

# LOW INPUT VOLTAGE, 1-A LOW-DROPOUT LINEAR REGULATORS WITH SUPERVISOR

Check for Samples: [TPS72501](#), [TPS72515](#), [TPS72516](#), [TPS72518](#), [TPS72525](#)

## FEATURES

- 1-A Output Current
- Available in 1.5-V, 1.6-V, 1.8-V, 2.5-V Fixed-Output and Adjustable Versions (1.2-V to 5.5-V)
- Input Voltage Down to 1.8 V
- Low 170-mV Dropout Voltage at 1 A (TPS72525)
- Stable With Any Type/Value Output Capacitor
- Integrated Supervisor (SVS) With 50-ms RESET Delay Time
- Low 210- $\mu$ A Ground Current at Full Load (TPS72525)
- Less than 1- $\mu$ A Standby Current
- $\pm 2\%$  Output Voltage Tolerance Over Line, Load, and Temperature ( $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ )
- Integrated UVLO
- Thermal and Overcurrent Protection
- 5-Lead SOT223-5 or DPAK and 8-Pin SOP (TPS72501 only) Surface Mount Package

## APPLICATIONS

- PCI Cards
- Modem Banks
- Telecom Boards
- DSP, FPGA, and Microprocessor Power Supplies
- Portable, Battery-Powered Applications

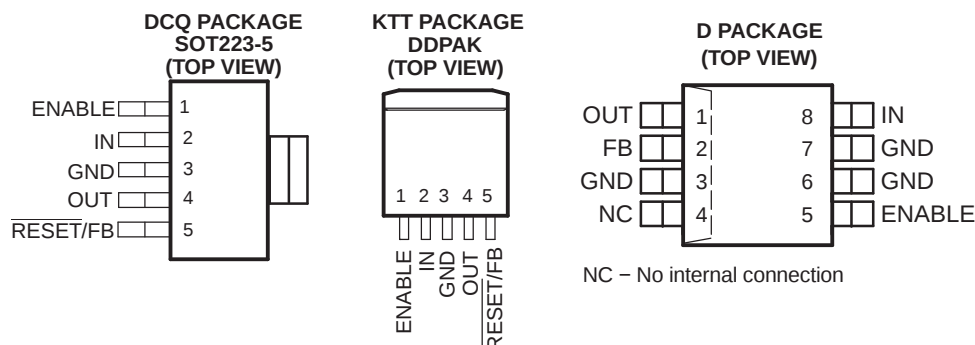
## DESCRIPTION

The TPS725xx family of 1-A low-dropout (LDO) linear regulators has fixed voltage options available that are commonly used to power the latest DSPs, FPGAs, and microcontrollers. An adjustable option ranging from 1.22 V to 5.5 V is also available. The integrated supervisory circuitry provides an active low RESET signal when the output falls out of regulation. The no capacitor/any capacitor feature allows the customer to tailor output transient performance as needed. Therefore, compared to other regulators capable of providing the same output current, this family of regulators can provide a stand-alone power supply solution or a post regulator for a switch mode power supply.

These regulators are ideal for higher current applications. The family operates over a wide range of input voltages (1.8 V to 6 V) and has very low dropout (170 mV at 1-A).

Ground current is typically 210  $\mu$ A at full load and drops to less than 80  $\mu$ A at no load. Standby current is less than 1  $\mu$ A.

Each regulator option is available in either a SOT223-5, D (TPS72501 only), or DPAK package. With a low input voltage and properly heatsinked package, the regulator dissipates more power and achieves higher efficiencies than similar regulators requiring 2.5 V or more minimum input voltage and higher quiescent currents. These features make it a viable power supply solution for portable, battery-powered equipment.



NOTE: TPS72501 replaces RESET with FB. Tab is GND for the DCK and KTT packages.



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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.

## DESCRIPTION (CONTINUED)

Although an output capacitor is not required for stability, transient response and output noise are improved with a 10- $\mu$ F output capacitor.

Unlike some regulators that have a minimum current requirement, the TPS725 family is stable with no output load current. The low noise capability of this family, coupled with its high current operation and ease of power dissipation, make it ideal for telecom boards, modem banks, and other noise-sensitive applications.

## ORDERING INFORMATION

| T <sub>J</sub> | VOLTAGE <sup>(1)</sup>    | SOT223-5 <sup>(2)</sup> | SYMBOL  | DDPAK <sup>(3)</sup> | D <sup>(4)</sup> | SYMBOL   |
|----------------|---------------------------|-------------------------|---------|----------------------|------------------|----------|
| -40°C to 125°C | Adjustable (1.2 V to 5 V) | TPS72501DCQ             | PS72501 | TPS72501KTT          | TPS72501D        | TPS72501 |
|                | 1.5 V                     | TPS72515DCQ             | PS72515 | TPS72515KTT          | —                | TPS72515 |
|                | 1.6 V                     | TPS72516DCQ             | PS72516 | TPS72516KTT          | —                | TPS72516 |
|                | 1.8 V                     | TPS72518DCQ             | PS72518 | TPS72518KTT          | —                | TPS72518 |
|                | 2.5 V                     | TPS72525DCQ             | PS72525 | TPS72525KTT          | —                | TPS72525 |

(1) Other voltage options are available upon request from the manufacturer.

(2) To order a taped and reeled part, add the suffix **R** to the part number (e.g., TPS72501DCQR).

(3) To order a 50-piece reel, add the suffix **T** (e.g., TPS72501KTTT); to order a 500-piece reel, add the suffix **R** (e.g., TPS72501KTRR).

(4) To order a taped and reeled part, add the suffix **R** or **T** (2500 or 500) to the part number (e.g. TPS72501DR)

## ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range unless otherwise noted<sup>(1)</sup>

|                                                      |                               | UNIT |
|------------------------------------------------------|-------------------------------|------|
| Input voltage, V <sub>I</sub> <sup>(2)</sup>         | -0.3 to 7                     | V    |
| Voltage range at EN, FB                              | -0.3 to V <sub>I</sub> + 0.3  | V    |
| Voltage on OUT, RESET                                | 6                             | V    |
| ESD rating, HBM                                      | 2                             | kV   |
| Continuous total power dissipation                   | See Dissipation Ratings Table |      |
| Operating junction temperature range, T <sub>J</sub> | -50 to 150                    | °C   |
| Maximum junction temperature range, T <sub>J</sub>   | 150                           | °C   |
| Storage temperature, T <sub>stg</sub>                | -65 to 150                    | °C   |

(1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) All voltage values are with respect to network ground terminal.

## RECOMMENDED OPERATING CONDITIONS

|                                                | MIN | NOM | MAX | UNIT |
|------------------------------------------------|-----|-----|-----|------|
| Input voltage, V <sub>I</sub> <sup>(1)</sup>   | 1.8 |     | 6   | V    |
| Continuous output current, I <sub>O</sub>      | 0   |     | 1   | A    |
| Operating junction temperature, T <sub>J</sub> | -40 |     | 125 | °C   |

(1) Minimum V<sub>I</sub> = V<sub>O</sub> (nom) + V<sub>DO</sub>.

## PACKAGE DISSIPATION RATINGS

| PACKAGE | BOARD                 | R <sub>θJC</sub> | R <sub>θJA</sub> |
|---------|-----------------------|------------------|------------------|
| DDPAK   | High K <sup>(1)</sup> | 2 °C/W           | 23 °C/W          |
| SOT223  | Low K <sup>(2)</sup>  | 15 °C/W          | 53 °C/W          |
| D-8     | High K <sup>(1)</sup> | 39.4 °C/W        | 55 °C/W          |

- (1) The JEDEC high-K (2s2p) board design used to derive this data was a 3-inch x 3-inch (7.5-cm x 7.5-cm), multilayer board with 1 ounce internal power and ground planes and 2 ounce copper traces on top and bottom of the board.
- (2) The JEDEC low-K (1s) board design used to derive this data was a 3-inch x 3-inch (7.5-cm x 7.5-cm), two-layer board with 2 ounce copper traces on top of the board.

## ELECTRICAL CHARACTERISTICS

over recommended operating free-air temperature range  $V_I = V_{O(typ)} + 1\text{ V}$ ,  $I_O = 1\text{ mA}$ ,  $EN = IN$ ,  $C_O = 1\text{ }\mu\text{F}$ ,  $C_I = 1\text{ }\mu\text{F}$  (unless otherwise noted)

| PARAMETER                 |                                                                                  | TEST CONDITIONS                               |                                            | MIN                                           | TYP                  | MAX                  | UNIT |     |
|---------------------------|----------------------------------------------------------------------------------|-----------------------------------------------|--------------------------------------------|-----------------------------------------------|----------------------|----------------------|------|-----|
| Bandgap voltage reference |                                                                                  |                                               |                                            | 1.177                                         | 1.220                | 1.263                | V    |     |
| V <sub>O</sub>            | Output voltage                                                                   | TPS72501 Adjustable                           | 0 μA < I <sub>O</sub> < 1 A <sup>(1)</sup> | 1.22 V ≤ V <sub>O</sub> ≤ 5.5 V               | 0.965 V <sub>O</sub> | 1.035 V <sub>O</sub> | V    |     |
|                           |                                                                                  | TPS72515                                      | T <sub>J</sub> = 25°C                      |                                               | 1.5                  |                      |      |     |
|                           |                                                                                  |                                               | 0 μA< I <sub>O</sub> < 1 A                 | 1.8 V ≤ V <sub>I</sub> ≤ 5.5 V                | 1.47                 | 1.53                 |      |     |
|                           |                                                                                  | TPS72516                                      | T <sub>J</sub> = 25°C                      |                                               | 1.6                  |                      |      |     |
|                           |                                                                                  |                                               | 0 μA < I <sub>O</sub> < 1 A                | 2.6 V ≤ V <sub>I</sub> ≤ 5.5 V                | 1.568                | 1.632                |      |     |
|                           |                                                                                  | TPS72518                                      | T <sub>J</sub> = 25°C                      |                                               | 1.8                  |                      |      |     |
|                           |                                                                                  |                                               | 0 μA < I <sub>O</sub> < 1 A                | 2.8 V ≤ V <sub>I</sub> ≤ 5.5 V                | 1.764                | 1.836                |      |     |
|                           |                                                                                  | TPS72525                                      | T <sub>J</sub> = 25°C                      |                                               | 2.5                  |                      |      |     |
|                           | 0 μA < I <sub>O</sub> < 1 A                                                      | 3.5 V ≤ V <sub>I</sub> ≤ 5.5 V                | 2.45                                       | 2.55                                          |                      |                      |      |     |
| I                         | Ground current                                                                   | I <sub>O</sub> = 0 μA                         |                                            |                                               | 75                   | 120                  | μA   |     |
|                           |                                                                                  | I <sub>O</sub> = 1 A                          |                                            |                                               | 210                  | 300                  |      |     |
|                           | Standby current                                                                  | EN < 0.4 V                                    | T <sub>J</sub> = 25°C                      |                                               | 0.2                  |                      | μA   |     |
|                           |                                                                                  | EN < 0.4 V                                    |                                            |                                               | 1                    |                      |      |     |
| V <sub>n</sub>            | Output noise voltage                                                             | BW = 200 Hz to 100 kHz, T <sub>J</sub> = 25°C |                                            | C <sub>O</sub> = 10 μF, I <sub>O</sub> = 1 mA | 150                  |                      | μV   |     |
| PSRR                      | Ripple rejection                                                                 | f = 1 kHz, C <sub>O</sub> = 10 μF             | T <sub>J</sub> = 25°C                      |                                               | 60                   |                      | dB   |     |
|                           | Current limit <sup>(2)</sup>                                                     |                                               |                                            | 1.1                                           | 1.6                  | 2.3                  | A    |     |
|                           | Output voltage line regulation (ΔV <sub>O</sub> /V <sub>O</sub> ) <sup>(3)</sup> | V <sub>O</sub> + 1 V < V <sub>I</sub> ≤ 5.5 V |                                            |                                               | -0.15                | 0.02                 | 0.15 | %/V |
|                           | Output voltage load regulation                                                   | 0 μA < I <sub>O</sub> < 1 A                   |                                            |                                               | -0.25                | 0.05                 | 0.25 | %/A |
| V <sub>IH</sub>           | EN high level input <sup>(2)</sup>                                               |                                               |                                            | 1.3                                           |                      |                      | V    |     |
| V <sub>IL</sub>           | EN low level input <sup>(2)</sup>                                                |                                               |                                            | -0.2                                          |                      | 0.4                  |      |     |
| I <sub>I</sub>            | EN input current                                                                 | EN = 0 V or V <sub>I</sub>                    |                                            |                                               | 0.01                 | 100                  | nA   |     |
| I <sub>(FB)</sub>         | Feedback current                                                                 | TPS72501                                      | V <sub>(FB)</sub> = 1.22                   | -100                                          |                      | 100                  | nA   |     |
|                           | UVLO threshold                                                                   | V <sub>CC</sub> rising                        |                                            | 1.45                                          | 1.57                 | 1.70                 | V    |     |
|                           | UVLO hysteresis                                                                  | T <sub>J</sub> = 25°C, V <sub>CC</sub> rising |                                            | 50                                            |                      |                      | mV   |     |
|                           | UVLO deglitch                                                                    | T <sub>J</sub> = 25°C, V <sub>CC</sub> rising |                                            | 10                                            |                      |                      | μs   |     |
|                           | UVLO delay                                                                       | T <sub>J</sub> = 25°C, V <sub>CC</sub> rising |                                            | 100                                           |                      |                      | μs   |     |

- (1) Minimum IN operating voltage used for testing is V<sub>O(typ)</sub> + 1 V.
- (2) Test condition includes output voltage V<sub>O</sub> = V<sub>O</sub> - 15% and pulse duration = 10 ms.
- (3) V<sub>Imin</sub> = (V<sub>O</sub> + 1) or 1.8 V whichever is greater.

$$\text{Line regulation (mV)} = (\%/\text{V}) \times \frac{V_O(5.5\text{ V} - V_{Imin})}{100} \times 1000$$

## ELECTRICAL CHARACTERISTICS (continued)

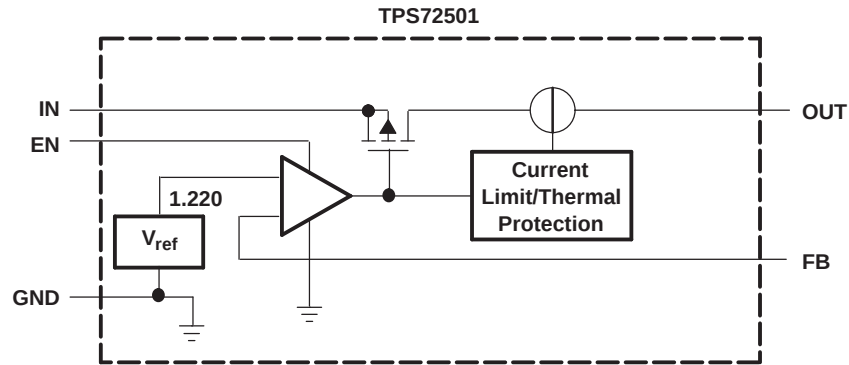
over recommended operating free-air temperature range  $V_I = V_{O(typ)} + 1\text{ V}$ ,  $I_O = 1\text{ mA}$ ,  $EN = IN$ ,  $C_O = 1\text{ }\mu\text{F}$ ,  $C_I = 1\text{ }\mu\text{F}$  (unless otherwise noted)

| PARAMETER                 |                                            | TEST CONDITIONS         |                    | MIN                      | TYP  | MAX | UNIT          |
|---------------------------|--------------------------------------------|-------------------------|--------------------|--------------------------|------|-----|---------------|
| $V_{DO}$                  | Dropout voltage                            | TPS72525 <sup>(4)</sup> | $I_O = 1\text{ A}$ | $T_J = 25^\circ\text{C}$ | 170  |     | mV            |
|                           |                                            |                         | $I_O = 1\text{ A}$ |                          |      | 280 |               |
|                           | TPS72518 <sup>(5)</sup>                    |                         | $I_O = 1\text{ A}$ | $T_J = 25^\circ\text{C}$ | 210  |     |               |
|                           |                                            |                         | $I_O = 1\text{ A}$ |                          |      | 320 |               |
| $\overline{\text{RESET}}$ | Minimum input voltage for valid RESET      |                         |                    |                          | 1.3  |     | V             |
|                           | Trip threshold voltage                     |                         |                    |                          | 90   | 93  | % $V_O$       |
|                           | Hysteresis voltage                         |                         |                    |                          |      | 10  | mV            |
|                           | $t_{(\text{RESET})}$ delay time            |                         |                    |                          | 25   | 50  | ms            |
|                           | Rising edge deglitch                       |                         |                    |                          |      | 10  | $\mu\text{s}$ |
|                           | Output low voltage (at 700 $\mu\text{A}$ ) |                         |                    |                          | -0.3 | 0.4 | V             |
|                           | Leakage current                            |                         |                    |                          |      | 100 | nA            |

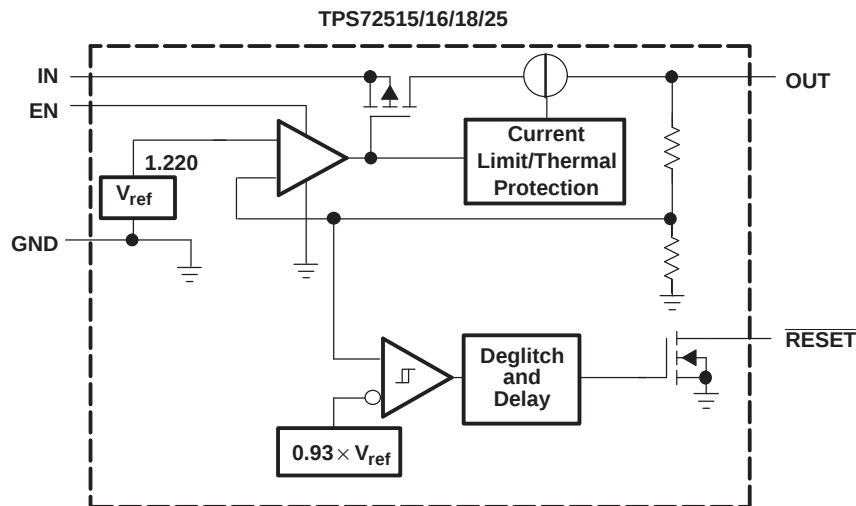
(4) Dropout voltage is defined as the differential voltage between  $V_O$  and  $V_I$  when  $V_O$  drops 100 mV below the value measured with  $V_I = V_O + 1\text{ V}$ .

(5) Dropout voltage is defined as the differential voltage between  $V_O$  and  $V_I$  when  $V_O$  drops 100 mV below the value measured with  $V_I = V_O + 1\text{ V}$ .

## FUNCTIONAL BLOCK DIAGRAM—ADJUSTABLE VERSION



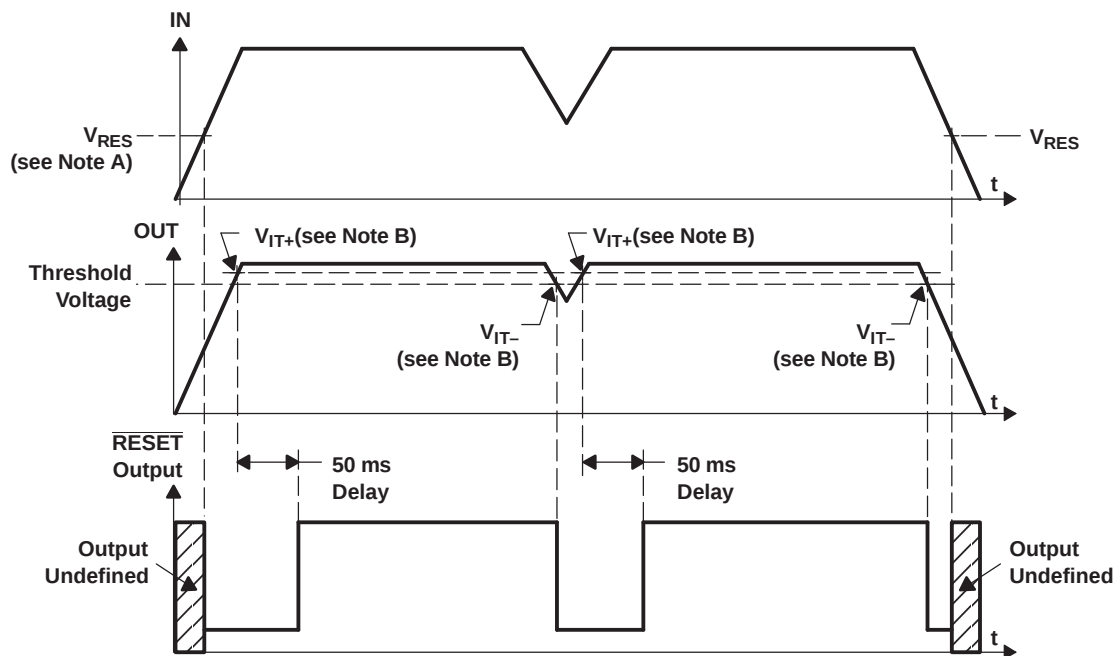
## FUNCTIONAL BLOCK DIAGRAM—FIXED VERSION



## TERMINAL FUNCTIONS

| TERMINAL |         |                | I/O | DESCRIPTION                                                                                                                                                                                                                                                                                                                                                                                   |
|----------|---------|----------------|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME     | NO. D   | NO. D CQ & KTT |     |                                                                                                                                                                                                                                                                                                                                                                                               |
| ENABLE   | 5       | 1              | I   | Enable input                                                                                                                                                                                                                                                                                                                                                                                  |
| FB       | 2       |                |     | Feedback                                                                                                                                                                                                                                                                                                                                                                                      |
| GND      | 3, 6, 7 | 3              |     | Ground                                                                                                                                                                                                                                                                                                                                                                                        |
| IN       | 8       | 2              | I   | Input supply voltage                                                                                                                                                                                                                                                                                                                                                                          |
| RESET/FB | —       | 5              | O/I | This terminal is the feedback point for the adjustable option TPS72501. For all other options, this terminal is the <b>RESET</b> output terminal. When used with a pullup resistor, this open-drain output provides the active low <b>RESET</b> signal when the regulator output voltage drops more than 5% below its nominal output voltage. The <b>RESET</b> delay time is typically 50 ms. |
| NC       | 4       | —              |     | No connection                                                                                                                                                                                                                                                                                                                                                                                 |
| OUT      | 1       | 4              | O   | Regulated output voltage                                                                                                                                                                                                                                                                                                                                                                      |

## RESET TIMING DIAGRAM



NOTES: A.  $V_{RES}$  is the minimum input voltage for a valid RESET. The symbol  $V_{RES}$  is not currently listed within EIA or JEDEC standards for semiconductor symbology.

B.  $V_{IT-}$  Trip voltage is typically 7% lower than the output voltage ( $93\%V_O$ ).  $V_{IT-}$  to  $V_{IT+}$  is the hysteresis voltage.

## TYPICAL CHARACTERISTICS

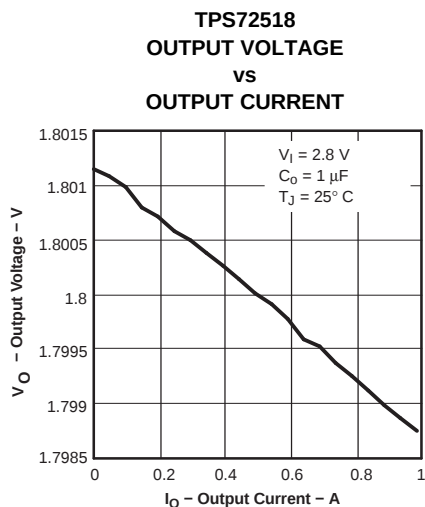


Figure 1.

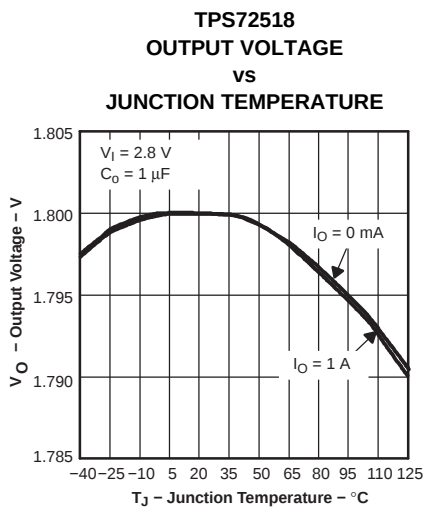


Figure 2.

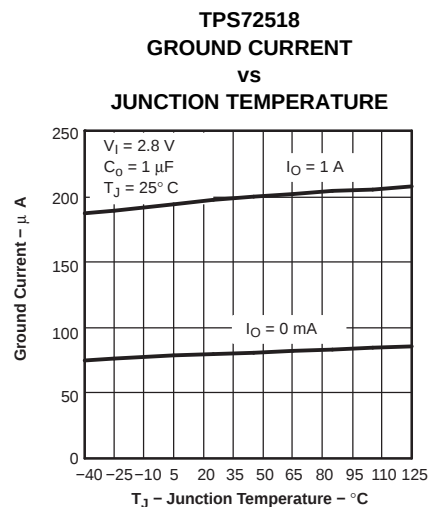


Figure 3.

## TYPICAL CHARACTERISTICS (continued)

**TPS72518  
GROUND CURRENT  
vs  
OUTPUT CURRENT**

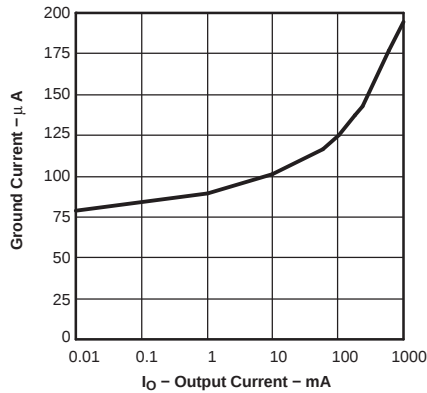


Figure 4.

**TPS72525  
DC DROPOUT VOLTAGE  
vs  
OUTPUT CURRENT**

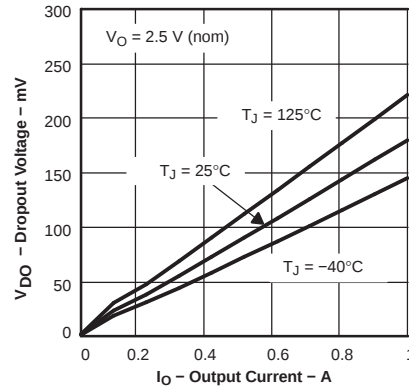


Figure 5.

**TPS72518  
DROPOUT VOLTAGE  
vs  
JUNCTION TEMPERATURE**

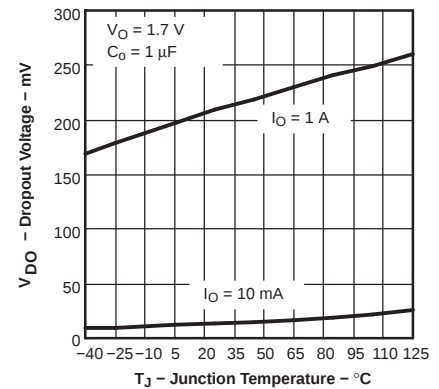


Figure 6.

**MINIMUM REQUIRED  
INPUT VOLTAGE  
vs  
OUTPUT VOLTAGE**

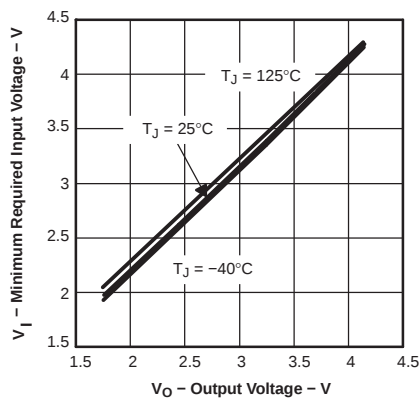


Figure 7.

**TPS72518  
LINE TRANSIENT RESPONSE**

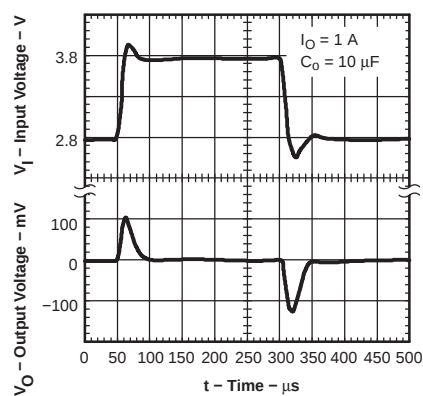


Figure 8.

**TPS72518  
LOAD TRANSIENT RESPONSE**

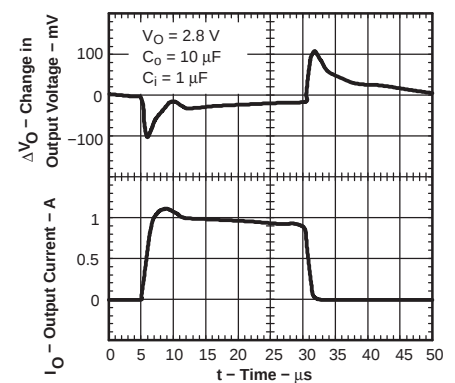


Figure 9.

## TYPICAL CHARACTERISTICS (continued)

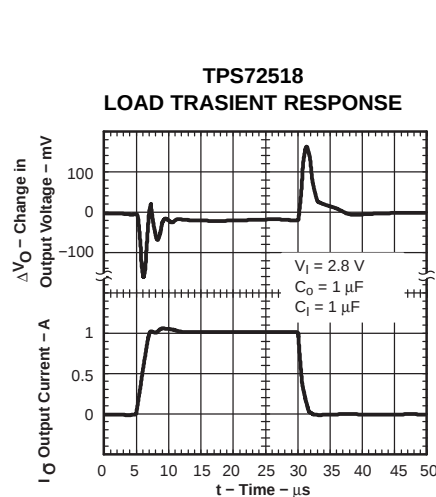


Figure 10.

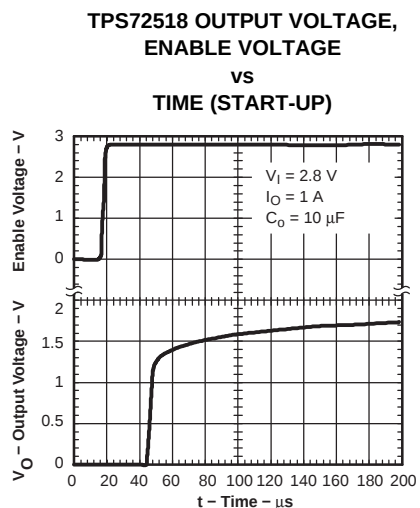


Figure 11.

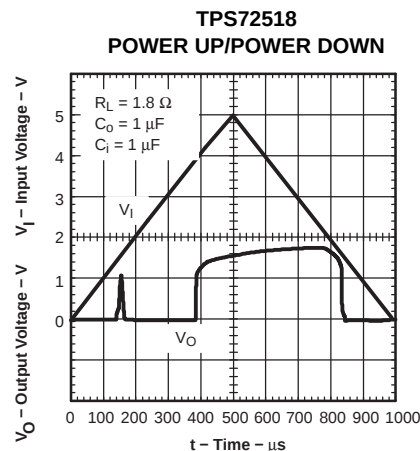


Figure 12.

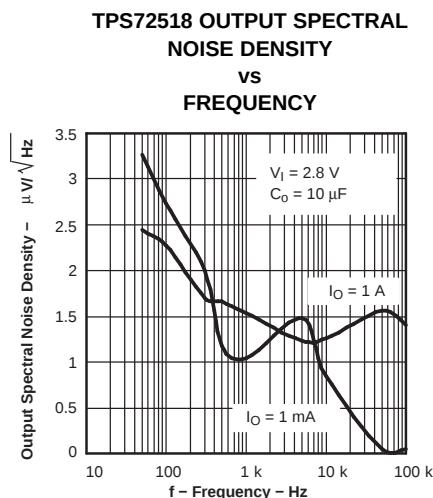


Figure 13.

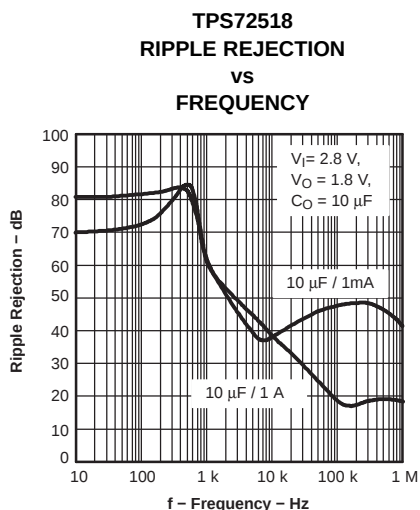


Figure 14.

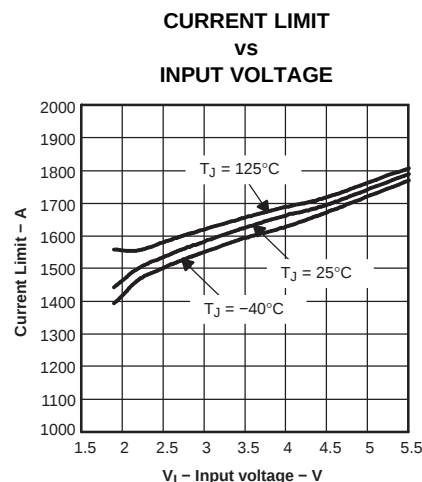


Figure 15.

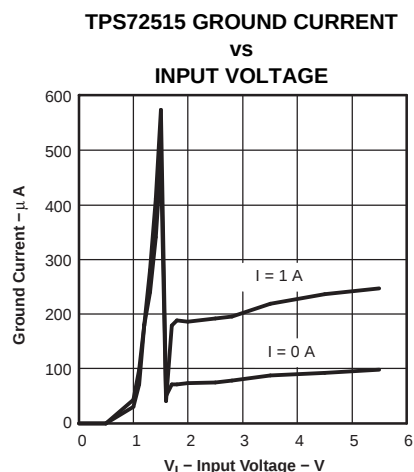


Figure 16.

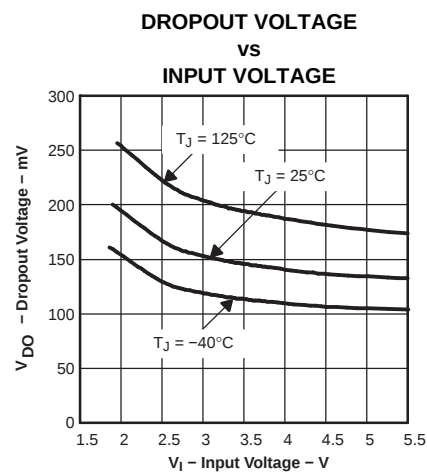


Figure 17.

## APPLICATION INFORMATION

The TPS725xx family of low-dropout (LDO) regulators has numerous features that make it applicable to a wide range of applications. The family operates with very low input voltage ( $\geq 1.8$  V) and low dropout voltage (typically 200 mV at full load), making it an efficient stand-alone power supply or post regulator for battery or switch mode power supplies. Both the active low RESET and 1-A output current make the TPS725xx family ideal for powering processor and FPGA supplies. The TPS725xx family also has low output noise (typically 150  $\mu\text{V}_{\text{RMS}}$  with 10- $\mu\text{F}$  output capacitor), making it ideal for use in telecom equipment.

### External Capacitor Requirements

A 1- $\mu\text{F}$  or larger ceramic input bypass capacitor, connected between IN and GND and located close to the TPS725xx, is required for stability. To improve transient response, noise rejection, and ripple rejection, an additional 10- $\mu\text{F}$  or larger, low ESR capacitor is recommended. A higher-value, low ESR 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, especially if the minimum input voltage of 1.8 V is used.

Although an output capacitor is not required for stability, transient response and output noise are improved with a 10- $\mu\text{F}$  output capacitor.

### Programming the TPS72501 Adjustable LDO Regulator

The output voltage of the TPS72501 adjustable regulator is programmed using an external resistor divider as shown in Figure 18. The output voltage is calculated using:

$$V_O = V_{\text{ref}} \times \left(1 + \frac{R1}{R2}\right) \quad (1)$$

Where:

- $V_{\text{FB}} = V_{\text{REF}} = 1.22$  V typical (see the electrical characteristics for  $V_{\text{REF}}$  range)

Resistors R1 and R2 should be chosen for approximately 10- $\mu\text{A}$  divider current. Lower value resistors offer no inherent advantage and waste more power. Higher values should be avoided as leakage currents at FB increase the output voltage error. The recommended design procedure is to choose  $R2 = 120$  k $\Omega$  to set the divider current at 10  $\mu\text{A}$  and then calculate R1 using:

$$R1 = \left(\frac{V_O}{V_{\text{ref}}} - 1\right) \times R2 \quad (2)$$

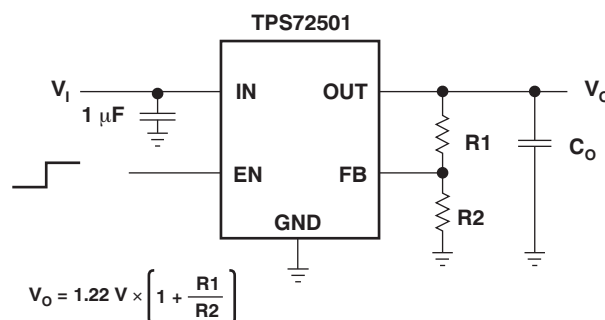


Figure 18. TPS72501 Adjustable Typical Application Diagram

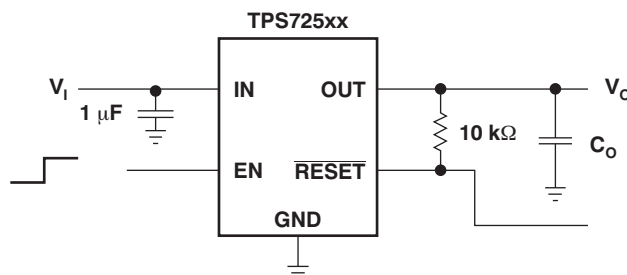


Figure 19. TPS72501 Fixed Output Typical Application Diagram

Table 1. Output Voltage Programming Guide (Standard 1% Resistor Values)

| PROGRAM VOLTAGE | R1 (kΩ) | R2 (kΩ) | ACTUAL VOLTAGE |
|-----------------|---------|---------|----------------|
| 1.8 V           | 56.2    | 118     | 1.801          |
| 2.5 V           | 127     | 121     | 2.5            |
| 3.3 V           | 196     | 115     | 3.299          |
| 3.6 V           | 205     | 105     | 3.602          |

## Regulator Protection

The TPS725xx pass element has a built-in back diode that safely 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 is anticipated, external limiting might be appropriate.

The TPS725xx also features internal current limiting and thermal protection. During normal operation, the TPS725xx limits output current to approximately 1.6 A. 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 165°C, thermal-protection circuitry shuts it down. Once the device has cooled down to below 145°C, regulator operation resumes.

## THERMAL INFORMATION

The amount of heat that an LDO linear regulator generates is directly proportional to the amount of power it dissipates during operation. All integrated circuits have a maximum allowable junction temperature ( $T_{J,max}$ ) above which normal operation is not assured. A system designer must design the operating environment so that the operating junction temperature ( $T_J$ ) does not exceed the maximum junction temperature ( $T_{J,max}$ ). The two main environmental variables that a designer can use to improve thermal performance are air flow and external heatsinks. The purpose of this information is to aid the designer in determining the proper operating environment for a linear regulator that is operating at a specific power level.

In general, the maximum expected power ( $P_{D(max)}$ ) consumed by a linear regulator is computed as:

$$P_{D,max} = (V_{I(avg)} - V_{O(avg)}) \times I_{O(avg)} + V_{I(avg)} \times I_{(Q)} \quad (3)$$

Where:

- $V_{I(avg)}$  is the average input voltage.
- $V_{O(avg)}$  is the average output voltage.
- $I_{O(avg)}$  is the average output current.
- $I_{(Q)}$  is the quiescent current.

For most TI LDO regulators, the quiescent current is insignificant compared to the average output current; therefore, the term  $V_{I(avg)} \times I_{(Q)}$  can be neglected. The operating junction temperature is computed by adding the ambient temperature ( $T_A$ ) and the increase in temperature due to the regulator's power dissipation. The temperature rise is computed by multiplying the maximum expected power dissipation by the sum of the thermal resistances between the junction and the case ( $R_{\theta JC}$ ), the case to heatsink ( $R_{\theta CS}$ ), and the heatsink to ambient ( $R_{\theta SA}$ ). Thermal resistances are measures of how effectively an object dissipates heat. Typically, the larger the device, the more surface area available for power dissipation and the lower the object's thermal resistance.

Figure 20 illustrates these thermal resistances for (a) a SOT223 package mounted in a JEDEC low-K board, and (b) a DDPAK package mounted on a JEDEC high-K board.

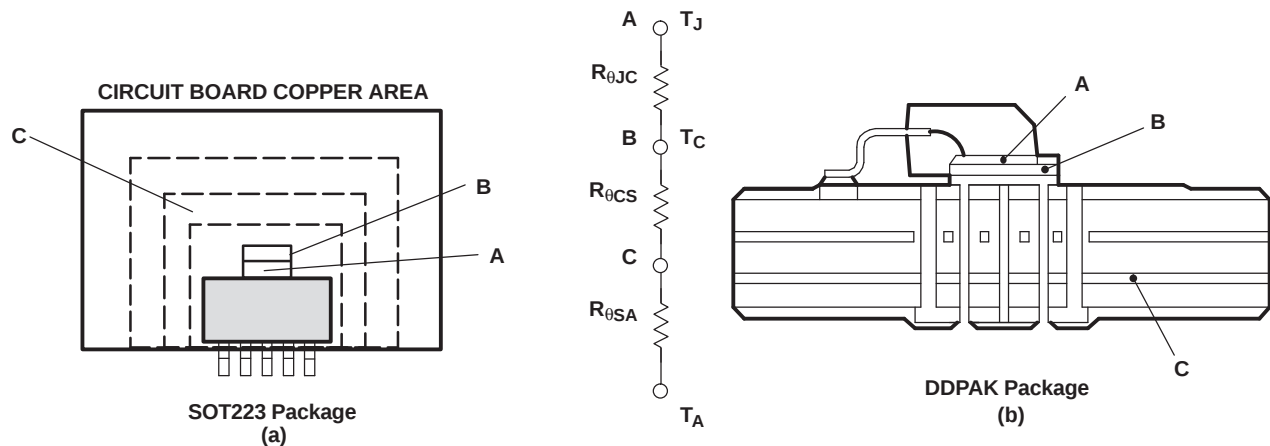


Figure 20. Thermal Resistances

Equation 4 summarizes the computation:

$$T_J = T_A + P_{D,max} \times (R_{\theta JC} + R_{\theta CS} + R_{\theta SA}) \quad (4)$$

The  $R_{\theta JC}$  is specific to each regulator as determined by its package, lead frame, and die size provided in the regulator's data sheet. The  $R_{\theta SA}$  is a function of the type and size of heatsink. For example, *black body radiator* type heatsinks can have  $R_{\theta CS}$  values ranging from 5°C/W for very large heatsinks to 50°C/W for very small heatsinks. The  $R_{\theta CS}$  is a function of how the package is attached to the heatsink. For example, if a thermal compound is used to attach a heatsink to a SOT223 package,  $R_{\theta CS}$  of 1°C/W is reasonable.

Even if no external *black body radiator* type heatsink is attached to the package, the board on which the regulator is mounted provides some heatsinking through the pin solder connections. Some packages, like the DDPAK and SOT223 packages, use a copper plane underneath the package or the circuit board's ground plane for additional heatsinking to improve their thermal performance. Computer-aided thermal modeling can be used to compute very accurate approximations of an integrated circuit's thermal performance in different operating environments (e.g., different types of circuit boards, different types and sizes of heatsinks, different air flows, etc.). Using these models, the three thermal resistances can be combined into one thermal resistance between junction and ambient ( $R_{\theta JA}$ ). This  $R_{\theta JA}$  is valid only for the specific operating environment used in the computer model.

Equation 4 simplifies into Equation 5:

$$T_J = T_A + P_{Dmax} \times R_{\theta JA} \quad (5)$$

Rearranging Equation 5 gives Equation 6:

$$R_{\theta JA} = \frac{T_J - T_A}{P_{Dmax}} \quad (6)$$

Using Equation 5 and the computer model generated curves shown in Figure 21 and Figure 24, a designer can quickly compute the required heatsink thermal resistance/board area for a given ambient temperature, power dissipation, and operating environment.

## DDPAK Power Dissipation

The DDPAK package provides an effective means of managing power dissipation in surface mount applications. The DDPAK package dimensions are provided in the *Mechanical Data* section at the end of the data sheet. The addition of a copper plane directly underneath the DDPAK package enhances the thermal performance of the package.

To illustrate, the TPS72525 in a DDPAK package was chosen. For this example, the average input voltage is 5 V, the output voltage is 2.5 V, the average output current is 1 A, the ambient temperature 55°C, the air flow is 150 LFM, and the operating environment is the same as documented below. Neglecting the quiescent current, the maximum average power is:

$$P_{Dmax} = (5 - 2.5) V \times 1 A = 2.5 W \quad (7)$$

Substituting  $T_{Jmax}$  for  $T_J$  into Equation 6 gives Equation 8:

$$R_{\theta JAmax} = (125 - 55)^\circ C / 2.5 W = 28^\circ C/W \quad (8)$$

From Figure 21, DDPAK Thermal Resistance vs Copper Heatsink Area, the ground plane needs to be 1 cm<sup>2</sup> for the part to dissipate 2.5 W. The operating environment used in the computer model to construct Figure 21 consisted of a standard JEDEC High-K board (2S2P) with a 1 oz. internal copper plane and ground plane. The package is soldered to a 2 oz. copper pad. The pad is tied through thermal vias to the 1 oz. ground plane. Figure 22 shows the side view of the operating environment used in the computer model.

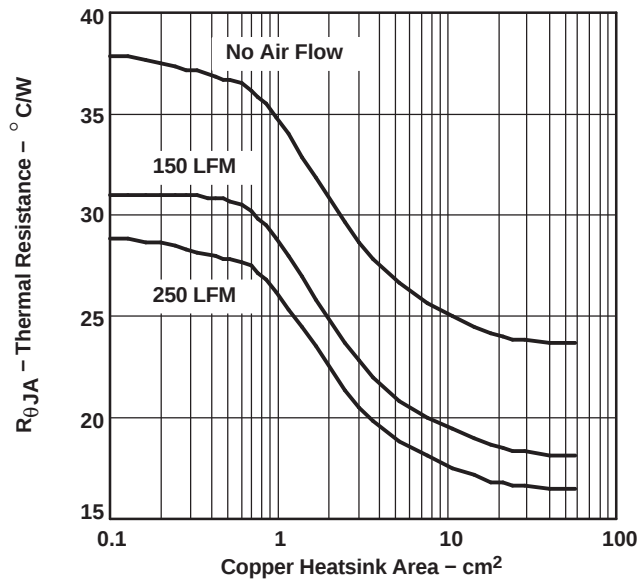


Figure 21. DPAK Thermal Resistance vs Copper Heatsink Area

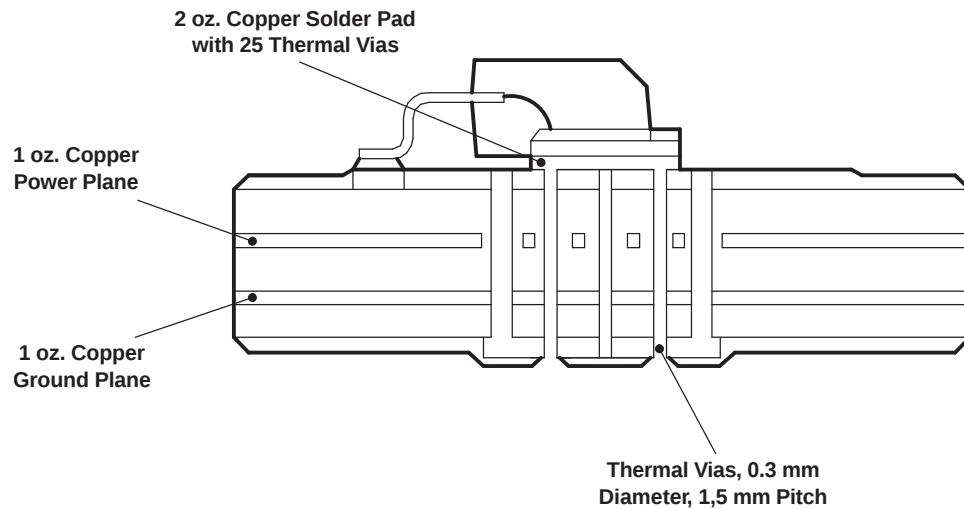


Figure 22. DPAK Thermal Resistance

From the data in [Figure 23](#) and rearranging [Equation 6](#), the maximum power dissipation for a different ground plane area and a specific ambient temperature can be computed.

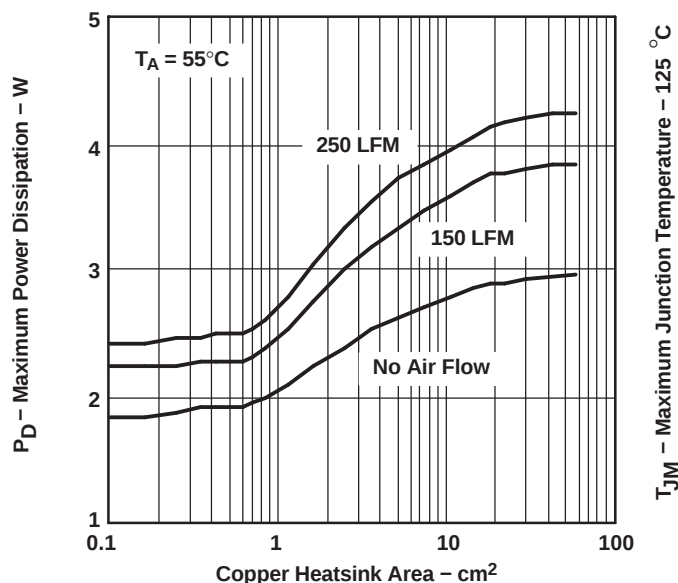


Figure 23. Maximum Power Dissipation vs Copper Heatsink Area

### SOT223 Power Dissipation

The SOT223 package provides an effective means of managing power dissipation in surface mount applications. The SOT223 package dimensions are provided in the *Mechanical Data* section at the end of the data sheet. The addition of a copper plane directly underneath the SOT223 package enhances the thermal performance of the package.

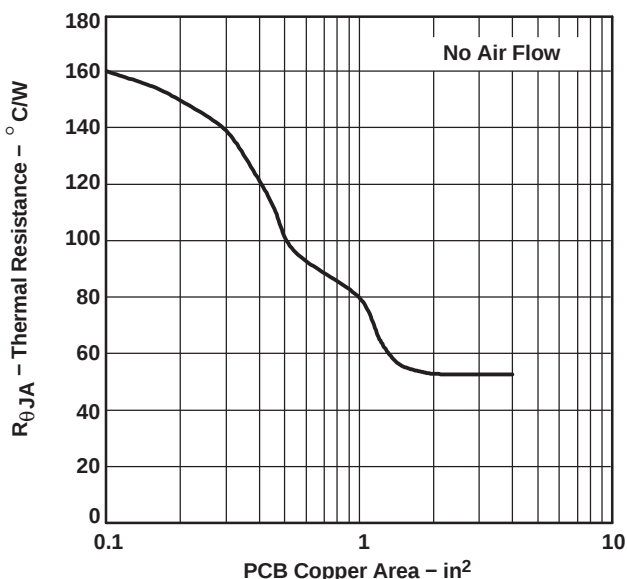
To illustrate, the TPS72525 in a SOT223 package was chosen. For this example, the average input voltage is 3.3 V, the output voltage is 2.5 V, the average output current is 1 A, the ambient temperature 55°C, no air flow is present, and the operating environment is the same as documented below. Neglecting the quiescent current, the maximum average power is:

$$P_{Dmax} = (3.3 - 2.5) V \times 1 A = 800 \text{ mW} \quad (9)$$

Substituting  $T_{Jmax}$  for  $T_J$  into Equation 6 gives Equation 10:

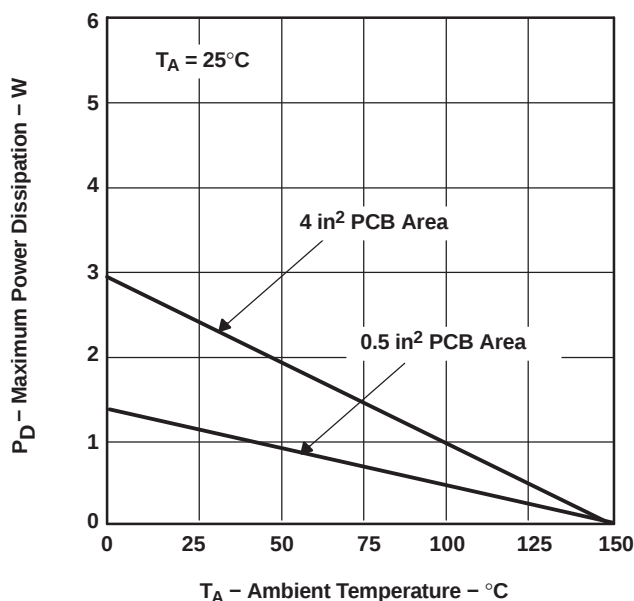
$$R_{\theta JA}^{max} = (125 - 55)^{\circ}C / 800 \text{ mW} = 87.5^{\circ}C/W \quad (10)$$

From Figure 24,  $R_{\theta JA}$  vs PCB Copper Area, the ground plane needs to be 0.55 in<sup>2</sup> for the part to dissipate 800 mW. The operating environment used to construct Figure 24 consisted of a board with 1 oz. copper planes. The package is soldered to a 1 oz. copper pad on the top of the board. The pad is tied through thermal vias to the 1 oz. ground plane.



**Figure 24. SOT223 Thermal Resistance vs PCB AREA**

From the data in [Figure 24](#) and rearranging [Equation 6](#), the maximum power dissipation for a different ground plane area and a specific ambient temperature can be computed (as shown in [Figure 25](#)).



**Figure 25. SOT223 Power Dissipation**

## REVISION HISTORY

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

| Changes from Revision D (March 2004) to Revision E                              | Page |
|---------------------------------------------------------------------------------|------|
| • Deleted Figure 14, <i>Output Impedance vs Frequency</i> .....                 | 8    |
| • Updated <a href="#">Figure 18</a> .....                                       | 9    |
| • Added <a href="#">Figure 19</a> .....                                         | 10   |
| • Added <a href="#">Table 1</a> , <i>Output Voltage Programming Guide</i> ..... | 10   |

**PACKAGING INFORMATION**

| Orderable part number        | Status<br>(1) | Material type<br>(2) | Package   Pins             | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|------------------------------|---------------|----------------------|----------------------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">TPS72501DCQ</a>  | Obsolete      | Production           | SOT-223 (DCQ)   6          | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | PS72501             |
| <a href="#">TPS72501DCQR</a> | Active        | Production           | SOT-223 (DCQ)   6          | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | PS72501             |
| TPS72501DCQR.B               | Active        | Production           | SOT-223 (DCQ)   6          | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | PS72501             |
| TPS72501DCQRG4               | Active        | Production           | SOT-223 (DCQ)   6          | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | PS72501             |
| <a href="#">TPS72501KTTR</a> | Active        | Production           | DDPAK/<br>TO-263 (KTT)   5 | 500   LARGE T&R       | Yes         | SN                                   | Level-2-260C-1 YEAR               | -40 to 125   | TPS<br>72501        |
| TPS72501KTTR.B               | Active        | Production           | DDPAK/<br>TO-263 (KTT)   5 | 500   LARGE T&R       | Yes         | SN                                   | Level-2-260C-1 YEAR               | -40 to 125   | TPS<br>72501        |
| <a href="#">TPS72515DCQ</a>  | Obsolete      | Production           | SOT-223 (DCQ)   6          | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | PS72515             |
| <a href="#">TPS72515DCQR</a> | Active        | Production           | SOT-223 (DCQ)   6          | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | PS72515             |
| TPS72515DCQR.B               | Active        | Production           | SOT-223 (DCQ)   6          | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | PS72515             |
| <a href="#">TPS72515KTTR</a> | Active        | Production           | DDPAK/<br>TO-263 (KTT)   5 | 500   LARGE T&R       | Yes         | SN                                   | Level-2-260C-1 YEAR               | -40 to 125   | TPS<br>72515        |
| TPS72515KTTR.B               | Active        | Production           | DDPAK/<br>TO-263 (KTT)   5 | 500   LARGE T&R       | Yes         | SN                                   | Level-2-260C-1 YEAR               | -40 to 125   | TPS<br>72515        |
| <a href="#">TPS72516DCQ</a>  | Obsolete      | Production           | SOT-223 (DCQ)   6          | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | PS72516             |
| <a href="#">TPS72516DCQR</a> | Obsolete      | Production           | SOT-223 (DCQ)   6          | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | PS72516             |
| <a href="#">TPS72516KTTT</a> | Obsolete      | Production           | DDPAK/<br>TO-263 (KTT)   5 | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | TPS<br>72516        |
| <a href="#">TPS72518KTTR</a> | Obsolete      | Production           | DDPAK/<br>TO-263 (KTT)   5 | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | TPS<br>72518        |
| <a href="#">TPS72525DCQ</a>  | Obsolete      | Production           | SOT-223 (DCQ)   6          | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | PS72525             |
| <a href="#">TPS72525DCQR</a> | Active        | Production           | SOT-223 (DCQ)   6          | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | PS72525             |
| TPS72525DCQR.B               | Active        | Production           | SOT-223 (DCQ)   6          | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | PS72525             |
| TPS72525DCQRG4               | Active        | Production           | SOT-223 (DCQ)   6          | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | PS72525             |
| <a href="#">TPS72525KTTR</a> | Active        | Production           | DDPAK/<br>TO-263 (KTT)   5 | 500   LARGE T&R       | Yes         | SN                                   | Level-2-260C-1 YEAR               | -40 to 125   | TPS<br>72525        |
| TPS72525KTTR.B               | Active        | Production           | DDPAK/<br>TO-263 (KTT)   5 | 500   LARGE T&R       | Yes         | SN                                   | Level-2-260C-1 YEAR               | -40 to 125   | TPS<br>72525        |
| TPS72525KTTRG3               | Active        | Production           | DDPAK/<br>TO-263 (KTT)   5 | 500   LARGE T&R       | Yes         | SN                                   | Level-2-260C-1 YEAR               | -40 to 125   | TPS<br>72525        |

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

<sup>(2)</sup> **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.

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

<sup>(4)</sup> **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.

<sup>(5)</sup> **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.

<sup>(6)</sup> **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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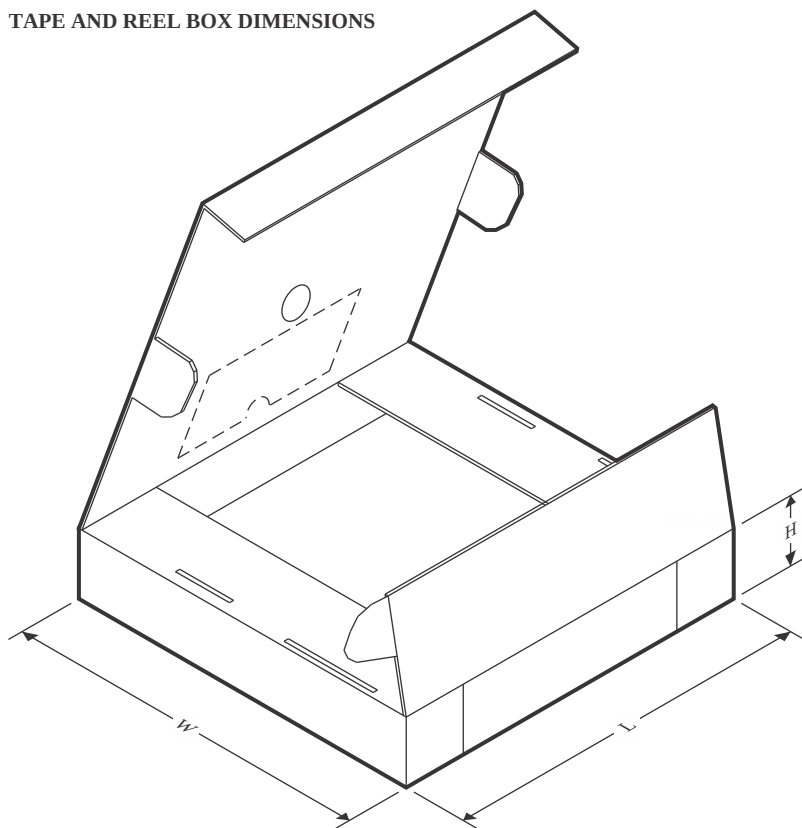
## TAPE AND REEL INFORMATION



\*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 |
|--------------|------------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS72501DCQR | SOT-223          | DCQ             | 6    | 2500 | 330.0              | 12.4               | 7.1     | 7.45    | 1.88    | 8.0     | 12.0   | Q3            |
| TPS72515DCQR | SOT-223          | DCQ             | 6    | 2500 | 330.0              | 12.4               | 7.1     | 7.45    | 1.88    | 8.0     | 12.0   | Q3            |
| TPS72515KTTR | DDPAK/<br>TO-263 | KTT             | 5    | 500  | 330.0              | 24.4               | 10.9    | 16.1    | 4.9     | 16.0    | 24.0   | Q2            |
| TPS72525DCQR | SOT-223          | DCQ             | 6    | 2500 | 330.0              | 12.4               | 7.1     | 7.45    | 1.88    | 8.0     | 12.0   | Q3            |

## TAPE AND REEL BOX DIMENSIONS

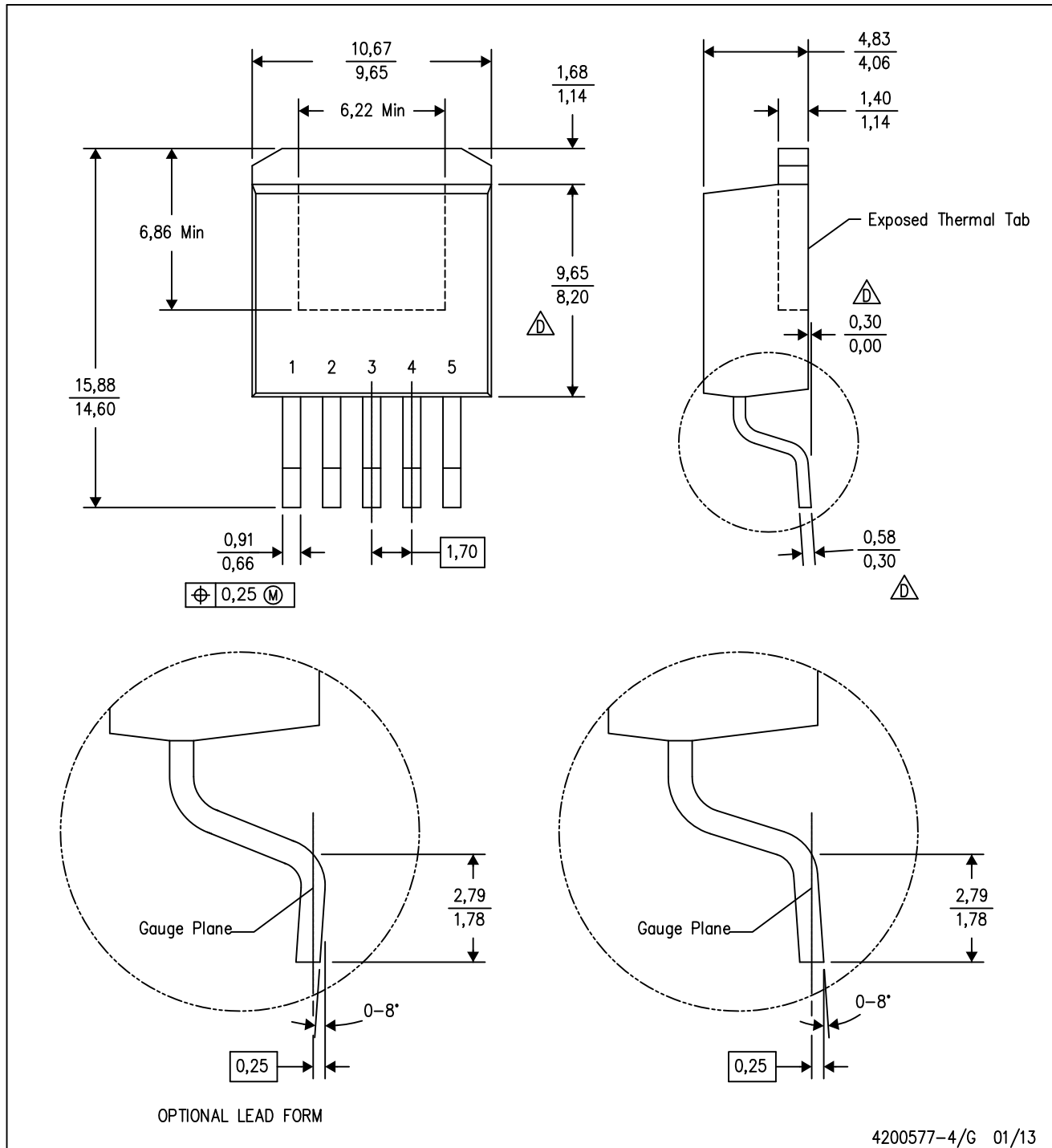


\*All dimensions are nominal

| Device       | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPS72501DCQR | SOT-223      | DCQ             | 6    | 2500 | 346.0       | 346.0      | 29.0        |
| TPS72515DCQR | SOT-223      | DCQ             | 6    | 2500 | 346.0       | 346.0      | 29.0        |
| TPS72515KTTR | DDPAK/TO-263 | KTT             | 5    | 500  | 356.0       | 356.0      | 45.0        |
| TPS72525DCQR | SOT-223      | DCQ             | 6    | 2500 | 346.0       | 346.0      | 29.0        |

KTT (R-PSFM-G5)

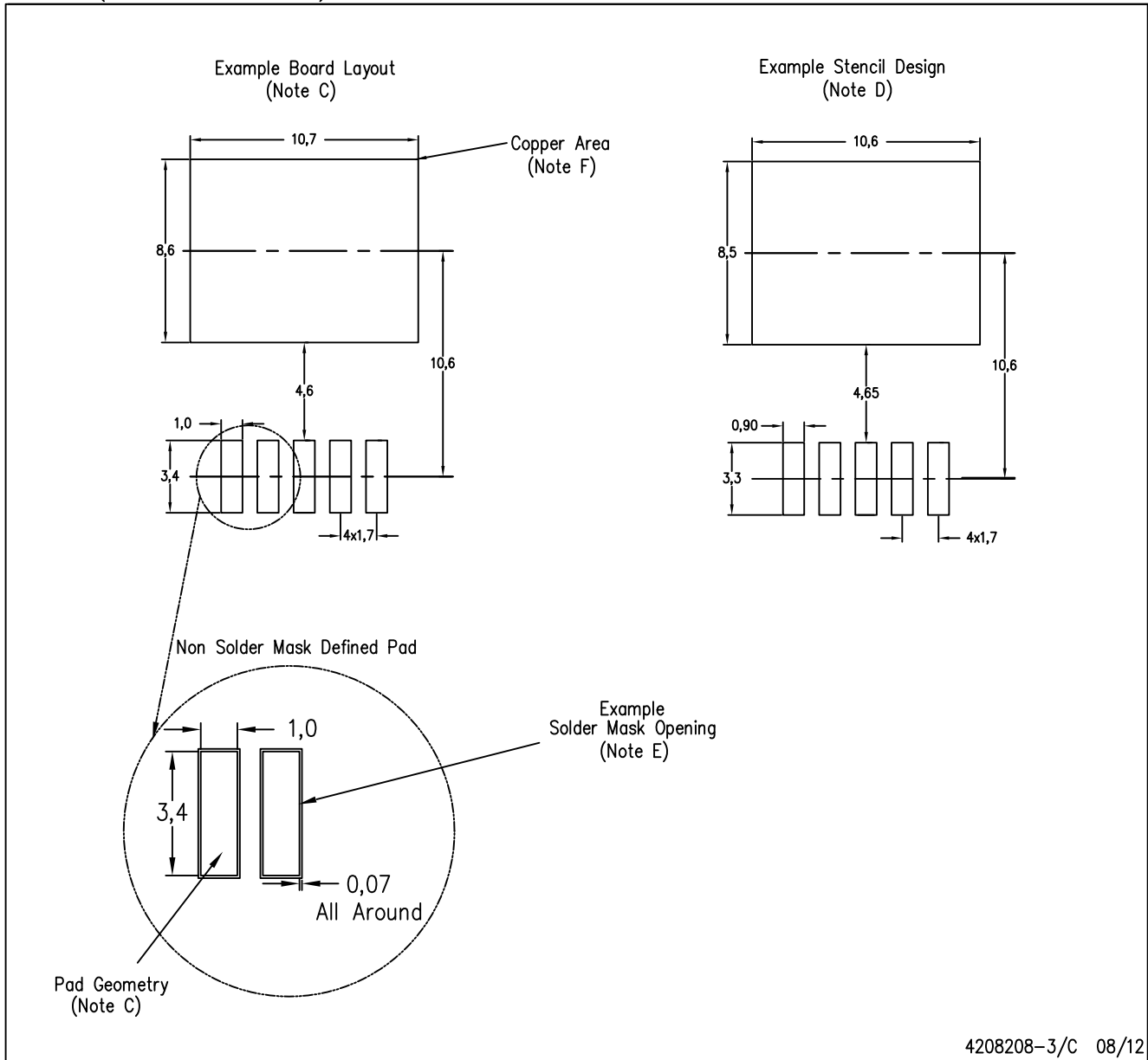
PLASTIC FLANGE-MOUNT PACKAGE



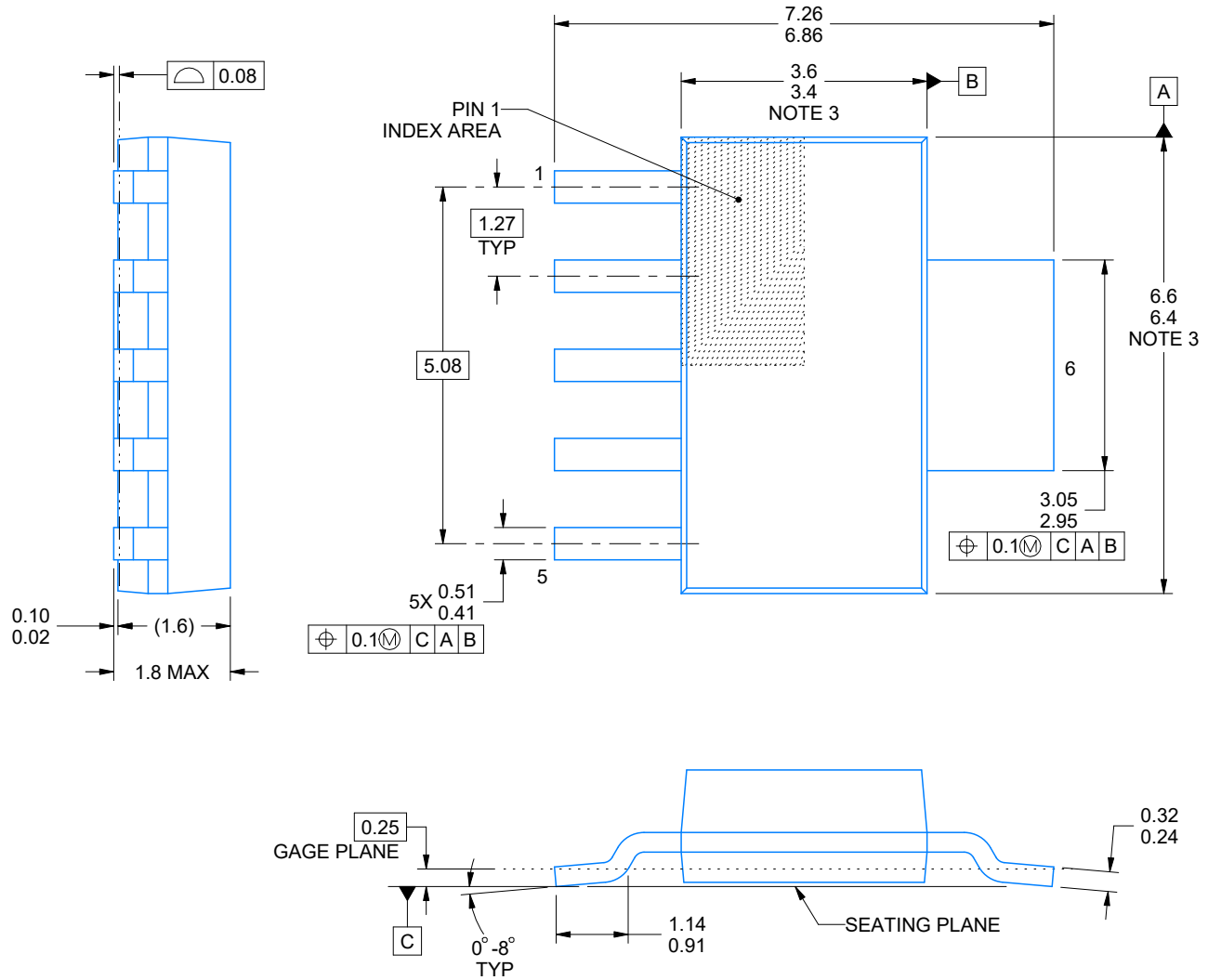
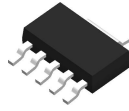
4200577-4/G 01/13

KTT (R-PSFM-G5)

PLASTIC FLANGE-MOUNT PACKAGE



- 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. Refer to IPC-7525.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.
  - This package is designed to be soldered to a thermal pad on the board. Refer to the Product Datasheet for specific thermal information, via requirements, and recommended thermal pad size. For thermal pad sizes larger than shown a solder mask defined pad is recommended in order to maintain the solderable pad geometry while increasing copper area.



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## NOTES:

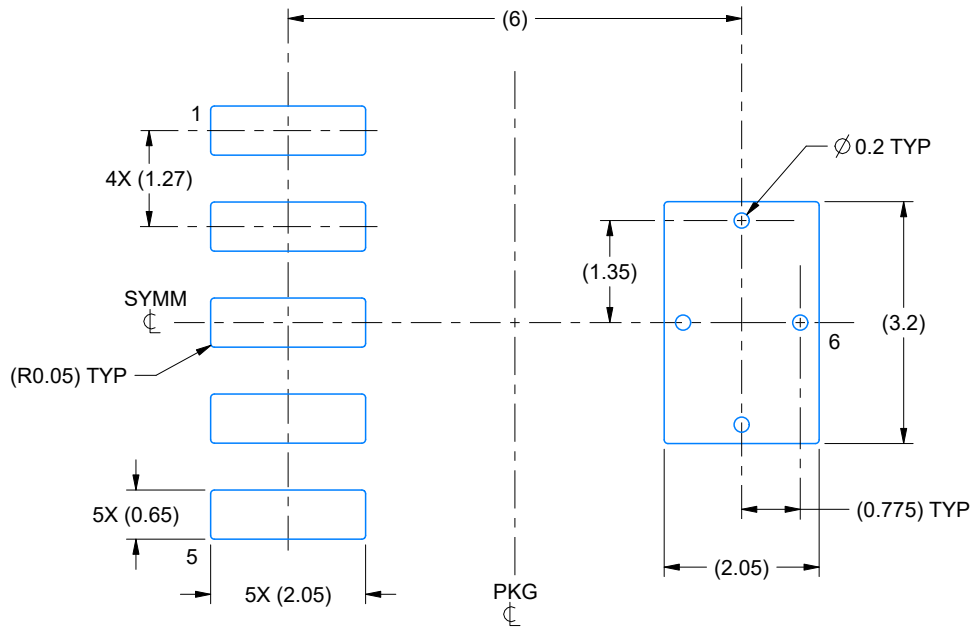
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.

# EXAMPLE BOARD LAYOUT

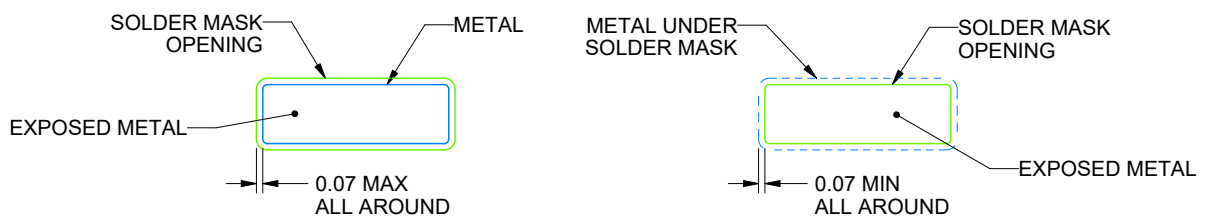
DCQ0006A

SOT - 1.8 mm max height

PLASTIC SMALL OUTLINE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



SOLDER MASK DETAILS

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NOTES: (continued)

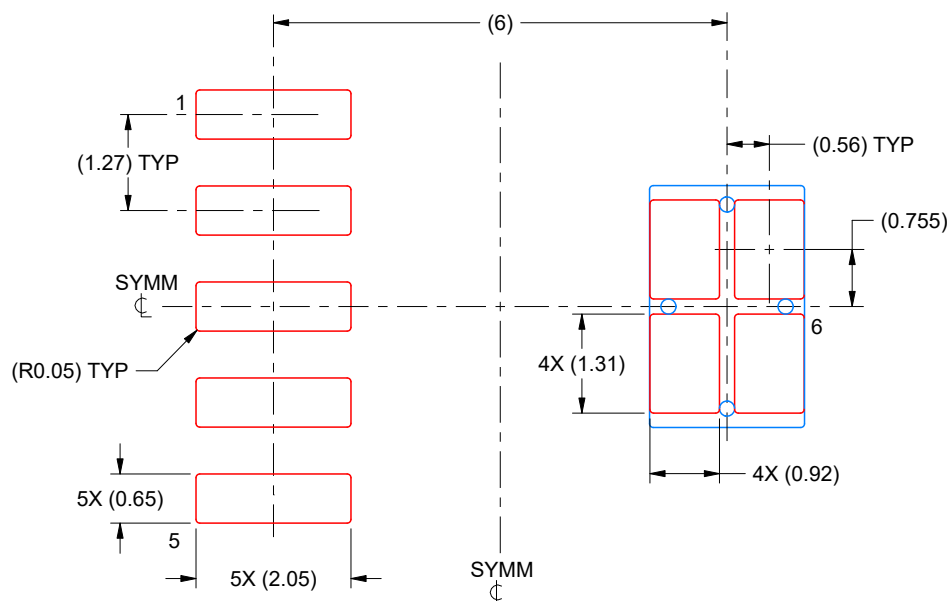
4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
6. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

# EXAMPLE STENCIL DESIGN

DCQ0006A

SOT - 1.8 mm max height

PLASTIC SMALL OUTLINE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE: 10X

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NOTES: (continued)

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

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