



# TPS7A8101-Q1 低噪声、宽带宽、高电源抑制比 (PSRR), 低压降 1A 线性稳压器

## 1 特性

- 符合汽车应用要求
- 具有符合 AEC-Q100 的下列结果：
  - 器件温度 1 级：-40°C 至 125°C 的环境运行温度范围
  - 器件人体模型 (HBM) 静电放电 (ESD) 分类等级 H2
  - 器件充电器件模型 (CDM) ESD 分类等级 C4B
- 具有使能功能的低压降 1A 稳压器
- 可调节输出电压：0.8V 至 6V
- 宽带宽高 PSRR：
  - 1kHz 时为 80dB
  - 100kHz 时为 60dB
  - 1MHz 时为 54dB
- 低噪声：23.5μV<sub>RMS</sub> 典型值 (100Hz 至 100kHz)
- 在使用 4.7μF 输出电容时保持稳定
- 出色的负载和线路瞬态响应
- 总体精度 3%（在负载、线路、温度范围内）
- 过流和过温保护
- 极低压降：1A 时的典型值为 170mV
- 封装方式：3mm x 3mm 小外形尺寸无引线 (SON)-8

## 2 应用范围

- 汽车应用中的射频 (RF) 电源
- 汽车用高级驾驶员辅助系统 (ADAS) 电子控制单元 (ECU)
- 远程信息处理控制单元
- 音频
- 高速接口 (I/F)（锁相环 (PLL) 和压控振荡器 (VCO)）

## 3 说明

TPS7A8101-Q1 低压降线性稳压器 (LDO) 在输出噪声情况下可提供极佳的性能和电源抑制比 (PSRR)。这款 LDO 使用一个先进的双极 CMOS (BiCMOS) 工艺和一个功率金属氧化物半导体场效应晶体管 (PMOSFET) 无源器件来实现极低噪声、出色瞬态响应和极佳的 PSRR 性能。

TPS7A8101-Q1 器件与 4.7μF 陶瓷输出电容器一起工作时保持稳定，并使用一个精确电压基准和反馈环路在所有负载、线路、过程和温度变化范围内实现至少 3% 的精度。

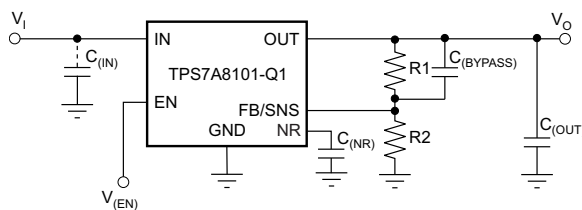
这款器件在  $T_A = -40^{\circ}\text{C}$  至  $+125^{\circ}\text{C}$  的温度范围完全额定运行，并采用装有散热焊盘的 3mm x 3mm SON-8 封装。

器件信息<sup>(1)</sup>

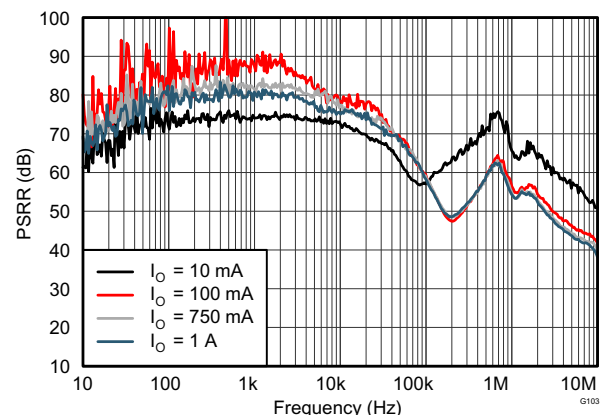
| 产品型号         | 封装      | 封装尺寸 (标称值)      |
|--------------|---------|-----------------|
| TPS7A8101-Q1 | SON (8) | 3.00mm x 3.00mm |

(1) 如需了解所有可用封装，请见数据表末尾的可订购产品附录。

## 4 典型应用电路



典型电源纹波抑制



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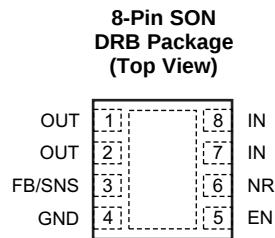
## 5 修订历史记录

### Changes from Original (April 2014) to Revision A

Page

|                                 |          |
|---------------------------------|----------|
| • 已更改 器件状态从 产品预览 更改为 生产数据 ..... | <b>1</b> |
|---------------------------------|----------|

## 6 Pin Configuration and Functions



### Pin Functions

| PIN         |     | DESCRIPTION                                                                                                                                                                                                                                                  |
|-------------|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME        | NO. |                                                                                                                                                                                                                                                              |
| EN          | 5   | Driving this pin high turns on the regulator. Driving this pin low puts the regulator into shutdown mode. See to the <a href="#">Shutdown</a> section for more details. The EN pin must not be left floating and can be connected to the IN pin if not used. |
| FB/SNS      | 3   | This pin is the input to the error amplifier and is used to set the output voltage of the device.                                                                                                                                                            |
| GND         | 4   | Ground                                                                                                                                                                                                                                                       |
| IN          | 7   | Unregulated input supply                                                                                                                                                                                                                                     |
|             | 8   |                                                                                                                                                                                                                                                              |
| NR          | 6   | Connect an external capacitor between this pin and ground to reduce output noise to very low levels. The capacitor also slows down the $V_O$ ramp (RC soft start).                                                                                           |
| OUT         | 1   | Regulator output. A 4.7- $\mu$ F or larger ceramic capacitor is required for stability.                                                                                                                                                                      |
|             | 2   |                                                                                                                                                                                                                                                              |
| Thermal Pad | —   | The Thermal Pad should be connected to GND.                                                                                                                                                                                                                  |

## 7 Specifications

### 7.1 Absolute Maximum Ratings

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

|                                       |            | MIN                | MAX               | UNIT |
|---------------------------------------|------------|--------------------|-------------------|------|
| Voltage                               | IN         | −0.3               | 7                 | V    |
|                                       | FB/SNS, NR | −0.3               | 3.6               | V    |
|                                       | EN         | −0.3               | $V_I + 0.3^{(2)}$ | V    |
|                                       | OUT        | −0.3               | 7                 | V    |
| Current                               | OUT        | Internally Limited |                   | A    |
| Operating junction temperature, $T_J$ |            | −55                | 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 is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2)  $V_{(EN)}$  absolute maximum rating is  $V_I + 0.3$  V or + 7 V, whichever is smaller.

### 7.2 Handling Ratings

|             |                           | MIN                                                                                       | MAX                          | UNIT     |
|-------------|---------------------------|-------------------------------------------------------------------------------------------|------------------------------|----------|
| $T_{stg}$   | Storage temperature range | −55                                                                                       | 150                          | °C       |
| $V_{(ESD)}$ | Electrostatic discharge   | Human body model (HBM), per AEC Q100-002, classification level H2 <sup>(1)</sup>          |                              | kV       |
|             |                           | Charged device model (CDM), per JEDEC specification JESD22-C101, classification level C4B | Corner pins (1, 4, 5, and 8) | −750 750 |
|             |                           |                                                                                           | Other pins                   | −500 500 |

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

### 7.3 Recommended Operating Conditions

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

|       |                                | MIN | MAX | UNIT |
|-------|--------------------------------|-----|-----|------|
| $V_I$ | Input voltage                  | 2.2 | 6.5 | V    |
| $I_O$ | Output current                 | 0   | 1   | A    |
| $T_A$ | Operating free air temperature | −40 | 125 | °C   |

### 7.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | DRB<br>(8 PINS) | UNIT |
|-------------------------------|----------------------------------------------|-----------------|------|
| $R_{\theta JA}$               | Junction-to-ambient thermal resistance       | 45.7            | °C/W |
| $R_{\theta JC(top)}$          | Junction-to-case (top) thermal resistance    | 53.1            |      |
| $R_{\theta JB}$               | Junction-to-board thermal resistance         | 21.2            |      |
| $\Psi_{JT}$                   | Junction-to-top characterization parameter   | 0.9             |      |
| $\Psi_{JB}$                   | Junction-to-board characterization parameter | 21.4            |      |
| $R_{\theta JC(bot)}$          | Junction-to-case (bottom) thermal resistance | 5.2             |      |

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953A.

## 7.5 Electrical Characteristics

Over the temperature range of  $-40^{\circ}\text{C} \leq T_A$ ,  $T_J \leq 125^{\circ}\text{C}$ ,  $V_I = V_{\text{Onom}} + 0.5\text{ V}$  or  $2.2\text{ V}$  (whichever is greater),  $I_O = 1\text{ mA}$ ,  $V_{(\text{EN})} = 2.2\text{ V}$ ,  $C_{(\text{OUT})} = 4.7\text{ }\mu\text{F}$ ,  $C_{(\text{NR})} = 0.01\text{ }\mu\text{F}$ , and  $C_{(\text{BYPASS})} = 0\text{ }\mu\text{F}$ , unless otherwise noted. The device is tested at  $V_O = 0.8\text{ V}$  and  $V_O = 6\text{ V}$ . Typical values are at  $T_J = 25^{\circ}\text{C}$ .

| PARAMETER                  |                                         | TEST CONDITIONS                                                                                                                                                                             | MIN                  | TYP         | MAX  | UNIT                       |
|----------------------------|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|-------------|------|----------------------------|
| $V_I$                      | Input voltage range <sup>(1)</sup>      |                                                                                                                                                                                             | 2.2                  |             | 6.5  | V                          |
| $V_{(\text{NR})}$          | Internal reference                      |                                                                                                                                                                                             | 0.79                 | 0.8         | 0.81 | V                          |
| $V_O$                      | Output voltage range                    |                                                                                                                                                                                             | 0.8                  |             | 6    | V                          |
|                            | Output accuracy <sup>(2)</sup>          | $V_O + 0.5\text{ V} \leq V_I \leq 6\text{ V}$ , $V_I \geq 2.5\text{ V}$ ,<br>$100\text{ mA} \leq I_O \leq 500\text{ mA}$ , $0^{\circ}\text{C} \leq T_J \leq 85^{\circ}\text{C}$             | -2%                  |             | 2%   |                            |
|                            |                                         | $V_O + 0.5\text{ V} \leq V_I \leq 6.5\text{ V}$ , $V_I \geq 2.2\text{ V}$ ,<br>$100\text{ mA} \leq I_O \leq 1\text{ A}$                                                                     | -3%                  | $\pm 0.3\%$ | 3%   |                            |
| $\Delta V_{O(\Delta V_I)}$ | Line regulation                         | $V_{\text{Onom}} + 0.5\text{ V} \leq V_I \leq 6.5\text{ V}$ , $V_I \geq 2.2\text{ V}$ ,<br>$I_O = 100\text{ mA}$                                                                            |                      | 150         |      | $\mu\text{V/V}$            |
| $\Delta V_{O(\Delta I_L)}$ | Load regulation                         | $100\text{ mA} \leq I_O \leq 1\text{ A}$                                                                                                                                                    |                      | 2           |      | $\mu\text{V/mA}$           |
| $V_{\text{DO}}$            | Dropout voltage <sup>(3)</sup>          | $V_O + 0.5\text{ V} \leq V_I \leq 6.5\text{ V}$ , $V_I \geq 2.2\text{ V}$ ,<br>$I_O = 500\text{ mA}$ , $V_{(\text{FB/SNS})} = \text{GND}$                                                   |                      |             | 250  | mV                         |
|                            |                                         | $V_O + 0.5\text{ V} \leq V_I \leq 6.5\text{ V}$ , $V_I \geq 2.5\text{ V}$ ,<br>$I_O = 750\text{ mA}$ , $V_{(\text{FB/SNS})} = \text{GND}$                                                   |                      |             | 350  | mV                         |
|                            |                                         | $V_O + 0.5\text{ V} \leq V_I \leq 6.5\text{ V}$ , $V_I \geq 2.5\text{ V}$ ,<br>$I_O = 1\text{ A}$ , $V_{(\text{FB/SNS})} = \text{GND}$                                                      |                      |             | 500  | mV                         |
| $I_L$                      | Output current-limit                    | $V_O = 0.85 \times V_{\text{Onom}}$ , $V_I \geq 3.3\text{ V}$                                                                                                                               | 1100                 | 1400        | 2000 | mA                         |
| $I_{(\text{GND})}$         | Ground pin current                      | $I_O = 1\text{ mA}$                                                                                                                                                                         |                      | 60          | 100  | $\mu\text{A}$              |
|                            |                                         | $I_O = 1\text{ A}$                                                                                                                                                                          |                      |             | 350  | $\mu\text{A}$              |
| $I_{L(\text{sd})}$         | Shutdown current ( $I_{(\text{GND})}$ ) | $V_{(\text{EN})} \leq 0.4\text{ V}$ , $V_I \geq 2.2\text{ V}$ , $R_L = 1\text{ k}\Omega$ ,<br>$0^{\circ}\text{C} \leq T_J \leq 125^{\circ}\text{C}$                                         |                      | 0.2         | 2.5  | $\mu\text{A}$              |
| $I_{(\text{FB/SNS})}$      | Feedback pin current                    | $V_I = 6.5\text{ V}$ , $V_{(\text{FB/SNS})} = 0.8\text{ V}$                                                                                                                                 |                      | 0.02        | 1    | $\mu\text{A}$              |
| PSRR                       | Power-supply rejection ratio            | $V_I = 4.3\text{ V}$ , $V_O = 3.3\text{ V}$ ,<br>$I_O = 750\text{ mA}$                                                                                                                      | $f = 100\text{ Hz}$  | 80          |      | dB                         |
|                            |                                         |                                                                                                                                                                                             | $f = 1\text{ kHz}$   | 82          |      | dB                         |
|                            |                                         |                                                                                                                                                                                             | $f = 10\text{ kHz}$  | 78          |      | dB                         |
|                            |                                         |                                                                                                                                                                                             | $f = 100\text{ kHz}$ | 60          |      | dB                         |
|                            |                                         |                                                                                                                                                                                             | $f = 1\text{ MHz}$   | 54          |      | dB                         |
| $V_n$                      | Output noise voltage                    | $\text{BW} = 100\text{ Hz to } 100\text{ kHz}$ ,<br>$V_I = 3.8\text{ V}$ , $V_O = 3.3\text{ V}$ ,<br>$I_O = 100\text{ mA}$ , $C_{(\text{NR})} = C_{(\text{BYPASS})} = 470\text{ nF}$        |                      | 23.5        |      | $\mu\text{V}_{\text{RMS}}$ |
| $V_{(\text{EN})\text{H}}$  | Enable high (enabled)                   | $2.2\text{ V} \leq V_I \leq 3.6\text{ V}$ , $R_L = 1\text{ k}\Omega$                                                                                                                        | 1.2                  |             |      | V                          |
|                            |                                         | $3.6\text{ V} < V_I \leq 6.5\text{ V}$ , $R_L = 1\text{ k}\Omega$                                                                                                                           | 1.35                 |             |      | V                          |
| $V_{(\text{EN})\text{L}}$  | Enable low (shutdown)                   | $R_L = 1\text{ k}\Omega$                                                                                                                                                                    | 0                    |             | 0.4  | V                          |
| $I_{(\text{EN})}$          | Enable pin current, enabled             | $V_I = V_{(\text{EN})} = 6.5\text{ V}$                                                                                                                                                      |                      | 0.02        | 1    | $\mu\text{A}$              |
| $t_{\text{st}}$            | Startup time                            | $V_{\text{Onom}} = 3.3\text{ V}$ , $V_O = 0\%$ to $90\%$ $V_{\text{Onom}}$ ,<br>$R_L = 3.3\text{ k}\Omega$ , $C_{(\text{OUT})} = 10\text{ }\mu\text{F}$ , $C_{(\text{NR})} = 470\text{ nF}$ |                      | 80          |      | ms                         |
| UVLO                       | Undervoltage lockout                    | $V_I$ rising, $R_L = 1\text{ k}\Omega$                                                                                                                                                      | 1.86                 | 2           | 2.1  | V                          |
|                            | Hysteresis                              | $V_I$ falling, $R_L = 1\text{ k}\Omega$                                                                                                                                                     |                      | 75          |      | mV                         |
| $T_{\text{sd}}$            | Thermal shutdown temperature            | Shutdown, temperature increasing                                                                                                                                                            |                      | 160         |      | $^{\circ}\text{C}$         |
|                            |                                         | Reset, temperature decreasing                                                                                                                                                               |                      | 140         |      | $^{\circ}\text{C}$         |

(1) Minimum  $V_I = V_O + V_{\text{DO}}$  or  $2.2\text{ V}$ , whichever is greater.

(2) The TPS7A8101-Q1 does not include external resistor tolerances and it is not tested at this condition:  $V_O = 0.8\text{ V}$ ,  $4.5\text{ V} \leq V_I \leq 6.5\text{ V}$ , and  $750\text{ mA} \leq I_O \leq 1\text{ A}$  because the power dissipation is greater than the maximum rating of the package.

(3)  $V_{\text{DO}}$  is not measured for fixed output voltage devices with  $V_O < 1.7\text{ V}$  because minimum  $V_I = 2.2\text{ V}$ .

## 7.6 Typical Characteristics

At  $V_{ONOM} = 3.3\text{ V}$ ,  $V_I = V_{ONOM} + 0.5\text{ V}$  or  $2.2\text{ V}$  (whichever is greater),  $I_O = 100\text{ mA}$ ,  $V_{(EN)} = V_I$ ,  $C_{(IN)} = 1\text{ }\mu\text{F}$ ,  $C_{(OUT)} = 4.7\text{ }\mu\text{F}$ , and  $C_{(NR)} = 0.01\text{ }\mu\text{F}$ ; all temperature values refer to  $T_J$ , unless otherwise noted.

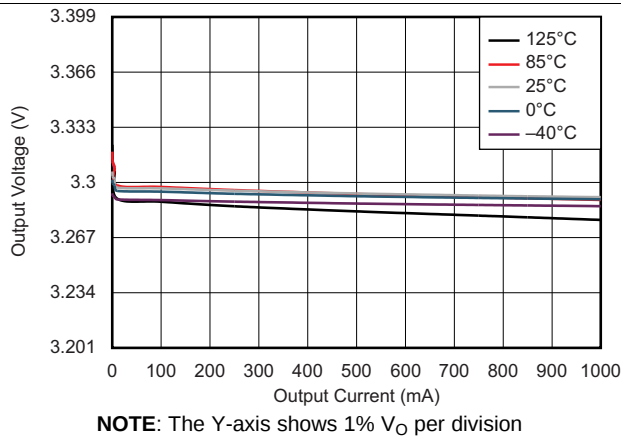


Figure 1. Load Regulation

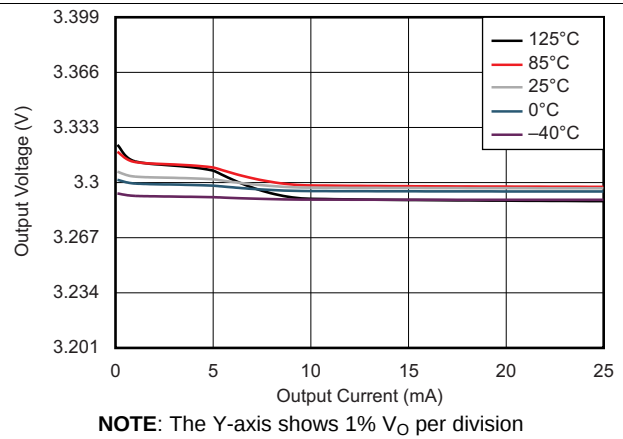


Figure 2. Load Regulation Under Light Loads

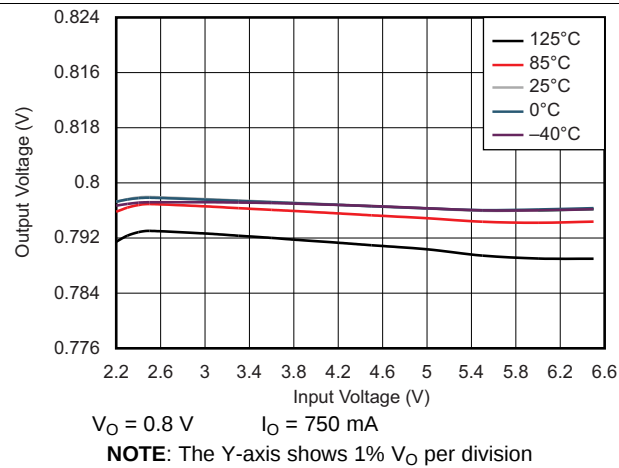


Figure 3. Line Regulation

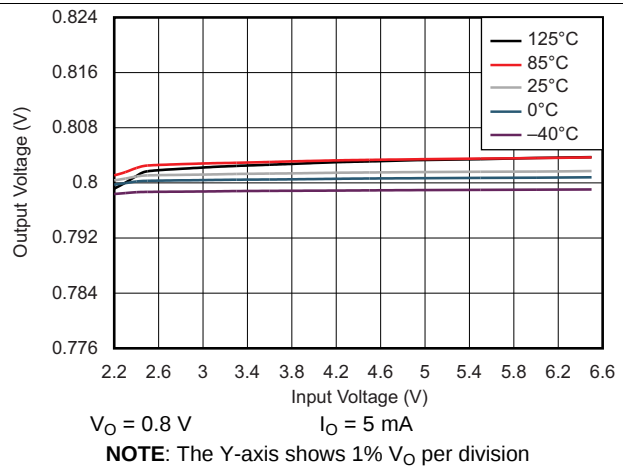


Figure 4. Line Regulation Under Light Loads

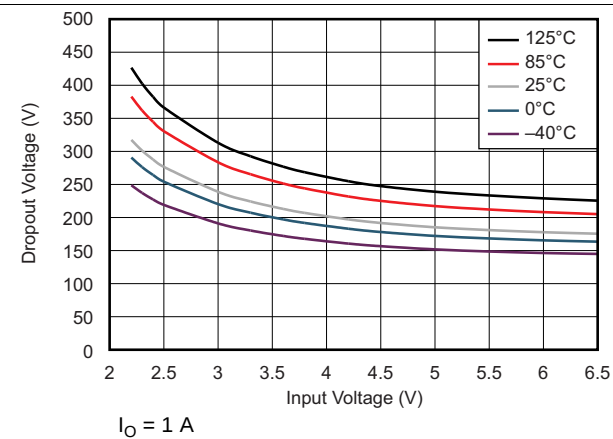


Figure 5. Dropout Voltage vs Input Voltage

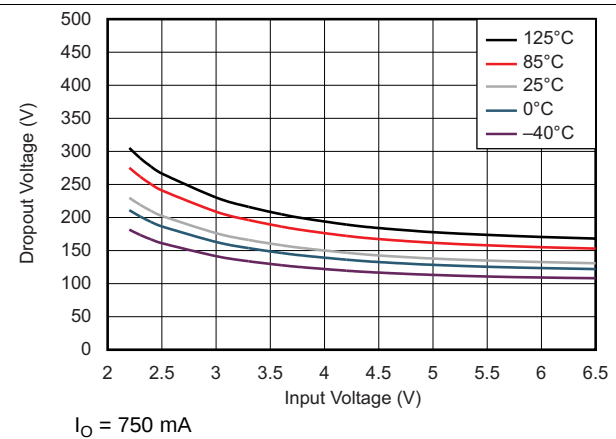


Figure 6. Dropout Voltage vs Input Voltage

## Typical Characteristics (continued)

At  $V_{ONOM} = 3.3\text{ V}$ ,  $V_I = V_{ONOM} + 0.5\text{ V}$  or  $2.2\text{ V}$  (whichever is greater),  $I_O = 100\text{ mA}$ ,  $V_{(EN)} = V_I$ ,  $C_{(IN)} = 1\text{ }\mu\text{F}$ ,  $C_{(OUT)} = 4.7\text{ }\mu\text{F}$ , and  $C_{(NR)} = 0.01\text{ }\mu\text{F}$ ; all temperature values refer to  $T_J$ , unless otherwise noted.

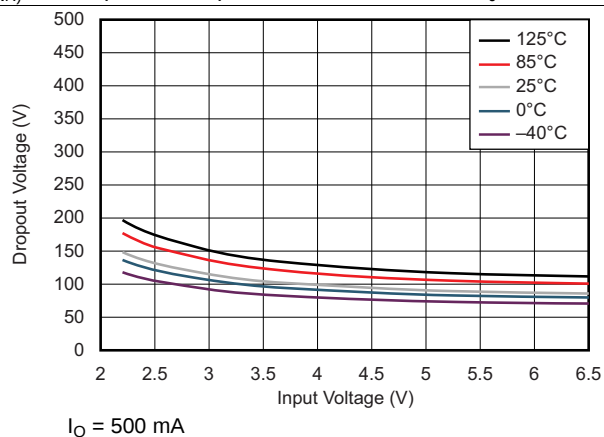


Figure 7. Dropout Voltage vs Input Voltage

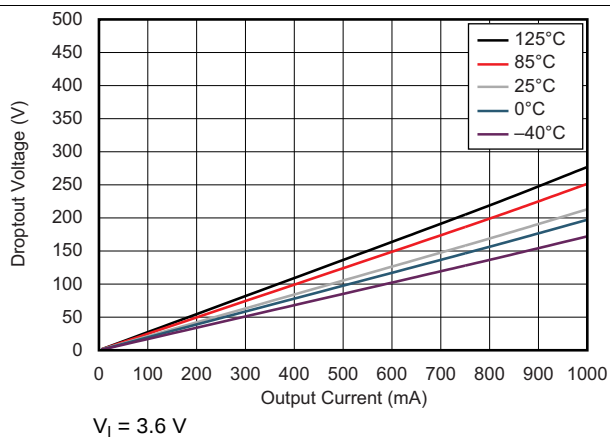


Figure 8. Dropout Voltage vs Load Current

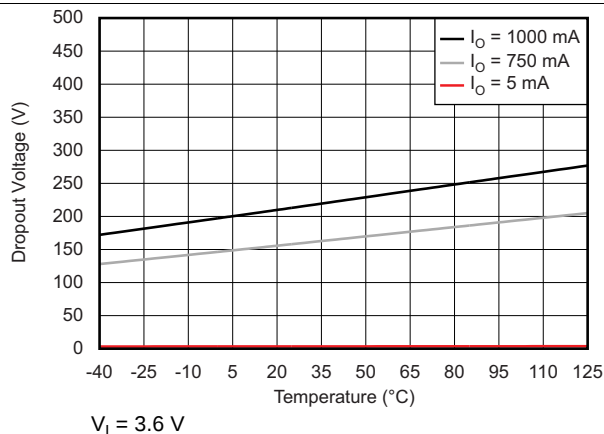


Figure 9. Dropout Voltage vs Temperature

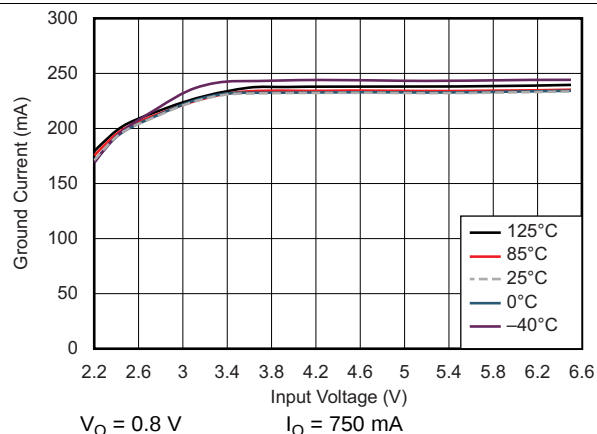


Figure 10. Ground Pin Current vs Input Voltage

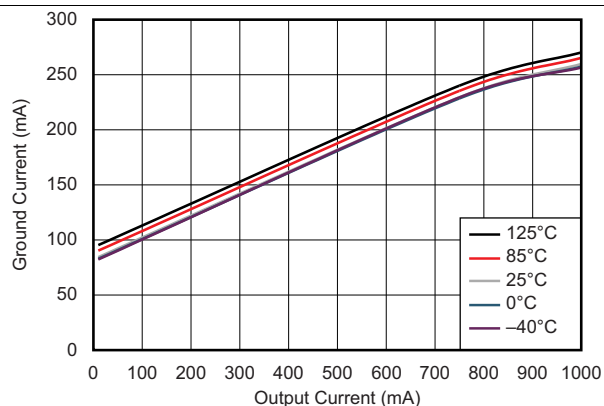


Figure 11. Ground Pin Current vs Load Current

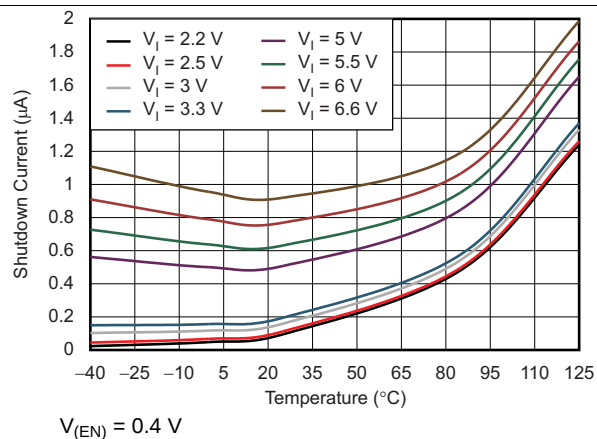
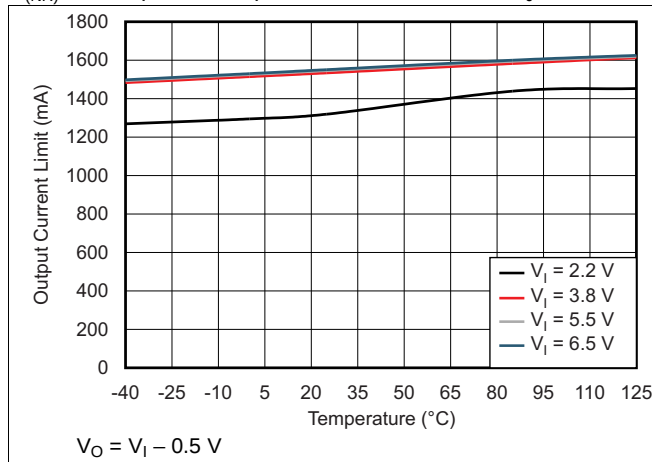


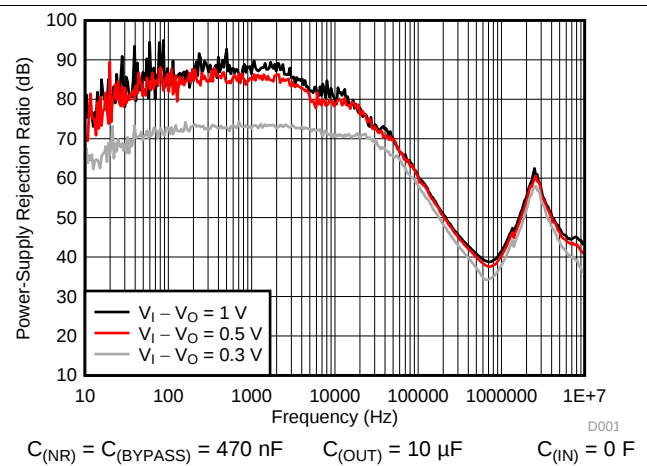
Figure 12. Shutdown Current vs Temperature

## Typical Characteristics (continued)

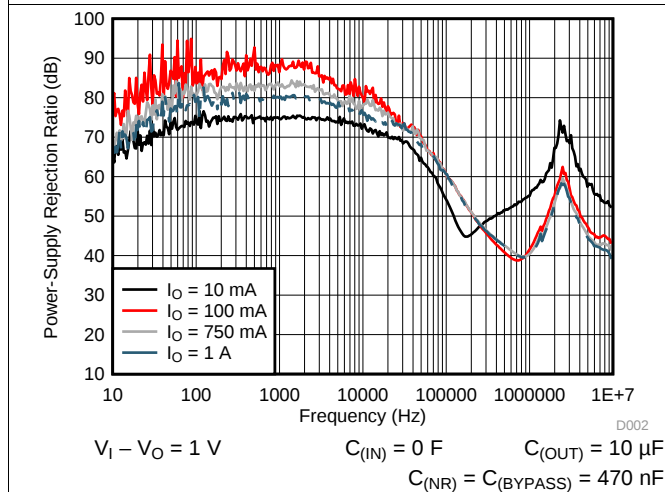
At  $V_{ONOM} = 3.3\text{ V}$ ,  $V_I = V_{ONOM} + 0.5\text{ V}$  or  $2.2\text{ V}$  (whichever is greater),  $I_O = 100\text{ mA}$ ,  $V_{(EN)} = V_I$ ,  $C_{(IN)} = 1\text{ }\mu\text{F}$ ,  $C_{(OUT)} = 4.7\text{ }\mu\text{F}$ , and  $C_{(NR)} = 0.01\text{ }\mu\text{F}$ ; all temperature values refer to  $T_J$ , unless otherwise noted.



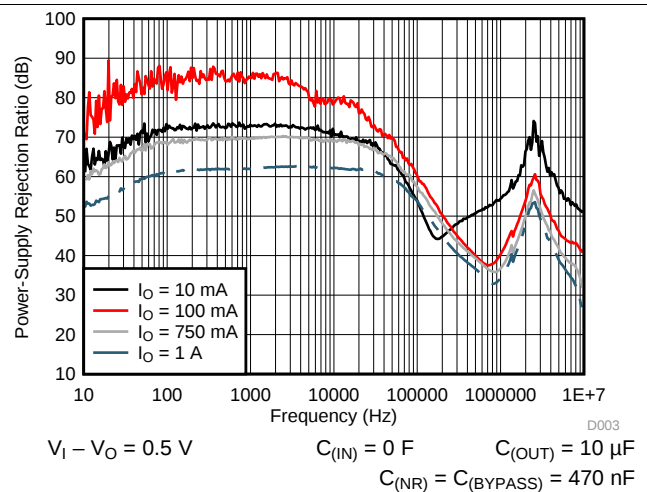
**Figure 13. Current-Limit vs Temperature**



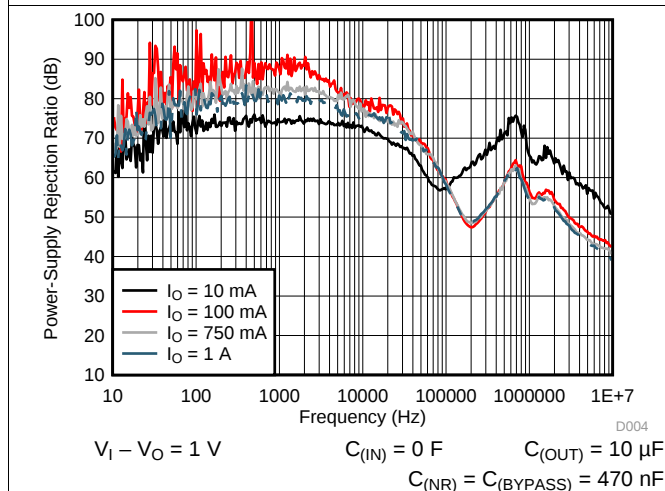
**Figure 14. PSRR vs Frequency**



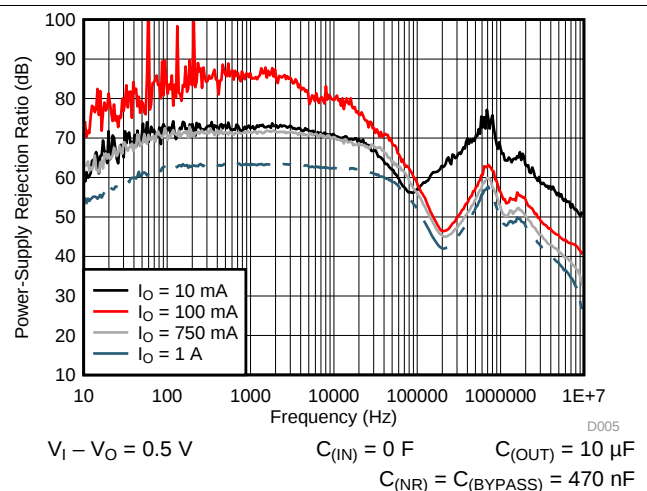
**Figure 15. PSRR vs Frequency**



**Figure 16. PSRR vs Frequency**



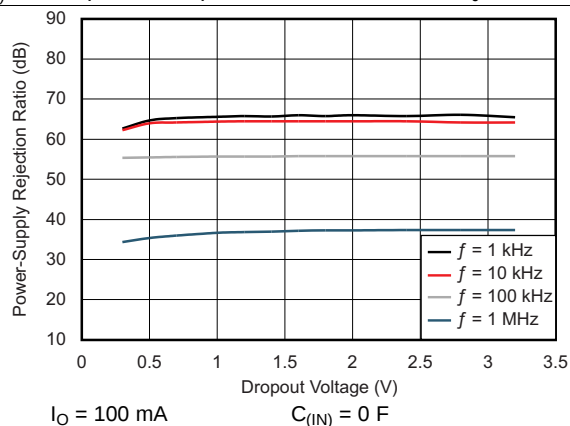
**Figure 17. PSRR vs Frequency**



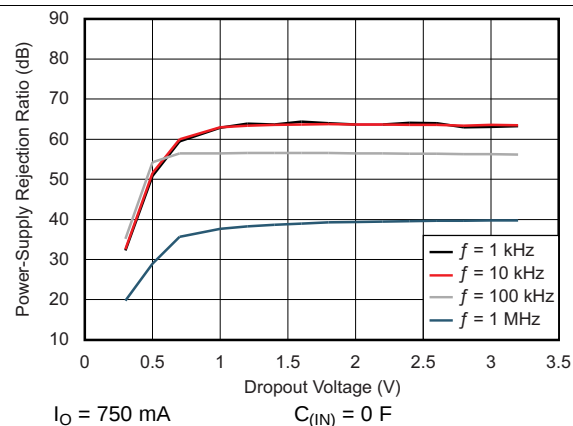
**Figure 18. PSRR vs Frequency**

## Typical Characteristics (continued)

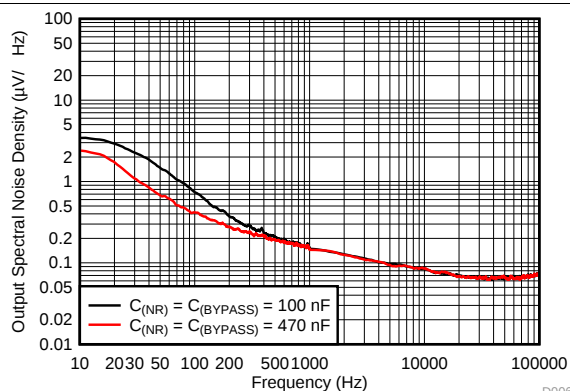
At  $V_{ONOM} = 3.3\text{ V}$ ,  $V_I = V_{ONOM} + 0.5\text{ V}$  or  $2.2\text{ V}$  (whichever is greater),  $I_O = 100\text{ mA}$ ,  $V_{(EN)} = V_I$ ,  $C_{(IN)} = 1\text{ }\mu\text{F}$ ,  $C_{(OUT)} = 4.7\text{ }\mu\text{F}$ , and  $C_{(NR)} = 0.01\text{ }\mu\text{F}$ ; all temperature values refer to  $T_J$ , unless otherwise noted.



**Figure 19. PSRR vs Dropout Voltage**

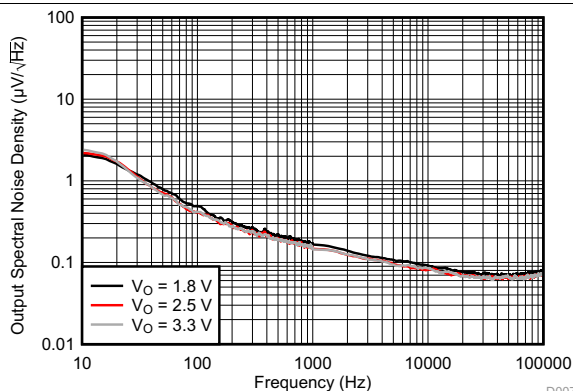


**Figure 20. PSRR vs Dropout Voltage**



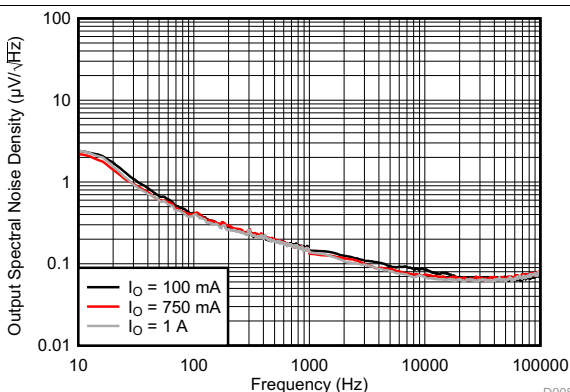
$V_I - V_O = 0.5\text{ V}$   $C_{(OUT)} = 10\text{ }\mu\text{F}$   $C_{(IN)} = 10\text{ }\mu\text{F}$   
 $24.09\text{ }\mu\text{V}_{\text{RMS}}$  ( $C_{(NR)} = C_{(BYPASS)} = 100\text{ nF}$ )  
 $23.54\text{ }\mu\text{V}_{\text{RMS}}$  ( $C_{(NR)} = C_{(BYPASS)} = 470\text{ nF}$ )

**Figure 21. Output Spectral Noise Density vs Frequency (RMS noise (100 Hz to 100 kHz))**



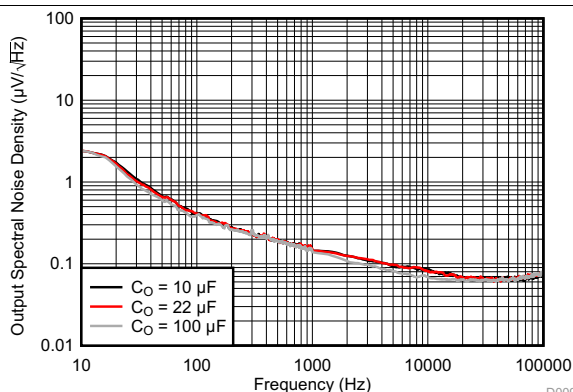
$25.89\text{ }\mu\text{V}_{\text{RMS}}$  ( $V_O = 1.8\text{ V}$ )  $C_{(IN)} = 10\text{ }\mu\text{F}$   $V_I - V_O = 0.5\text{ V}$   
 $23.54\text{ }\mu\text{V}_{\text{RMS}}$  ( $V_O = 2.5\text{ V}$ )  $C_{(NR)} = 470\text{ nF}$   $C_{(OUT)} = 10\text{ }\mu\text{F}$   
 $23.54\text{ }\mu\text{V}_{\text{RMS}}$  ( $V_O = 3.3\text{ V}$ )  $C_{(BYPASS)} = 470\text{ nF}$

**Figure 22. Output Spectral Noise Density vs Frequency (RMS noise (100 Hz to 100 kHz))**



$23.54\text{ }\mu\text{V}_{\text{RMS}}$  ( $I_O = 100\text{ mA}$ )  $C_{(IN)} = 10\text{ }\mu\text{F}$   $V_I - V_O = 0.5\text{ V}$   
 $23.71\text{ }\mu\text{V}_{\text{RMS}}$  ( $I_O = 750\text{ mA}$ )  $C_{(NR)} = 470\text{ nF}$   $C_{(OUT)} = 10\text{ }\mu\text{F}$   
 $22.78\text{ }\mu\text{V}_{\text{RMS}}$  ( $I_O = 1\text{ A}$ )  $C_{(BYPASS)} = 470\text{ nF}$

**Figure 23. Output Spectral Noise Density vs Frequency (RMS noise (100 Hz to 100 kHz))**

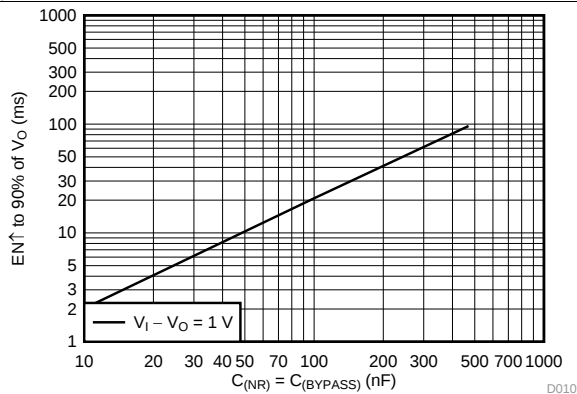


$23.54\text{ }\mu\text{V}_{\text{RMS}}$  ( $C_O = 10\text{ }\mu\text{F}$ )  $C_{(IN)} = 10\text{ }\mu\text{F}$   $V_I - V_O = 0.5\text{ V}$   
 $23.91\text{ }\mu\text{V}_{\text{RMS}}$  ( $C_O = 22\text{ }\mu\text{F}$ )  $C_{(NR)} = 470\text{ nF}$   $C_{(OUT)} = 10\text{ }\mu\text{F}$   
 $22.78\text{ }\mu\text{V}_{\text{RMS}}$  ( $C_O = 100\text{ }\mu\text{F}$ )  $C_{(BYPASS)} = 470\text{ nF}$

**Figure 24. Output Spectral Noise Density vs Frequency (RMS noise (100 Hz to 100 kHz))**

## Typical Characteristics (continued)

At  $V_{Onom} = 3.3\text{ V}$ ,  $V_I = V_{Onom} + 0.5\text{ V}$  or  $2.2\text{ V}$  (whichever is greater),  $I_O = 100\text{ mA}$ ,  $V_{(EN)} = V_I$ ,  $C_{(IN)} = 1\text{ }\mu\text{F}$ ,  $C_{(OUT)} = 4.7\text{ }\mu\text{F}$ , and  $C_{(NR)} = 0.01\text{ }\mu\text{F}$ ; all temperature values refer to  $T_J$ , unless otherwise noted.



Using the same value of  $C_{(NR)}$  and  $C_{(BYPASS)}$  in the X-Axis

Figure 25. Startup Time vs Noise Reduction Capacitance

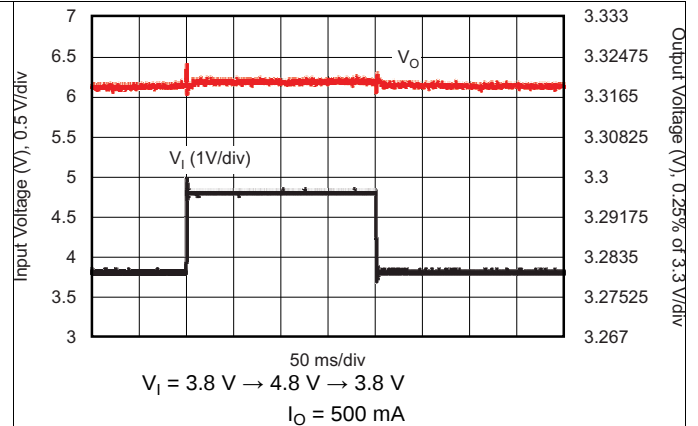


Figure 26. Line Transient Response

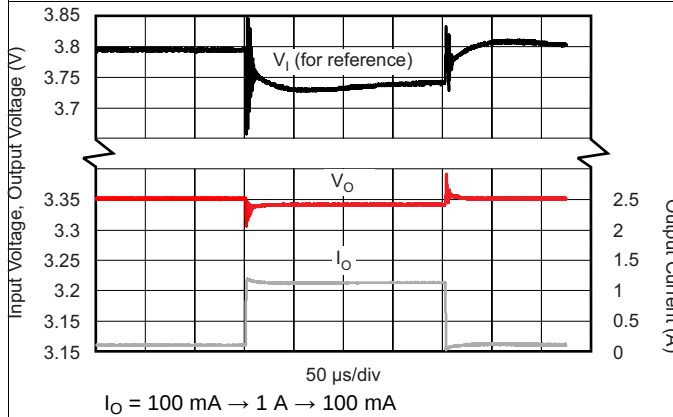


Figure 27. Load Transient Response

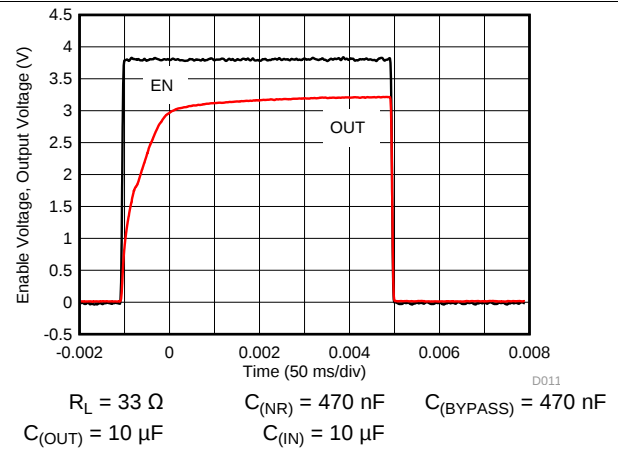
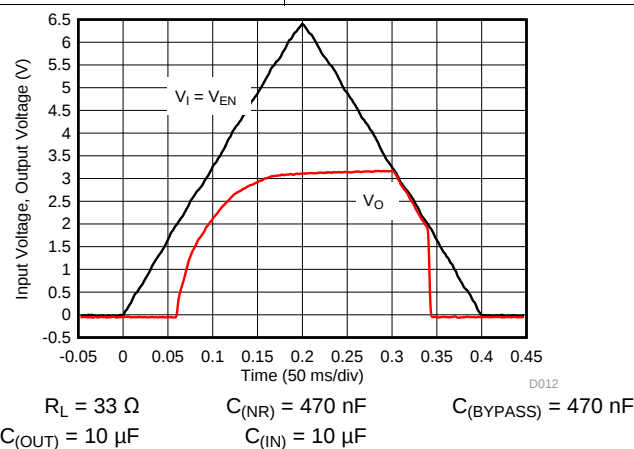


Figure 28. Enable Pulse Response, see (1) in Figure 29



(1) The internal reference requires approximately 80 ms of rampup time (see [Startup](#)) from the enable event; therefore,  $V_O$  fully reaches the target output voltage of 3.3 V in 80 ms from startup.

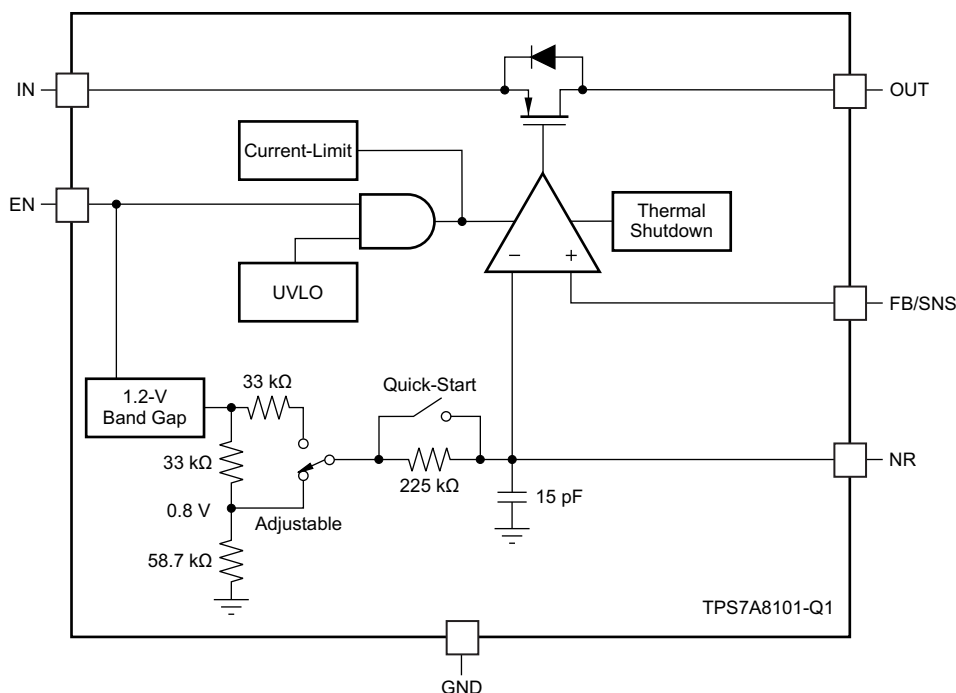
Figure 29. Power-Up and Power-Down Response

## 8 Detailed Description

### 8.1 Overview

The TPS7A8101-Q1 device belongs to a family of new-generation LDO regulators that use innovative circuitry to achieve wide bandwidth and high loop gain, resulting in extremely high PSRR (over a 1-MHz range) even with very low headroom ( $V_I - V_O$ ). A noise-reduction capacitor ( $C_{(NR)}$ ) at the NR pin and a bypass capacitor ( $C_{(BYPASS)}$ ) decrease noise generated by the bandgap reference in order to improve PSRR, while a quick-start circuit fast-charges the noise-reduction capacitor. This family of regulators offers sub-bandgap output voltages, current-limit, and thermal protection, and is fully specified from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### 8.2 Functional Block Diagram



**Figure 30. Functional Block Diagram**

### 8.3 Feature Description

#### 8.3.1 Internal Current-Limit

The TPS7A8101-Q1 internal current-limit helps protect the regulator during fault conditions. During the current-limit, the output sources a fixed amount of current that is largely independent of the output voltage. For reliable operation, the device should not be operated in a current-limit state for extended periods of time.

The PMOS pass element in the TPS7A8101-Q1 device has a built-in body diode that conducts current when the voltage at the OUT pin ( $V_{(OUT)}$ ) exceeds the voltage at the IN pin ( $V_{(IN)}$ ). This current is not limited, so if extended reverse-voltage operation is anticipated, external limiting may be appropriate.

#### 8.3.2 Shutdown

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

## Feature Description (continued)

### 8.3.3 Startup

Through a lower resistance, the bandgap reference can quickly charge the noise-reduction capacitor ( $C_{(NR)}$ ). The TPS7A8101-Q1 device has a *quick-start* circuit to quickly charge  $C_{(NR)}$ , if present; see [Figure 30](#). At startup, this quick-start switch is closed, with only 33 k $\Omega$  of resistance between the bandgap reference and the NR pin. The quick-start switch opens approximately 100 ms after any device-enabling event, and the resistance between the bandgap reference and the NR pin becomes higher in value (approximately 250 k $\Omega$ ) to form a very-good low-pass (RC) filter. This low-pass filter reduces the noise present on the reference voltage; therefore, reducing the noise on the output.

Inrush current can cause problems in many applications. The 33-k $\Omega$  resistance during the startup period is intentionally placed between the bandgap reference and the NR pin in order to slow down the reference voltage rampup, thus reducing the inrush current.

Use [Equation 1](#) to calculate the startup time with other  $C_{(NR)}$  values. For example, the capacitance of connecting the recommended  $C_{(NR)}$  value of 0.47  $\mu$ F along with the 33-k $\Omega$  resistance causes an 80-ms RC delay (approximately).

$$t_{st} (s) = 170000 \times C_{(NR)} (F) \quad (1)$$

Although the noise-reduction effect is nearly saturated at 0.47  $\mu$ F, connecting a  $C_{(NR)}$  value greater than 0.47  $\mu$ F can additionally help reduce noise. However, when connecting a  $C_{(NR)}$  value greater than 0.47  $\mu$ F, the startup time is extremely long because the quick-start switch opens after approximately 100 ms. That is, if  $C_{(NR)}$  is not fully charged during this 100-ms period,  $C_{(NR)}$  finishes charging through a higher resistance of 250 k $\Omega$ , and takes much longer to fully charge.

#### NOTE

A low-leakage capacitor should be used for  $C_{(NR)}$ . Most ceramic capacitors are suitable

### 8.3.4 Undervoltage Lockout (UVLO)

The TPS7A8101-Q1 device uses an undervoltage-lockout (UVLO) circuit to ensure that the output is shut off until the internal circuitry has enough voltage to operate properly. The UVLO circuit has a deglitch feature so that the circuit typically ignores undershoot transients on the input if the duration is less than 50- $\mu$ s.

## 8.4 Device Functional Modes

Driving the EN pin over 1.2 V for  $V_I$  between 2.2 V to 3.6 V or 1.35 V for  $V_I$  between 3.6 V and 6.5 V turns on the regulator. Driving the EN pin below 0.4 V causes the regulator to enter shutdown mode.

In shutdown, the current consumption of the device is reduced to 0.02  $\mu$ A typically.

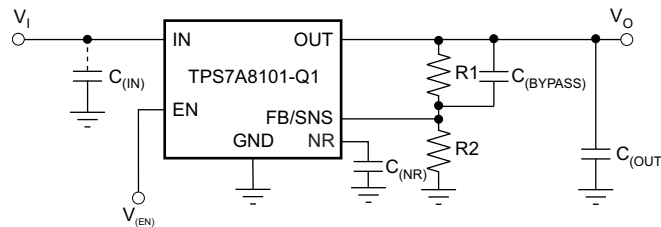
## 9 Application and Implementation

### 9.1 Application Information

The TPS7A8101-Q1 device belongs to a family of new-generation LDO regulators that use innovative circuitry to achieve wide bandwidth and high loop gain, resulting in extremely high PSRR (over a 1-MHz range) even with very low headroom ( $V_I - V_O$ ). A noise-reduction capacitor ( $C_{(NR)}$ ) at the NR pin and a bypass capacitor ( $C_{(BYPASS)}$ ) decrease noise generated by the bandgap reference in order to improve PSRR, while a quick-start circuit fast-charges the noise-reduction capacitor. This family of regulators offers sub-bandgap output voltages, current-limit, and thermal protection, and is fully specified from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### 9.2 Typical Application

Figure 31 shows the connections for the device.



**Figure 31. Typical Application Circuit**

The voltage on the FB pin sets the output voltage and is determined by the values of the resistors R1 and R2. Use Equation 2 to calculate the values of R1 and R2 any voltage.

$$V_O = \frac{(R1 + R2)}{R2} \times 0.8 \quad (2)$$

Table 1 lists sample resistor values for common output voltages. In Table 1, E96 series resistors are used, and all values meet 1% of the target  $V_O$ , assuming resistors with zero error. For the actual design, pay attention to any resistor error-factors. Using lower values for R1 and R2 reduces the noise injected into the FB pin.

#### 9.2.1 Design Requirements

##### 9.2.1.1 Dropout Voltage

The TPS7A8101-Q1 device uses a PMOS pass transistor to achieve low dropout. When  $(V_I - V_{Onom})$  is less than the dropout voltage ( $V_{DO}$ ), the PMOS pass device is in the linear region of operation and the input-to-output resistance is the  $r_{DS(on)}$  of the PMOS pass element.  $V_{DO}$  is proportional to the output current because the PMOS device in dropout functions in the same way as a resistor.

As with any linear regulator, PSRR and transient responses are degraded as  $(V_I - V_O)$  approaches dropout. Figure 19 and Figure 20 in the *Typical Characteristics* section shown this effect.

##### 9.2.1.2 Minimum Load

The TPS7A8101-Q1 device is stable and functions well with no output load. Traditional PMOS-LDO regulators suffer from lower loop gain at very light output loads. The TPS7A8101-Q1 device employs an innovative low-current mode circuit to increase loop gain under very light or no-load conditions, resulting in improved output voltage regulation performance down to zero output current.

##### 9.2.1.3 Input And Output Capacitor Requirements

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

## Typical Application (continued)

The TPS7A8101-Q1 device is designed to be stable with standard ceramic capacitors of capacitance values 4.7  $\mu\text{F}$  or larger. This device was evaluated using a 10- $\mu\text{F}$  ceramic capacitor of 10-V rating, 10% tolerance, X5R type, and 0805 size (2 mm  $\times$  1.25 mm).

X5R-type and X7R-type capacitors are highly recommended because they have minimal variation in capacitance and ESR over temperature. The maximum ESR should be less than 1  $\Omega$ .

**Table 1. Recommended Feedback Resistor Values for Common Output Voltages**

| $V_O$ | R1                 | R2            |
|-------|--------------------|---------------|
| 0.8 V | 0 $\Omega$ (Short) | 10 k $\Omega$ |
| 1 V   | 2.49 k $\Omega$    | 10 k $\Omega$ |
| 1.2 V | 4.99 k $\Omega$    | 10 k $\Omega$ |
| 1.5 V | 8.87 k $\Omega$    | 10 k $\Omega$ |
| 1.8 V | 12.5 k $\Omega$    | 10 k $\Omega$ |
| 2.5 V | 21 k $\Omega$      | 10 k $\Omega$ |
| 3.3 V | 30.9 k $\Omega$    | 10 k $\Omega$ |
| 5 V   | 52.3 k $\Omega$    | 10 k $\Omega$ |

**Table 2. Recommended Capacitor Values**

| NAME           | DESCRIPTION                                           | VALUE            |
|----------------|-------------------------------------------------------|------------------|
| $C_{(NR)}$     | Noise-reduction capacitor between the NR and GND pins | 470 nF           |
| $C_{(BYPASS)}$ | Noise-reduction capacitor across R1                   | 470 nF           |
| $C_{(OUTPUT)}$ | Output capacitor                                      | 10 $\mu\text{F}$ |
| $C_{(IN)}$     | Input capacitor                                       | 10 $\mu\text{F}$ |

### 9.2.1.4 Transient Response

As with any regulator, increasing the size of the output capacitor reduces overshoot and undershoot magnitude but increases the duration of the transient response. Using a larger noise-reduction capacitor ( $C_{(NR)}$ ), bypass capacitor ( $C_{(BYPASS)}$ ), or both types of capacitors can improve line-transient performance.

## 9.2.2 Detailed Design Procedure

### 9.2.2.1 Output Noise

In most LDOs, the bandgap is the dominant noise source. If a noise reduction capacitor ( $C_{(NR)}$ ) is used with the TPS7A8101-Q1 device, the bandgap does not contribute significantly to noise. Instead, noise is dominated by the output resistor-divider and the error-amplifier input. If a bypass capacitor ( $C_{(BYPASS)}$ ) across the high-side feedback resistor (R1) is used with the TPS7A8101-Q1 device, noise from these other sources can also be significantly reduced.

To maximize noise performance in a given application, use a 0.47- $\mu\text{F}$  noise-reduction capacitor plus a 0.47- $\mu\text{F}$  bypass capacitor.

## 9.2.3 Application Curves

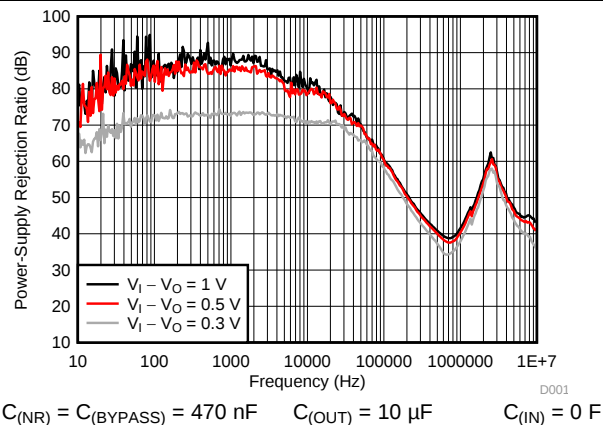


Figure 32. PSRR vs Frequency

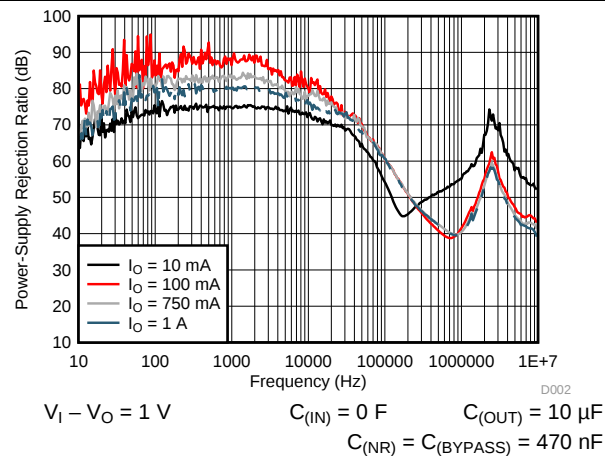


Figure 33. PSRR vs Frequency

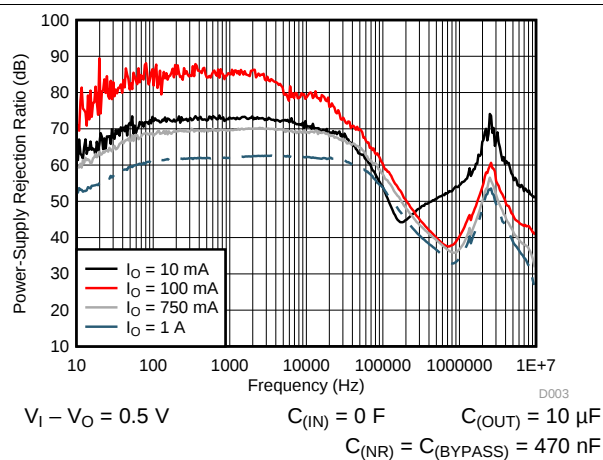


Figure 34. PSRR vs Frequency

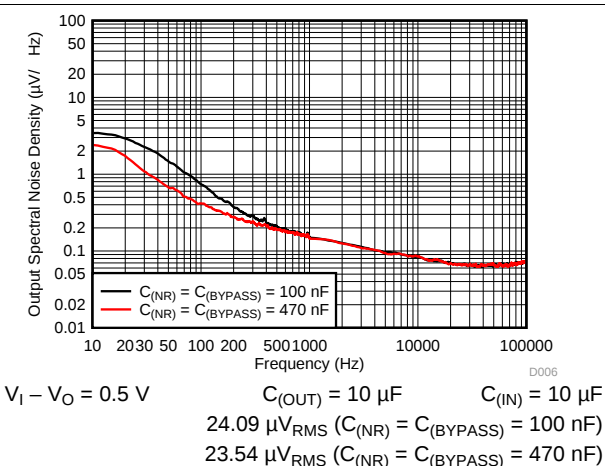


Figure 35. Output Spectral Noise Density vs Frequency (RMS noise (100 Hz to 100 kHz))

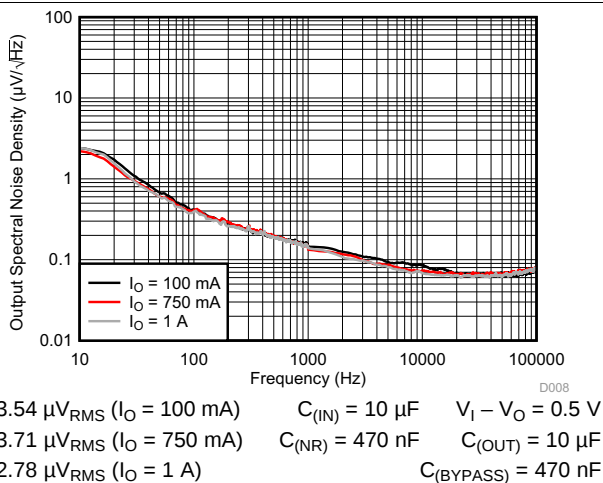


Figure 36. Output Spectral Noise Density vs Frequency (RMS noise (100 Hz to 100 kHz))

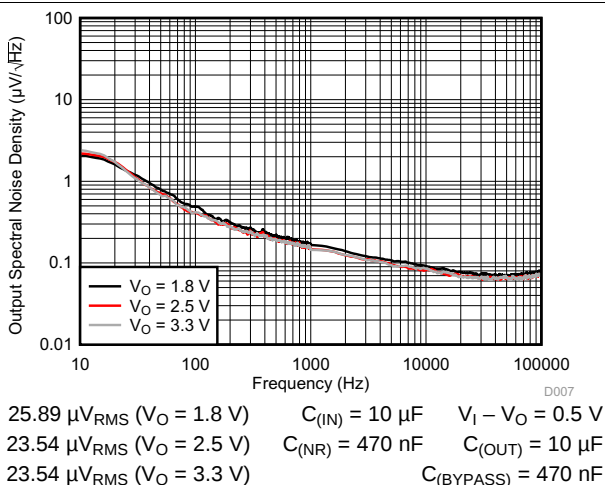
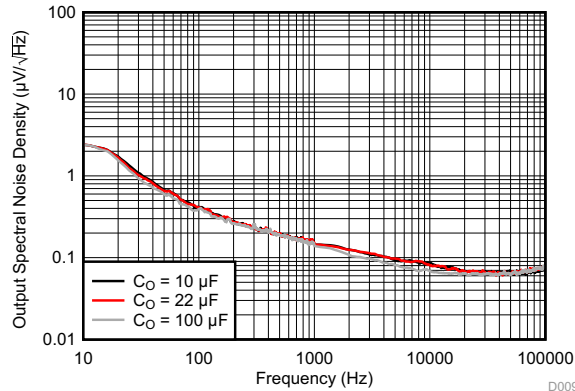
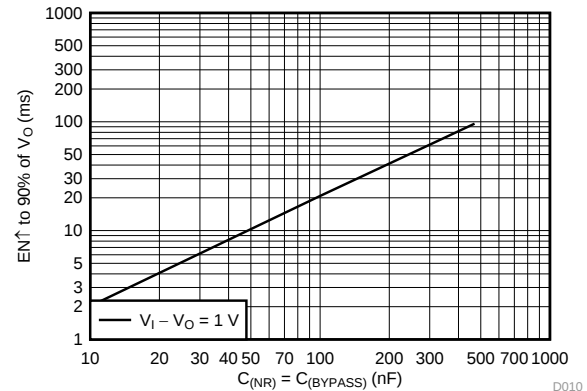


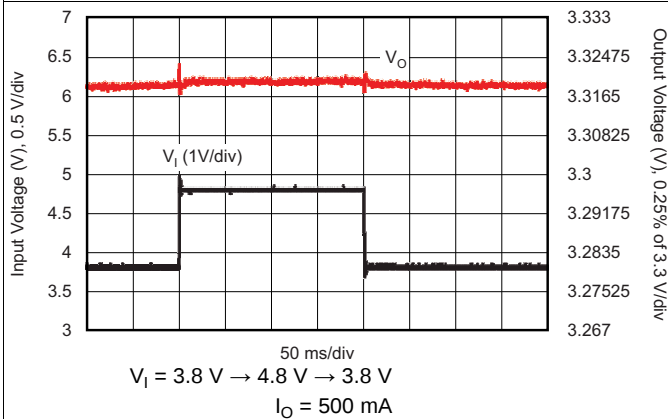
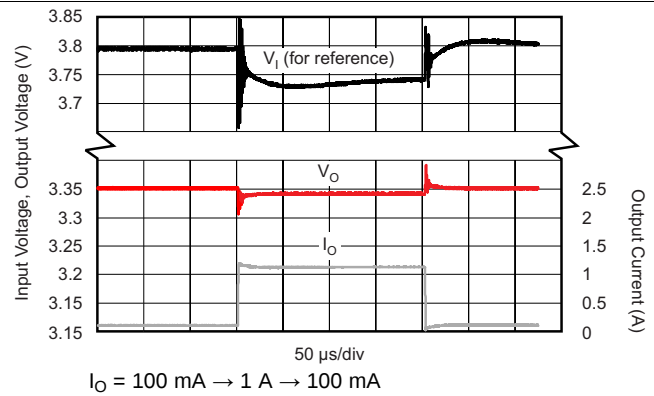
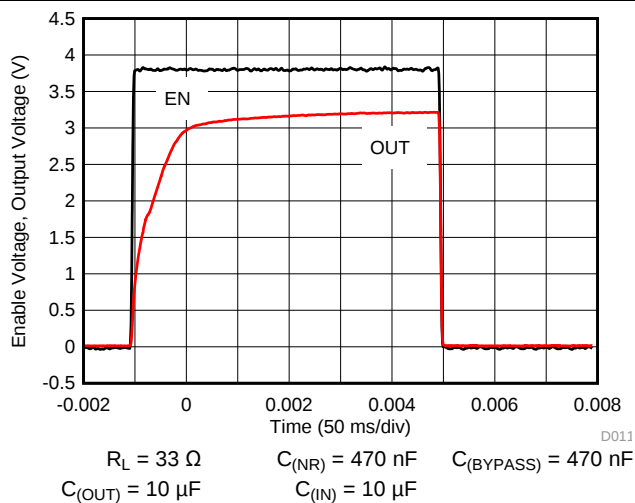
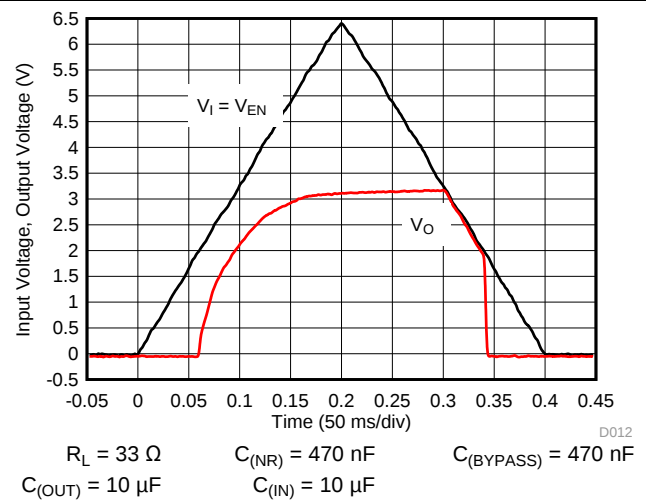
Figure 37. Output Spectral Noise Density vs Frequency (RMS noise (100 Hz to 100 kHz))



23.54  $\mu\text{V}_{\text{RMS}}$  ( $C_O = 10 \mu\text{F}$ )     $C_{(\text{IN})} = 10 \mu\text{F}$      $V_I - V_O = 0.5 \text{ V}$   
 23.91  $\mu\text{V}_{\text{RMS}}$  ( $C_O = 22 \mu\text{F}$ )     $C_{(\text{NR})} = 470 \text{ nF}$      $C_{(\text{OUT})} = 10 \mu\text{F}$   
 22.78  $\mu\text{V}_{\text{RMS}}$  ( $C_O = 100 \mu\text{F}$ )     $C_{(\text{BYPASS})} = 470 \text{ nF}$

**Figure 38. Output Spectral Noise Density vs Frequency (RMS noise (100 Hz to 100 kHz))**


Using the same value of  $C_{(\text{NR})}$  and  $C_{(\text{BYPASS})}$  in the X-Axis

**Figure 39. Startup Time vs Noise Reduction Capacitance**

**Figure 40. Line Transient Response**

**Figure 41. Load Transient Response**

**Figure 42. Enable Pulse Response, See (1) in Figure 43**

**Figure 43. Power-Up and Power-Down Response**

## 10 Power Supply Recommendations

The device is designed to operate from an input voltage supply range between 2.2 V and 6.5 V. The input voltage range should provide adequate headroom in order for the device to have a regulated output. This input supply should be well regulated. If the input supply is noisy, additional input capacitors with low ESR can help improve the output noise performance.

## 11 Layout

### 11.1 Layout Guidelines

#### 11.1.1 Board Layout Recommendations To Improve PSRR And Noise Performance

To improve AC performance such as PSRR, output noise, and transient response, designing with separate ground planes for  $V_I$  and  $V_O$ , with each ground plane connected only at the GND pin of the device, is recommended. In addition, the ground connection for the noise-reduction capacitor should connect directly to the GND pin of the device.

High ESR capacitors may degrade PSRR.

#### 11.2 Layout Example

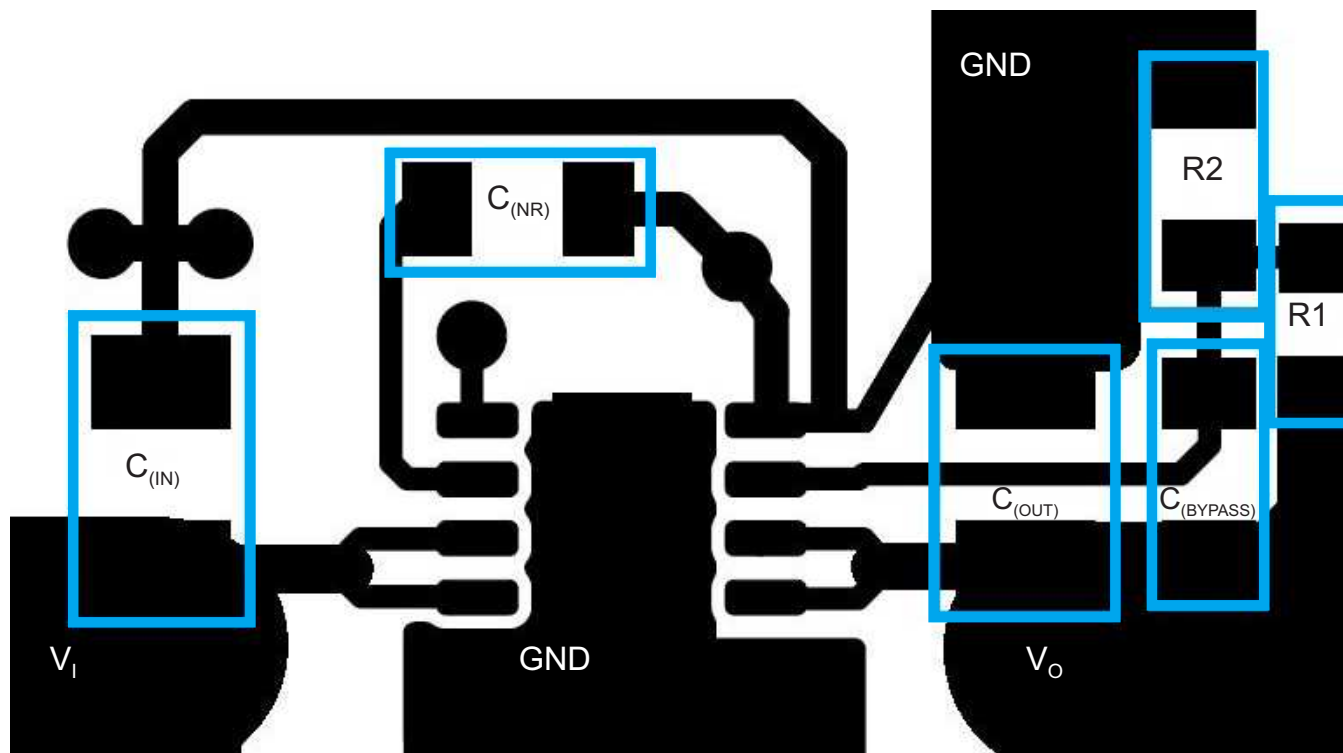


Figure 44. TPS7A8101-Q1 Layout Example

## 11.3 Thermal Information

### 11.3.1 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 cycling limits the dissipation of the regulator, protecting it from damage because of overheating.

Any activation of 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 particular application. This configuration produces a worst-case junction temperature of 125°C at the highest expected ambient temperature and worst-case load.

The internal protection circuitry of the TPS7A8101-Q1 device has been designed to protect against overload conditions. The internal thermal protection circuitry was not intended to replace proper heatsinking. Continuously running the TPS7A8101-Q1 device into thermal shutdown degrades device reliability.

### 11.3.2 Package Mounting

See the [机械封装和可订购信息](#) section for solder pad footprint recommendations and recommended land patterns.

### 11.3.3 Power Dissipation

Knowing the device power dissipation and proper sizing of the thermal plane that is connected to the tab or pad is critical to avoiding thermal shutdown and ensuring reliable operation.

The power dissipation of the device depends on input voltage and load conditions. To calculate the device power dissipation, use [Equation 3](#).

$$P_D = (V_I - V_O) \times I_O \quad (3)$$

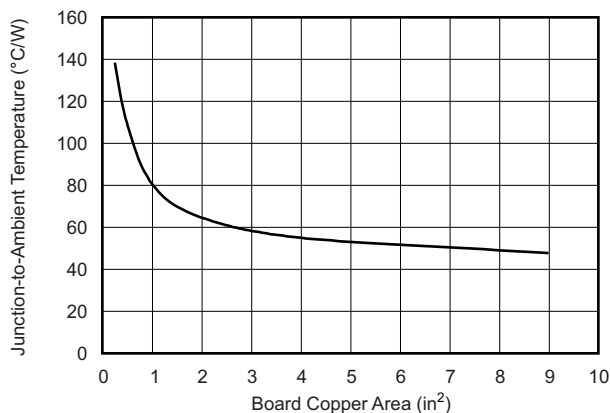
Using the lowest possible input voltage necessary to achieve the required output voltage regulation minimizes power dissipation and achieves greater efficiency.

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

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

Once the maximum  $R_{\theta JA}$  value is calculated, use [Figure 45](#) to estimate the minimum amount of PCB copper area needed for appropriate heatsinking.

## Thermal Information (continued)



Note: The  $R_{\theta JA}$  value at board size of 9 in<sup>2</sup> (that is, 3 in × 3 in) is a JEDEC standard.

**Figure 45.  $R_{\theta JA}$  vs Board Size**

Figure 45 shows the variation of  $R_{\theta JA}$  as a function of ground plane copper area in the board. Figure 45 is intended as a guideline only to demonstrate the effects of heat spreading in the ground plane and should not be used to estimate actual thermal performance in real application environments.

### NOTE

When the device is mounted on an application PCB, using  $\Psi_{JT}$  and  $\Psi_{JB}$ , as explained in the section is strongly recommended.

### 11.3.4 Estimating Junction Temperature

Using the thermal metrics  $\Psi_{JT}$  and  $\Psi_{JB}$ , as shown in the [Thermal Information](#) table, the junction temperature can be estimated with the corresponding equations, [Equation 5](#) and [Equation 6](#). For backwards compatibility, an older  $\theta_{JC, Top}$  parameter is listed as well.

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

where

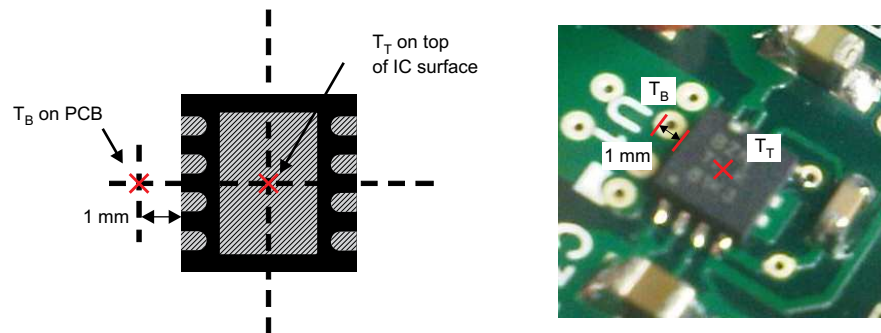
- $P_D$  is the power dissipation (see [Equation 4](#))
- $T_T$  is the temperature at the center-top of the IC package

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

where

- $T_B$  is the PCB temperature measured 1-mm away from the IC package *on the PCB surface* as shown in [Figure 46](#)

## Thermal Information (continued)



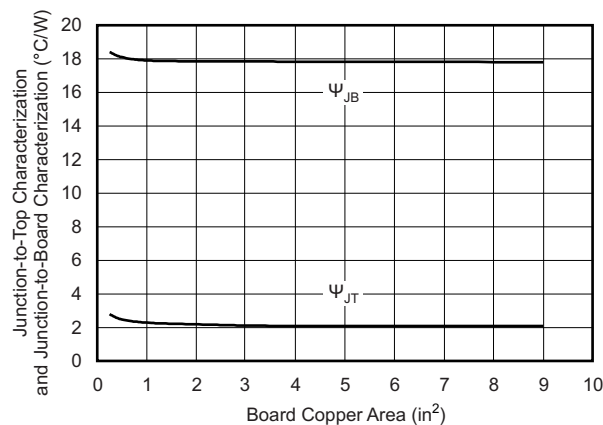
**Figure 46. Measuring Points for  $T_T$  and  $T_B$**

### NOTE

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

For more information about measuring  $T_T$  and  $T_B$ , see TI's application report [SBVA025](#), *Using New Thermal Metrics*.

As shown in [Figure 47](#), the new thermal metrics ( $\Psi_{JT}$  and  $\Psi_{JB}$ ) have very little dependency on board size. That is, using  $\Psi_{JT}$  or  $\Psi_{JB}$  with [Equation 5](#) is a good way to estimate  $T_J$  by simply measuring  $T_T$  or  $T_B$ , regardless of the application board size.



**Figure 47.  $\Psi_{JT}$  and  $\Psi_{JB}$  vs Board Size**

For a more detailed discussion of why TI does not recommend using  $R_{\theta JC(top)}$  to determine thermal characteristics, refer to TI's application report [SBVA025](#), *Using New Thermal Metrics*. For further information, refer to TI's application report [SPRA953](#), *IC Package Thermal Metrics*.

## 12 器件和文档支持

### 12.1 文档支持

#### 12.1.1 相关文档

相关文档如下：

- 《LDO 噪声详细检查》，[SLYT489](#)
- 《LDO 在接近压降电压时的性能》，[SBVA029](#)
- *TPS7A8101EVM* 评估模块，[SLVU600](#)
- LDO 的宽带宽 *PSRR* 作者 Nogawa 和 Van Renterghem *Bodo's Power Systems®*：运动和转换中的电子元器件，2011 年 3 月

### 12.2 Trademarks

Bodo's Power Systems is a registered trademark of Arlt Bodo.  
All other trademarks are the property of their respective owners.

### 12.3 Electrostatic Discharge Caution



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.

### 12.4 术语表

[SLYZ022](#) — *TI* 术语表。

这份术语表列出并解释术语、首字母缩略词和定义。

## 13 机械封装和可订购信息

以下页中包括机械封装和可订购信息。 这些信息是针对指定器件可提供的最新数据。 这些数据会在无通知且不对本文档进行修订的情况下发生改变。 欲获得该数据表的浏览器版本，请查阅左侧的导航栏。

## 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="#">TPS7A8101QDRBRQ1</a> | Active        | Production           | SON (DRB)   8  | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | SLY                 |
| TPS7A8101QDRBRQ1.A               | Active        | Production           | SON (DRB)   8  | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | SLY                 |

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

### OTHER QUALIFIED VERSIONS OF TPS7A8101-Q1 :

- Catalog : [TPS7A8101](#)

NOTE: Qualified Version Definitions:

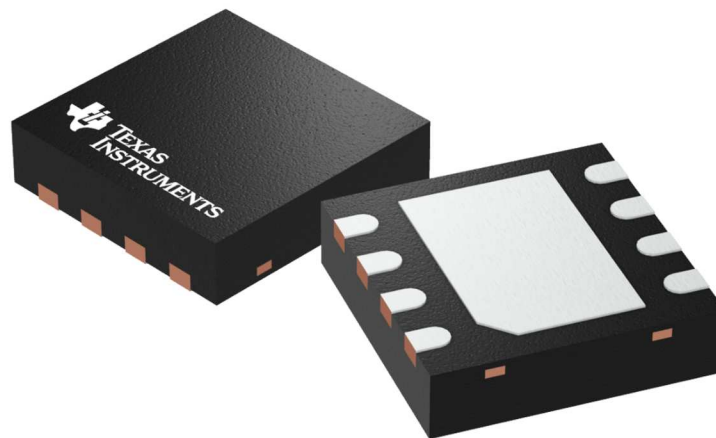
- Catalog - TI's standard catalog product

**DRB 8**

**GENERIC PACKAGE VIEW**

**VSON - 1 mm max height**

PLASTIC SMALL OUTLINE - NO LEAD



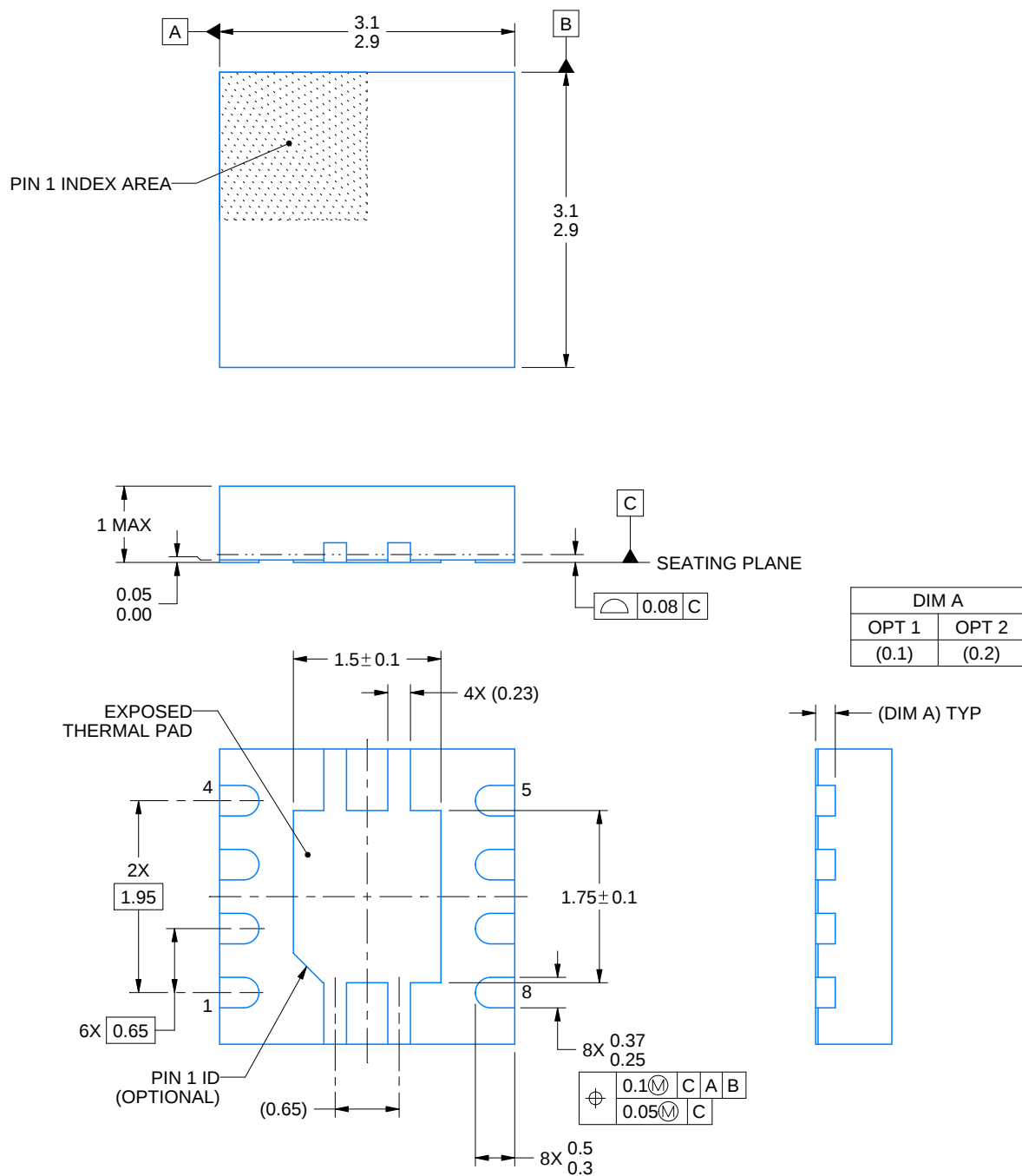
Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

4203482/L



**VSON - 1 mm max height**

PLASTIC SMALL OUTLINE - NO LEAD



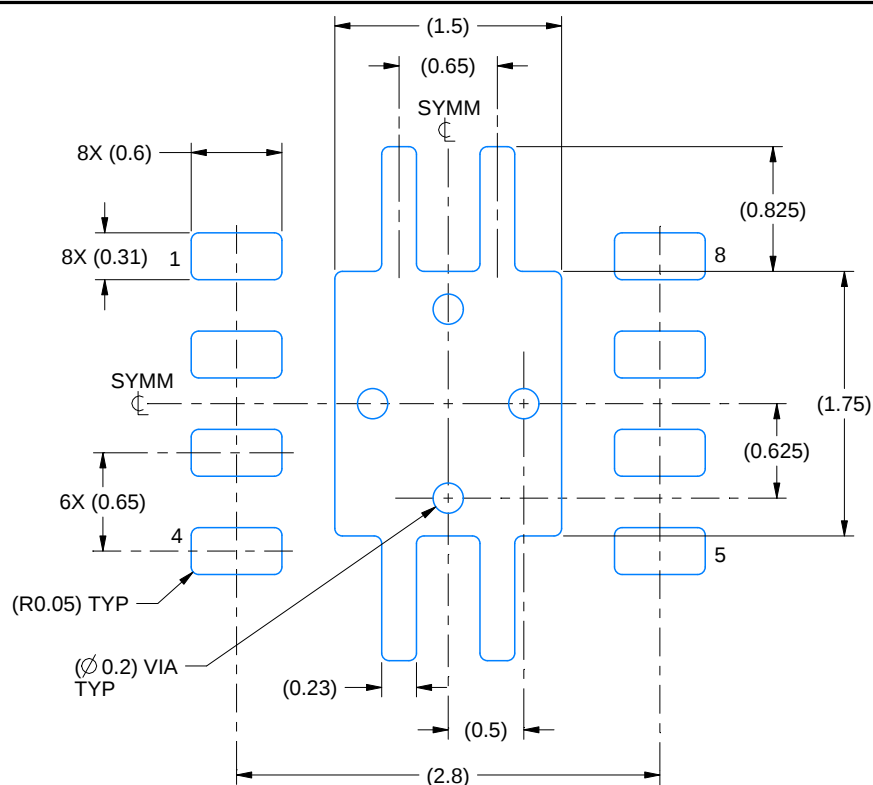
4218875/A 01/2018

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

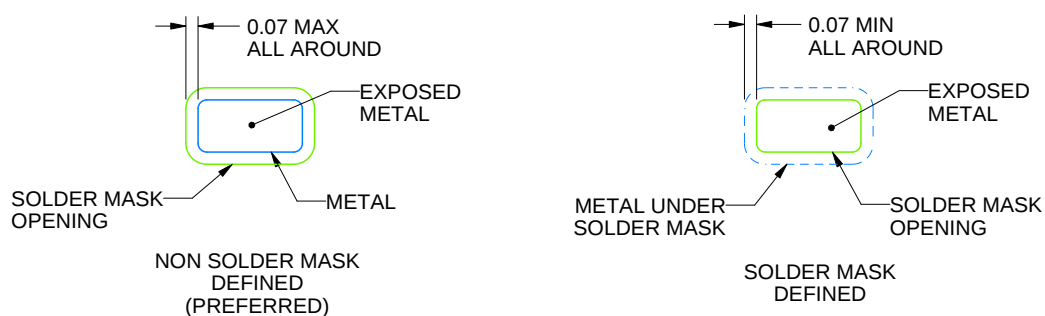
**DRB0008A**

**VSON - 1 mm max height**

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:20X



## SOLDER MASK DETAILS

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NOTES: (continued)

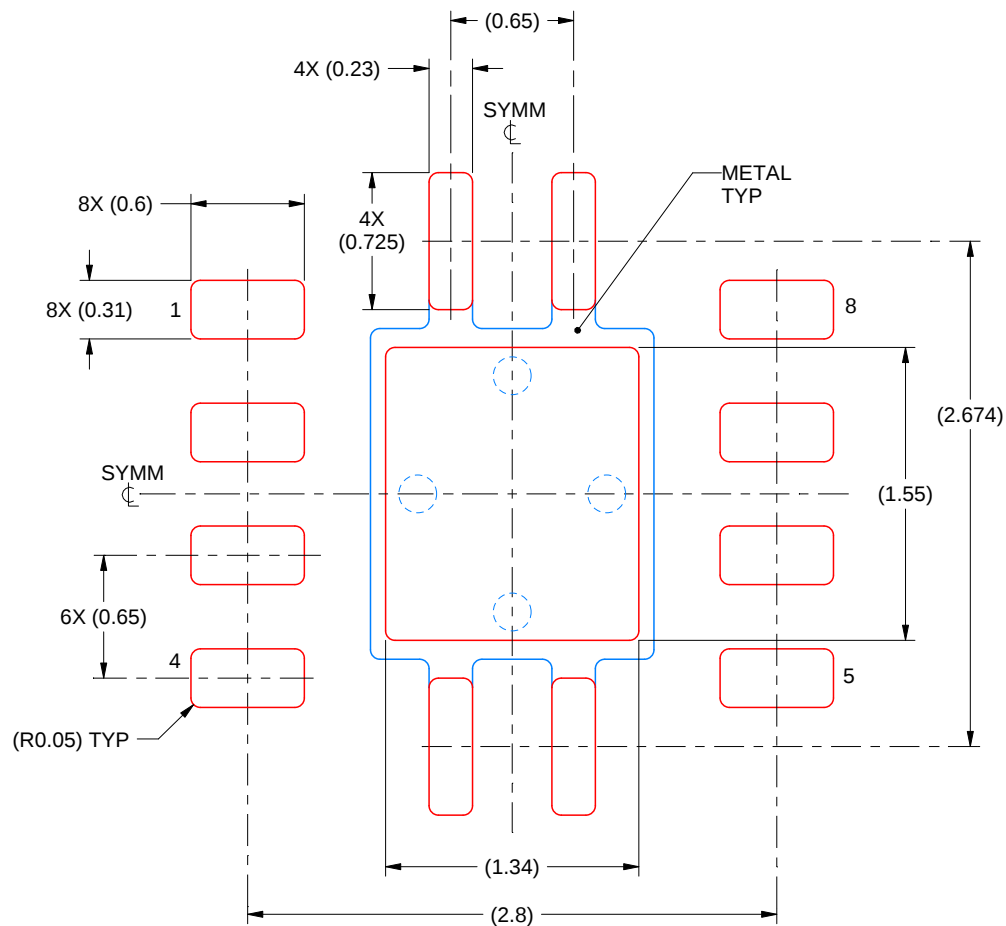
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/slua271](http://www.ti.com/lit/slua271)).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

# EXAMPLE STENCIL DESIGN

DRB0008A

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD  
84% PRINTED SOLDER COVERAGE BY AREA  
SCALE:25X

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NOTES: (continued)

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

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