

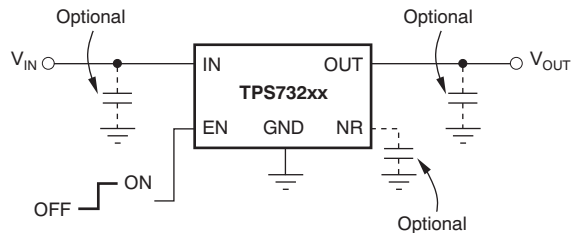
## Cap-Free, NMOS, 250mA Low Dropout Regulator with Reverse Current Protection

### FEATURES

- **Stable with No Output Capacitor or Any Value or Type of Capacitor**
- **Input Voltage Range: 1.7V to 5.5V**
- **Ultralow Dropout Voltage: 40mV Typ at 250mA**
- **Excellent Load Transient Response—with or without Optional Output Capacitor**
- **New NMOS Topology Provides Low Reverse Leakage Current**
- **Low Noise: 30 $\mu$ V<sub>RMS</sub> Typ (10kHz to 100kHz)**
- **0.5% Initial Accuracy**
- **1% Overall Accuracy (Line, Load, and Temperature)**
- **Less Than 1 $\mu$ A Max I<sub>Q</sub> in Shutdown Mode**
- **Thermal Shutdown and Specified Min/Max Current Limit Protection**
- **Available in Multiple Output Voltage Versions**
  - Fixed Outputs of 1.20V to 5.0V
  - Adjustable Outputs from 1.20V to 5.5V
  - Custom Outputs Available

### APPLICATIONS

- **Portable/Battery-Powered Equipment**
- **Post-Regulation for Switching Supplies**
- **Noise-Sensitive Circuitry such as VCOs**
- **Point of Load Regulation for DSPs, FPGAs, ASICs, and Microprocessors**

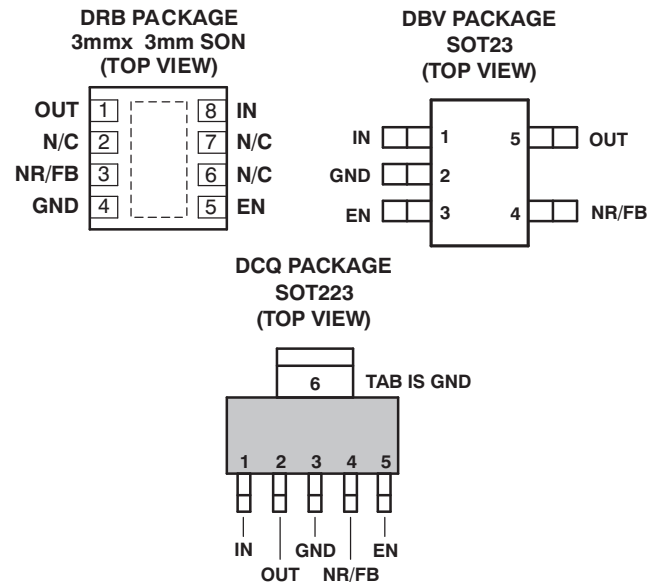


Typical Application Circuit for Fixed-Voltage Versions

### DESCRIPTION

The TPS732xx family of low-dropout (LDO) voltage regulators uses a new topology: an NMOS pass element in a voltage-follower configuration. This topology is stable using output capacitors with low ESR, and even allows operation without a capacitor. It also provides high reverse blockage (low reverse current) and ground pin current that is nearly constant over all values of output current.

The TPS732xx uses an advanced BiCMOS process to yield high precision while delivering very low dropout voltages and low ground pin current. Current consumption, when not enabled, is under 1 $\mu$ A and ideal for portable applications. The extremely low output noise (30 $\mu$ V<sub>RMS</sub> with 0.1 $\mu$ F C<sub>NR</sub>) is ideal for powering VCOs. These devices are protected by thermal shutdown and foldback current limit.



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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

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

| PRODUCT        | V <sub>OUT</sub> <sup>(2)</sup>                                                                                                                 |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| TPS732xx yy yz | XX is nominal output voltage (for example, 25 = 2.5V, 01 = Adjustable <sup>(3)</sup> ).<br>YYY is package designator.<br>Z is package quantity. |

- (1) For the most current specification and package information, refer to the Package Option Addendum located at the end of this datasheet or see the TI website at [www.ti.com](http://www.ti.com).
- (2) Most output voltages of 1.25V and 1.3V to 5.0V in 100mV increments are available through the use of innovative factory EEPROM programming; minimum order quantities may apply. Contact factory for details and availability.
- (3) For fixed 1.20V operation, tie FB to OUT.

### ABSOLUTE MAXIMUM RATINGS

over operating junction temperature range unless otherwise noted<sup>(1)</sup>

| PARAMETER                                  | TPS732xx                                      | UNIT |
|--------------------------------------------|-----------------------------------------------|------|
| V <sub>IN</sub> range                      | –0.3 to 6.0                                   | V    |
| V <sub>EN</sub> range                      | –0.3 to 6.0                                   | V    |
| V <sub>OUT</sub> range                     | –0.3 to 5.5                                   | V    |
| V <sub>NR</sub> , V <sub>FB</sub> range    | –0.3 to 6.0                                   | V    |
| Peak output current                        | Internally limited                            |      |
| Output short-circuit duration              | Indefinite                                    |      |
| Continuous total power dissipation         | See <a href="#">Thermal Information</a> Table |      |
| Junction temperature range, T <sub>J</sub> | –55 to +150                                   | °C   |
| Storage temperature range                  | –65 to +150                                   | °C   |
| ESD rating, HBM                            | 2                                             | kV   |
| ESD rating, CDM                            | 500                                           | V    |

- (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 the Electrical Characteristics is not implied. Exposure to absolute maximum rated conditions for extended periods may affect device reliability.

## THERMAL INFORMATION

| THERMAL METRIC <sup>(1)(2)</sup> |                                                             | TPS732xx <sup>(3)</sup> |        |        | UNITS |
|----------------------------------|-------------------------------------------------------------|-------------------------|--------|--------|-------|
|                                  |                                                             | DRB                     | DCQ    | DBV    |       |
|                                  |                                                             | 8 PINS                  | 6 PINS | 5 PINS |       |
| $\theta_{JA}$                    | Junction-to-ambient thermal resistance <sup>(4)</sup>       | 47.8                    | 70.4   | 180    | °C/W  |
| $\theta_{JCTop}$                 | Junction-to-case (top) thermal resistance <sup>(5)</sup>    | 83                      | 70     | 64     |       |
| $\theta_{JB}$                    | Junction-to-board thermal resistance <sup>(6)</sup>         | N/A                     | N/A    | 35     |       |
| $\psi_{JT}$                      | Junction-to-top characterization parameter <sup>(7)</sup>   | 2.1                     | 6.8    | N/A    |       |
| $\psi_{JB}$                      | Junction-to-board characterization parameter <sup>(8)</sup> | 17.8                    | 30.1   | N/A    |       |
| $\theta_{JCbott}$                | Junction-to-case (bottom) thermal resistance <sup>(9)</sup> | 12.1                    | 6.3    | N/A    |       |

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953A](#).
- (2) For thermal estimates of this device based on PCB copper area, see the [TI PCB Thermal Calculator](#).
- (3) Thermal data for the DRB, DCQ, and DRV packages are derived by thermal simulations based on JEDEC-standard methodology as specified in the JESD51 series. The following assumptions are used in the simulations:
  - (a) i. DRB: The exposed pad is connected to the PCB ground layer through a 2x2 thermal via array.
  - ii. DCQ: The exposed pad is connected to the PCB ground layer through a 3x2 thermal via array.
  - iii. DBV: There is no exposed pad with the DBV package.
  - (b) i. DRB: The top and bottom copper layers are assumed to have a 20% thermal conductivity of copper representing a 20% copper coverage.
  - ii. DCQ: Each of top and bottom copper layers has a dedicated pattern for 20% copper coverage.
  - iii. DBV: The top and bottom copper layers are assumed to have a 20% thermal conductivity of copper representing a 20% copper coverage.
  - (c) These data were generated with only a single device at the center of a JEDEC high-K (2s2p) board with 3in × 3in copper area. To understand the effects of the copper area on thermal performance, see the [Power Dissipation](#) section of this data sheet.
- (4) The junction-to-ambient thermal resistance under natural convection is obtained in a simulation on a JEDEC-standard, high-K board, as specified in JESD51-7, in an environment described in JESD51-2a.
- (5) The junction-to-case (top) thermal resistance is obtained by simulating a cold plate test on the top of the package. No specific JEDEC-standard test exists, but a close description can be found in the ANSI SEMI standard G30-88.
- (6) The junction-to-board thermal resistance is obtained by simulating in an environment with a ring cold plate fixture to control the PCB temperature, as described in JESD51-8.
- (7) The junction-to-top characterization parameter,  $\psi_{JT}$ , estimates the junction temperature of a device in a real system and is extracted from the simulation data to obtain  $\theta_{JA}$  using a procedure described in JESD51-2a (sections 6 and 7).
- (8) The junction-to-board characterization parameter,  $\psi_{JB}$ , estimates the junction temperature of a device in a real system and is extracted from the simulation data to obtain  $\theta_{JA}$  using a procedure described in JESD51-2a (sections 6 and 7).
- (9) The junction-to-case (bottom) thermal resistance is obtained by simulating a cold plate test on the exposed (power) pad. No specific JEDEC standard test exists, but a close description can be found in the ANSI SEMI standard G30-88.

## ELECTRICAL CHARACTERISTICS

Over operating temperature range ( $T_J = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ ),  $V_{IN} = V_{OUT(nom)} + 0.5\text{V}^{(1)}$ ,  $I_{OUT} = 10\text{mA}$ ,  $V_{EN} = 1.7\text{V}$ , and  $C_{OUT} = 0.1\mu\text{F}$ , unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ .

| PARAMETER                       |                                                                             | TEST CONDITIONS                | MIN                                                                                                                      | TYP             | MAX                  | UNIT                |
|---------------------------------|-----------------------------------------------------------------------------|--------------------------------|--------------------------------------------------------------------------------------------------------------------------|-----------------|----------------------|---------------------|
| $V_{IN}$                        | Input voltage range <sup>(1)</sup>                                          |                                | 1.7                                                                                                                      |                 | 5.5                  | V                   |
| $V_{FB}$                        | Internal reference (TPS73201)                                               | $T_J = +25^{\circ}\text{C}$    | 1.198                                                                                                                    | 1.20            | 1.210                | V                   |
| $V_{OUT}$                       | Output voltage range (TPS73201) <sup>(2)</sup>                              |                                | $V_{FB}$                                                                                                                 | $5.5 - V_{DO}$  |                      | V                   |
|                                 | Accuracy <sup>(1)(3)</sup>                                                  | Nominal                        | $T_J = +25^{\circ}\text{C}$                                                                                              |                 | -0.5                 | +0.5                |
|                                 |                                                                             | $V_{IN}$ , $I_{OUT}$ , and $T$ | $V_{OUT} + 0.5\text{V} \leq V_{IN} \leq 5.5\text{V}$ ;<br>$10\text{mA} \leq I_{OUT} \leq 250\text{mA}$                   |                 | -1.0                 | $\pm 0.5$<br>+1.0   |
| $\Delta V_{OUT}/\Delta V_{IN}$  | Line regulation <sup>(1)</sup>                                              |                                | $V_{OUT(nom)} + 0.5\text{V} \leq V_{IN} \leq 5.5\text{V}$                                                                |                 | 0.01                 | %/V                 |
| $\Delta V_{OUT}/\Delta I_{OUT}$ | Load regulation                                                             |                                | $1\text{mA} \leq I_{OUT} \leq 250\text{mA}$                                                                              |                 | 0.002                | %mA                 |
|                                 |                                                                             |                                | $10\text{mA} \leq I_{OUT} \leq 250\text{mA}$                                                                             |                 | 0.0005               |                     |
| $V_{DO}$                        | Dropout voltage <sup>(4)</sup><br>( $V_{IN} = V_{OUT(nom)} - 0.1\text{V}$ ) |                                | $I_{OUT} = 250\text{mA}$                                                                                                 |                 | 40                   | 150                 |
| $Z_O(\text{DO})$                | Output impedance in dropout                                                 |                                | $1.7\text{V} \leq V_{IN} \leq V_{OUT} + V_{DO}$                                                                          |                 | 0.25                 | $\Omega$            |
| $I_{CL}$                        | Output current limit                                                        |                                | $V_{OUT} = 0.9 \times V_{OUT(nom)}$                                                                                      |                 | 250                  | 425                 |
| $I_{SC}$                        | Short-circuit current                                                       |                                | $V_{OUT} = 0\text{V}$                                                                                                    |                 | 300                  | mA                  |
| $I_{REV}$                       | Reverse leakage current <sup>(5)</sup> ( $-I_{IN}$ )                        |                                | $V_{EN} \leq 0.5\text{V}$ , $0\text{V} \leq V_{IN} \leq V_{OUT}$                                                         |                 | 0.1                  | 10                  |
| $I_{GND}$                       | GND pin current                                                             |                                | $I_{OUT} = 10\text{mA}$ ( $I_Q$ )                                                                                        |                 | 400                  | 550                 |
|                                 |                                                                             |                                | $I_{OUT} = 250\text{mA}$                                                                                                 |                 | 650                  | 950                 |
| $I_{SHDN}$                      | Shutdown current ( $I_{GND}$ )                                              |                                | $V_{EN} \leq 0.5\text{V}$ , $V_{OUT} \leq V_{IN} \leq 5.5$ ,<br>$-40^{\circ}\text{C} \leq T_J \leq +100^{\circ}\text{C}$ |                 | 0.02                 | 1                   |
| $I_{FB}$                        | FB pin current (TPS73201)                                                   |                                |                                                                                                                          |                 | 0.1                  | 0.3                 |
| PSRR                            | Power-supply rejection ratio<br>(ripple rejection)                          |                                | $f = 100\text{Hz}$ , $I_{OUT} = 250\text{mA}$                                                                            |                 | 58                   | dB                  |
|                                 |                                                                             |                                | $f = 10\text{kHz}$ , $I_{OUT} = 250\text{mA}$                                                                            |                 | 37                   |                     |
| $V_N$                           | Output noise voltage<br>BW = 10Hz – 100kHz                                  |                                | $C_{OUT} = 10\mu\text{F}$ , No $C_{NR}$                                                                                  |                 | $27 \times V_{OUT}$  | $\mu\text{V}_{RMS}$ |
|                                 |                                                                             |                                | $C_{OUT} = 10\mu\text{F}$ , $C_{NR} = 0.01\mu\text{F}$                                                                   |                 | $8.5 \times V_{OUT}$ |                     |
| $t_{STR}$                       | Startup time                                                                |                                | $V_{OUT} = 3\text{V}$ , $R_L = 30\Omega$<br>$C_{OUT} = 1\mu\text{F}$ , $C_{NR} = 0.01\mu\text{F}$                        |                 | 600                  | $\mu\text{s}$       |
| $V_{EN(HI)}$                    | EN pin high (enabled)                                                       |                                | 1.7                                                                                                                      |                 | $V_{IN}$             | V                   |
| $V_{EN(LO)}$                    | EN pin low (shutdown)                                                       |                                | 0                                                                                                                        |                 | 0.5                  | V                   |
| $I_{EN(HI)}$                    | EN pin current (enabled)                                                    |                                | $V_{EN} = 5.5\text{V}$                                                                                                   |                 | 0.02                 | 0.1                 |
| $T_{SD}$                        | Thermal shutdown temperature                                                |                                | Shutdown                                                                                                                 | Temp increasing | +160                 | $^{\circ}\text{C}$  |
|                                 |                                                                             |                                | Reset                                                                                                                    | Temp decreasing | +140                 |                     |
| $T_J$                           | Operating junction temperature                                              |                                | -40                                                                                                                      |                 | +125                 | $^{\circ}\text{C}$  |

(1) Minimum  $V_{IN} = V_{OUT} + V_{DO}$  or 1.7V, whichever is greater.

(2) TPS73201 is tested at  $V_{OUT} = 2.5\text{V}$ .

(3) Tolerance of external resistors not included in this specification.

(4)  $V_{DO}$  is not measured for fixed output versions with  $V_{OUT(nom)} < 1.8\text{V}$  since minimum  $V_{IN} = 1.7\text{V}$ .

(5) Fixed-voltage versions only; refer to [Applications](#) section for more information.

## FUNCTIONAL BLOCK DIAGRAMS

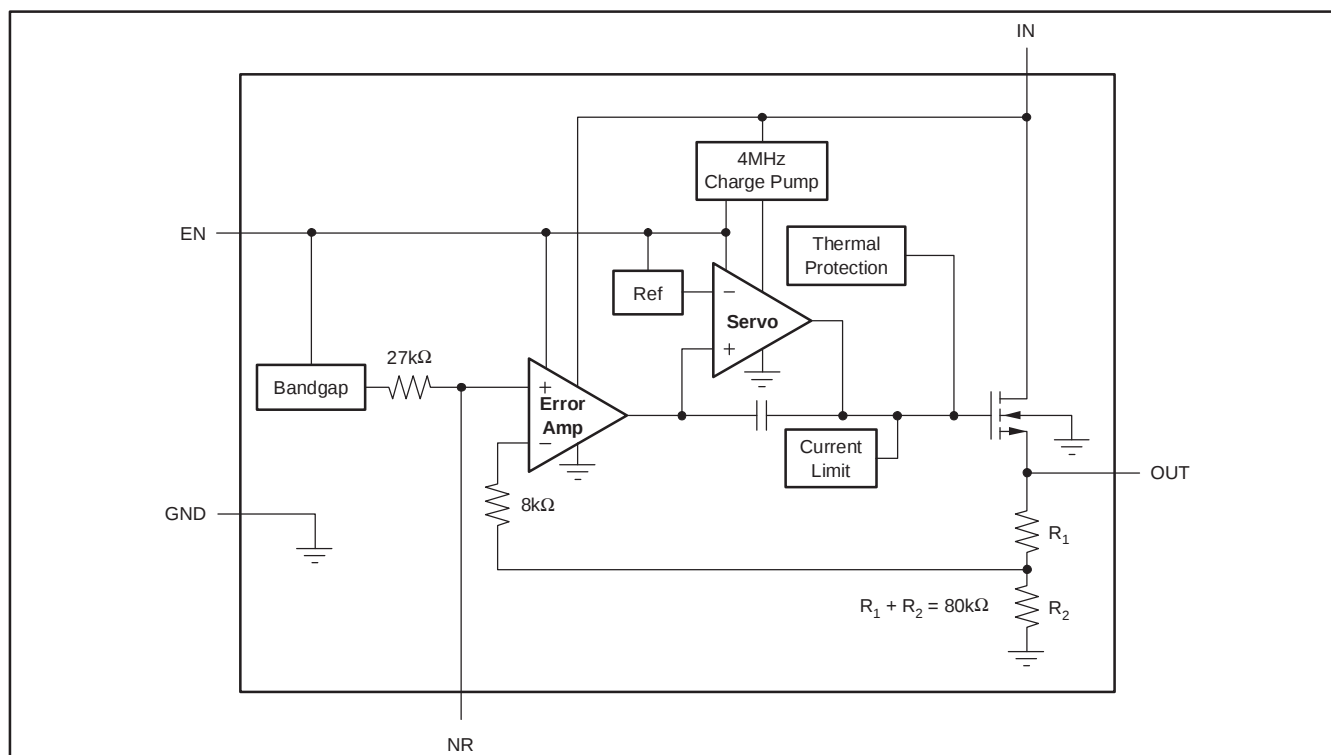


Figure 1. Fixed Voltage Version

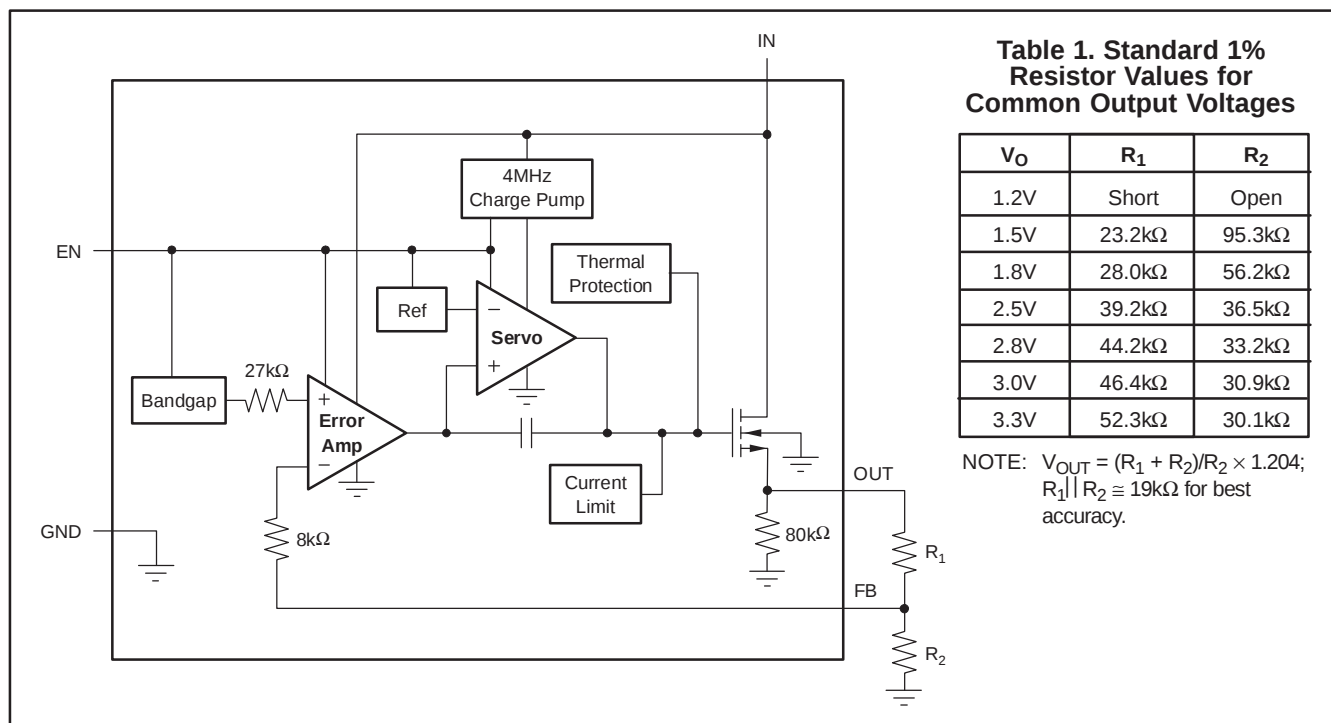
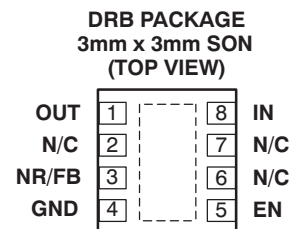
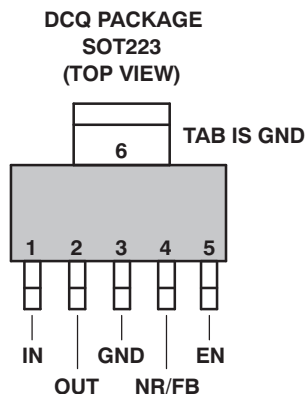
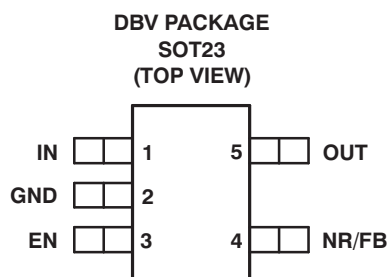


Figure 2. Adjustable Voltage Version

## PIN CONFIGURATIONS



## PIN DESCRIPTIONS

| NAME | SOT23<br>(DBV)<br>PIN NO. | SOT223<br>(DCQ)<br>PIN NO. | 3x3 SON<br>(DRB)<br>PIN NO. | DESCRIPTION                                                                                                                                                                                                                                                |
|------|---------------------------|----------------------------|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| IN   | 1                         | 1                          | 8                           | Input supply                                                                                                                                                                                                                                               |
| GND  | 2                         | 3, 6                       | 4, Pad                      | Ground                                                                                                                                                                                                                                                     |
| EN   | 3                         | 5                          | 5                           | Driving the enable pin (EN) high turns on the regulator. Driving this pin low puts the regulator into shutdown mode. Refer to the <a href="#">Shutdown</a> section under Applications Information for more details. EN can be connected to IN if not used. |
| NR   | 4                         | 4                          | 3                           | Fixed voltage versions only—connecting an external capacitor to this pin bypasses noise generated by the internal bandgap, reducing output noise to very low levels.                                                                                       |
| FB   | 4                         | 4                          | 3                           | Adjustable voltage version only—this is the input to the control loop error amplifier, and is used to set the output voltage of the device.                                                                                                                |
| OUT  | 5                         | 2                          | 1                           | Output of the Regulator. There are no output capacitor requirements for stability.                                                                                                                                                                         |

## TYPICAL CHARACTERISTICS

For all voltage versions at  $T_J = 25^\circ\text{C}$ ,  $V_{IN} = V_{OUT(nom)} + 0.5\text{V}$ ,  $I_{OUT} = 10\text{mA}$ ,  $V_{EN} = 1.7\text{V}$ , and  $C_{OUT} = 0.1\mu\text{F}$ , unless otherwise noted.

LOAD REGULATION

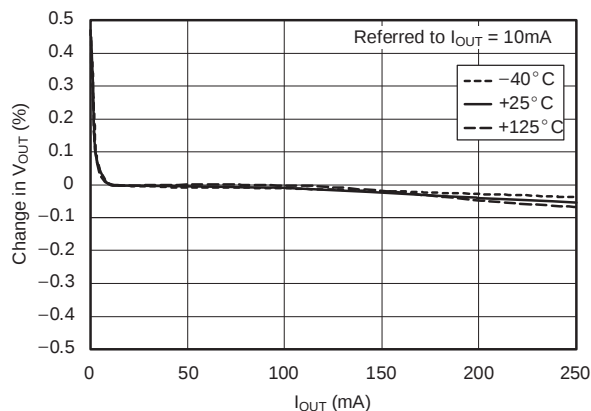


Figure 3.

LINE REGULATION

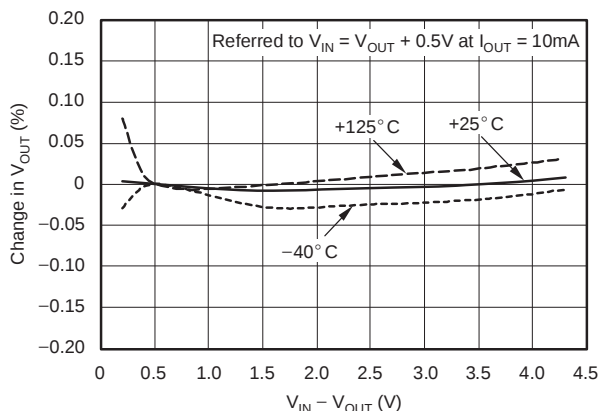


Figure 4.

DROPOUT VOLTAGE vs OUTPUT CURRENT

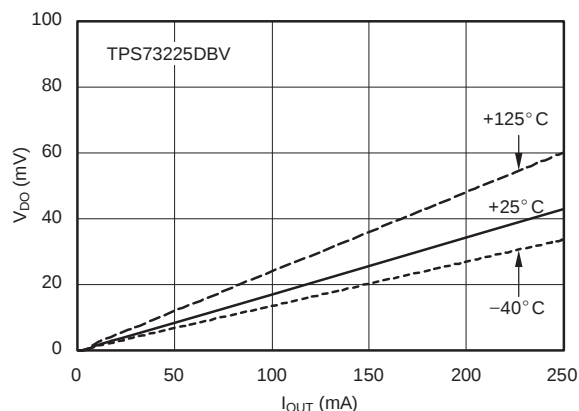


Figure 5.

DROPOUT VOLTAGE vs TEMPERATURE

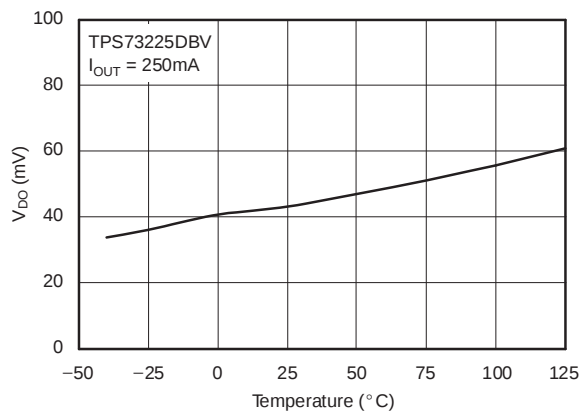


Figure 6.

OUTPUT VOLTAGE ACCURACY HISTOGRAM

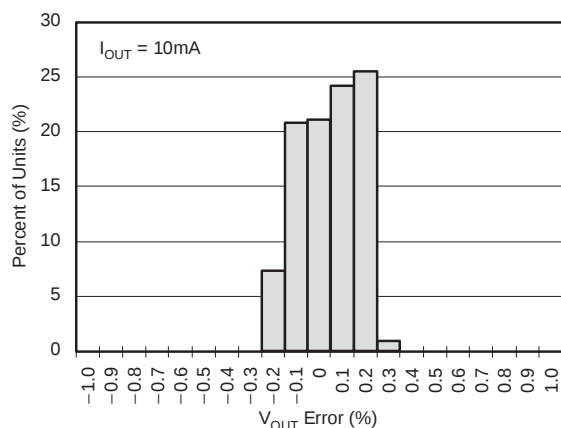


Figure 7.

OUTPUT VOLTAGE DRIFT HISTOGRAM

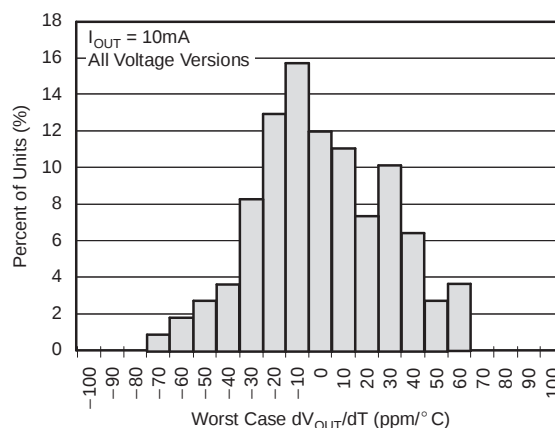
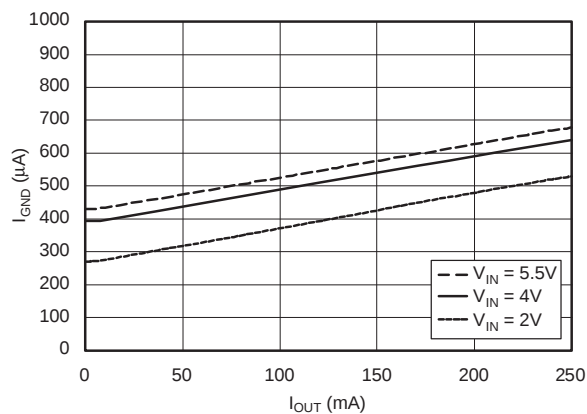


Figure 8.

## TYPICAL CHARACTERISTICS (continued)

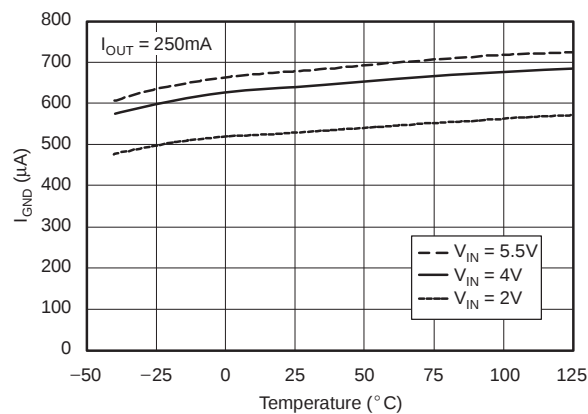
For all voltage versions at  $T_J = 25^\circ\text{C}$ ,  $V_{IN} = V_{OUT(nom)} + 0.5\text{V}$ ,  $I_{OUT} = 10\text{mA}$ ,  $V_{EN} = 1.7\text{V}$ , and  $C_{OUT} = 0.1\mu\text{F}$ , unless otherwise noted.

**GROUND PIN CURRENT vs OUTPUT CURRENT**



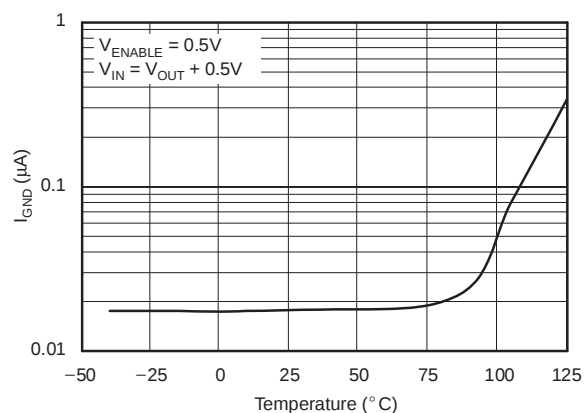
**Figure 9.**

**GROUND PIN CURRENT vs TEMPERATURE**



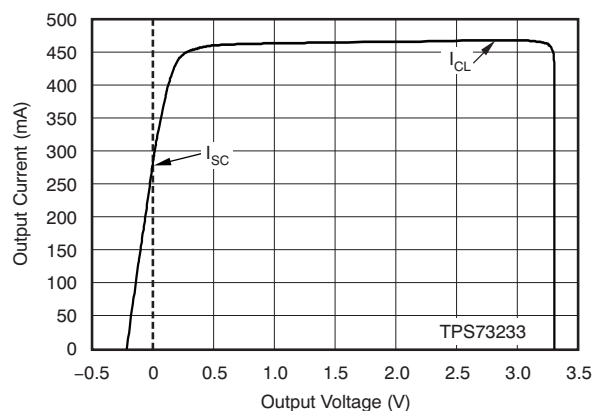
**Figure 10.**

**GROUND PIN CURRENT IN SHUTDOWN vs TEMPERATURE**



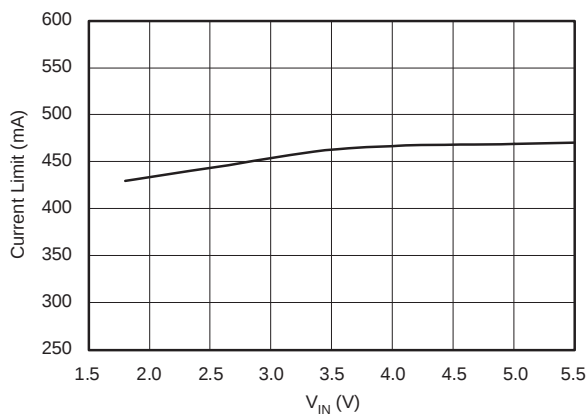
**Figure 11.**

**CURRENT LIMIT vs V\_OUT (FOLDBACK)**



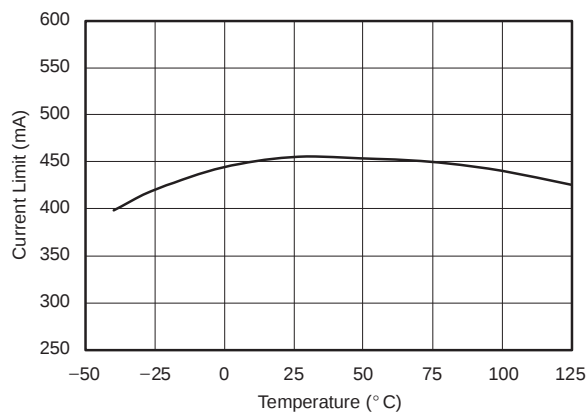
**Figure 12.**

**CURRENT LIMIT vs V\_IN**



**Figure 13.**

**CURRENT LIMIT vs TEMPERATURE**



**Figure 14.**

## TYPICAL CHARACTERISTICS (continued)

For all voltage versions at  $T_J = 25^\circ\text{C}$ ,  $V_{IN} = V_{OUT(nom)} + 0.5\text{V}$ ,  $I_{OUT} = 10\text{mA}$ ,  $V_{EN} = 1.7\text{V}$ , and  $C_{OUT} = 0.1\mu\text{F}$ , unless otherwise noted.

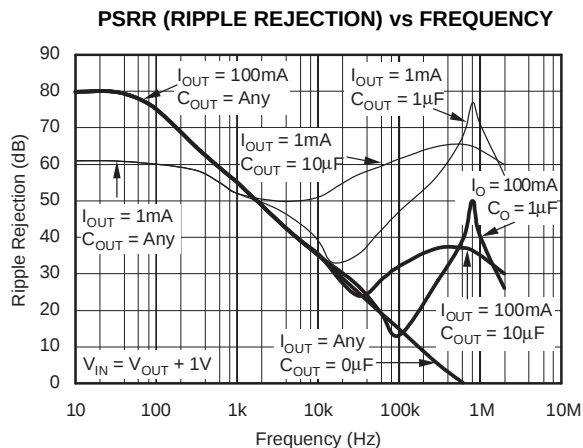


Figure 15.

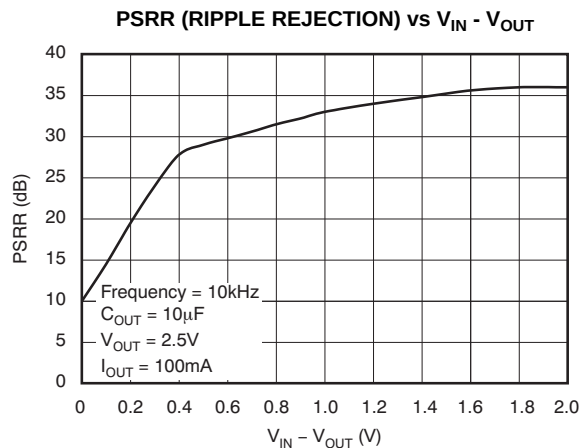


Figure 16.

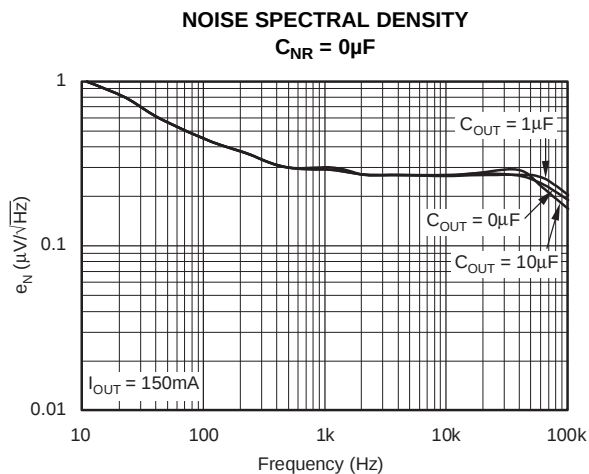


Figure 17.

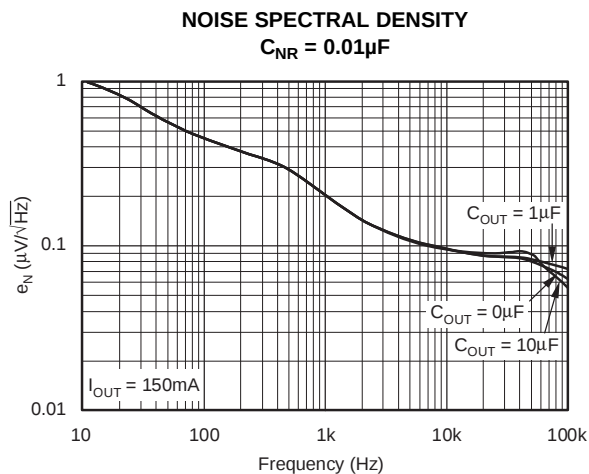


Figure 18.

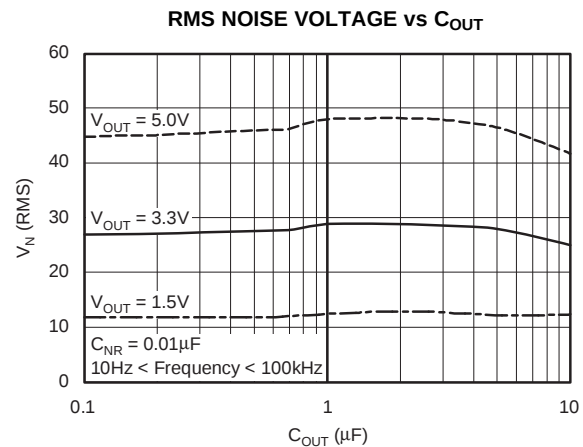


Figure 19.

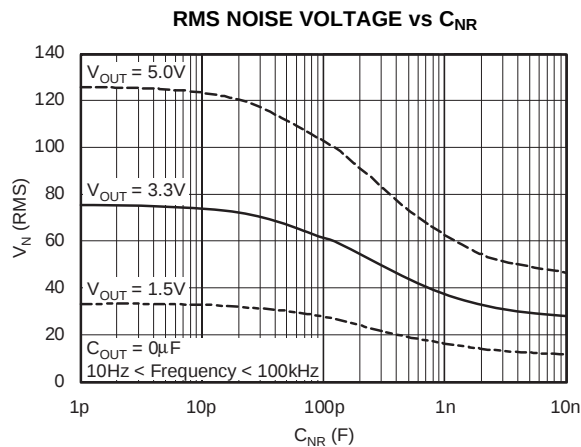


Figure 20.

## TYPICAL CHARACTERISTICS (continued)

For all voltage versions at  $T_J = 25^\circ\text{C}$ ,  $V_{IN} = V_{OUT(nom)} + 0.5\text{V}$ ,  $I_{OUT} = 10\text{mA}$ ,  $V_{EN} = 1.7\text{V}$ , and  $C_{OUT} = 0.1\mu\text{F}$ , unless otherwise noted.

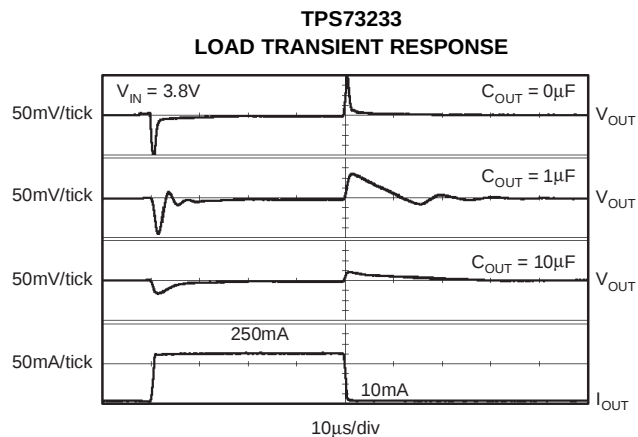


Figure 21.

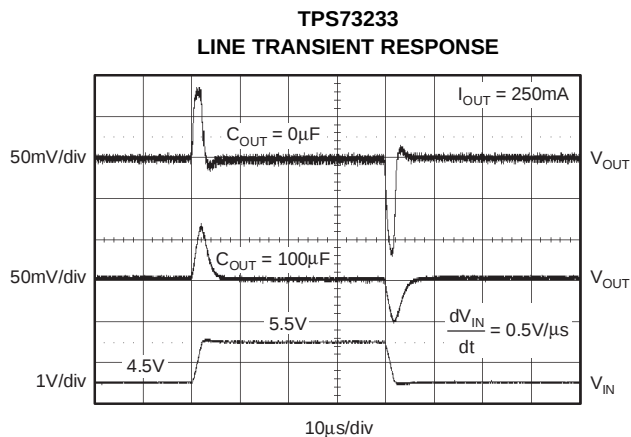


Figure 22.

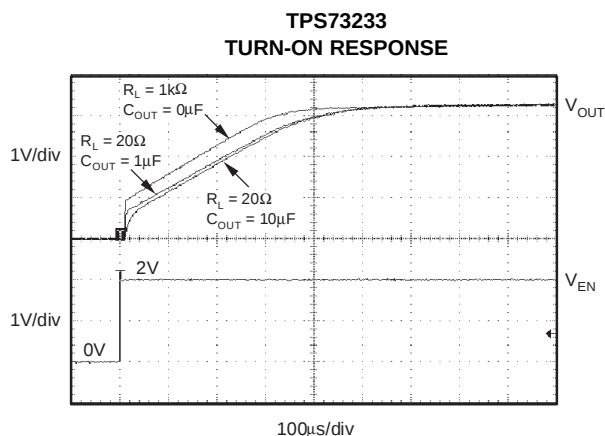


Figure 23.

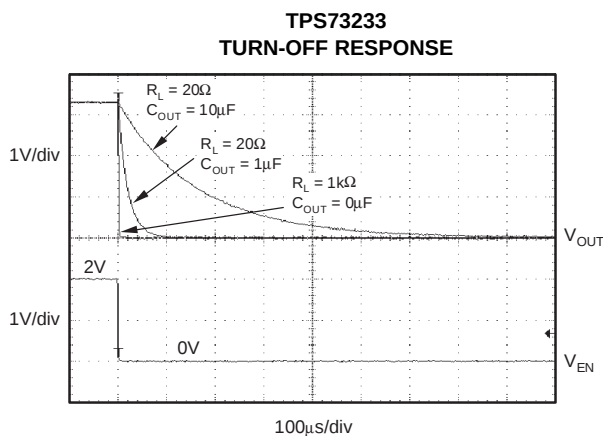


Figure 24.

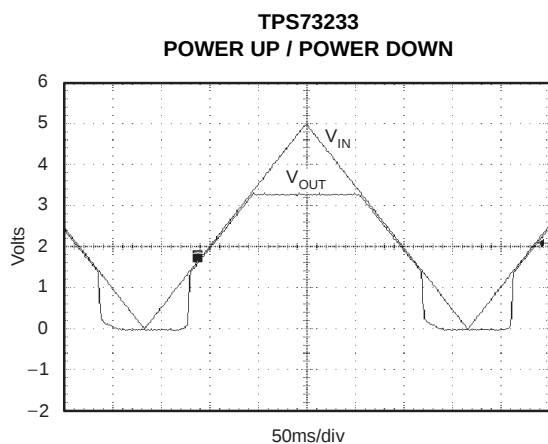


Figure 25.

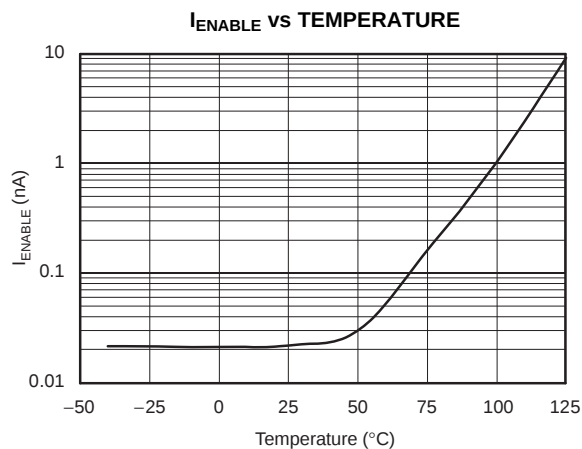


Figure 26.

## TYPICAL CHARACTERISTICS (continued)

For all voltage versions at  $T_J = 25^\circ\text{C}$ ,  $V_{IN} = V_{OUT(nom)} + 0.5\text{V}$ ,  $I_{OUT} = 10\text{mA}$ ,  $V_{EN} = 1.7\text{V}$ , and  $C_{OUT} = 0.1\mu\text{F}$ , unless otherwise noted.

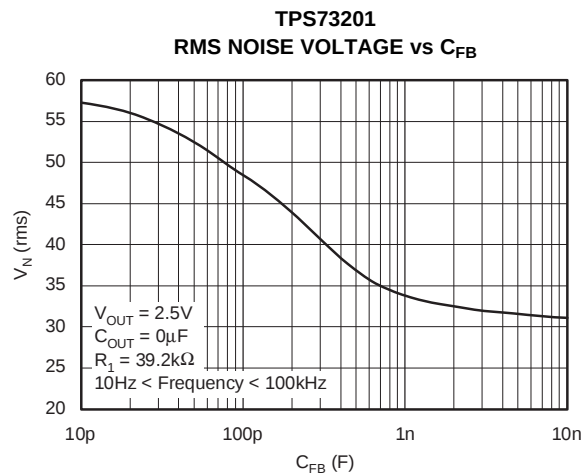


Figure 27.

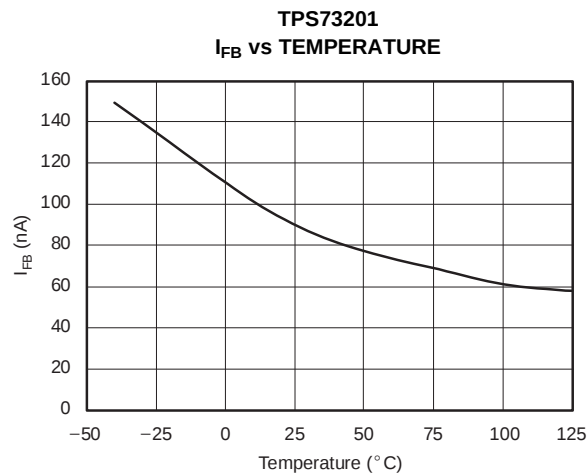


Figure 28.

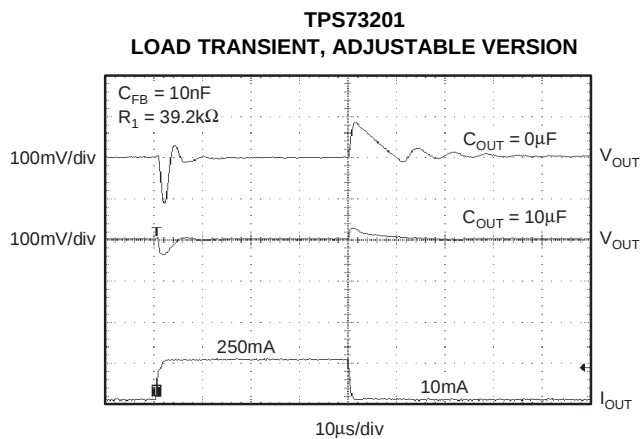


Figure 29.

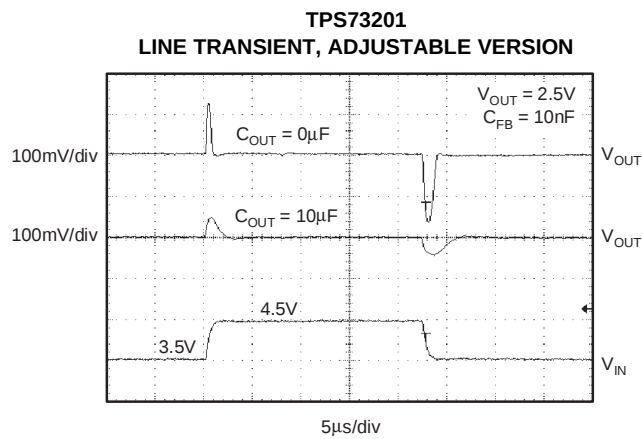
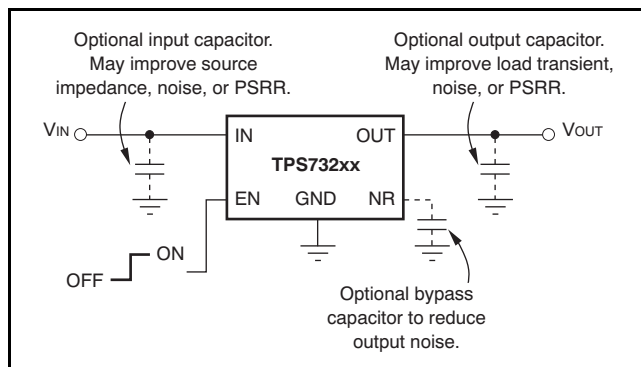


Figure 30.

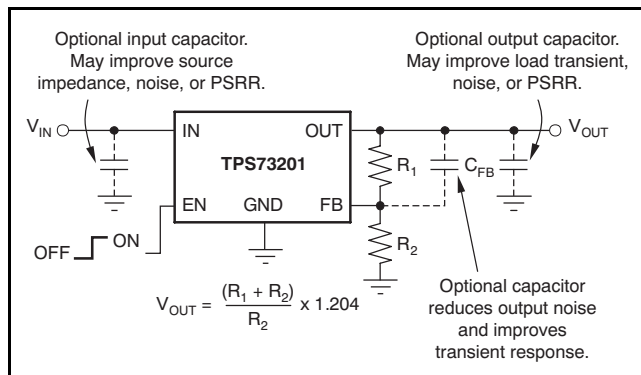
## APPLICATION INFORMATION

The TPS732xx belongs to a family of new generation LDO regulators that use an NMOS pass transistor to achieve ultra-low-dropout performance, reverse current blockage, and freedom from output capacitor constraints. These features, combined with low noise and an enable input, make the TPS732xx ideal for portable applications. This regulator family offers a wide selection of fixed output voltage versions and an adjustable output version. All versions have thermal and over-current protection, including foldback current limit.

Figure 31 shows the basic circuit connections for the fixed voltage models. Figure 32 gives the connections for the adjustable output version (TPS73201).



**Figure 31. Typical Application Circuit for Fixed-Voltage Versions**



**Figure 32. Typical Application Circuit for Adjustable-Voltage Version**

$R_1$  and  $R_2$  can be calculated for any output voltage using the formula shown in Figure 32. Sample resistor values for common output voltages are shown in Figure 2.

For best accuracy, make the parallel combination of  $R_1$  and  $R_2$  approximately equal to  $19k\Omega$ . This  $19k\Omega$ , in addition to the internal  $8k\Omega$  resistor, presents the same impedance to the error amp as the  $27k\Omega$  bandgap reference output. This impedance helps compensate for leakages into the error amp terminals.

## INPUT AND OUTPUT CAPACITOR REQUIREMENTS

Although an input capacitor is not required for stability, it is good analog design practice to connect a  $0.1\mu F$  to  $1\mu F$  low ESR capacitor across the input supply near the regulator. This counteracts reactive input sources and improves transient response, noise rejection, and ripple rejection. A higher-value capacitor may be necessary if large, fast rise-time load transients are anticipated or the device is located several inches from the power source.

The TPS732xx does not require an output capacitor for stability and has maximum phase margin with no capacitor. It is designed to be stable for all available types and values of capacitors. In applications where multiple low ESR capacitors are in parallel, ringing may occur when the product of  $C_{OUT}$  and total ESR drops below  $50nF$ . Total ESR includes all parasitic resistances, including capacitor ESR and board, socket, and solder joint resistance. In most applications, the sum of capacitor ESR and trace resistance will meet this requirement.

## OUTPUT NOISE

A precision band-gap reference is used to generate the internal reference voltage,  $V_{REF}$ . This reference is the dominant noise source within the TPS732xx and it generates approximately  $32\mu V_{RMS}$  (10Hz to 100kHz) at the reference output (NR). The regulator control loop gains up the reference noise with the same gain as the reference voltage, so that the noise voltage of the regulator is approximately given by:

$$V_N = 32\mu V_{RMS} \times \frac{(R_1 + R_2)}{R_2} = 32\mu V_{RMS} \times \frac{V_{OUT}}{V_{REF}} \quad (1)$$

Since the value of  $V_{REF}$  is 1.2V, this relationship reduces to:

$$V_N(\mu V_{RMS}) = 27 \left( \frac{\mu V_{RMS}}{V} \right) \times V_{OUT}(V) \quad (2)$$

for the case of no  $C_{NR}$ .

An internal 27kΩ resistor in series with the noise reduction pin (NR) forms a low-pass filter for the voltage reference when an external noise reduction capacitor,  $C_{NR}$ , is connected from NR to ground. For  $C_{NR} = 10\text{nF}$ , the total noise in the 10Hz to 100kHz bandwidth is reduced by a factor of ~3.2, giving the approximate relationship:

$$V_N(\mu\text{V}_{\text{RMS}}) = 8.5 \left( \frac{\mu\text{V}_{\text{RMS}}}{V} \right) \times V_{\text{OUT}}(V) \quad (3)$$

for  $C_{NR} = 10\text{nF}$ .

This noise reduction effect is shown as *RMS Noise Voltage vs  $C_{NR}$*  in the Typical Characteristics section.

The TPS73201 adjustable version does not have the NR pin available. However, connecting a feedback capacitor,  $C_{FB}$ , from the output to the feedback pin (FB) will reduce output noise and improve load transient performance.

The TPS732xx uses an internal charge pump to develop an internal supply voltage sufficient to drive the gate of the NMOS pass element above  $V_{\text{OUT}}$ . The charge pump generates ~250μV of switching noise at ~4MHz; however, charge-pump noise contribution is negligible at the output of the regulator for most values of  $I_{\text{OUT}}$  and  $C_{\text{OUT}}$ .

## BOARD LAYOUT RECOMMENDATION TO IMPROVE PSRR AND NOISE PERFORMANCE

To improve ac performance such as PSRR, output noise, and transient response, it is recommended that the PCB be designed with separate ground planes for  $V_{\text{IN}}$  and  $V_{\text{OUT}}$ , with each ground plane connected only at the GND pin of the device. In addition, the ground connection for the bypass capacitor should connect directly to the GND pin of the device.

## INTERNAL CURRENT LIMIT

The TPS732xx internal current limit helps protect the regulator during fault conditions. Foldback current limit helps to protect the regulator from damage during output short-circuit conditions by reducing current limit when  $V_{\text{OUT}}$  drops below 0.5V. See [Figure 12](#) in the Typical Characteristics section for a graph of  $I_{\text{OUT}}$  vs  $V_{\text{OUT}}$ .

Note from [Figure 12](#) that approximately –0.2V of  $V_{\text{OUT}}$  results in a current limit of 0mA. Therefore, if OUT is forced below –0.2V before EN goes high, the device may not start up. In applications that work with both a positive and negative voltage supply, the TPS732xx should be enabled first.

## ENABLE PIN AND SHUTDOWN

The enable pin (EN) is active high and is compatible with standard TTL-CMOS levels. A  $V_{\text{EN}}$  below 0.5V (max) turns the regulator off and drops the GND pin current to approximately 10nA. When EN is used to shutdown the regulator, all charge is removed from the pass transistor gate, and the output ramps back up to a regulated  $V_{\text{OUT}}$  (see [Figure 23](#)).

When shutdown capability is not required, EN can be connected to  $V_{\text{IN}}$ . However, the pass gate may not be discharged using this configuration, and the pass transistor may be left on (enhanced) for a significant time after  $V_{\text{IN}}$  has been removed. This scenario can result in reverse current flow (if the IN pin is low impedance) and faster ramp times upon power-up. In addition, for  $V_{\text{IN}}$  ramp times slower than a few milliseconds, the output may overshoot upon power-up.

Note that current limit foldback can prevent device start-up under some conditions. See the [Internal Current Limit](#) section.

## DROPOUT VOLTAGE

The TPS732xx uses an NMOS pass transistor to achieve extremely low dropout. When  $(V_{\text{IN}} - V_{\text{OUT}})$  is less than the dropout voltage ( $V_{\text{DO}}$ ), the NMOS pass device is in its linear region of operation and the input-to-output resistance is the  $R_{\text{DS-ON}}$  of the NMOS pass element.

For large step changes in load current, the TPS732xx requires a larger voltage drop from  $V_{\text{IN}}$  to  $V_{\text{OUT}}$  to avoid degraded transient response. The boundary of this transient dropout region is approximately twice the dc dropout. Values of  $V_{\text{IN}} - V_{\text{OUT}}$  above this line insure normal transient response.

Operating in the transient dropout region can cause an increase in recovery time. The time required to recover from a load transient is a function of the magnitude of the change in load current rate, the rate of change in load current, and the available headroom ( $V_{\text{IN}}$  to  $V_{\text{OUT}}$  voltage drop). Under worst-case conditions [full-scale instantaneous load change with  $(V_{\text{IN}} - V_{\text{OUT}})$  close to dc dropout levels], the TPS732xx can take a couple of hundred microseconds to return to the specified regulation accuracy.

## TRANSIENT RESPONSE

The low open-loop output impedance provided by the NMOS pass element in a voltage follower configuration allows operation without an output capacitor for many applications. As with any regulator, the addition of a capacitor (nominal value 1 $\mu$ F) from the OUT pin to ground will reduce undershoot magnitude but increase its duration. In the adjustable version, the addition of a capacitor,  $C_{FB}$ , from the OUT pin to the FB pin will also improve the transient response.

The TPS732xx does not have active pull-down when the output is over-voltage. This allows applications that connect higher voltage sources, such as alternate power supplies, to the output. This also results in an output overshoot of several percent if the load current quickly drops to zero when a capacitor is connected to the output. The duration of overshoot can be reduced by adding a load resistor. The overshoot decays at a rate determined by output capacitor  $C_{OUT}$  and the internal/external load resistance. The rate of decay is given by:

(Fixed voltage version)

$$dV/dt = \frac{V_{OUT}}{C_{OUT} \times 80k\Omega \parallel R_{LOAD}} \quad (4)$$

(Adjustable voltage version)

$$dV/dt = \frac{V_{OUT}}{C_{OUT} \times 80k\Omega \parallel (R_1 + R_2) \parallel R_{LOAD}} \quad (5)$$

## REVERSE CURRENT

The NMOS pass element of the TPS732xx provides inherent protection against current flow from the output of the regulator to the input when the gate of the pass device is pulled low. To ensure that all charge is removed from the gate of the pass element, the EN pin must be driven low before the input voltage is removed. If this is not done, the pass element may be left on due to stored charge on the gate.

After the EN pin is driven low, no bias voltage is needed on any pin for reverse current blocking. Note that reverse current is specified as the current flowing out of the IN pin due to voltage applied on the OUT pin. There will be additional current flowing into the OUT pin due to the 80k $\Omega$  internal resistor divider to ground (see [Figure 1](#) and [Figure 2](#)).

For the TPS73201, reverse current may flow when  $V_{FB}$  is more than 1.0V above  $V_{IN}$ .

## THERMAL PROTECTION

Thermal protection disables the output when the junction temperature rises to approximately +160°C, allowing the device to cool. When the junction temperature cools to approximately +140°C, the output circuitry is again enabled. Depending on power dissipation, thermal resistance, and ambient temperature, the thermal protection circuit may cycle on and off. This limits the dissipation of the regulator, protecting it from damage due to overheating.

Any tendency to activate the thermal protection circuit indicates excessive power dissipation or an inadequate heatsink. For reliable operation, junction temperature should be limited to +125°C maximum. To estimate the margin of safety 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, thermal protection should trigger at least +35°C above the maximum expected ambient condition of your application. This 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 TPS732xx has been designed to protect against overload conditions. It was not intended to replace proper heatsinking. Continuously running the TPS732xx into thermal shutdown will degrade device reliability.

## 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 shown in the Power Dissipation Ratings table. Using heavier copper will increase the effectiveness in removing heat from the device. The addition of plated through-holes to heat-dissipating layers will also improve the heat-sink effectiveness.

Power dissipation depends on input voltage and load conditions. Power dissipation ( $P_D$ ) is equal to the product of the output current times the voltage drop across the output pass element ( $V_{IN}$  to  $V_{OUT}$ ):

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} \quad (6)$$

Power dissipation can be minimized by using the lowest possible input voltage necessary to assure the required output voltage.

## PACKAGE MOUNTING

Solder pad footprint recommendations for the TPS732xx are presented in Application Bulletin *Solder Pad Recommendations for Surface-Mount Devices* (SBFA015), available from the Texas Instruments web site at [www.ti.com](http://www.ti.com).

## REVISION HISTORY

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

| Changes from Revision N (August, 2009) to Revision O                                                                                                                                                                                                                                                                      | Page          |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| <ul style="list-style-type: none"> <li>Replaced the <i>Dissipation Ratings</i> table with the <i>Thermal Information</i> table .....</li> </ul>                                                                                                                                                                           | 3             |
| Changes from Revision M (May, 2008) to Revision N                                                                                                                                                                                                                                                                         | Page          |
| <ul style="list-style-type: none"> <li>Changed <a href="#">Figure 12</a> .....</li> <li>Added paragraph about recommended start-up sequence to <i>Internal Current Limit</i> section .....</li> <li>Added paragraph about current foldback and device start-up to <i>Enable Pin and Shutdown</i> section .....</li> </ul> | 8<br>13<br>13 |

**PACKAGING INFORMATION**

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup>    | Lead/<br>Ball Finish | MSL Peak Temp <sup>(3)</sup> | Samples<br>(Requires Login) |
|------------------|-----------------------|--------------|-----------------|------|-------------|----------------------------|----------------------|------------------------------|-----------------------------|
| TPS73201DBVR     | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73201DBVRG4   | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73201DBVT     | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73201DBVTG4   | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73201DCQ      | ACTIVE                | SOT-223      | DCQ             | 6    | 78          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73201DCQG4    | ACTIVE                | SOT-223      | DCQ             | 6    |             | TBD                        | Call TI              | Call TI                      |                             |
| TPS73201DCQR     | ACTIVE                | SOT-223      | DCQ             | 6    | 2500        | Green (RoHS<br>& no Sb/Br) | CU SN                | Level-2-260C-1 YEAR          |                             |
| TPS73201DCQRG4   | ACTIVE                | SOT-223      | DCQ             | 6    |             | TBD                        | Call TI              | Call TI                      |                             |
| TPS73201DRBR     | ACTIVE                | SON          | DRB             | 8    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73201DRBRG4   | ACTIVE                | SON          | DRB             | 8    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73201DRBT     | ACTIVE                | SON          | DRB             | 8    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73201DRBTG4   | ACTIVE                | SON          | DRB             | 8    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73213DBVR     | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73213DBVRG4   | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73213DBVT     | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73213DBVTG4   | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73215DBVR     | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73215DBVRG4   | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup>    | Lead/<br>Ball Finish | MSL Peak Temp <sup>(3)</sup> | Samples<br>(Requires Login) |
|------------------|-----------------------|--------------|-----------------|------|-------------|----------------------------|----------------------|------------------------------|-----------------------------|
| TPS73215DBVT     | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73215DBVTG4   | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73215DCQ      | ACTIVE                | SOT-223      | DCQ             | 6    | 78          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73215DCQG4    | ACTIVE                | SOT-223      | DCQ             | 6    | 78          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73215DCQR     | ACTIVE                | SOT-223      | DCQ             | 6    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73215DCQRG4   | ACTIVE                | SOT-223      | DCQ             | 6    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73216DBVR     | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73216DBVRG4   | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73216DBVT     | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73216DBVTG4   | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73218DBVR     | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73218DBVRG4   | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73218DBVT     | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73218DBVTG4   | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73218DCQ      | ACTIVE                | SOT-223      | DCQ             | 6    | 78          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73218DCQG4    | ACTIVE                | SOT-223      | DCQ             | 6    |             | TBD                        | Call TI              | Call TI                      |                             |
| TPS73218DCQR     | ACTIVE                | SOT-223      | DCQ             | 6    | 2500        | Green (RoHS<br>& no Sb/Br) | CU SN                | Level-2-260C-1 YEAR          |                             |
| TPS73218DCQRG4   | ACTIVE                | SOT-223      | DCQ             | 6    |             | TBD                        | Call TI              | Call TI                      |                             |
| TPS73219DBVR     | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup>    | Lead/<br>Ball Finish | MSL Peak Temp <sup>(3)</sup> | Samples<br>(Requires Login) |
|------------------|-----------------------|--------------|-----------------|------|-------------|----------------------------|----------------------|------------------------------|-----------------------------|
| TPS73219DBVRG4   | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73219DBVT     | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73219DBVTG4   | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73225DBVR     | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73225DBVRG4   | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73225DBVT     | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73225DBVTG4   | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73225DCQ      | ACTIVE                | SOT-223      | DCQ             | 6    | 78          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73225DCQG4    | ACTIVE                | SOT-223      | DCQ             | 6    | 78          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73225DCQR     | ACTIVE                | SOT-223      | DCQ             | 6    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73225DCQRG4   | ACTIVE                | SOT-223      | DCQ             | 6    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73230DBVR     | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73230DBVRG4   | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73230DBVT     | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73230DBVTG4   | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73230DCQR     | ACTIVE                | SOT-223      | DCQ             | 6    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73230DCQRG4   | ACTIVE                | SOT-223      | DCQ             | 6    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73233DBVR     | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |

| Orderable Device | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup>    | Lead/<br>Ball Finish | MSL Peak Temp <sup>(3)</sup> | Samples<br>(Requires Login) |
|------------------|-----------------------|--------------|-----------------|------|-------------|----------------------------|----------------------|------------------------------|-----------------------------|
| TPS73233DBVRG4   | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73233DBVT     | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73233DBVTG4   | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73233DCQ      | ACTIVE                | SOT-223      | DCQ             | 6    | 78          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73233DCQG4    | ACTIVE                | SOT-223      | DCQ             | 6    |             | TBD                        | Call TI              | Call TI                      |                             |
| TPS73233DCQR     | ACTIVE                | SOT-223      | DCQ             | 6    | 2500        | Green (RoHS<br>& no Sb/Br) | CU SN                | Level-2-260C-1 YEAR          |                             |
| TPS73233DCQRG4   | ACTIVE                | SOT-223      | DCQ             | 6    |             | TBD                        | Call TI              | Call TI                      |                             |
| TPS73250DBVR     | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73250DBVRG4   | ACTIVE                | SOT-23       | DBV             | 5    | 3000        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73250DBVT     | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73250DBVTG4   | ACTIVE                | SOT-23       | DBV             | 5    | 250         | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-1-260C-UNLIM           |                             |
| TPS73250DCQ      | ACTIVE                | SOT-223      | DCQ             | 6    | 78          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73250DCQG4    | ACTIVE                | SOT-223      | DCQ             | 6    | 78          | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73250DCQR     | ACTIVE                | SOT-223      | DCQ             | 6    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |
| TPS73250DCQRG4   | ACTIVE                | SOT-223      | DCQ             | 6    | 2500        | Green (RoHS<br>& no Sb/Br) | CU NIPDAU            | Level-2-260C-1 YEAR          |                             |

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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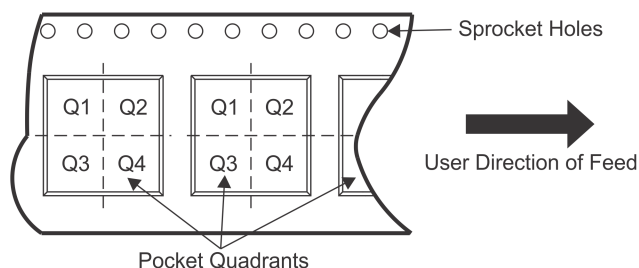
**OTHER QUALIFIED VERSIONS OF TPS73201, TPS73215, TPS73216, TPS73218, TPS73225, TPS73230, TPS73233, TPS73250 :**

- Automotive: [TPS73201-Q1](#), [TPS73225-Q1](#), [TPS73250-Q1](#)
- Enhanced Product: [TPS73201-EP](#), [TPS73215-EP](#), [TPS73216-EP](#), [TPS73218-EP](#), [TPS73225-EP](#), [TPS73230-EP](#), [TPS73233-EP](#), [TPS73250-EP](#)

**NOTE: Qualified Version Definitions:**

- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

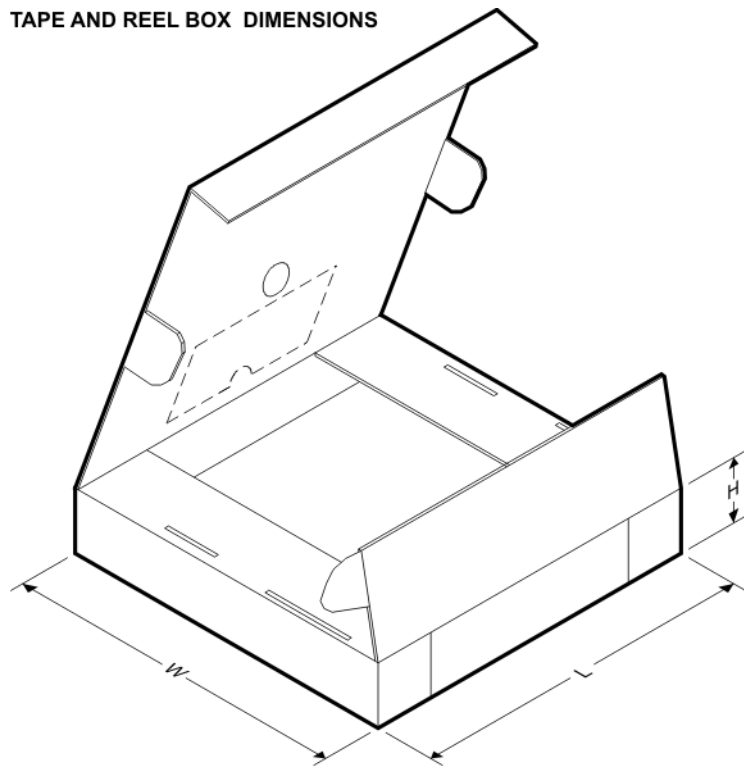
**TAPE AND REEL INFORMATION**

**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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS73201DBVR | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73201DBVT | SOT-23       | DBV             | 5    | 250  | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73201DCQR | SOT-223      | DCQ             | 6    | 2500 | 330.0              | 12.4               | 6.8     | 7.3     | 1.88    | 8.0     | 12.0   | Q3            |
| TPS73201DRBR | SON          | DRB             | 8    | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| TPS73201DRBR | SON          | DRB             | 8    | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.0     | 8.0     | 12.0   | Q2            |
| TPS73201DRBT | SON          | DRB             | 8    | 250  | 180.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| TPS73201DRBT | SON          | DRB             | 8    | 250  | 180.0              | 12.4               | 3.3     | 3.3     | 1.0     | 8.0     | 12.0   | Q2            |
| TPS73213DBVR | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73213DBVT | SOT-23       | DBV             | 5    | 250  | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73215DBVR | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73215DBVT | SOT-23       | DBV             | 5    | 250  | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73215DCQR | SOT-223      | DCQ             | 6    | 2500 | 330.0              | 12.4               | 6.8     | 7.3     | 1.88    | 8.0     | 12.0   | Q3            |
| TPS73216DBVR | SOT-23       | DBV             | 5    | 3000 | 179.0              | 8.4                | 3.2     | 3.2     | 1.4     | 4.0     | 8.0    | Q3            |
| TPS73216DBVT | SOT-23       | DBV             | 5    | 250  | 179.0              | 8.4                | 3.2     | 3.2     | 1.4     | 4.0     | 8.0    | Q3            |
| TPS73218DBVR | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73218DBVT | SOT-23       | DBV             | 5    | 250  | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73218DCQR | SOT-223      | DCQ             | 6    | 2500 | 330.0              | 12.4               | 6.8     | 7.3     | 1.88    | 8.0     | 12.0   | Q3            |
| TPS73219DBVR | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |

| 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 |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS73219DBVT | SOT-23       | DBV             | 5    | 250  | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73225DBVR | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73225DBVT | SOT-23       | DBV             | 5    | 250  | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73225DCQR | SOT-223      | DCQ             | 6    | 2500 | 330.0              | 12.4               | 6.8     | 7.3     | 1.88    | 8.0     | 12.0   | Q3            |
| TPS73230DBVR | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73230DBVT | SOT-23       | DBV             | 5    | 250  | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73230DCQR | SOT-223      | DCQ             | 6    | 2500 | 330.0              | 12.4               | 6.8     | 7.3     | 1.88    | 8.0     | 12.0   | Q3            |
| TPS73233DBVR | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73233DBVT | SOT-23       | DBV             | 5    | 250  | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73233DCQR | SOT-223      | DCQ             | 6    | 2500 | 330.0              | 12.4               | 6.8     | 7.3     | 1.88    | 8.0     | 12.0   | Q3            |
| TPS73250DBVR | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73250DBVT | SOT-23       | DBV             | 5    | 250  | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS73250DCQR | SOT-223      | DCQ             | 6    | 2500 | 330.0              | 12.4               | 6.8     | 7.3     | 1.88    | 8.0     | 12.0   | Q3            |

**TAPE AND REEL BOX DIMENSIONS**


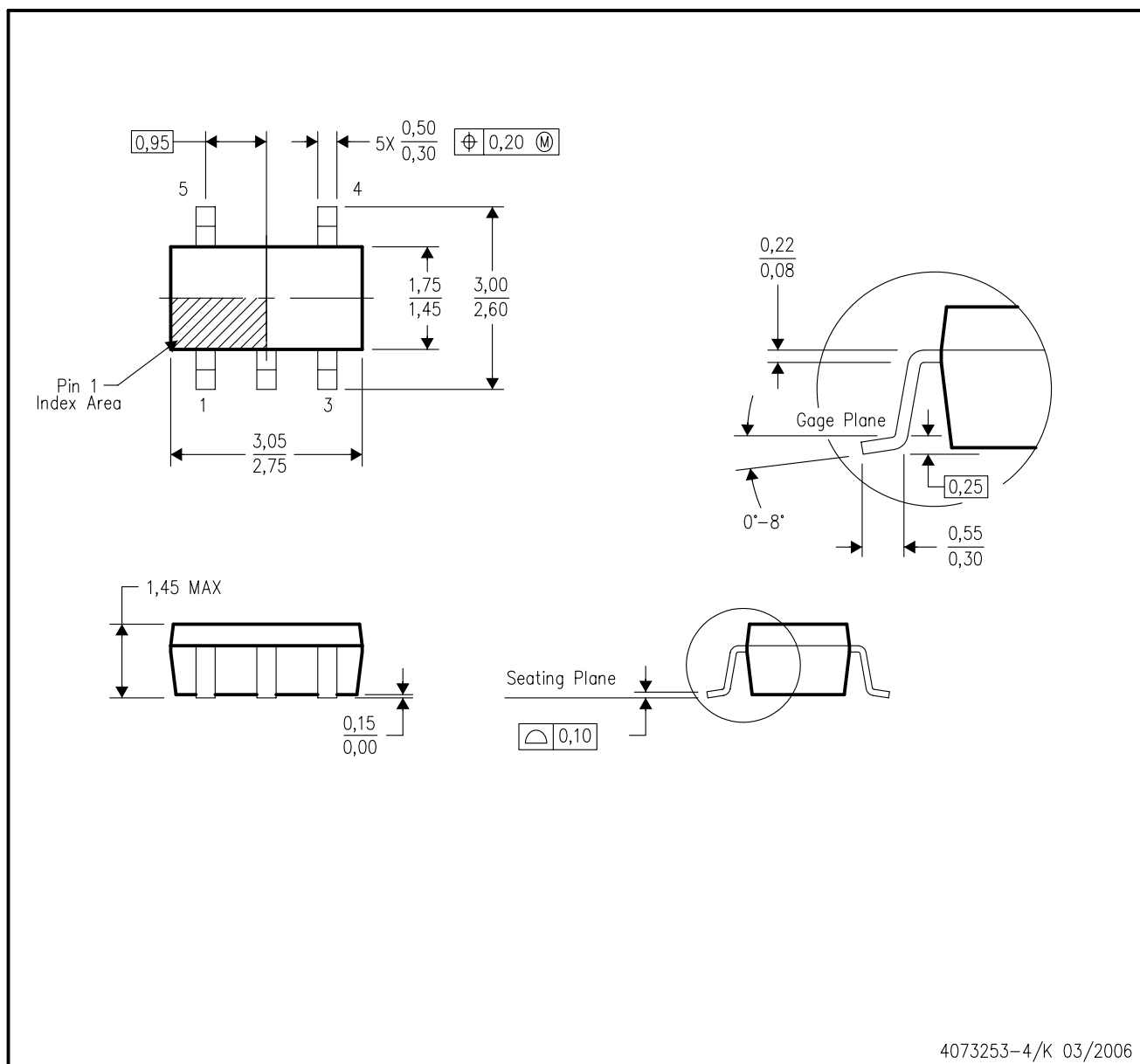
\*All dimensions are nominal

| Device       | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPS73201DBVR | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS73201DBVT | SOT-23       | DBV             | 5    | 250  | 180.0       | 180.0      | 18.0        |
| TPS73201DCQR | SOT-223      | DCQ             | 6    | 2500 | 358.0       | 335.0      | 35.0        |
| TPS73201DRBR | SON          | DRB             | 8    | 3000 | 367.0       | 367.0      | 35.0        |

| Device       | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPS73201DRBR | SON          | DRB             | 8    | 3000 | 370.0       | 355.0      | 55.0        |
| TPS73201DRBT | SON          | DRB             | 8    | 250  | 210.0       | 185.0      | 35.0        |
| TPS73201DRBT | SON          | DRB             | 8    | 250  | 220.0       | 205.0      | 50.0        |
| TPS73213DBVR | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS73213DBVT | SOT-23       | DBV             | 5    | 250  | 180.0       | 180.0      | 18.0        |
| TPS73215DBVR | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS73215DBVT | SOT-23       | DBV             | 5    | 250  | 180.0       | 180.0      | 18.0        |
| TPS73215DCQR | SOT-223      | DCQ             | 6    | 2500 | 358.0       | 335.0      | 35.0        |
| TPS73216DBVR | SOT-23       | DBV             | 5    | 3000 | 195.0       | 200.0      | 45.0        |
| TPS73216DBVT | SOT-23       | DBV             | 5    | 250  | 195.0       | 200.0      | 45.0        |
| TPS73218DBVR | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS73218DBVT | SOT-23       | DBV             | 5    | 250  | 180.0       | 180.0      | 18.0        |
| TPS73218DCQR | SOT-223      | DCQ             | 6    | 2500 | 358.0       | 335.0      | 35.0        |
| TPS73219DBVR | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS73219DBVT | SOT-23       | DBV             | 5    | 250  | 180.0       | 180.0      | 18.0        |
| TPS73225DBVR | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS73225DBVT | SOT-23       | DBV             | 5    | 250  | 180.0       | 180.0      | 18.0        |
| TPS73225DCQR | SOT-223      | DCQ             | 6    | 2500 | 358.0       | 335.0      | 35.0        |
| TPS73230DBVR | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS73230DBVT | SOT-23       | DBV             | 5    | 250  | 180.0       | 180.0      | 18.0        |
| TPS73230DCQR | SOT-223      | DCQ             | 6    | 2500 | 358.0       | 335.0      | 35.0        |
| TPS73233DBVR | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS73233DBVT | SOT-23       | DBV             | 5    | 250  | 180.0       | 180.0      | 18.0        |
| TPS73233DCQR | SOT-223      | DCQ             | 6    | 2500 | 358.0       | 335.0      | 35.0        |
| TPS73250DBVR | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS73250DBVT | SOT-23       | DBV             | 5    | 250  | 180.0       | 180.0      | 18.0        |
| TPS73250DCQR | SOT-223      | DCQ             | 6    | 2500 | 358.0       | 335.0      | 35.0        |

## DBV (R-PDSO-G5)

## PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
  - Falls within JEDEC MO-178 Variation AA.

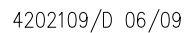
DBV (R-PDSO-G5)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - D. Publication IPC-7351 is recommended for alternate designs.
  - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

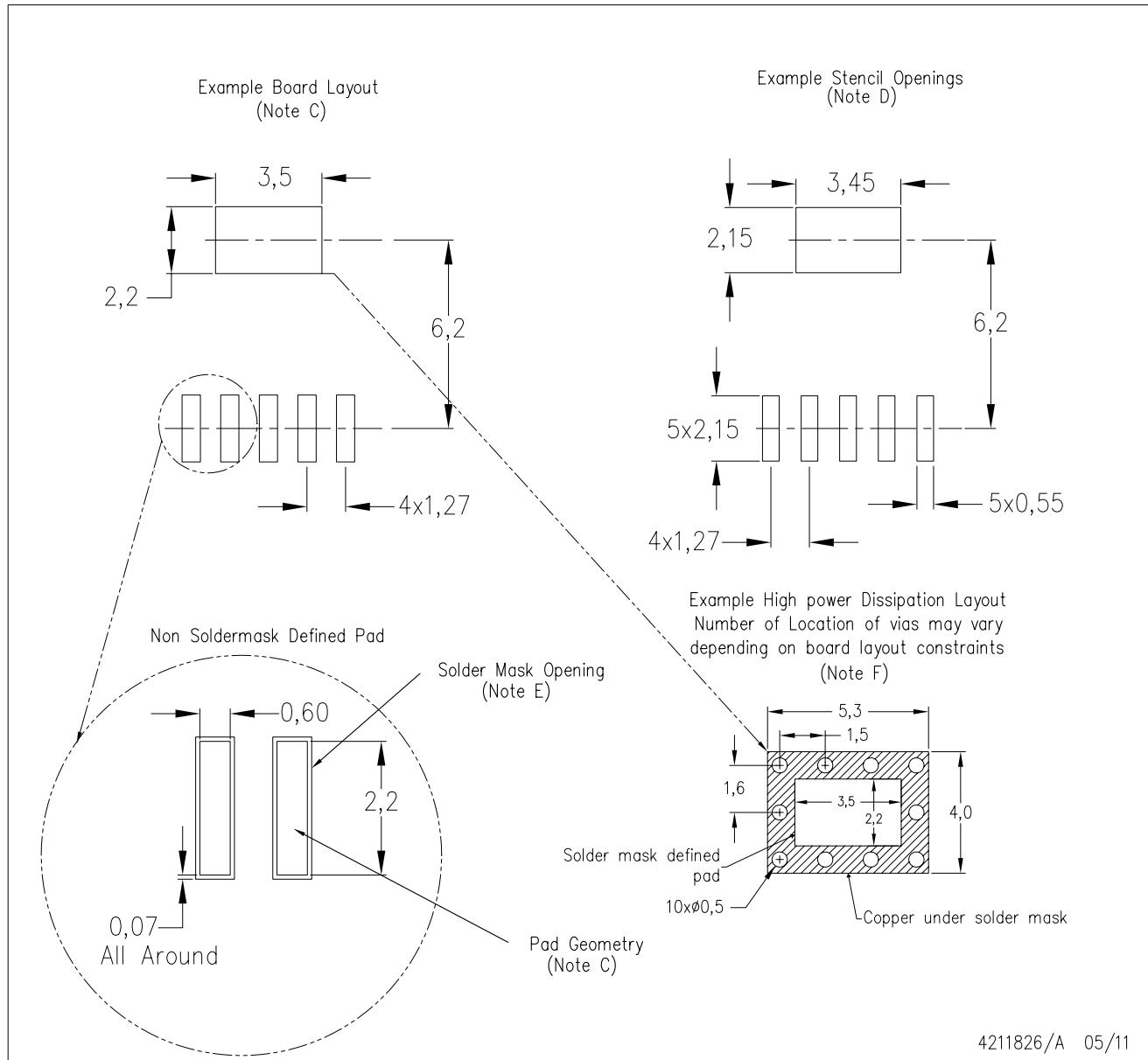
## PLASTIC SMALL-OUTLINE



- NOTES:
- |                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                       |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| A. All linear dimensions are in inches (millimeters).                                                                                                                                                                                                                                                                                     |  Lead width and thickness dimensions apply to solder plated leads. |
| B. This drawing is subject to change without notice.                                                                                                                                                                                                                                                                                      |                                                                                                                                                       |
| C. Controlling dimension in inches.                                                                                                                                                                                                                                                                                                       | G. Interlead flash allow 0.008 inch max.                                                                                                              |
|  Body length and width dimensions are determined at the outermost extremes of the plastic body exclusive of mold flash, tie bar burrs, gate burrs, and interlead flash, but including any mismatch between the top and the bottom of the plastic body. | H. Gate burr/protrusion max. 0.006 inch.                                                                                                              |
|  Lead width dimension does not include dambar protrusion.                                                                                                                                                                                              | I. Datums A and B are to be determined at Datum H.                                                                                                    |

DCQ (R-PDSO-G6)

PLASTIC SMALL OUTLINE

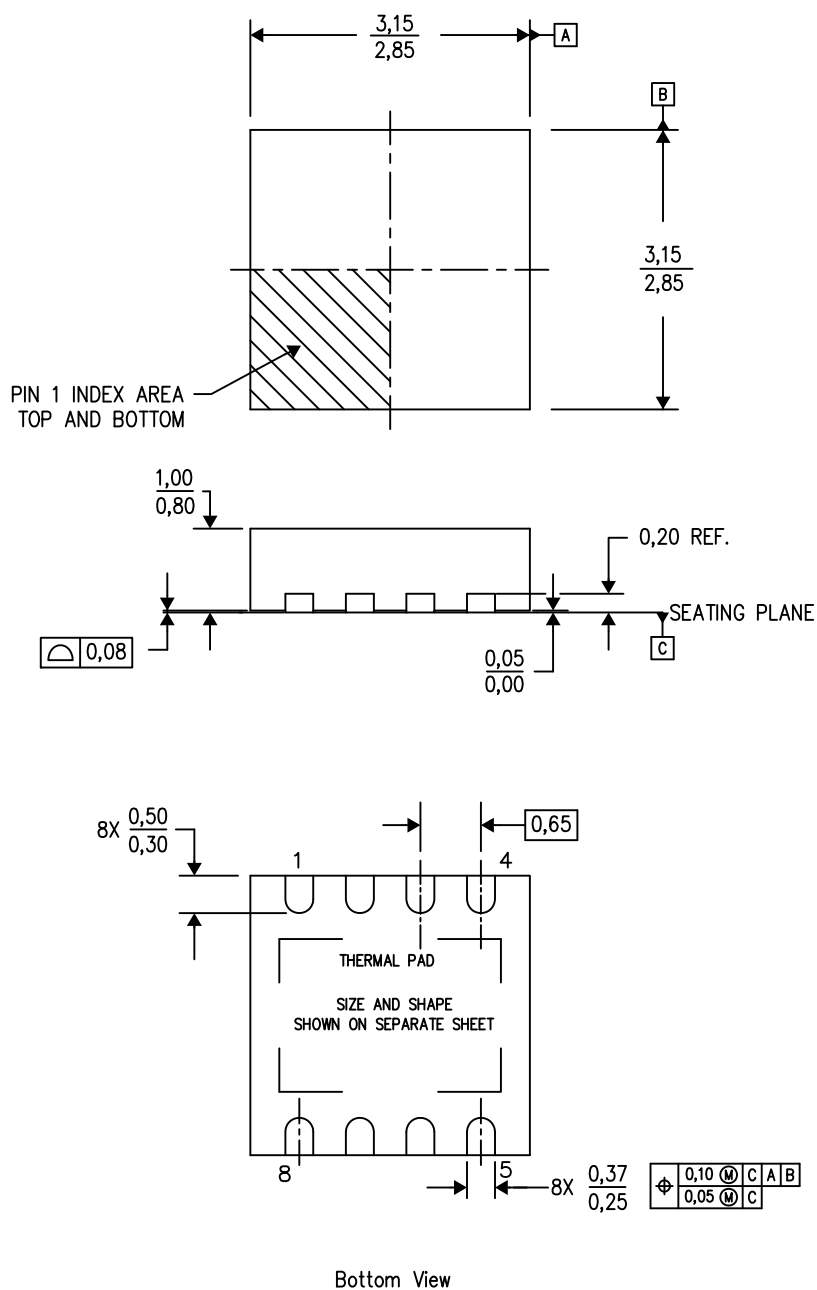


4211826/A 05/11

- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-SM-782 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.
  - Please refer to the product data sheet for specific via and thermal dissipation requirements.

DRB (S-PVSON-N8)

PLASTIC SMALL OUTLINE NO-LEAD



4203482-2/K 06/12

- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - This drawing is subject to change without notice.
  - Small Outline No-Lead (SON) package configuration.
  - The package thermal pad must be soldered to the board for thermal and mechanical performance.
  - See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.

DRB (S-PVSON-N8)

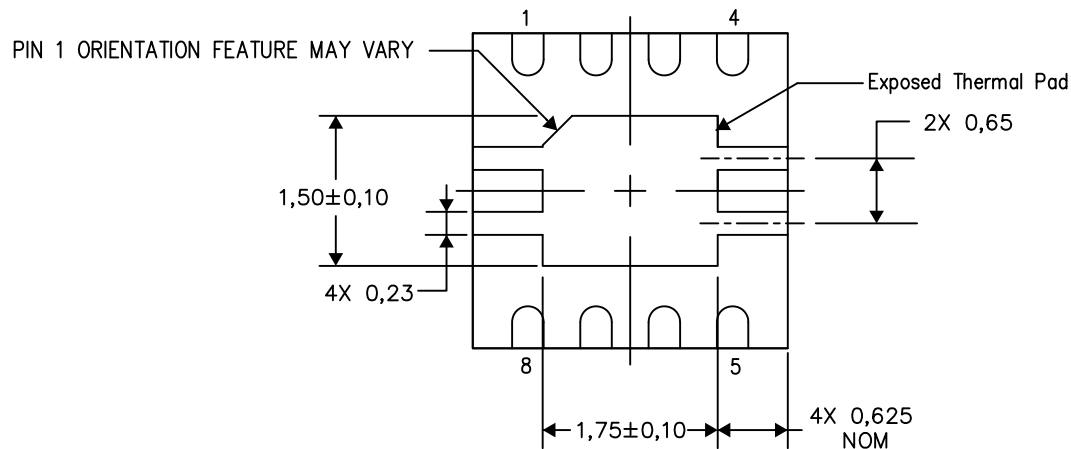
PLASTIC SMALL OUTLINE NO-LEAD

## THERMAL INFORMATION

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

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

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



Bottom View

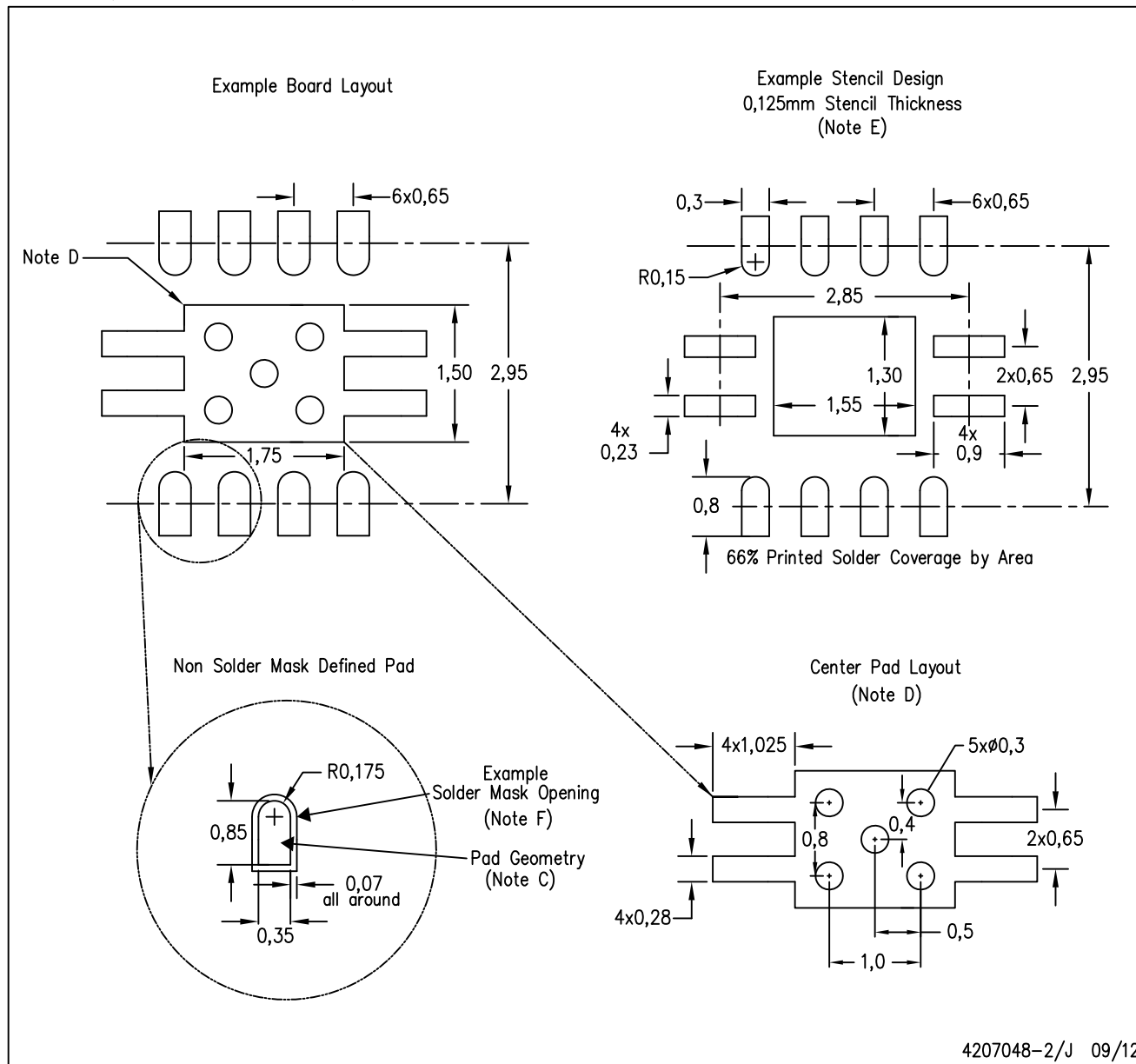
Exposed Thermal Pad Dimensions

4206340-2/N 09/12

NOTE: All linear dimensions are in millimeters

DRB (S-PVSON-N8)

PLASTIC SMALL OUTLINE NO-LEAD



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

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|                               |                                                                                          |
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