



## TPS709-Q1 150-mA, 30-V, 1- $\mu$ A $I_Q$ Voltage Regulators with Enable

### 1 Features

- Qualified for Automotive Applications
- AEC-Q100 Qualified With the Following Results:
  - Device Temperature Grade 1:  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  Ambient Operating Temperature
  - Device HBM ESD Classification Level 2
  - Device CDM ESD Classification Level C4B
- Input Voltage Range: 2.7 V to 30 V
- Ultralow  $I_Q$ : 1  $\mu\text{A}$
- Reverse Current Protection
- Low  $I_{\text{SHUTDOWN}}$ : 150 nA
- Supports 200-mA Peak Output
- 2% Accuracy Over Temperature
- Available in Fixed-Output Voltages: 1.2 V to 6.5 V
- Thermal Shutdown and Overcurrent Protection
- Packages: SOT-23-5, WSON-6

### 2 Applications

- Automotive
- Infotainment
- Body Control Modules
- Navigation Systems
- Standby Power for Microcontrollers

### 3 Description

The TPS709-Q1 series of linear regulators are ultralow, quiescent current devices designed for power-sensitive applications. A precision band-gap and error amplifier provides 2% accuracy over temperature. Quiescent current of only 1  $\mu\text{A}$  makes these devices ideal solutions for battery-powered, always-on systems that require very little idle-state power dissipation. These devices have thermal-shutdown, current-limit, and reverse-current protections for added safety.

These regulators can be put into shutdown mode by pulling the EN pin low. The shutdown current in this mode goes down to 150 nA, typical.

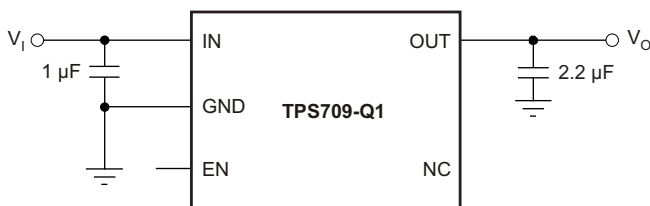
The TPS709-Q1 series is available in WSON-6 and SOT-23-5 packages.

**Device Information<sup>(1)</sup>**

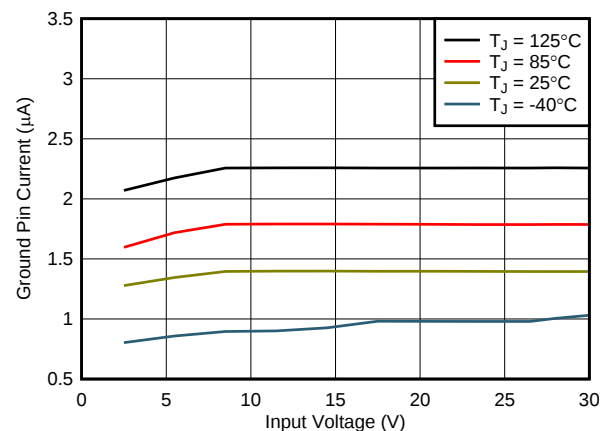
| PART NUMBER | PACKAGE    | BODY SIZE (NOM)          |
|-------------|------------|--------------------------|
| TPS709-Q1   | SOT-23 (5) | 2.90 mm $\times$ 1.60 mm |
|             | WSON (6)   | 2.00 mm $\times$ 2.00 mm |

(1) For all available packages, see the orderable addendum at the end of the datasheet.

**Typical Application Circuit**



**GND Current vs  $V_{\text{IN}}$  and Temperature**



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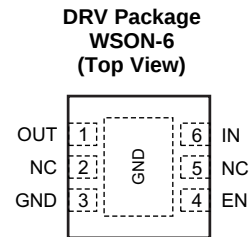
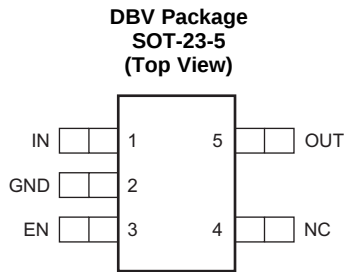
## 4 Revision History

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

| Changes from Revision A (December 2013) to Revision B                                                                                                                                                                                                                                                                                           | Page      |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| • Added DRV package to document, <i>ESD Ratings</i> , <i>Recommended Operating Conditions</i> , and <i>Timing Requirements</i> tables, and <i>Overview</i> , <i>Device Functional Modes</i> , <i>Typical Application</i> , <i>Device and Documentation Support</i> , and <i>Mechanical, Packaging, and Orderable Information</i> sections ..... | <b>1</b>  |
| • Changed <i>Application Information</i> , <i>Feature Description</i> , <i>Power Supply Recommendations</i> , and <i>Layout</i> sections .....                                                                                                                                                                                                  | <b>1</b>  |
| • Deleted <i>Low Dropout Features</i> bullet .....                                                                                                                                                                                                                                                                                              | <b>1</b>  |
| • Changed <i>Applications</i> section .....                                                                                                                                                                                                                                                                                                     | <b>1</b>  |
| • Changed last sentence of <i>Description</i> section .....                                                                                                                                                                                                                                                                                     | <b>1</b>  |
| • Added Device Information table .....                                                                                                                                                                                                                                                                                                          | <b>1</b>  |
| • Added front-page curve .....                                                                                                                                                                                                                                                                                                                  | <b>1</b>  |
| • Added DRV package drawing to <i>Pin Configuration and Functions</i> section .....                                                                                                                                                                                                                                                             | <b>3</b>  |
| • Changed <i>Pin Functions</i> table: added DRV and I/O columns, added Thermal pad row, and changed EN pin description....                                                                                                                                                                                                                      | <b>3</b>  |
| • Changed <i>Recommended Operating Conditions</i> table .....                                                                                                                                                                                                                                                                                   | <b>4</b>  |
| • Added DRV column to <i>Thermal Information</i> table .....                                                                                                                                                                                                                                                                                    | <b>4</b>  |
| • Changed <i>Electrical Characteristics</i> conditions .....                                                                                                                                                                                                                                                                                    | <b>5</b>  |
| • Changed $V_{OUT}$ , $I_{CL}$ , $I_{SHDN}$ , and $I_{REV}$ symbols in <i>Electrical Characteristics</i> table .....                                                                                                                                                                                                                            | <b>5</b>  |
| • Changed $V_{EN(HI)}$ parameter into $V_{EN(HI)}$ and $V_{EN(LO)}$ parameters in <i>Electrical Characteristics</i> table .....                                                                                                                                                                                                                 | <b>5</b>  |
| • Changed $T_A$ parameter to $T_j$ in <i>Electrical Characteristics</i> table .....                                                                                                                                                                                                                                                             | <b>5</b>  |
| • Changed <i>Typical Characteristics</i> section .....                                                                                                                                                                                                                                                                                          | <b>6</b>  |
| • Changed junction temperature values in first paragraph of <i>Thermal Protection</i> section .....                                                                                                                                                                                                                                             | <b>14</b> |
| • Changed 6.3-V to 10-V in second sentence of <i>Detailed Design Procedure</i> section .....                                                                                                                                                                                                                                                    | <b>17</b> |

| Changes from Original (December 2013) to Revision A | Page     |
|-----------------------------------------------------|----------|
| • Changed to production data .....                  | <b>1</b> |

## 5 Pin Configuration and Functions



### Pin Functions

| PIN         |      |     | I/O | DESCRIPTION                                                                                                                                                                                                            |
|-------------|------|-----|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME        | NO.  |     |     |                                                                                                                                                                                                                        |
|             | DRV  | DBV |     |                                                                                                                                                                                                                        |
| EN          | 4    | 3   | I   | Enable pin. Driving this pin high enables the device. Driving this pin low puts the device into low current shutdown. This pin can be left floating to enable the device. The maximum voltage must remain below 6.5 V. |
| GND         | 3    | 2   | —   | Ground                                                                                                                                                                                                                 |
| IN          | 6    | 1   | I   | Unregulated input to the device                                                                                                                                                                                        |
| NC          | 2, 5 | 4   | —   | No internal connection                                                                                                                                                                                                 |
| OUT         | 1    | 5   | O   | Regulated output voltage. Connect a small 2.2-μF or greater ceramic capacitor from this pin to ground to assure stability.                                                                                             |
| Thermal pad |      | —   | —   | The thermal pad is electrically connected to the GND node. Connect to the GND plane for improved thermal performance.                                                                                                  |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

specified at  $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , unless otherwise noted; all voltages are with respect to GND<sup>(1)</sup>

|                                    |            | MIN                                     | MAX | UNIT               |
|------------------------------------|------------|-----------------------------------------|-----|--------------------|
| Voltage                            | $V_{IN}$   | -0.3                                    | 32  | V                  |
|                                    | $V_{EN}$   | -0.3                                    | 7   | V                  |
|                                    | $V_{OUT}$  | -0.3                                    | 7   | V                  |
| Maximum output current             | $I_{OUT}$  | Internally limited                      |     |                    |
| Output short-circuit duration      |            | Indefinite                              |     |                    |
| Continuous total power dissipation | $P_{DISS}$ | See <a href="#">Thermal Information</a> |     |                    |
| Junction temperature, $T_J$        |            | -55                                     | 150 | $^{\circ}\text{C}$ |
| Storage temperature, $T_{stg}$     |            | -55                                     | 150 | $^{\circ}\text{C}$ |
| Ambient temperature, $T_A$         |            | -40                                     | 125 | $^{\circ}\text{C}$ |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

### 6.2 ESD Ratings

|                                     |                                                                                | VALUE | UNIT |
|-------------------------------------|--------------------------------------------------------------------------------|-------|------|
| $V_{(ESD)}$ Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | ±2000 | V    |
|                                     | Charged device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> | ±750  |      |

- (1) JEDEC document JEP155 states that 2-kV HBM allows safe manufacturing with a standard ESD control process.  
(2) JEDEC document JEP157 states that 500-V CDM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Conditions

over operating junction temperature range (unless otherwise noted)

|           |                                | MIN | NOM | MAX | UNIT               |
|-----------|--------------------------------|-----|-----|-----|--------------------|
| $V_{IN}$  | Input voltage                  | 2.7 |     | 30  | V                  |
| $V_{OUT}$ | Output voltage                 | 1.2 |     | 6.5 | V                  |
| $I_{OUT}$ | Output current                 | 0   |     | 150 | mA                 |
| $V_{EN}$  | Enable voltage                 | 0   |     | 6.5 | V                  |
| $C_{IN}$  | Input capacitor                |     | 1   |     | $\mu\text{F}$      |
| $C_{OUT}$ | Output capacitor               | 2   | 2.2 | 47  | $\mu\text{F}$      |
| $T_J$     | Operating junction temperature | -40 |     | 125 | $^{\circ}\text{C}$ |

### 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | TPS709-Q1    |            | UNIT                        |
|-------------------------------|----------------------------------------------|--------------|------------|-----------------------------|
|                               |                                              | DBV (SOT-23) | DRV (WSON) |                             |
|                               |                                              | 5 PINS       | 6 PINS     |                             |
| $R_{\theta JA}$               | Junction-to-ambient thermal resistance       | 210.9        | 73.1       | $^{\circ}\text{C}/\text{W}$ |
| $R_{\theta JC(top)}$          | Junction-to-case (top) thermal resistance    | 127.4        | 97.0       |                             |
| $R_{\theta JB}$               | Junction-to-board thermal resistance         | 39.4         | 42.6       |                             |
| $\Psi_{JT}$                   | Junction-to-top characterization parameter   | 16.8         | 2.9        |                             |
| $\Psi_{JB}$                   | Junction-to-board characterization parameter | 38.4         | 42.9       |                             |
| $R_{\theta JC(bot)}$          | Junction-to-case (bottom) thermal resistance | N/A          | 12.8       |                             |

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

## 6.5 Electrical Characteristics

At  $-40^{\circ}\text{C} \leq T_J$ ,  $T_A \leq 125^{\circ}\text{C}$ ,  $V_{IN} = V_{OUT(nom)} + 1\text{ V}$  or  $2.7\text{ V}$  (whichever is greater),  $I_{OUT} = 1\text{ mA}$ ,  $V_{EN} = 2\text{ V}$ , and  $C_{IN} = C_{OUT} = 2.2\text{-}\mu\text{F}$  ceramic, unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ .

| PARAMETER        |                                         | TEST CONDITIONS                                                                                                                         | MIN | TYP | MAX  | UNIT                       |
|------------------|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|-----|-----|------|----------------------------|
| $V_{IN}$         | Input voltage range                     |                                                                                                                                         | 2.7 |     | 30   | V                          |
| $V_{OUT}$        | Output voltage range                    |                                                                                                                                         | 1.2 |     | 6.5  | V                          |
| $V_{OUT}$        | DC output accuracy                      | $V_{OUT} < 3.3\text{ V}$                                                                                                                | –2% |     | 2%   |                            |
|                  |                                         | $V_{OUT} \geq 3.3\text{ V}$                                                                                                             | –1% |     | 1%   |                            |
| $\Delta V_{OUT}$ | Line regulation                         | $(V_{OUT(nom)} + 1\text{ V}, 2.7\text{ V}) \leq V_{IN} \leq 30\text{ V}$                                                                |     | 3   | 10   | mV                         |
|                  | Load regulation                         | $V_{IN} = V_{OUT(nom)} + 1.5\text{ V}$ or $3\text{ V}$ (whichever is greater), $100\text{ }\mu\text{A} \leq I_{OUT} \leq 150\text{ mA}$ |     | 20  | 50   | mV                         |
| $V_{DO}$         | Dropout voltage <sup>(1)(2)</sup>       | TPS70933-Q1, $I_{OUT} = 50\text{ mA}$                                                                                                   |     | 295 | 650  | mV                         |
|                  |                                         | TPS70933-Q1, $I_{OUT} = 150\text{ mA}$                                                                                                  |     | 975 | 1540 | mV                         |
|                  |                                         | TPS70950-Q1, $I_{OUT} = 50\text{ mA}$                                                                                                   |     | 245 | 500  | mV                         |
|                  |                                         | TPS70950-Q1, $I_{OUT} = 150\text{ mA}$                                                                                                  |     | 690 | 1200 | mV                         |
| $I_{CL}$         | Output current limit <sup>(3)</sup>     | $V_{OUT} = 0.9 \times V_{OUT(nom)}$                                                                                                     | 200 | 320 | 500  | mA                         |
| $I_{GND}$        | Ground pin current                      | $I_{OUT} = 0\text{ mA}$ , $V_{OUT} \leq 3.3\text{ V}$                                                                                   |     | 1.3 | 2.55 | $\mu\text{A}$              |
|                  |                                         | $I_{OUT} = 0\text{ mA}$ , $V_{OUT} > 3.3\text{ V}$                                                                                      |     | 1.4 | 2.7  | $\mu\text{A}$              |
|                  |                                         | $I_{OUT} = 100\text{ }\mu\text{A}$ , $V_{IN} = 30\text{ V}$                                                                             |     | 6.7 | 10   | $\mu\text{A}$              |
|                  |                                         | $I_{OUT} = 150\text{ mA}$                                                                                                               |     | 350 |      | $\mu\text{A}$              |
| $I_{SHDN}$       | Shutdown current                        | $V_{EN} \leq 0.4\text{ V}$ , $V_{IN} = 2.7\text{ V}$                                                                                    |     | 150 |      | nA                         |
| PSRR             | Power-supply rejection ratio            | $f = 10\text{ Hz}$                                                                                                                      |     | 80  |      | dB                         |
|                  |                                         | $f = 100\text{ Hz}$                                                                                                                     |     | 62  |      | dB                         |
|                  |                                         | $f = 1\text{ kHz}$                                                                                                                      |     | 52  |      | dB                         |
| $V_n$            | Output noise voltage                    | $\text{BW} = 10\text{ Hz to } 100\text{ kHz}$ , $I_{OUT} = 10\text{ mA}$ , $V_{IN} = 2.7\text{ V}$ , $V_{OUT} = 1.2\text{ V}$           |     | 190 |      | $\mu\text{V}_{\text{RMS}}$ |
| $V_{EN(HI)}$     | Enable pin high (enabled)               |                                                                                                                                         | 0.9 |     |      | V                          |
| $V_{EN(LO)}$     | Enable pin high (disabled)              |                                                                                                                                         | 0   |     | 0.4  | V                          |
| $I_{EN}$         | Enable pin current                      | $\text{EN} = 1.0\text{ V}$ , $V_{IN} = 5.5\text{ V}$                                                                                    |     | 300 |      | nA                         |
| $I_{REV}$        | Reverse current (flowing out of IN pin) | $V_{OUT} = 3\text{ V}$ , $V_{IN} = V_{EN} = 0\text{ V}$                                                                                 |     | 10  |      | nA                         |
|                  | Reverse current (flowing into OUT pin)  | $V_{OUT} = 3\text{ V}$ , $V_{IN} = V_{EN} = 0\text{ V}$                                                                                 |     | 100 |      | nA                         |
| $T_{SD}$         | Thermal shutdown temperature            | Shutdown, temperature increasing                                                                                                        |     | 158 |      | $^{\circ}\text{C}$         |
|                  |                                         | Reset, temperature decreasing                                                                                                           |     | 140 |      | $^{\circ}\text{C}$         |
| $T_J$            | Operating junction temperature          |                                                                                                                                         | –40 |     | 125  | $^{\circ}\text{C}$         |

(1)  $V_{DO}$  is measured with  $V_{IN} = 0.98 \times V_{OUT(nom)}$ .

(2) Dropout is only valid when  $V_{OUT} \geq 2.8\text{ V}$  because of the minimum input voltage limits.

(3) Measured with  $V_{IN} = V_{OUT} + 3\text{ V}$  for  $V_{OUT} \leq 2.5\text{ V}$ . Measured with  $V_{IN} = V_{OUT} + 2.5\text{ V}$  for  $V_{OUT} > 2.5\text{ V}$ .

## 6.6 Timing Requirements

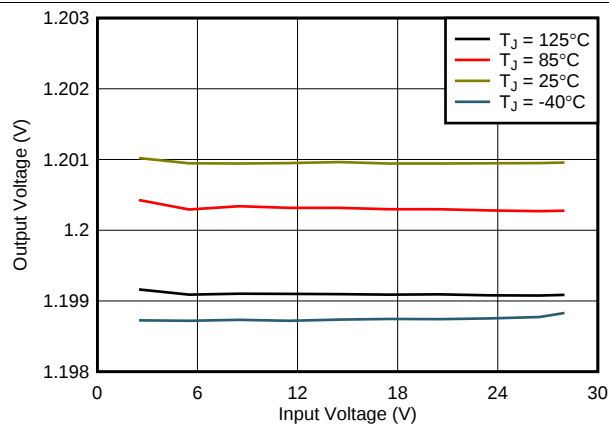
At  $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ,  $V_{IN} = V_{OUT(nom)} + 1\text{ V}$  or  $2.7\text{ V}$  (whichever is greater),  $R_L = 47\text{ }\Omega$ ,  $V_{EN} = 2\text{ V}$ , and  $C_{IN} = C_{OUT} = 2.2\text{-}\mu\text{F}$  ceramic, unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ .

|           |                              | MIN                              | NOM | MAX  | UNIT          |
|-----------|------------------------------|----------------------------------|-----|------|---------------|
| $t_{STR}$ | Start-up time <sup>(1)</sup> | $V_{OUT(nom)} \leq 3.3\text{ V}$ | 200 | 600  | $\mu\text{s}$ |
|           |                              | $V_{OUT(nom)} > 3.3\text{ V}$    | 500 | 1500 | $\mu\text{s}$ |

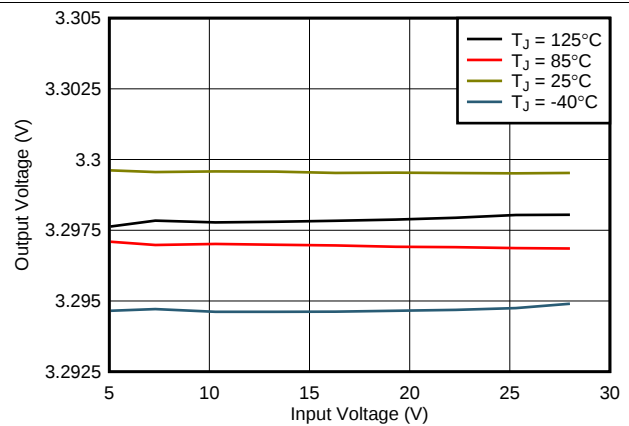
(1) Startup time = time from EN assertion to  $0.95 \times V_{OUT(nom)}$  and load =  $47\text{ }\Omega$ .

## 6.7 Typical Characteristics

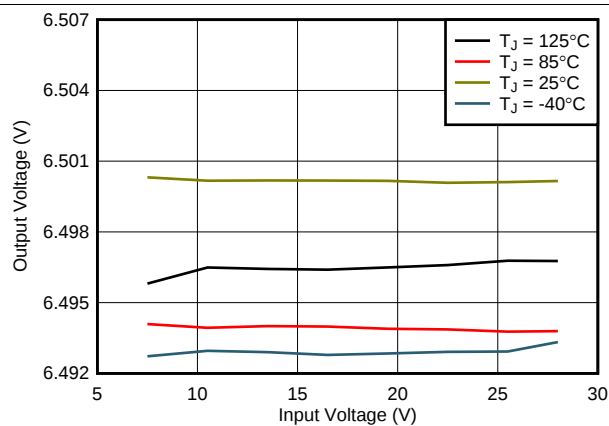
Over operating temperature range ( $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ),  $I_{OUT} = 10\text{ mA}$ ,  $V_{EN} = 2\text{ V}$ ,  $C_{OUT} = 2.2\text{ }\mu\text{F}$ , and  $V_{IN} = V_{OUT(nom)} + 1\text{ V}$  or  $2.7\text{ V}$  (whichever is greater), unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ .



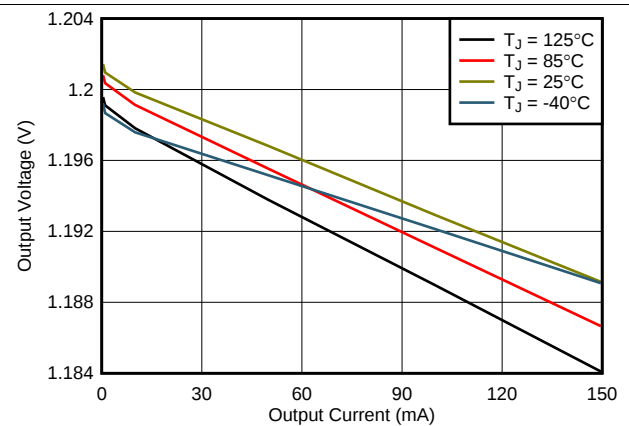
**Figure 1. 1.2-V Line Regulation vs  $V_{IN}$  and Temperature**



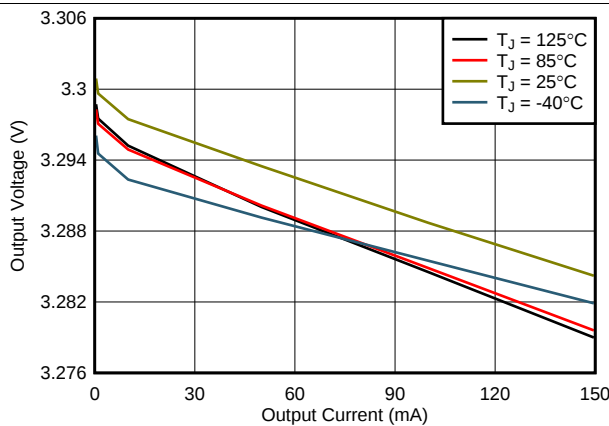
**Figure 2. 3.3-V Line Regulation vs  $V_{IN}$  and Temperature**



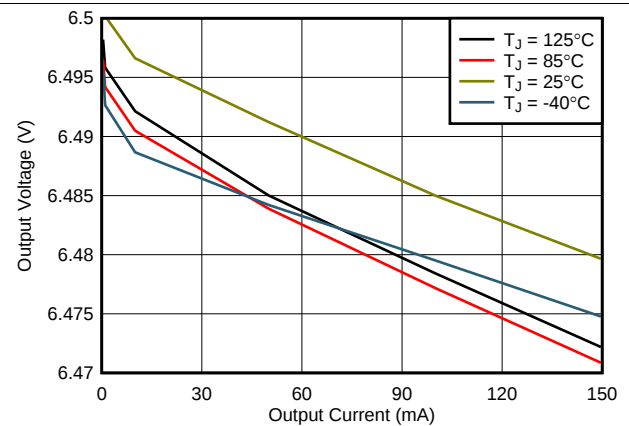
**Figure 3. 6.5-V Line Regulation vs  $V_{IN}$  and Temperature**



**Figure 4. 1.2-V Load Regulation vs  $I_{OUT}$  and Temperature**



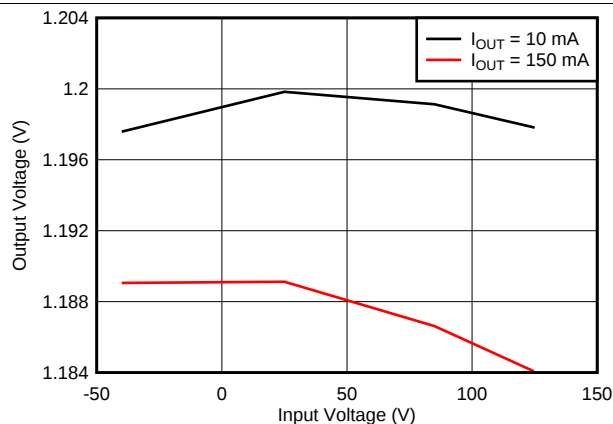
**Figure 5. 3.3-V Load Regulation vs  $I_{OUT}$  and Temperature**



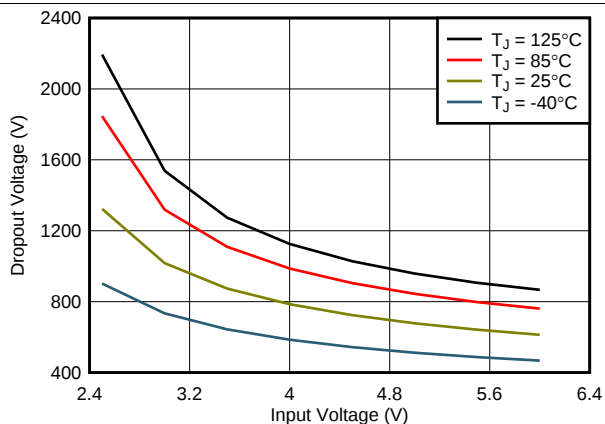
**Figure 6. 6.5-V Load Regulation vs  $I_{OUT}$  and Temperature**

## Typical Characteristics (continued)

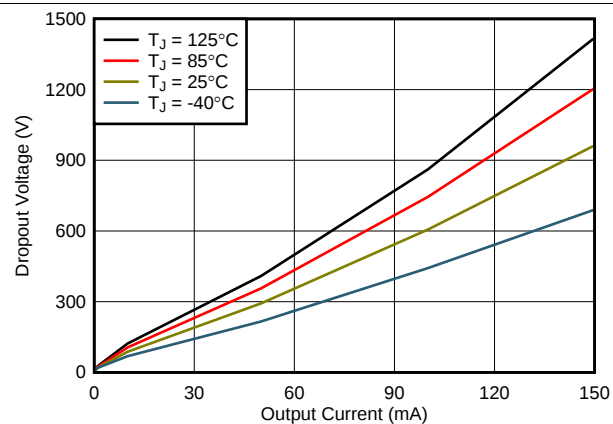
Over operating temperature range ( $T_J = -40^\circ\text{C}$  to  $125^\circ\text{C}$ ),  $I_{OUT} = 10\text{ mA}$ ,  $V_{EN} = 2\text{ V}$ ,  $C_{OUT} = 2.2\text{ }\mu\text{F}$ , and  $V_{IN} = V_{OUT(nom)} + 1\text{ V}$  or  $2.7\text{ V}$  (whichever is greater), unless otherwise noted. Typical values are at  $T_J = 25^\circ\text{C}$ .



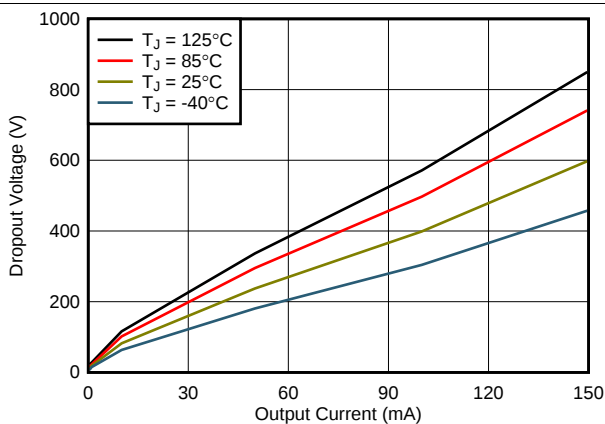
**Figure 7. 1.2-V Output Voltage vs Temperature**



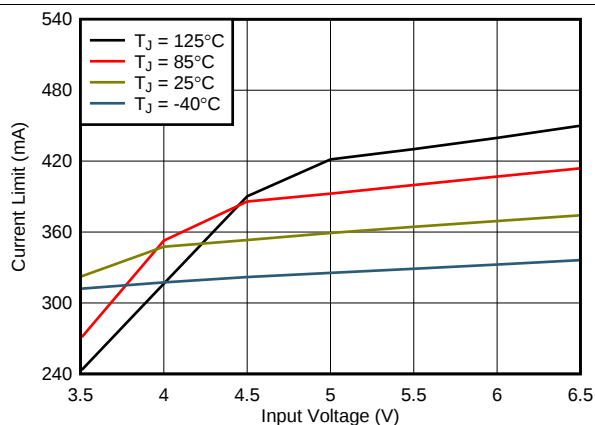
**Figure 8. 6.5-V Dropout Voltage vs  $V_{IN}$  and Temperature**



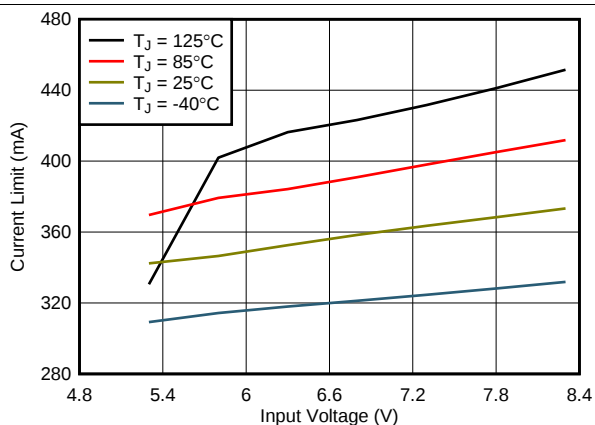
**Figure 9. 3.3-V Dropout Voltage vs  $I_{OUT}$  and Temperature**



**Figure 10. Dropout Voltage vs  $I_{OUT}$  and Temperature**



**Figure 11. 1.2-V Current Limit vs  $V_{IN}$  and Temperature**



**Figure 12. 3.3-V Current Limit vs  $V_{IN}$  and Temperature**

## Typical Characteristics (continued)

Over operating temperature range ( $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ),  $I_{\text{OUT}} = 10\text{ mA}$ ,  $V_{\text{EN}} = 2\text{ V}$ ,  $C_{\text{OUT}} = 2.2\text{ }\mu\text{F}$ , and  $V_{\text{IN}} = V_{\text{OUT(nom)}} + 1\text{ V}$  or  $2.7\text{ V}$  (whichever is greater), unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ .

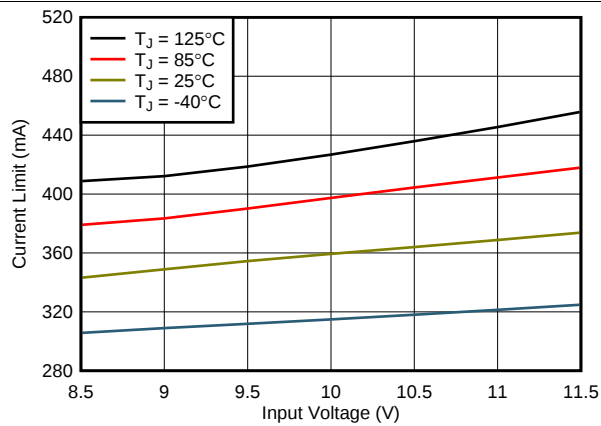


Figure 13. 6.5-V Current Limit vs  $V_{\text{IN}}$  and Temperature

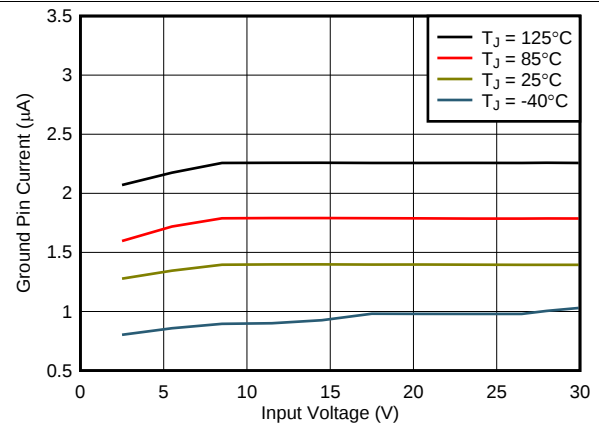


Figure 14. 1.2-V Ground Pin Current vs  $V_{\text{IN}}$  and Temperature

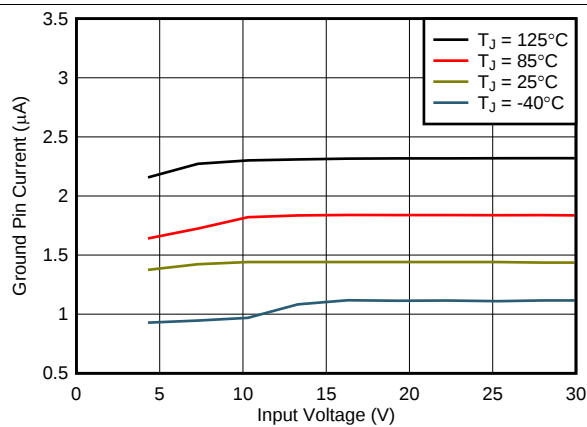


Figure 15. 3.3-V Ground Pin Current vs  $V_{\text{IN}}$  and Temperature

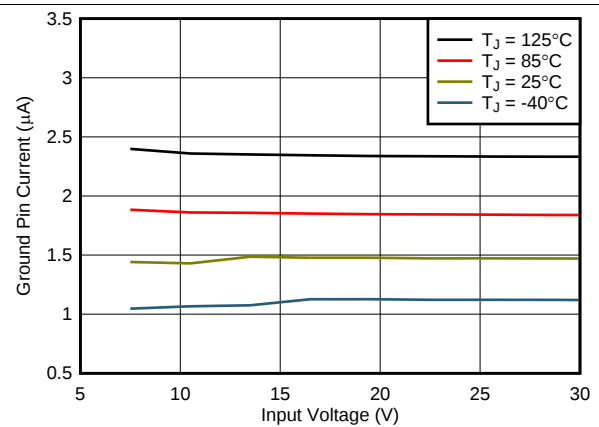


Figure 16. 6.5-V Ground Pin Current vs  $V_{\text{IN}}$  and Temperature

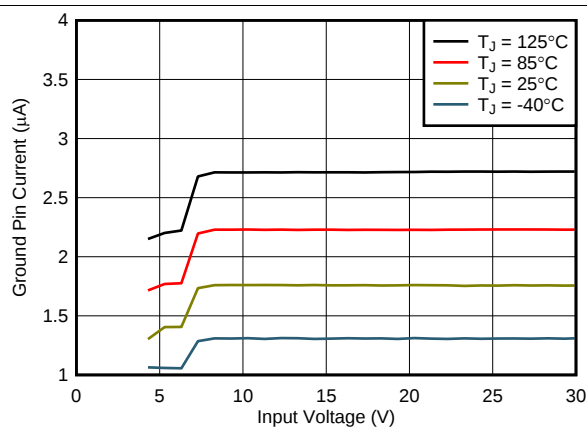


Figure 17. 3.3-V Ground Current vs  $V_{\text{IN}}$  and Temperature with EN Floating

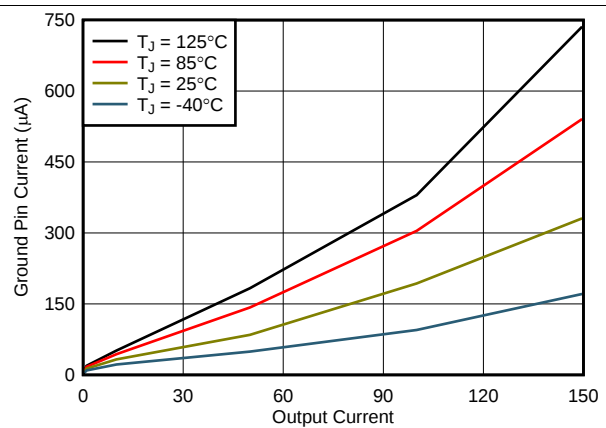


Figure 18. 1.2-V Ground Pin Current vs  $I_{\text{OUT}}$  and Temperature

## Typical Characteristics (continued)

Over operating temperature range ( $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ),  $I_{\text{OUT}} = 10\text{ mA}$ ,  $V_{\text{EN}} = 2\text{ V}$ ,  $C_{\text{OUT}} = 2.2\text{ }\mu\text{F}$ , and  $V_{\text{IN}} = V_{\text{OUT(nom)}} + 1\text{ V}$  or  $2.7\text{ V}$  (whichever is greater), unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ .

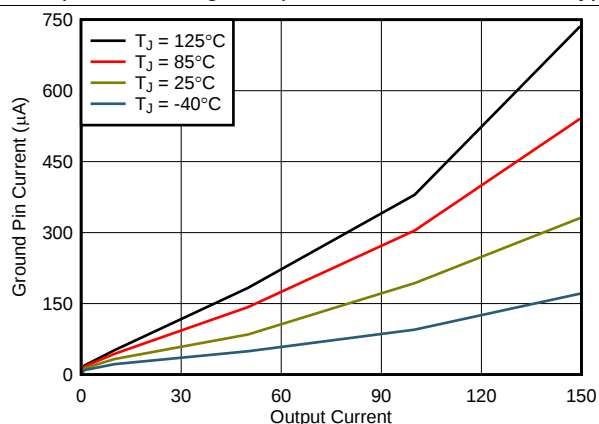


Figure 19. 3.3-V Ground Pin Current vs  $I_{\text{OUT}}$  and Temperature

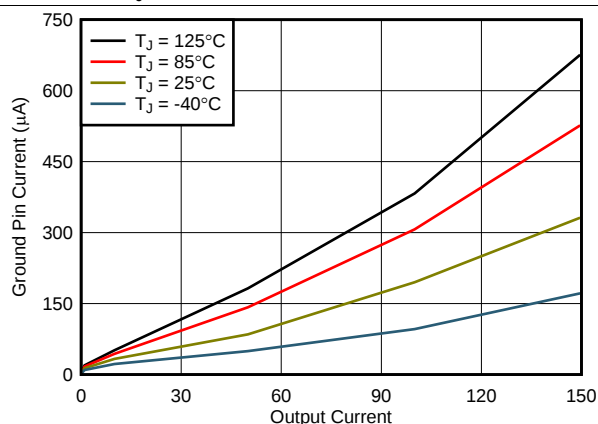


Figure 20. 6.5-V Ground Pin Current vs  $I_{\text{OUT}}$  and Temperature

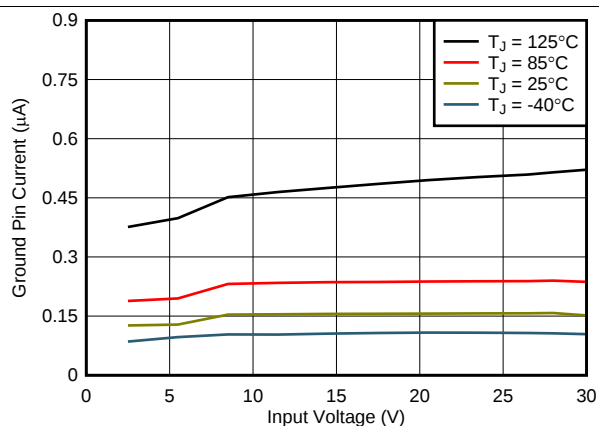


Figure 21. 1.2-V Shutdown Current vs  $V_{\text{IN}}$  and Temperature

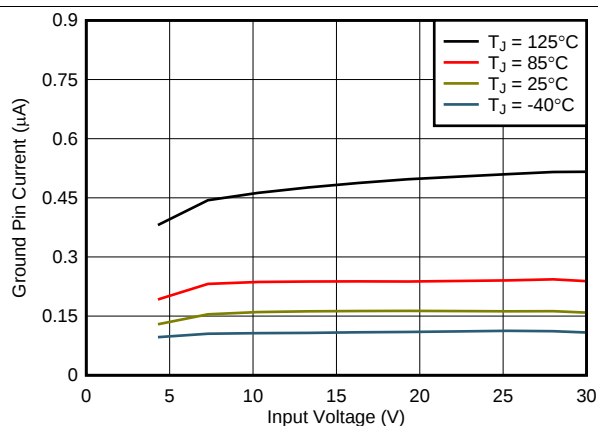


Figure 22. 3.3-V Shutdown Current vs  $V_{\text{IN}}$  and Temperature

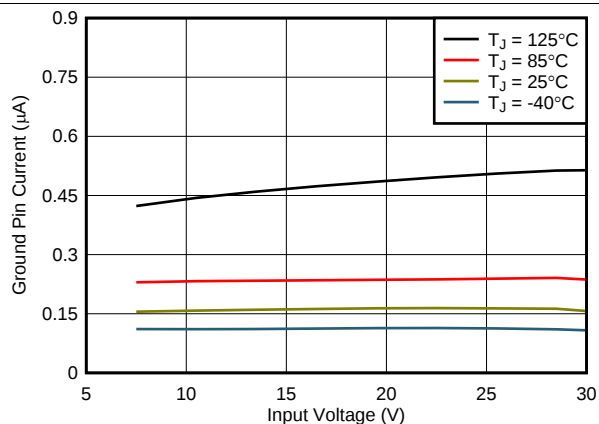


Figure 23. 6.5-V Shutdown Current vs  $V_{\text{IN}}$  and Temperature

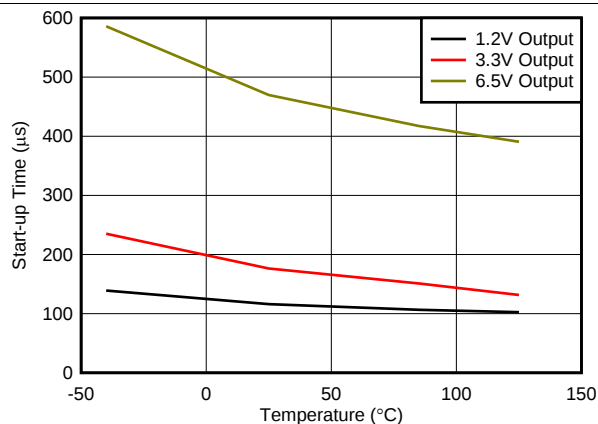
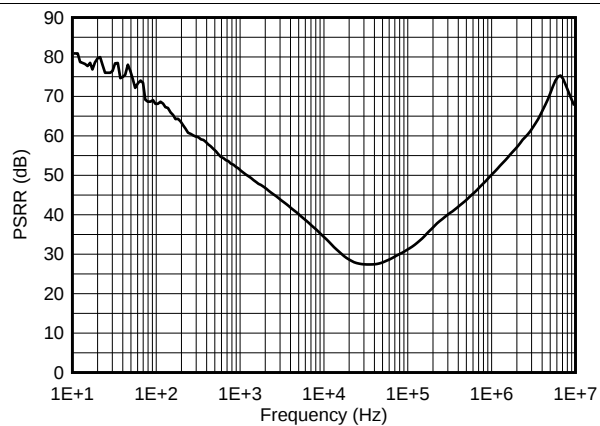


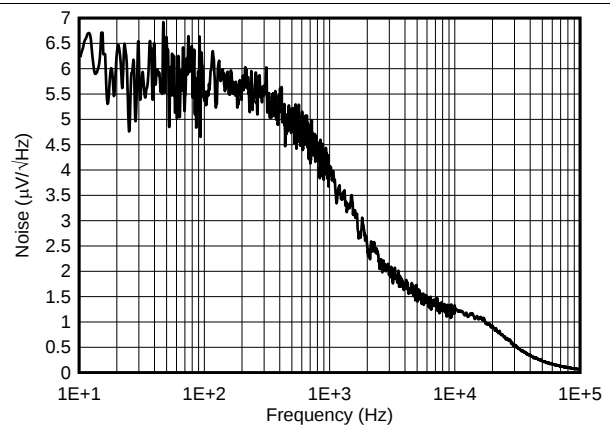
Figure 24. Start-Up Time vs Temperature

## Typical Characteristics (continued)

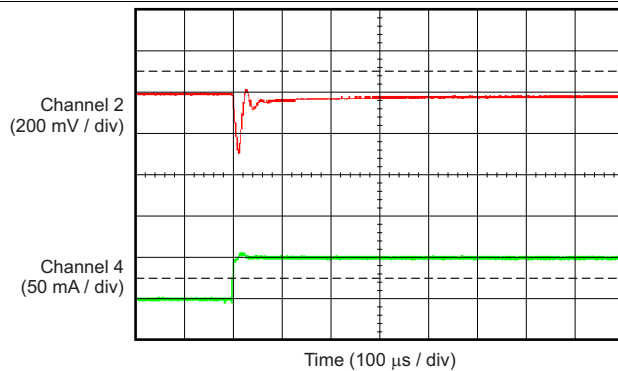
Over operating temperature range ( $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ),  $I_{\text{OUT}} = 10\text{ mA}$ ,  $V_{\text{EN}} = 2\text{ V}$ ,  $C_{\text{OUT}} = 2.2\text{ }\mu\text{F}$ , and  $V_{\text{IN}} = V_{\text{OUT(nom)}} + 1\text{ V}$  or  $2.7\text{ V}$  (whichever is greater), unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ .



**Figure 25. Power-Supply Rejection Ratio vs Frequency**

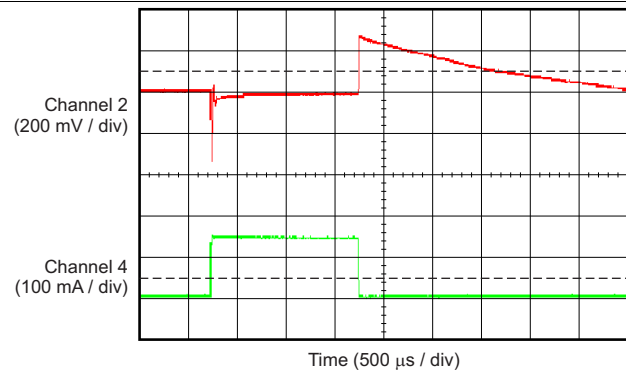


**Figure 26. Noise**



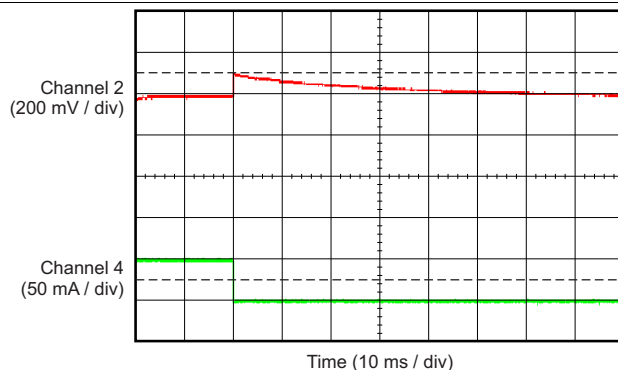
Channel 2 =  $V_{\text{OUT}}$ , channel 4 =  $I_{\text{OUT}}$ ,  $V_{\text{IN}} = 2.7\text{ V}$

**Figure 27. TPS70912-Q1 Load Transient (0 mA to 50 mA)**



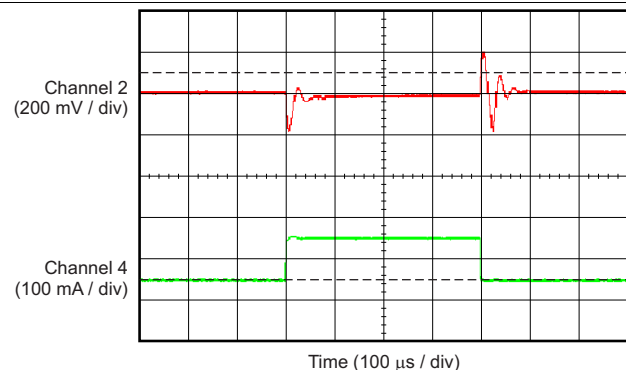
Channel 2 =  $V_{\text{OUT}}$ , channel 4 =  $I_{\text{OUT}}$ ,  $V_{\text{IN}} = 2.7\text{ V}$

**Figure 28. TPS70912-Q1 Load Transient (1 mA to 150 mA)**



Channel 2 =  $V_{\text{OUT}}$ , channel 4 =  $I_{\text{OUT}}$ ,  $V_{\text{IN}} = 2.7\text{ V}$

**Figure 29. TPS70912-Q1 Load Transient (50 mA to 0 mA)**

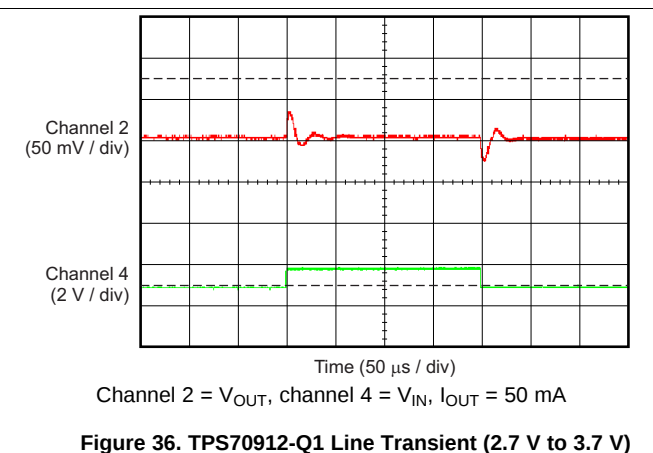
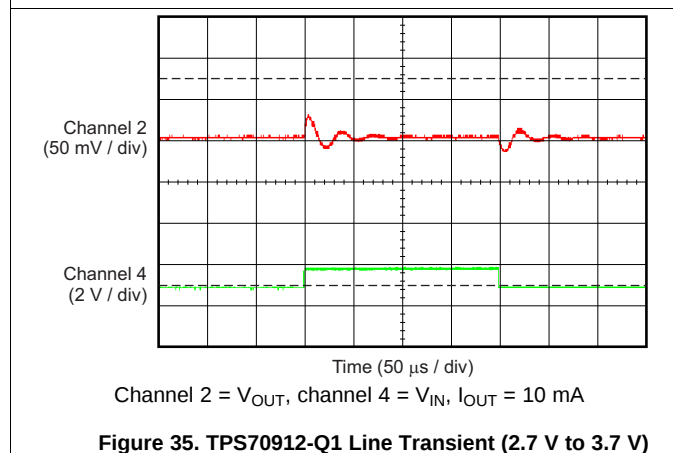
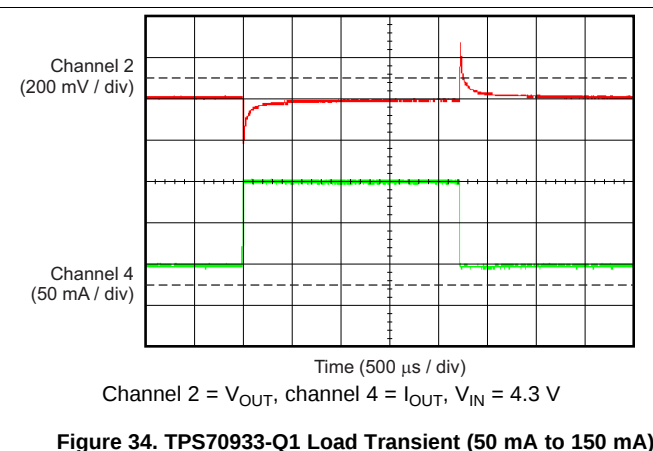
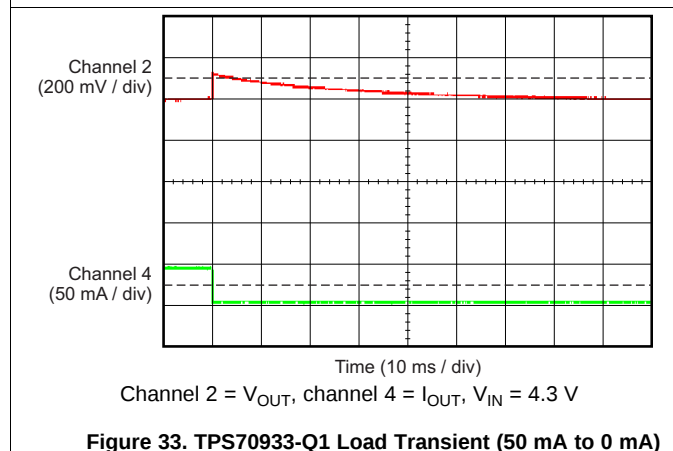
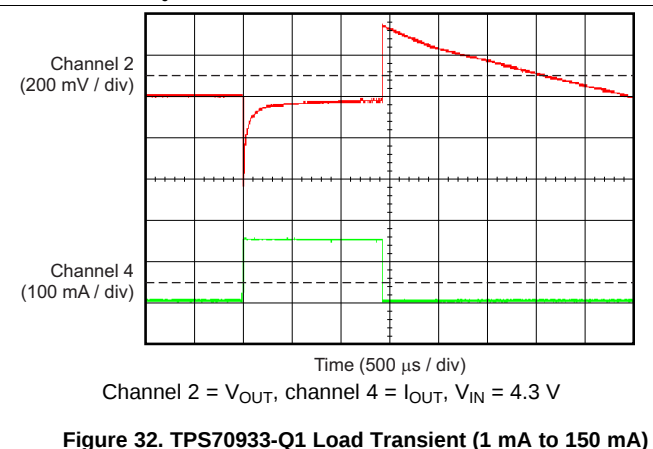
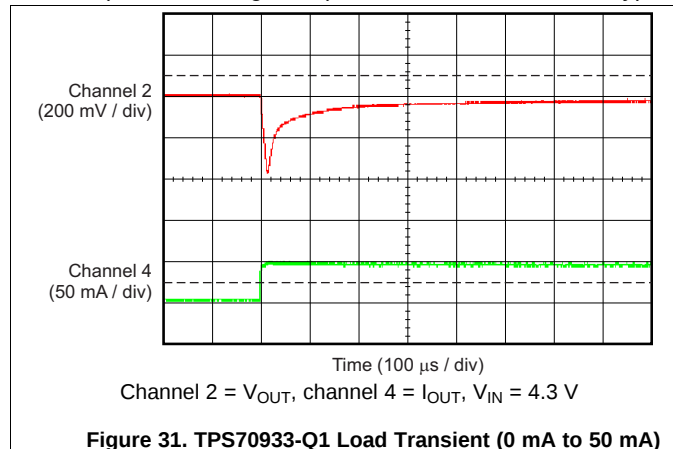


Channel 2 =  $V_{\text{OUT}}$ , channel 4 =  $I_{\text{OUT}}$ ,  $V_{\text{IN}} = 2.7\text{ V}$

**Figure 30. TPS70912-Q1 Load Transient (50 mA to 150 mA)**

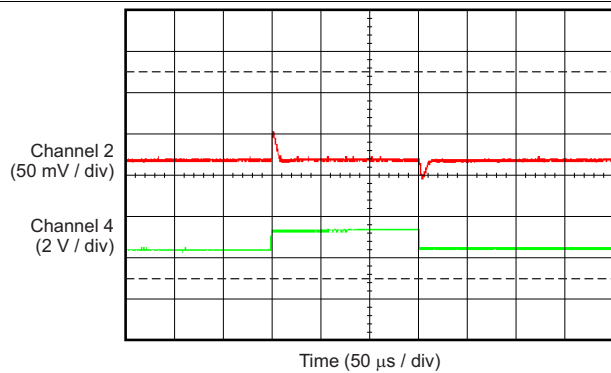
## Typical Characteristics (continued)

Over operating temperature range ( $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ),  $I_{OUT} = 10\text{ mA}$ ,  $V_{EN} = 2\text{ V}$ ,  $C_{OUT} = 2.2\text{ }\mu\text{F}$ , and  $V_{IN} = V_{OUT(nom)} + 1\text{ V}$  or  $2.7\text{ V}$  (whichever is greater), unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ .



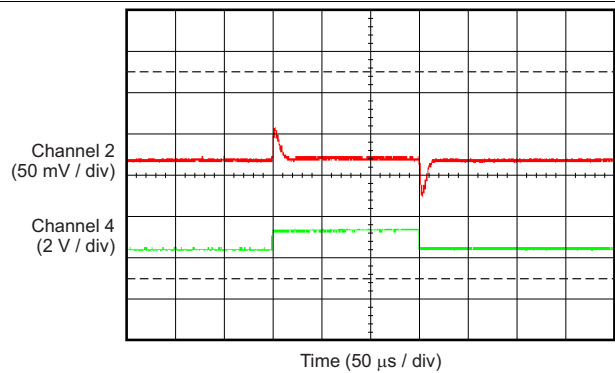
## Typical Characteristics (continued)

Over operating temperature range ( $T_J = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ ),  $I_{OUT} = 10\text{ mA}$ ,  $V_{EN} = 2\text{ V}$ ,  $C_{OUT} = 2.2\text{ }\mu\text{F}$ , and  $V_{IN} = V_{OUT(nom)} + 1\text{ V}$  or  $2.7\text{ V}$  (whichever is greater), unless otherwise noted. Typical values are at  $T_J = 25^{\circ}\text{C}$ .



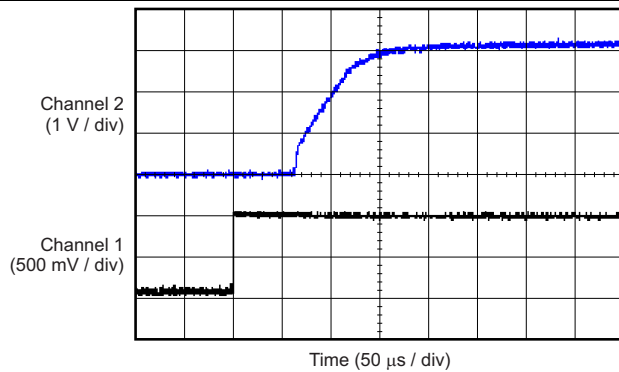
Channel 2 =  $V_{OUT}$ , channel 4 =  $V_{IN}$ ,  $I_{OUT} = 10\text{ mA}$

**Figure 37. TPS70933-Q1 Line Transient (4.3 V to 5.3 V)**



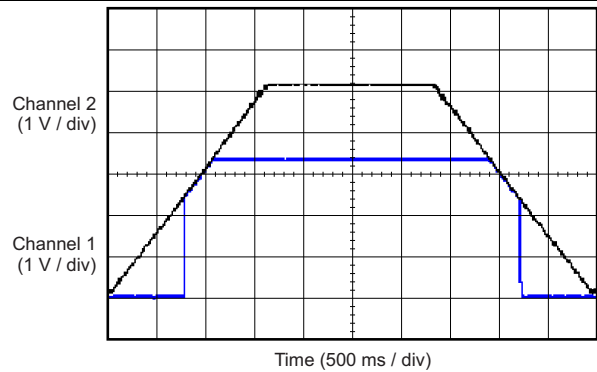
Channel 2 =  $V_{OUT}$ , channel 4 =  $V_{IN}$ ,  $I_{OUT} = 50\text{ mA}$

**Figure 38. TPS70933-Q1 Line Transient (4.3 V to 5.3 V)**



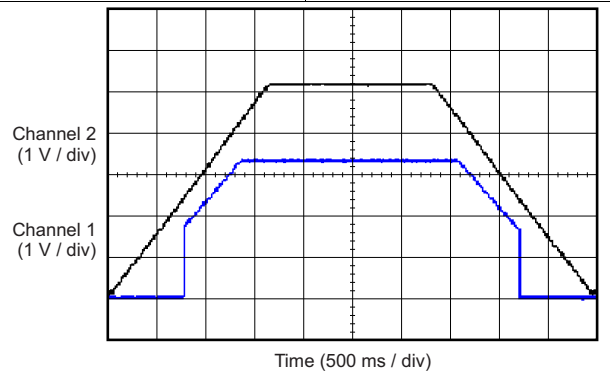
Channel 1 = EN, channel 2 =  $V_{OUT}$ ,  $V_{IN} = 4.3\text{ V}$ ,  $C_{OUT} = 2.2\text{ }\mu\text{F}$ , TPS70633

**Figure 39. Power-Up with Enable**



Channel 1 =  $V_{IN}$ , channel 2 =  $V_{OUT}$ ,  $I_{OUT} = 3\text{ mA}$ , TPS70633

**Figure 40. Power-Up and Power-Down Response**



Channel 1 =  $V_{IN}$ , channel 2 =  $V_{OUT}$ ,  $I_{OUT} = 150\text{ mA}$ , TPS70633

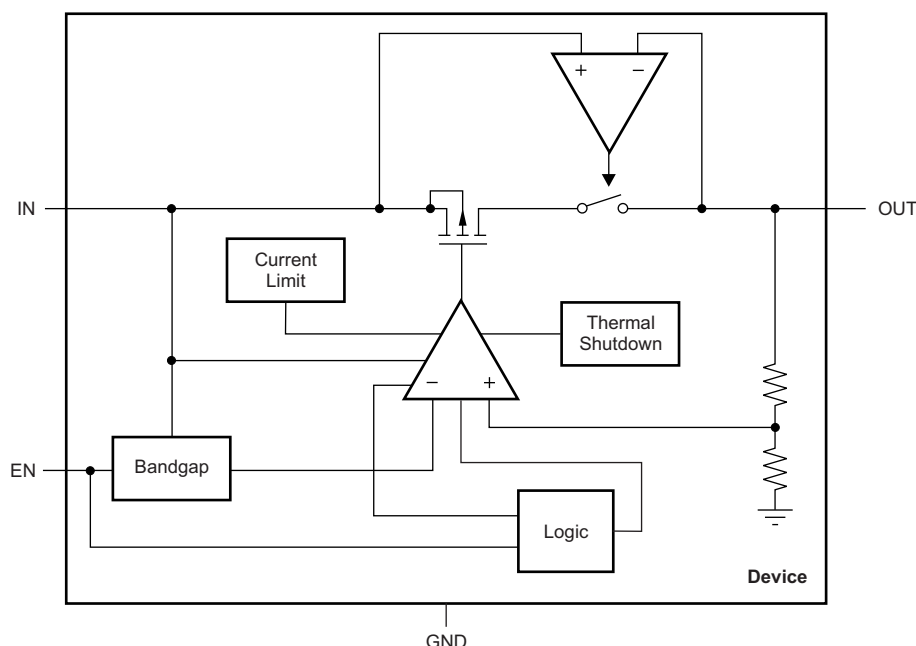
**Figure 41. Power-Up and Power-Down Response**

## 7 Detailed Description

### 7.1 Overview

The TPS709-Q1 series are ultralow quiescent current, low-dropout (LDO) linear regulators. The TPS709-Q1 offers reverse current protection to block any discharge current from the output into the input. The TPS709-Q1 also features current limit and thermal shutdown for reliable operation.

### 7.2 Functional Block Diagram



### 7.3 Feature Description

#### 7.3.1 Undervoltage Lockout (UVLO)

The TPS709-Q1 uses an undervoltage lockout (UVLO) circuit to keep the output shut off until the internal circuitry operates properly.

#### 7.3.2 Shutdown

The enable pin (EN) is active high. Enable the device by forcing the EN pin to exceed  $V_{EN(HI)}$  (0.9 V, minimum). Turn off the device by forcing the EN pin to drop below 0.4 V. If shutdown capability is not required, connect EN to IN.

#### 7.3.3 Reverse Current Protection

The TPS709-Q1 has integrated reverse current protection. Reverse current protection prevents the flow of current from the OUT pin to the IN pin when output voltage is higher than input voltage. The reverse current protection circuitry places the power path in high impedance when the output voltage is higher than the input voltage. This setting reduces leakage current from the output to the input to 10 nA, typical. The reverse current protection is always active regardless of the enable pin logic state or if the OUT pin voltage is greater than 1.8 V. Reverse current can flow if the output voltage is less than 1.8 V and if input voltage is less than the output voltage.

If voltage is applied to the input pin, then the maximum voltage that can be applied to the OUT pin is the lower of three times the nominal output voltage or 6.5 V. For example, if the 1.2-V output voltage version is used, then the maximum reverse bias voltage that can be applied to the OUT pin is 3.6 V. If the 3.3-V output voltage version is used, then the maximum reverse bias voltage that can be applied to the OUT pin is 6.5 V.

## Feature Description (continued)

### 7.3.4 Internal Current Limit

The TPS709-Q1 internal current limit helps protect the regulator during fault conditions. During current limit, the output sources a fixed amount of current that is largely independent of output voltage. In such a case, the output voltage is not regulated, and can be measured as ( $V_{OUT} = I_{LIMIT} \times R_{LOAD}$ ). The PMOS pass transistor dissipates  $[(V_{IN} - V_{OUT}) \times I_{LIMIT}]$  until a thermal shutdown is triggered and the device turns off. When cool, the device is turned on by the internal thermal shutdown circuit. If the fault condition continues, the device cycles between current limit and thermal shutdown; see the [Thermal Information](#) section for more details.

The TPS709-Q1 is characterized over the recommended operating output current range up to 150 mA. The internal current limit begins to limit the output current at a minimum of 200 mA of output current.

### 7.3.5 Thermal Protection

Thermal protection disables the output when the junction temperature rises to approximately 158°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 can cycle on and off. This cycling limits the dissipation of the regulator, protecting it from damage as a result of overheating.

Any tendency to activate the thermal protection circuit indicates excessive power dissipation or an inadequate heatsink. For reliable operation, limit junction temperature to 125°C, maximum. To estimate the 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 must trigger at least 35°C above the maximum expected ambient condition of the particular application. This configuration produces a worst-case junction temperature of 125°C at the highest expected ambient temperature and worst-case load.

The TPS709-Q1 internal protection circuitry is designed to protect against overload conditions. This circuitry is not intended to replace proper heatsinking. Continuously running the TPS709-Q1 into thermal shutdown degrades device reliability.

## 7.4 Device Functional Modes

### 7.4.1 Normal Operation

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

- The input voltage is at least as high as  $V_{IN(min)}$ .
- The input voltage is greater than the nominal output voltage added to the dropout voltage.
- The enable voltage has previously exceeded the enable rising threshold voltage and has not decreased below the enable falling threshold.
- The output current is less than the current limit.
- The device junction temperature is less than the maximum specified junction temperature.

### 7.4.2 Dropout Operation

If the input voltage is lower than the nominal output voltage plus the specified dropout voltage, but all other conditions are met for normal operation, the device operates in dropout mode. In this mode of operation, the output voltage is the same as the input voltage minus the dropout voltage. The transient performance of the device is significantly degraded because the pass device is in the linear region and no longer controls the current through the LDO. Line or load transients in dropout can result in large output voltage deviations.

### 7.4.3 Disabled

The device is disabled under the following conditions:

- The enable voltage is less than the enable falling threshold voltage or has not yet exceeded the enable rising threshold.
- The device junction temperature is greater than the thermal shutdown temperature.

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

**Table 1. Device Functional Mode Comparison**

| OPERATING MODE                                            | PARAMETER                                                      |                        |                     |                      |
|-----------------------------------------------------------|----------------------------------------------------------------|------------------------|---------------------|----------------------|
|                                                           | $V_{IN}$                                                       | $V_{EN}$               | $I_{OUT}$           | $T_J$                |
| Normal mode                                               | $V_{IN} > V_{OUT(nom)} + V_{DO}$ and<br>$V_{IN} > V_{IN(min)}$ | $V_{EN} > V_{EN(HI)}$  | $I_{OUT} < I_{LIM}$ | $T_J < 125^{\circ}C$ |
| Dropout mode                                              | $V_{IN(min)} < V_{IN} < V_{OUT(nom)} + V_{DO}$                 | $V_{EN} > V_{EN(HI)}$  | —                   | $T_J < 125^{\circ}C$ |
| Disabled mode<br>(any true condition disables the device) | —                                                              | $V_{EN} < V_{EN(low)}$ | —                   | $T_J > 158^{\circ}C$ |

## 8 Application and Implementation

### NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 8.1 Application Information

The TPS709-Q1 consumes low quiescent current and delivers excellent line and load transient performance. This performance, combined with low noise and good PSRR with little ( $V_{IN} - V_{OUT}$ ) headroom, makes these devices ideal for RF portable applications, current limit, and thermal protection. The TPS709-Q1 devices are specified from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

#### 8.1.1 Input and Output Capacitor Considerations

The TPS709-Q1 devices are stable with output capacitors with an effective capacitance of  $2.0\ \mu\text{F}$  or greater for output voltages below  $1.5\ \text{V}$ . For output voltages equal or greater than  $1.5\ \text{V}$ , the minimum effective capacitance for stability is  $1.5\ \mu\text{F}$ . The maximum capacitance for stability is  $47\ \mu\text{F}$ . The equivalent series resistance (ESR) of the output capacitor must be between  $0\ \Omega$  and  $0.2\ \Omega$  for stability.

The effective capacitance is the minimum capacitance value of a capacitor after taking into account variations resulting from tolerances, temperature, and dc bias effects. X5R- and X7R-type ceramic capacitors are recommended because these capacitors have minimal variation in value and ESR over temperature.

Although an input capacitor is not required for stability, good analog design practice is to connect a  $0.1\text{-}\mu\text{F}$  to  $2.2\text{-}\mu\text{F}$  capacitor from IN to GND. This capacitor counteracts reactive input sources and improves transient response, input ripple rejection, and PSRR.

#### 8.1.2 Dropout Voltage

The TPS709-Q1 uses a PMOS pass transistor to achieve low dropout. When ( $V_{IN} - V_{OUT}$ ) is less than the dropout voltage ( $V_{DO}$ ), the PMOS pass device is in the linear region of operation and the input-to-output resistance is the  $R_{DS(ON)}$  of the PMOS pass element.  $V_{DO}$  approximately scales with the output current because the PMOS device functions like a resistor in dropout.

The ground pin current of many linear voltage regulators increases substantially when the device is operated in dropout. This increase in ground pin current while operating in dropout can be several orders of magnitude larger than when the device is not in dropout. The TPS709-Q1 employs a special control loop that limits the increase in ground pin current while operating in dropout. This functionality allows for the most efficient operation while in dropout conditions that can greatly increase battery run times.

#### 8.1.3 Transient Response

As with any regulator, increasing the output capacitor size reduces over- and undershoot magnitude, but increases transient response duration.

## 8.2 Typical Application

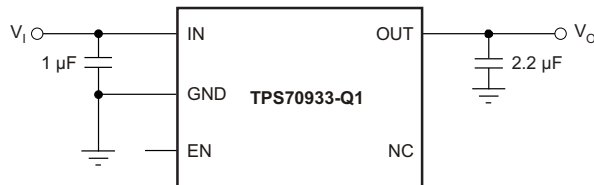


Figure 42. 3.3-V, Low- $I_Q$  Rail

### 8.2.1 Design Requirements

Table 2 summarizes the design requirements for Figure 42.

Table 2. Design Requirements for a 3.3-V, Low- $I_Q$  Rail Application

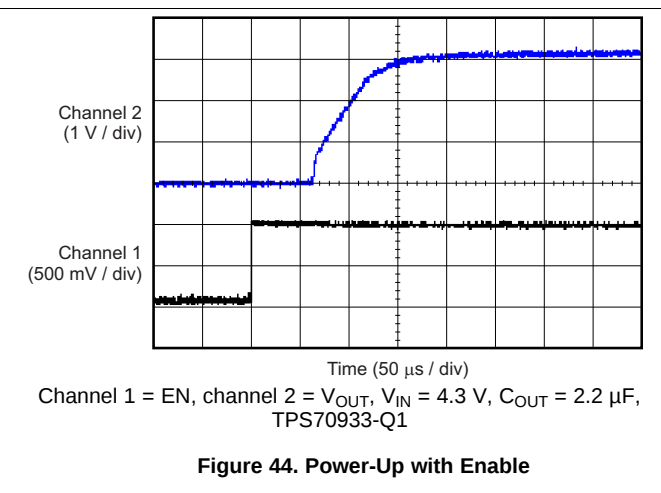
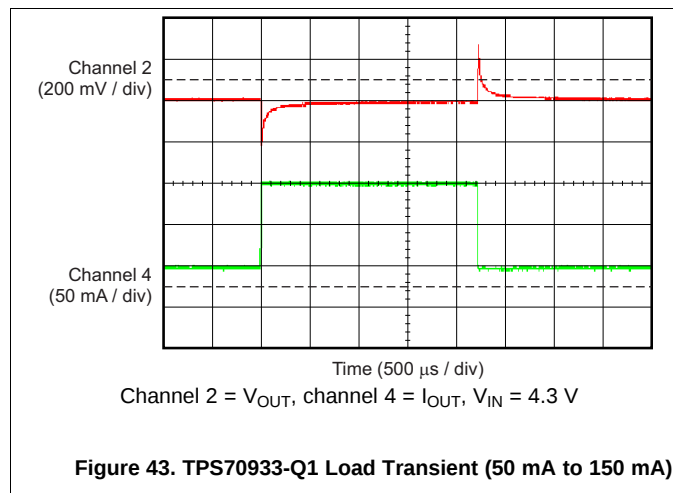
| PARAMETER          | DESIGN SPECIFICATION |
|--------------------|----------------------|
| $V_{IN}$           | 4.3 V                |
| $V_{OUT}$          | 3.3 V                |
| $I_{IN}$ (no load) | < 5 $\mu$ A          |
| $I_{OUT}$ (max)    | 150 mA               |

### 8.2.2 Detailed Design Procedure

Select a 2.2- $\mu$ F, 10-V X7R output capacitor to satisfy the minimum output capacitance requirement with a 3.3-V dc bias.

Select a 1.0- $\mu$ F, 10-V X7R input capacitor to provide input noise filtering and eliminate high-frequency voltage transients.

### 8.2.3 Application Curves



## 9 Power Supply Recommendations

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

## 10 Layout

### 10.1 Layout Guidelines

#### 10.1.1 Board Layout Recommendations to Improve PSRR and Noise Performance

Input and output capacitors must be placed as close to the device pins as possible. To improve ac performance (such as PSRR, output noise, and transient response), TI recommends that the board be designed with separate ground planes for  $V_{IN}$  and  $V_{OUT}$ , with the ground plane connected only at the device GND pin. In addition, the output capacitor ground connection must be connected directly to the device GND pin. High ESR capacitors may degrade PSRR performance.

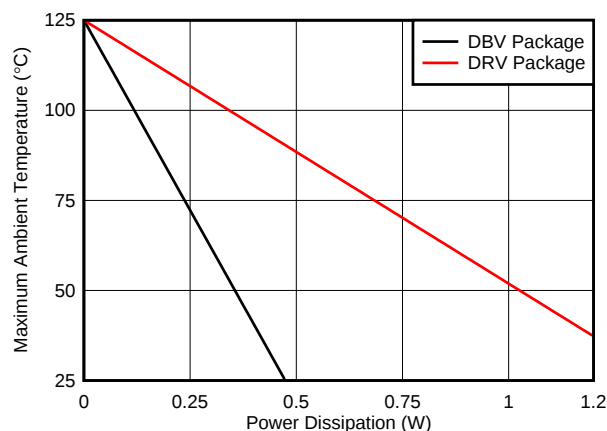
#### 10.1.2 Power Dissipation

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

Power dissipation depends on input voltage and load conditions. Power dissipation ( $P_D$ ) can be approximated by the product of the output current times the voltage drop across the output pass element ( $V_{IN}$  to  $V_{OUT}$ ), as shown in [Equation 1](#).

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} \quad (1)$$

[Figure 45](#) shows the maximum ambient temperature versus the power dissipation of the TPS709-Q1. This figure assumes the device is soldered on a JEDEC standard, high-K layout with no airflow over the board. Actual board thermal impedances vary widely. If the application requires high power dissipation, having a thorough understanding of the board temperature and thermal impedances is helpful to ensure the TPS709-Q1 does not operate above a junction temperature of 125°C.



**Figure 45. Maximum Ambient Temperature vs Device Power Dissipation**

## Layout Guidelines (continued)

Estimating the junction temperature can be done by using the thermal metrics  $\Psi_{JT}$  and  $\Psi_{JB}$ , shown in the [Thermal Information](#). These metrics are a more accurate representation of the heat transfer characteristics of the die and the package than  $R_{\theta JA}$ . The junction temperature can be estimated with [Equation 2](#).

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

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

where:

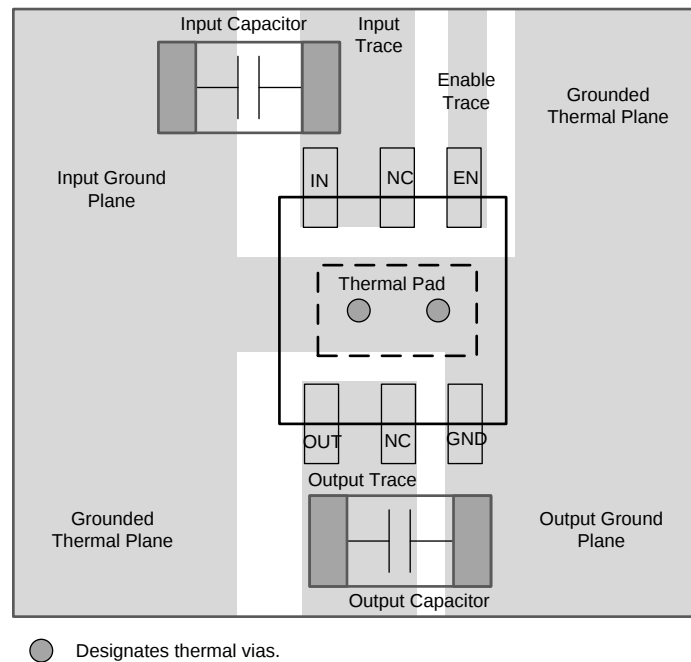
- $P_D$  is the power dissipation shown by [Equation 1](#),
- $T_T$  is the temperature at the center-top of the IC package,
- $T_B$  is the PCB temperature measured 1 mm away from the IC package *on the PCB surface*. (2)

### NOTE

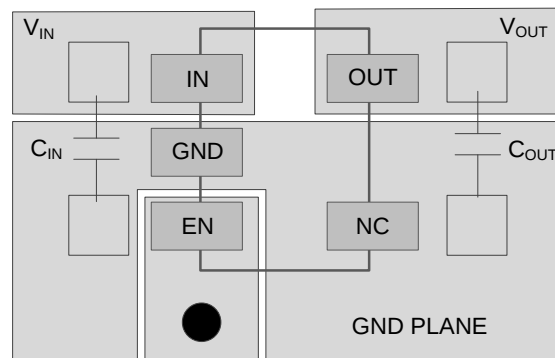
Both  $T_T$  and  $T_B$  can be measured on actual application boards using a thermo-gun (an infrared thermometer).

For more information about measuring  $T_T$  and  $T_B$ , see the application note *Using New Thermal Metrics* ([SBVA025](#)), available for download at [www.ti.com](http://www.ti.com).

## 10.2 Layout Examples



**Figure 46. WSON Layout Example**



**Figure 47. SOT23-5 Layout Example**

## 11 Device and Documentation Support

### 11.1 Device Support

#### 11.1.1 Development Support

##### 11.1.1.1 Evaluation Modules

An evaluation module (EVM) is available to assist in the initial circuit performance evaluation using the TPS709-Q1. The [TPS70933EVM-110 evaluation module](#) (and [related user guide](#)) can be requested at the Texas Instruments website through the product folders or purchased directly from the [TI eStore](#).

##### 11.1.1.2 Spice Models

Computer simulation of circuit performance using SPICE is often useful when analyzing the performance of analog circuits and systems. A SPICE model for the TPS709 is available through the product folders under *Simulation Models*.

#### 11.1.2 Device Nomenclature

**Table 3. Device Nomenclature<sup>(1)</sup>**

| PRODUCT            | V <sub>OUT</sub>                                                                                                                                                                                                                                                                                                                          |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| TPS709xx(x)yyyz-Q1 | <p><b>XX(X)</b> is the nominal output voltage. For output voltages with a resolution of 100 mV, two digits are used in the ordering number; otherwise, three digits are used (for example, 28 = 2.8 V; 125 = 1.25 V).</p> <p><b>YYY</b> is the package designator.</p> <p><b>Z</b> is the tape and reel quantity (R = 3000, T = 250).</p> |

(1) For the most current package and ordering information see the Package Option Addendum at the end of this document, or see the TI web site at [www.ti.com](http://www.ti.com).

### 11.2 Documentation Support

#### 11.2.1 Related Documentation

[SLVU689](#) — TPS70933EVM-110 Evaluation Module User Guide

### 11.3 Trademarks

All trademarks are the property of their respective owners.

### 11.4 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.

### 11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| TPS70912QDBVRQ1  | ACTIVE        | SOT-23       | DBV                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SLR                     | <a href="#">Samples</a> |
| TPS70912QDRVRQ1  | ACTIVE        | WSO          | DRV                | 6    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SJD                     | <a href="#">Samples</a> |
| TPS70915QDRVRQ1  | ACTIVE        | WSO          | DRV                | 6    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SJE                     | <a href="#">Samples</a> |
| TPS70918QDBVRQ1  | ACTIVE        | SOT-23       | DBV                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SLS                     | <a href="#">Samples</a> |
| TPS70918QDRVRQ1  | ACTIVE        | WSO          | DRV                | 6    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SJF                     | <a href="#">Samples</a> |
| TPS70925QDBVRQ1  | ACTIVE        | SOT-23       | DBV                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SLT                     | <a href="#">Samples</a> |
| TPS70925QDRVRQ1  | ACTIVE        | WSO          | DRV                | 6    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SJG                     | <a href="#">Samples</a> |
| TPS70927QDRVRQ1  | ACTIVE        | WSO          | DRV                | 6    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SJH                     | <a href="#">Samples</a> |
| TPS70928QDBVRQ1  | ACTIVE        | SOT-23       | DBV                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SLU                     | <a href="#">Samples</a> |
| TPS70928QDRVRQ1  | ACTIVE        | WSO          | DRV                | 6    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SJI                     | <a href="#">Samples</a> |
| TPS70930QDBVRQ1  | ACTIVE        | SOT-23       | DBV                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SLV                     | <a href="#">Samples</a> |
| TPS70930QDRVRQ1  | ACTIVE        | WSO          | DRV                | 6    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SJJ                     | <a href="#">Samples</a> |
| TPS70933QDBVRQ1  | ACTIVE        | SOT-23       | DBV                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SLJ                     | <a href="#">Samples</a> |
| TPS70933QDRVRQ1  | ACTIVE        | WSO          | DRV                | 6    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SJK                     | <a href="#">Samples</a> |
| TPS70936QDBVRQ1  | ACTIVE        | SOT-23       | DBV                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SLW                     | <a href="#">Samples</a> |
| TPS70950QDBVRQ1  | ACTIVE        | SOT-23       | DBV                | 5    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SLX                     | <a href="#">Samples</a> |
| TPS70950QDRVRQ1  | ACTIVE        | WSO          | DRV                | 6    | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-1-260C-UNLIM   | -40 to 125   | SJL                     | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

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

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

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

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

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

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

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

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

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

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

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

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#### **OTHER QUALIFIED VERSIONS OF TPS709-Q1 :**

- Catalog: [TPS709](#)

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NOTE: Qualified Version Definitions:

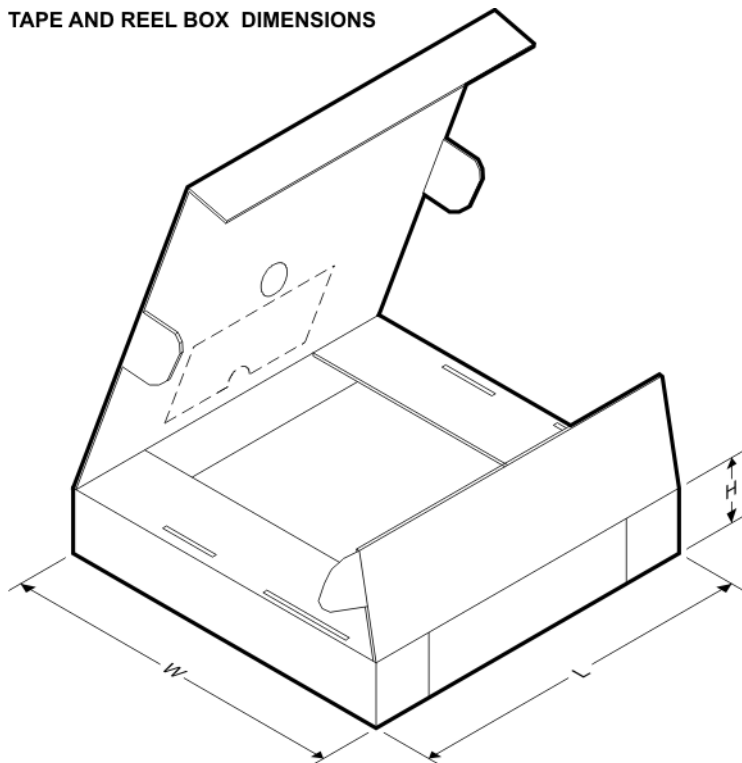
- Catalog - TI's standard catalog product

**TAPE AND REEL INFORMATION**


\*All dimensions are nominal

| Device          | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPS70912QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS70912QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 179.0              | 8.4                | 2.2     | 2.2     | 1.2     | 4.0     | 8.0    | Q2            |
| TPS70915QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 179.0              | 8.4                | 2.2     | 2.2     | 1.2     | 4.0     | 8.0    | Q2            |
| TPS70918QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS70918QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 179.0              | 8.4                | 2.2     | 2.2     | 1.2     | 4.0     | 8.0    | Q2            |
| TPS70925QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS70925QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 179.0              | 8.4                | 2.2     | 2.2     | 1.2     | 4.0     | 8.0    | Q2            |
| TPS70927QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 179.0              | 8.4                | 2.2     | 2.2     | 1.2     | 4.0     | 8.0    | Q2            |
| TPS70928QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS70928QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 179.0              | 8.4                | 2.2     | 2.2     | 1.2     | 4.0     | 8.0    | Q2            |
| TPS70930QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS70930QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 179.0              | 8.4                | 2.2     | 2.2     | 1.2     | 4.0     | 8.0    | Q2            |
| TPS70933QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS70933QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 179.0              | 8.4                | 2.2     | 2.2     | 1.2     | 4.0     | 8.0    | Q2            |
| TPS70936QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS70950QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 178.0              | 9.0                | 3.23    | 3.17    | 1.37    | 4.0     | 8.0    | Q3            |
| TPS70950QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 179.0              | 8.4                | 2.2     | 2.2     | 1.2     | 4.0     | 8.0    | Q2            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device          | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPS70912QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS70912QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 203.0       | 203.0      | 35.0        |
| TPS70915QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 203.0       | 203.0      | 35.0        |
| TPS70918QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS70918QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 203.0       | 203.0      | 35.0        |
| TPS70925QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS70925QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 203.0       | 203.0      | 35.0        |
| TPS70927QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 203.0       | 203.0      | 35.0        |
| TPS70928QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS70928QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 203.0       | 203.0      | 35.0        |
| TPS70930QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS70930QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 203.0       | 203.0      | 35.0        |
| TPS70933QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS70933QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 203.0       | 203.0      | 35.0        |
| TPS70936QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS70950QDBVRQ1 | SOT-23       | DBV             | 5    | 3000 | 180.0       | 180.0      | 18.0        |
| TPS70950QDRVRQ1 | WSO          | DRV             | 6    | 3000 | 203.0       | 203.0      | 35.0        |



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

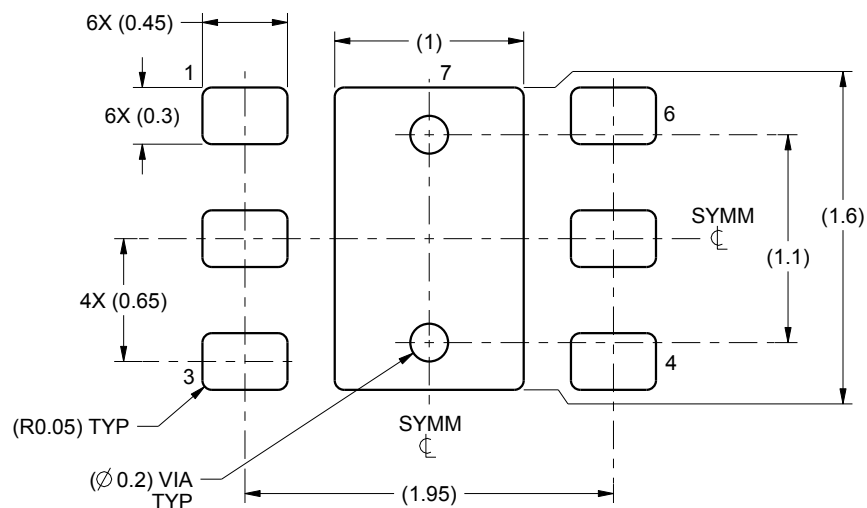


# EXAMPLE BOARD LAYOUT

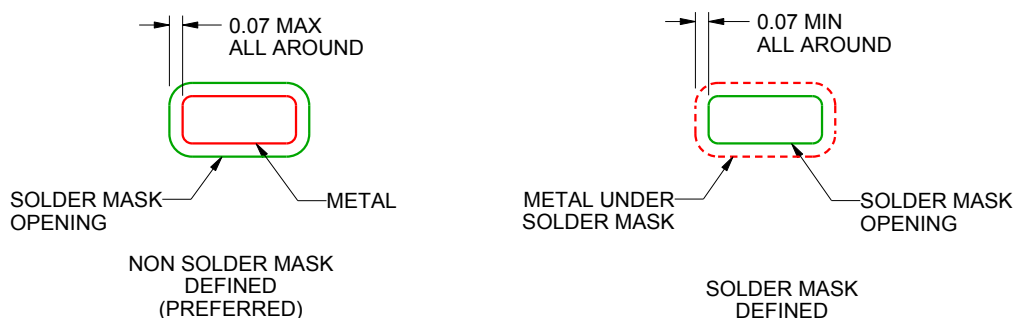
DRV0006A

WSN - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE  
SCALE:25X



SOLDER MASK DETAILS

4222173/A 12/2015

NOTES: (continued)

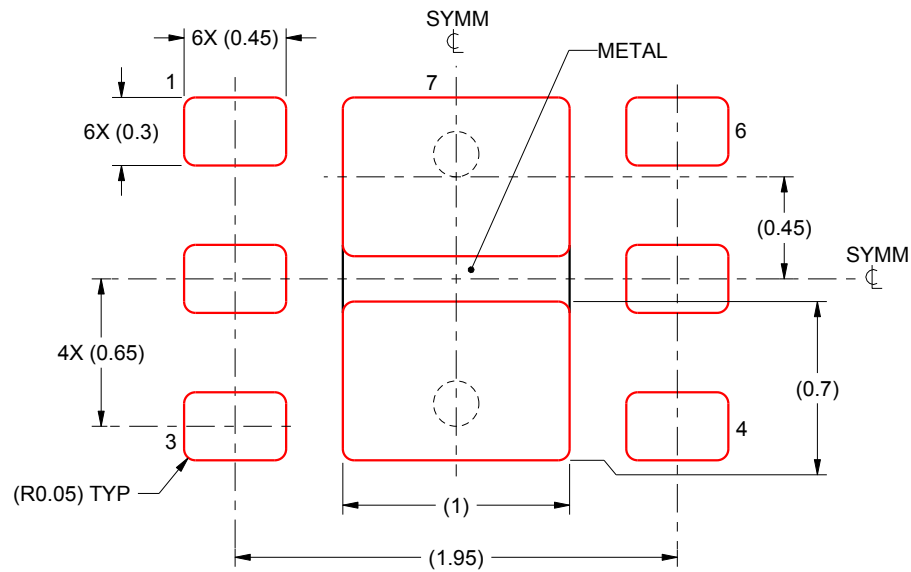
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
5. Vias are optional depending on application, refer to device data sheet. If some or all are implemented, recommended via locations are shown.

# EXAMPLE STENCIL DESIGN

DRV0006A

WSN - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD #7  
88% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE  
SCALE:30X

4222173/A 12/2015

NOTES: (continued)

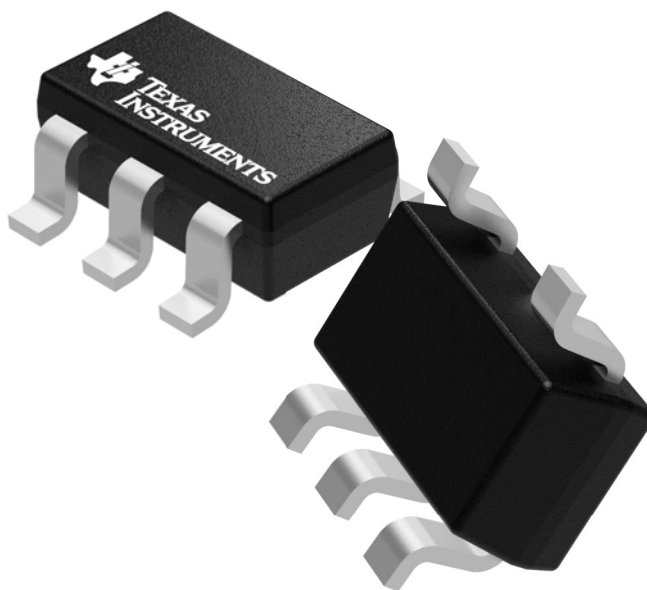
6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

## GENERIC PACKAGE VIEW

**DBV 5**

**SOT-23 - 1.45 mm max height**

SMALL OUTLINE TRANSISTOR



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

4073253/P

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