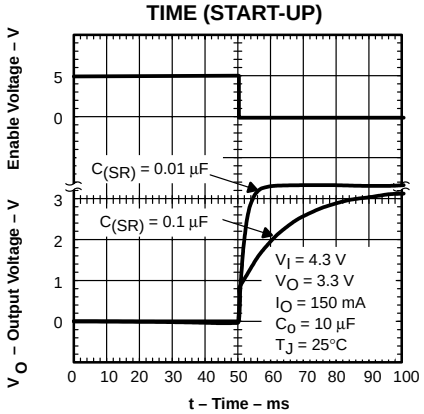
The usual PNP pass transistor has been replaced by a PMOS pass element. Because the PMOS pass element behaves as a low-value resistor, the dropout voltage is very low, typically 150 mV at 150 mA of load current, and is directly proportional to the load current.

The TPS788xx also features a logic-enabled sleep mode to shut down the regulator, reducing quiescent current to 1 μA typical at T_J = 25°C.

QUIESCENT CURRENT
vs
FREE-AIR TEMPERATURE



OUTPUT VOLTAGE, ENABLE VOLTAGE
vs
TIME (START-UP)



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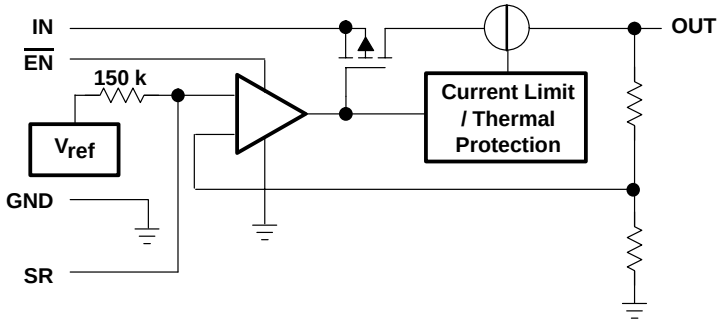
AVAILABLE OPTIONS

T_J	VOLTAGE	PACKAGE	PART NUMBER		SYMBOL
–40°C to 125°C	2.5 V	SOT-23 (DBV)	TPS78825DBVT†	TPS78825DBVR‡	PGZI
	3.3 V		TPS78833DBVT	TPS78833DBVR	PGTI

† The DBVT indicates tape and reel of 250 parts.
‡ The DBVR indicates tape and reel of 3000 parts.

functional block diagram



Terminal Functions

TERMINAL NAME	TERMINAL NO.	I/O	DESCRIPTION
$\overline{EN}$	3	I	Active low enable
GND	2		Regulator ground
IN	1	I	The IN terminal is the input to the device.
OUT	5	O	The OUT terminal is the regulated output of the device.
SR	4	I	The SR terminal is used to control the in-rush current.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)§

Input voltage range (see Note 1) . . . . . –0.3 V to 13.5 V
Voltage range at EN . . . . . –0.3 V to V_I + 0.3 V
Voltage on OUT . . . . . 7 V
Peak output current . . . . . Internally limited
ESD rating, HBM . . . . . 2 kV
Continuous total power dissipation . . . . . See Dissipation Rating Table
Operating virtual junction temperature range, T_J . . . . . –40°C to 150°C
Operating ambient temperature range, T_A . . . . . –40°C to 85°C
Storage temperature range, T_{stg} . . . . . –65°C to 150°C

§ 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.

NOTE 1: All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

BOARD	PACKAGE	$R_{\theta JC}$	$R_{\theta JA}$	DERATING FACTOR ABOVE T_A = 25°C	$T_A \le 25°C$ POWER RATING	T_A = 70°C POWER RATING	T_A = 85°C POWER RATING
Low K¶	DBV	65.8°C/W	259°C/W	3.9 mW/°C	386 mW	212 mW	154 mW
High K#	DBV	65.8°C/W	180°C/W	5.6 mW/°C	555 mW	305 mW	222 mW

¶ 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.
# 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.

electrical characteristics over recommended operating free-air temperature range $\overline{EN}$ = 0, T_J = –40 to 125 °C, $V_I = V_{O(typ)} + 1$ V, I_O = 1 mA, C_o = 4.7 µF, $C_{(SR)}$ = 0.01 µF (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_I Input voltage (see Note 2)				2.7		10	V
I_O Continuous output current (see Note 3)				0		150	mA
T_J Operating junction temperature				–40		125	°C
Output voltage	TPS78825	T_J = 25°C			2.5		V
		10 µA< I_O < 150 mA, 3.5 V < V_I < 10 V		2.425		2.575	
	TPS78833	T_J = 25°C			3.3		
		10 µA< I_O < 150 mA, 3.8 V < V_I < 10 V		3.201		3.399	
Quiescent current (GND current)		10 µA< I_O < 450 mA, T_J = 25°C			17		µA
		10 µA< I_O < 150 mA				28	
Load regulation		10 µA< I_O < 200 mA, T_J = 25°C			12		mV
Output voltage line regulation ($\Delta V_O/V_O$) (see Note 5)		V_O + 1 V < V_I ≤ 10 V, T_J = 25°C			0.04		%/V
		V_O + 1 V < V_I ≤ 10 V				0.1	
Output noise voltage (TPS78833)		BW = 200 Hz to 100 kHz, I_O = 150 mA, T_J = 25°C, C_o = 10 µF, $C_{(SR)}$ = 0.47 µF			56		μV_{RMS}
Time, start-up (TPS78833)		R_L = 22 Ω, C_o = 10 µF, T_J = 25°C	$C_{(byp)}$ = 0.01 µF		10		ms
			$C_{(byp)}$ = 0.1 µF		50		
			$C_{(byp)}$ = 0.47 µF		300		
Output current limit		V_O = 0 V (see Note 4)			350	750	mA
Standby current		EN = 0 V, 2.7 V < V_I < 10 V			1	2	µA
High level enable input voltage		2.7 V < V_I < 10 V		1.7			V
Low level enable input voltage		2.7 V < V_I < 10 V				0.9	V
Input current (EN)		EN = 0		–1		1	µA
Power supply ripple rejection	TPS78833	f = 1 kHz, T_J = 25°C, C_o = 10 µF	$C_{(SL)}$ = 0.01 µF, I_O = 150 mA,		70		dB
Dropout voltage (see Note 6)	TPS78833	I_O = 150 mA, T_J = 25°C			150		mV
		I_O = 150 mA				300	

NOTES: 2. To calculate the minimum input voltage for your maximum output current, use the following formula:
$V_I(min) = V_O(max) + V_{DO}$ (max load)

3. 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.

4. The minimum IN operating voltage is 2.7 V or $V_{O(typ)}$ + 1 V, whichever is greater. The maximum IN voltage is 5.5 V. The maximum output current is 200 mA.

5. If $V_O \le 2.5$ V then V_{Imin} = 2.7 V, V_{Imax} = 5.5 V:

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

If V_O > 2.5 V then $V_{Imin} = V_O$ + 1 V, V_{Imax} = 5.5 V.

6. IN voltage equals $V_O(typ)$ – 100 mV

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE vs LOAD CURRENT

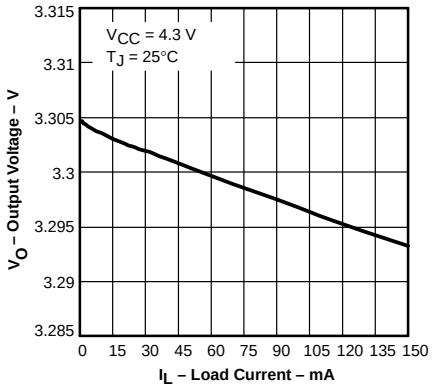


Figure 1

OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE

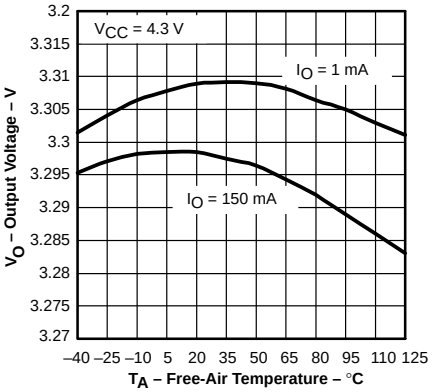


Figure 2

QUIESCENT CURRENT vs FREE-AIR TEMPERATURE

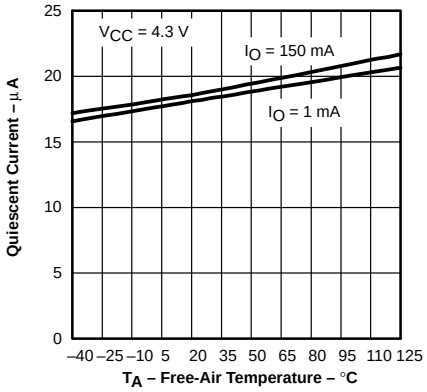


Figure 3

OUTPUT SPECTRAL NOISE DENSITY vs FREQUENCY

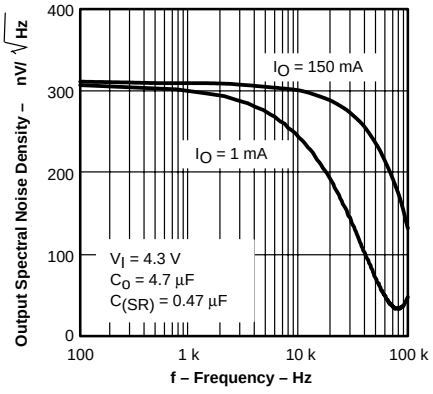


Figure 4

ROOT MEAN SQUARED OUTPUT NOISE vs SLEW RATE CAPACITANCE

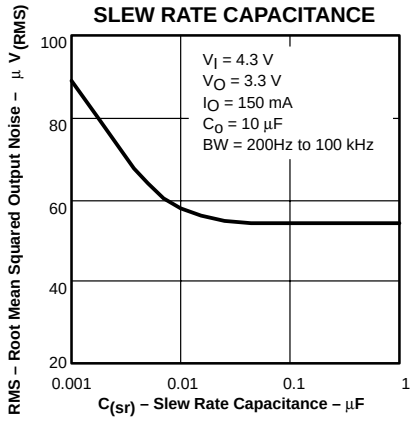


Figure 5

OUTPUT IMPEDANCE vs FREQUENCY

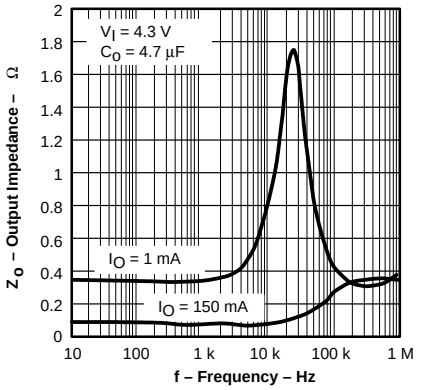


Figure 6

DROPOUT VOLTAGE vs FREE-AIR TEMPERATURE

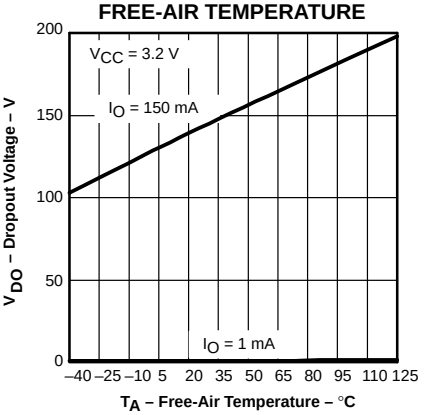


Figure 7

RIPPLE REJECTION vs FREQUENCY

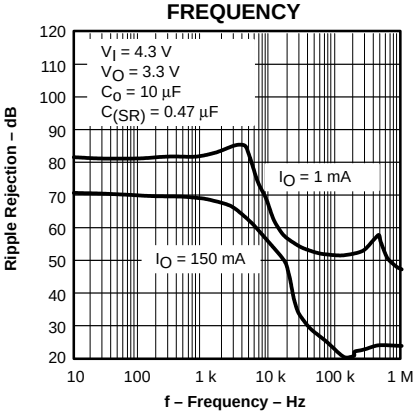


Figure 8

OUTPUT VOLTAGE, ENABLE VOLTAGE vs TIME (START-UP)

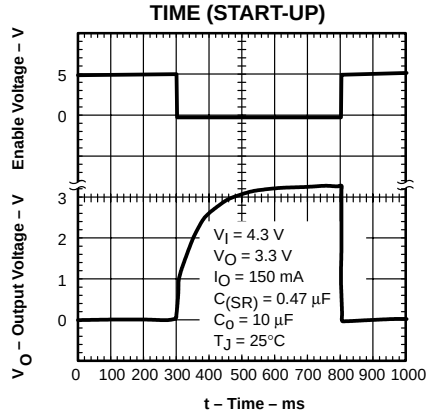


Figure 9

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE, ENABLE VOLTAGE vs TIME (START-UP)

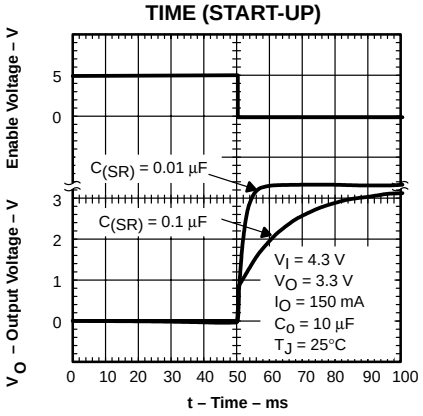


Figure 10

LINE TRANSIENT RESPONSE

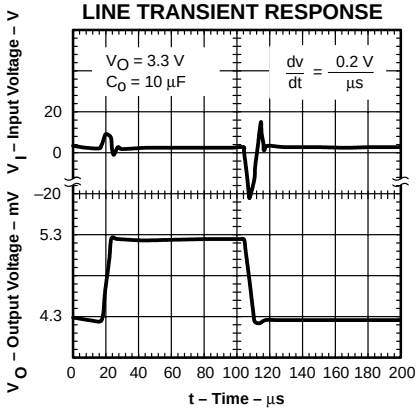


Figure 11

LOAD TRANSIENT RESPONSE

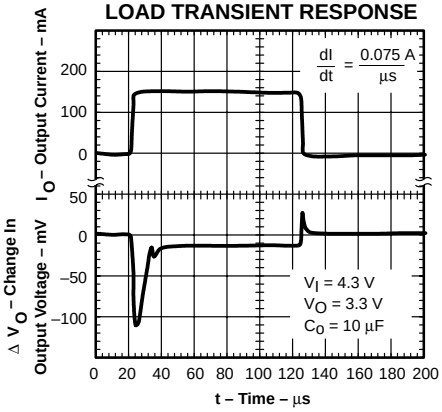


Figure 12

TYPICAL REGIONS OF STABILITY EQUIVALENT SERIES RESISTANCE (ESR) vs OUTPUT CURRENT

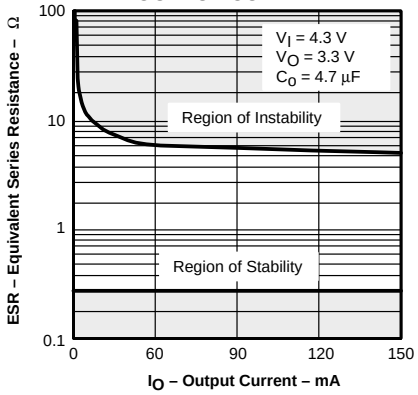


Figure 13

TYPICAL REGIONS OF STABILITY EQUIVALENT SERIES RESISTANCE (ESR) vs OUTPUT CURRENT

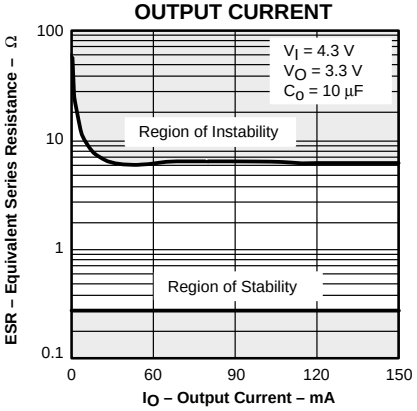


Figure 14

APPLICATION INFORMATION

The TPS788xx family of low-dropout (LDO) regulators has been optimized for use in battery-operated equipment. It features extremely low dropout voltages, low output noise, low quiescent current (17 μA typically), and enable inputs to reduce supply currents to 1 μA when the regulator is turned off. A typical application circuit is shown in Figure 15.

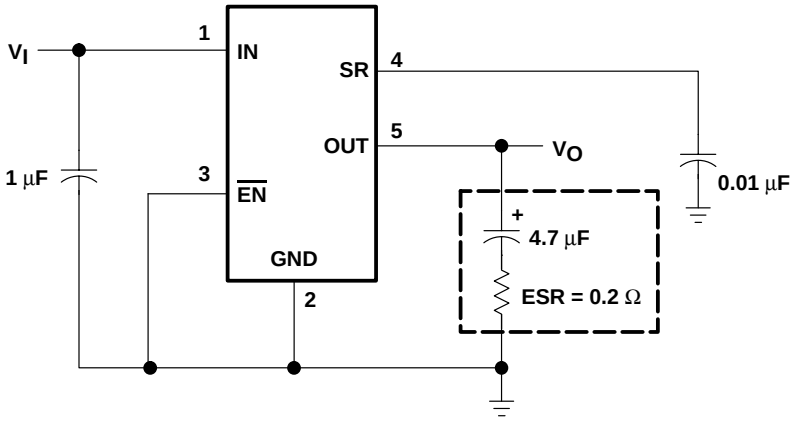


Figure 15. Typical Application Circuit

external capacitor requirements

Although not required, a 0.047-μF or larger ceramic input bypass capacitor, connected between IN and GND and located close to the TPS788xx, is recommended 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 TPS788xx requires an output capacitor connected between OUT and GND to stabilize the internal control loop. The minimum recommended capacitance is 4.7 μF. The ESR (equivalent series resistance) of the capacitor should be between 0.2 Ω and 10 Ω. to ensure stability. Capacitor values larger than 4.7 μF are acceptable, and allow the use of smaller ESR values. Capacitances less than 4.7 μF 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 μF surface-mount solid tantalum capacitors, including devices from Sprague, Kemet, and Nichico, meet the ESR requirements stated above. Multilayer ceramic capacitors may have very small equivalent series resistances and may thus require the addition of a low value series resistor to ensure stability.

CAPACITOR SELECTION

PART NO.	MFR.	VALUE	MAX ESR†	SIZE (H × L × W)†
T494B475K016AS	Kemet	4.7 μF	1.5 Ω	1.9 × 3.5 × 2.8
195D106x0016x2T	Sprague	10 μF	1.5 Ω	1.3 × 7.0 × 2.7
695D106x003562T	Sprague	10 μF	1.3 Ω	2.5 × 7.6 × 2.5
TPSC475K035R0600	AVX	4.7 μF	0.6 Ω	2.6 × 6.0 × 3.2

† Size is in mm. The ESR maximum resistance is in Ohms at 100 kHz and T_A = 25°C. Contact the manufacturer for the minimum ESR values.

APPLICATION INFORMATION

external capacitor requirements (continued)

The external bypass capacitor, used in conjunction with an internal resistor to form a low-pass filter, should be a low ESR ceramic capacitor. For example, the TPS78833 exhibits only 56 μV_{RMS} of output voltage noise using a 0.01 μF ceramic bypass capacitor and a 10-μF ceramic output capacitor. Note that the output will start up slower as the bypass capacitance increases due to the RC time constant at the bypass pin that is created by the internal 150-kΩ resistor and external capacitor.

power dissipation and junction temperature

Specified regulator operation is assured to a junction temperature of 125°C; the maximum junction temperature should 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 the following equation:

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

Where:

$T_J max$ 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.

The regulator dissipation is calculated using:

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

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

regulator protection

The TPS788xx PMOS-pass transistor has a built-in back diode that conducts reverse current when the input voltage drops below the output voltage (e.g., 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 TPS788xx features internal current limiting and thermal protection. During normal operation, the TPS78833 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 should 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.

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)
TPS78825DBVR	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	PGZI
TPS78825DBVR.A	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	PGZI
TPS78825DBVT	Active	Production	SOT-23 (DBV) | 5	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	PGZI
TPS78825DBVT.A	Active	Production	SOT-23 (DBV) | 5	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	PGZI
TPS78833DBVR	NRND	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	PGTI
TPS78833DBVR.A	NRND	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	PGTI
TPS78833DBVT	Active	Production	SOT-23 (DBV) | 5	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	PGTI
TPS78833DBVT.A	Active	Production	SOT-23 (DBV) | 5	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	PGTI

(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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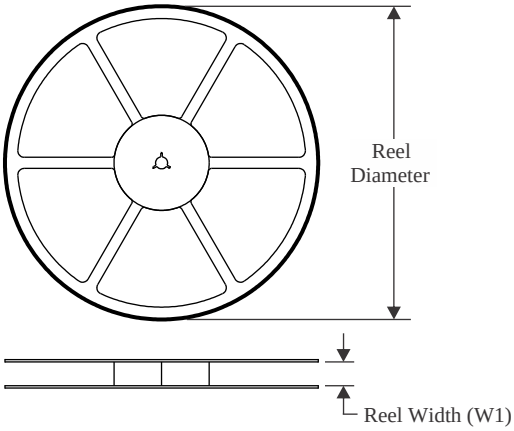
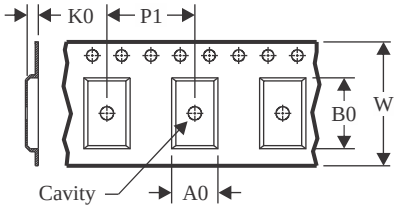
TAPE AND REEL INFORMATION

REEL DIMENSIONS

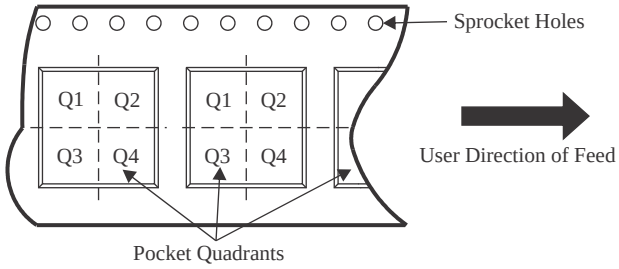


TAPE DIMENSIONS



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

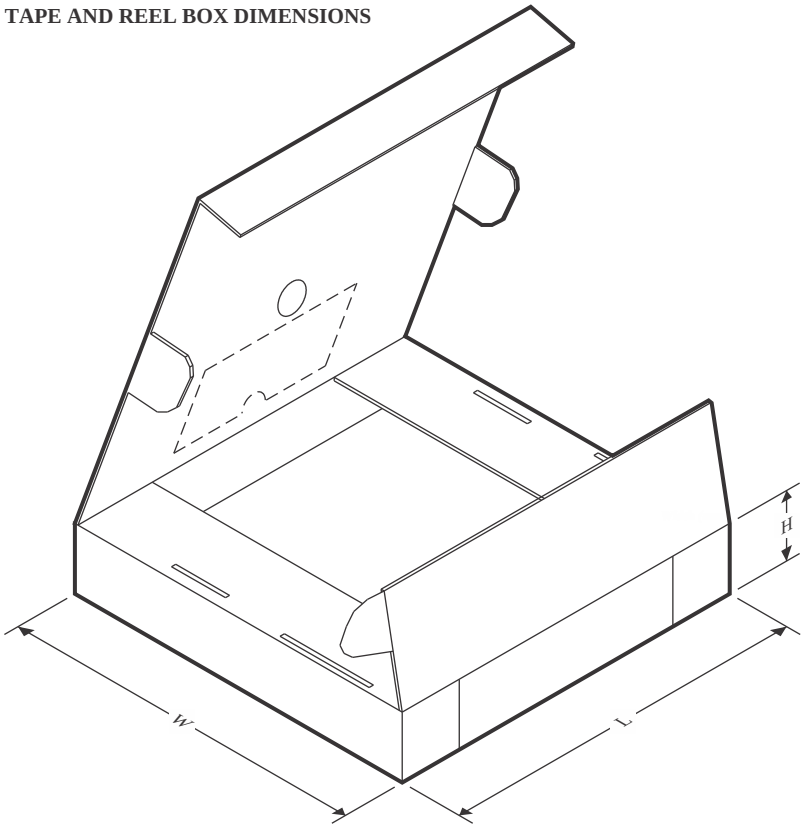
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TPS78825DBVR	SOT-23	DBV	5	3000	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS78825DBVT	SOT-23	DBV	5	250	180.0	9.0	3.15	3.2	1.4	4.0	8.0	Q3
TPS78833DBVR	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TPS78833DBVT	SOT-23	DBV	5	250	180.0	8.4	3.2	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)
TPS78825DBVR	SOT-23	DBV	5	3000	182.0	182.0	20.0
TPS78825DBVT	SOT-23	DBV	5	250	182.0	182.0	20.0
TPS78833DBVR	SOT-23	DBV	5	3000	210.0	185.0	35.0
TPS78833DBVT	SOT-23	DBV	5	250	210.0	185.0	35.0

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