TPS61089x 12.6-V, 7-A Fully-Integrated Synchronous Boost Converters
in 2.0-mm x 2.5-mm VQFN Package

1 Features
- Input Voltage Range: 2.7 V to 12 V
- Output Voltage Range: 4.5 V to 12.6 V
- Up to 90% Efficiency at \( V_{\text{IN}} = 3.3 \) V, \( V_{\text{OUT}} = 9 \) V, and \( I_{\text{OUT}} = 2 \) A
- Resistor-Programmable Peak Current Limit up to 10 A for high pulse current
- Adjustable Switching Frequency: 200 kHz to 2.2 MHz
- 4-ms Built-in Soft Start Time
- PFM Operation Mode at Light Load (TPS61089)
- Forced PWM Operation Mode at Light Load (TPS610891)
- Internal Output Overvoltage Protection at 13.2 V
- Cycle-by-Cycle Overcurrent Protection
- Thermal Shutdown
- 2.00-mm × 2.50-mm VQFN Hotrod Package

2 Applications
- Bluetooth™ Speaker
- Quick Charge Power Bank
- Portable POS Terminal
- E-Cigarette

3 Description
The TPS61089x represents the TPS61089 and the TPS610891. The TPS61089x is a fully-integrated synchronous boost converter with a 19-mΩ main power switch and a 27-mΩ rectifier switch. The device provides a high efficiency and small size power solution for portable equipment. The TPS61089x features wide input voltage range from 2.7 V to 12 V to support applications powered with single cell or two cell Lithium ion/polymer batteries. The TPS61089x has 7-A continuous switch current capability and provides output voltage up to 12.6 V.

The TPS61089x uses adaptive constant off-time peak current control topology to regulate the output voltage. In moderate to heavy load condition, the TPS61089x works in the pulse width modulation (PWM) mode. In light load condition, the TPS61089 works in the pulse frequency modulation (PFM) mode to improve the efficiency, while the TPS610891 still works in the PWM mode to avoid application problems caused by low switching frequency. The switching frequency in the PWM mode is adjustable from 200 kHz to 2.2 MHz. The TPS61089x also implements a built-in 4-ms soft start function and an adjustable peak switch current limit function. In addition, the device provides 13.2-V output overvoltage protection, cycle-by-cycle overcurrent protection, and thermal shutdown protection.

The TPS61089x is available in an extremely compact size of a 2.0-mm × 2.5-mm 11-pin VQFN package.

Device Information (1)

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE (NOM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS61089x</td>
<td>VQFN (11)</td>
<td>2.00 mm × 2.50 mm</td>
</tr>
</tbody>
</table>

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

Typical Application Circuit

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. UNLESS OTHERWISE NOTED, this document contains PRODUCTION DATA.
Table of Contents

1 Features ................................................................. 1
2 Applications ....................................................... 1
3 Description .......................................................... 1
4 Revision History .................................................. 2
5 Device Comparison Table ...................................... 3
6 Pin Configuration and Functions .............................. 3
7 Specifications ....................................................... 4
  7.1 Absolute Maximum Ratings .............................. 4
  7.2 ESD Ratings .................................................... 4
  7.3 Recommended Operating Conditions .................. 4
  7.4 Thermal Information ........................................ 4
  7.5 Electrical Characteristics ................................ 5
  7.6 Typical Characteristics .................................. 6
8 Detailed Description .............................................. 8
  8.1 Overview ..................................................... 8
  8.2 Functional Block Diagram ................................ 8
  8.3 Feature Description ....................................... 9
  8.4 Device Functional Modes ................................ 10
9 Application and Implementation ............................. 12
  9.1 Application Information ................................ 12
  9.2 Typical Application ....................................... 12
10 Power Supply Recommendations ........................... 19
11 Layout .............................................................. 19
  11.1 Layout Guidelines ....................................... 19
  11.2 Layout Example ......................................... 19
  11.3 Thermal Considerations ................................. 20
12 Device and Documentation Support ......................... 21
  12.1 Device Support ............................................ 21
  12.2 Receiving Notification of Documentation Updates 21
  12.3 Community Resources .................................. 21
  12.4 Trademarks ................................................ 21
  12.5 Electrostatic Discharge Caution ....................... 21
  12.6 Glossary .................................................. 21
13 Mechanical, Packaging, and Orderable Information .... 21

4 Revision History
Changes from Revision A (April 2016) to Revision B Page

• Changed x axis in Figure 1 ........................................... 6
• Changed x axis in Figure 2 ........................................... 6

Changes from Original (November 2015) to Revision A Page

• Changed the device status From: Product Preview To: Mixed Status ........................................... 1

Copyright © 2015–2016, Texas Instruments Incorporated
5 Device Comparison Table

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>OPERATION MODE AT LIGHT LOAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS61089RNR</td>
<td>PFM</td>
</tr>
<tr>
<td>TPS610891RNR(1)</td>
<td>Forced PWM</td>
</tr>
</tbody>
</table>

(1) Product Preview. Contact TI factory for more information.

6 Pin Configuration and Functions

RNR Package
11 Pin VQFN With Thermal Pad
Top View

Pin Functions

<table>
<thead>
<tr>
<th>PIN</th>
<th>I/O</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
<td>NUMBER</td>
<td></td>
</tr>
<tr>
<td>FSW</td>
<td>1</td>
<td>I</td>
</tr>
<tr>
<td>VCC</td>
<td>2</td>
<td>O</td>
</tr>
<tr>
<td>FB</td>
<td>3</td>
<td>I</td>
</tr>
<tr>
<td>COMP</td>
<td>4</td>
<td>O</td>
</tr>
<tr>
<td>GND</td>
<td>5</td>
<td>PWR</td>
</tr>
<tr>
<td>VOUT</td>
<td>6</td>
<td>PWR</td>
</tr>
<tr>
<td>EN</td>
<td>7</td>
<td>I</td>
</tr>
<tr>
<td>ILIM</td>
<td>8</td>
<td>O</td>
</tr>
<tr>
<td>VIN</td>
<td>9</td>
<td>I</td>
</tr>
<tr>
<td>BOOT</td>
<td>10</td>
<td>O</td>
</tr>
<tr>
<td>SW</td>
<td>11</td>
<td>PWR</td>
</tr>
</tbody>
</table>
7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature (unless otherwise noted) (1)

<table>
<thead>
<tr>
<th>Voltage at terminals (2)</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOOT</td>
<td>−0.3</td>
<td>SW + 7</td>
<td>V</td>
</tr>
<tr>
<td>VIN, SW, FSW, VOUT</td>
<td>−0.3</td>
<td>14.5</td>
<td>V</td>
</tr>
<tr>
<td>EN, VCC, COMP</td>
<td>−0.3</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>ILIM, FB</td>
<td>−0.3</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Operating junction temperature, $T_J$</td>
<td>−40</td>
<td>150</td>
<td>°C</td>
</tr>
<tr>
<td>Storage temperature, $T_{stg}$</td>
<td>−65</td>
<td>150</td>
<td>°C</td>
</tr>
</tbody>
</table>

(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.

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

7.2 ESD Ratings

<table>
<thead>
<tr>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{(ESD)}$ Electrostatic discharge</td>
<td>±2000 V</td>
</tr>
</tbody>
</table>

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

(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

7.3 Recommended Operating Conditions

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

<table>
<thead>
<tr>
<th>THERMAL METRIC (1)</th>
<th>MIN</th>
<th>NOM</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IN}$ Input voltage range</td>
<td>2.7</td>
<td>12</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{OUT}$ Output voltage range</td>
<td>4.5</td>
<td>12.6</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$L$ Inductance, effective value</td>
<td>0.47</td>
<td>2.2</td>
<td>10 µH</td>
<td></td>
</tr>
<tr>
<td>$C_{IN}$ Input capacitance, effective value</td>
<td>10</td>
<td>µF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_{O}$ Output capacitance, effective value</td>
<td>10</td>
<td>47</td>
<td>1000 µF</td>
<td></td>
</tr>
<tr>
<td>$T_J$ Operating junction temperature</td>
<td>−40</td>
<td>125</td>
<td>°C</td>
<td></td>
</tr>
</tbody>
</table>

7.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC (1)</th>
<th>TPS61089x</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_{JA}$ Junction-to-ambient thermal resistance</td>
<td>53.4 °C/W</td>
</tr>
<tr>
<td>$R_{JC(top)}$ Junction-to-case (top) thermal resistance</td>
<td>59.2 °C/W</td>
</tr>
<tr>
<td>$R_{JB}$ Junction-to-board thermal resistance</td>
<td>9.6 °C/W</td>
</tr>
<tr>
<td>$ψ_{JT}$ Junction-to-top characterization parameter</td>
<td>0.5 °C/W</td>
</tr>
<tr>
<td>$ψ_{JB}$ Junction-to-board characterization parameter</td>
<td>9.5 °C/W</td>
</tr>
<tr>
<td>$R_{JC(bot)}$ Junction-to-case (bottom) thermal resistance</td>
<td>0.7 °C/W</td>
</tr>
<tr>
<td>$R_{JA(EVM)}$ Junction-to-ambient thermal resistance on EVM</td>
<td>39.2 °C/W</td>
</tr>
</tbody>
</table>

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

(2) The EVM board is a 4-layer PCB of 76-mm x 52-mm size. The copper thickness of top layer and bottom layer is 2 oz. The copper thickness of inner layers is 1 oz.
## 7.5 Electrical Characteristics

\( V_{\text{IN}} = 2.7 \text{ V to 5.5 V}, \ V_{\text{OUT}} = 9 \text{ V}, T_{J} = -40^\circ \text{C} \) to 125°C. Typical values are at \( T_{J} = 25^\circ \text{C} \), unless otherwise noted.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POWER SUPPLY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{\text{IN}} )</td>
<td>Input voltage range</td>
<td>2.7</td>
<td>12</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( V_{\text{IN,UVLO}} )</td>
<td>Input voltage undervoltage lockout (UVLO) threshold</td>
<td>( V_{\text{IN}} ) rising</td>
<td>2.7</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( V_{\text{IN}} )</td>
<td></td>
<td>( V_{\text{IN}} ) falling</td>
<td>2.4</td>
<td>2.5</td>
<td>V</td>
</tr>
<tr>
<td>( V_{\text{IN,HYS}} )</td>
<td>VIN UVLO hysteresis</td>
<td>200</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>( V_{\text{DC}} )</td>
<td>VCC regulation voltage</td>
<td>( I_{\text{CC}} = 2 \text{ mA}, \ V_{\text{IN}} = 8 \text{ V} )</td>
<td>5.8</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( V_{\text{DC,UVLO}} )</td>
<td>VCC UVLO threshold</td>
<td>( V_{\text{CC}} ) falling</td>
<td>2.1</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>( I_{\text{O}} )</td>
<td>Quiescent current into ( V_{\text{IN}} ) pin</td>
<td>IC enabled, No load, ( V_{\text{IN}} = 2.7 \text{ V to 5.5 V}, V_{\text{FB}} = 1.3 \text{ V}, V_{\text{OUT}} = 12 \text{ V}, T_{J} \leq 85^\circ \text{C} )</td>
<td>1</td>
<td>3</td>
<td>( \mu \text{A} )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Quiescent current into ( V_{\text{OUT}} ) pin</td>
<td>IC enabled, No load, ( V_{\text{IN}} = 2.7 \text{ V to 5.5 V}, V_{\text{FB}} = 1.3 \text{ V}, V_{\text{OUT}} = 12 \text{ V}, T_{J} \leq 85^\circ \text{C} )</td>
<td>100</td>
<td>180</td>
</tr>
<tr>
<td>( I_{\text{SD}} )</td>
<td>Shutdown current into ( V_{\text{IN}} ) pin</td>
<td>IC disabled, ( V_{\text{IN}} = 2.7 \text{ V to 5.5 V}, T_{J} \leq 85^\circ \text{C} )</td>
<td>1</td>
<td>3</td>
<td>( \mu \text{A} )</td>
</tr>
<tr>
<td><strong>OUTPUT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{\text{OUT}} )</td>
<td>Output voltage range</td>
<td>4.5</td>
<td>12.6</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( V_{\text{REF}} )</td>
<td>Reference voltage at ( V_{\text{FB}} ) pin</td>
<td>PWM mode</td>
<td>1.188</td>
<td>1.212</td>
<td>1.236</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PFM mode</td>
<td>1.224</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{\text{FB,LKG}} )</td>
<td>Leakage current into ( V_{\text{FB}} ) pin</td>
<td>( V_{\text{FB}} = 1.2 \text{ V} )</td>
<td>100</td>
<td>nA</td>
<td></td>
</tr>
<tr>
<td>( V_{\text{OVP}} )</td>
<td>Output overvoltage protection threshold</td>
<td>( V_{\text{OUT}} ) rising</td>
<td>12.7</td>
<td>13.2</td>
<td>13.6</td>
</tr>
<tr>
<td>( V_{\text{OVP,HYS}} )</td>
<td>Output overvoltage protection hysteresis</td>
<td>( V_{\text{OUT}} ) falling below ( V_{\text{OVP}} )</td>
<td>0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t_{\text{SS}} )</td>
<td>Soft startup time</td>
<td>( C_{\text{OUT}} ) (effective) = 47 ( \mu \text{F} ), ( V_{\text{OUT}} = 0 \text{ A} )</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td><strong>ERROR AMPLIFIER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{\text{SNK}} )</td>
<td>COMP pin sink current</td>
<td>( V_{\text{FB}} = V_{\text{REF}} + 200 \text{ mV}, V_{\text{COMP}} = 1.9 \text{ V} )</td>
<td>20</td>
<td></td>
<td>( \mu \text{A} )</td>
</tr>
<tr>
<td>( I_{\text{SOURCE}} )</td>
<td>COMP pin source current</td>
<td>( V_{\text{FB}} = V_{\text{REF}} - 200 \text{ mV}, V_{\text{COMP}} = 1.9 \text{ V} )</td>
<td>20</td>
<td></td>
<td>( \mu \text{A} )</td>
</tr>
<tr>
<td>( V_{\text{CCLP,H}} )</td>
<td>High clamp voltage at the COMP pin</td>
<td>( V_{\text{FB}} = 1 \text{ V}, R_{\text{ILIM}} = 127 \text{ k} \Omega )</td>
<td>2.3</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>( V_{\text{CCLP,L}} )</td>
<td>Low clamp voltage at the COMP pin</td>
<td>( V_{\text{FB}} = 1.4 \text{ V}, R_{\text{ILIM}} = 127 \text{ k} \Omega )</td>
<td>1.4</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>( G_{\text{EA}} )</td>
<td>Error amplifier transconductance</td>
<td>( V_{\text{COMP}} = 1.9 \text{ V} )</td>
<td>190</td>
<td></td>
<td>( \mu \text{S} )</td>
</tr>
<tr>
<td><strong>POWER SWITCH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( R_{\text{DS(on)}} )</td>
<td>High-side MOSFET on-resistance</td>
<td>( V_{\text{CC}} = 6 \text{ V} )</td>
<td>27</td>
<td>44</td>
<td>mΩ</td>
</tr>
<tr>
<td></td>
<td>Low-side MOSFET on-resistance</td>
<td>( V_{\text{CC}} = 6 \text{ V} )</td>
<td>19</td>
<td>31</td>
<td>mΩ</td>
</tr>
<tr>
<td><strong>SWITCHING FREQUENCY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_{\text{SW}} )</td>
<td>Switching frequency</td>
<td>( R_{\text{SW}} = 301 \text{ k} \Omega )</td>
<td>500</td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( R_{\text{SW}} = 46.4 \text{ k} \Omega )</td>
<td>2000</td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td>( t_{\text{ON,MIN}} )</td>
<td>Minimum on time</td>
<td>( V_{\text{CC}} = 6 \text{ V} )</td>
<td>90</td>
<td>180</td>
<td>ns</td>
</tr>
<tr>
<td><strong>CURRENT LIMIT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{\text{LIM}} )</td>
<td>Peak switch current limit, TPS61089</td>
<td>( R_{\text{LIM}} = 127 \text{ k} \Omega )</td>
<td>7.3</td>
<td>8.1</td>
<td>8.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( R_{\text{LIM}} = 100 \text{ k} \Omega )</td>
<td>9.0</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>( V_{\text{ILIM}} )</td>
<td>Internal reference voltage at ILIM pin</td>
<td>1.212</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td><strong>EN LOGIC INPUT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{\text{EN,H}} )</td>
<td>EN Logic high threshold</td>
<td></td>
<td>1.2</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>( V_{\text{EN,L}} )</td>
<td>EN Logic Low threshold</td>
<td></td>
<td>0.4</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>( R_{\text{EN}} )</td>
<td>EN pulldown resistor</td>
<td></td>
<td>800</td>
<td></td>
<td>kΩ</td>
</tr>
<tr>
<td><strong>PROTECTION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( T_{\text{SD}} )</td>
<td>Thermal shutdown threshold</td>
<td>( T_{J} ) rising</td>
<td>150</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>( T_{\text{SD,HYS}} )</td>
<td>Thermal shutdown hysteresis</td>
<td>( T_{J} ) falling below ( T_{\text{SD}} )</td>
<td>20</td>
<td></td>
<td>°C</td>
</tr>
</tbody>
</table>
7.6 Typical Characteristics

$V_{IN} = 3.6\, \text{V}, \, V_{OUT} = 9\, \text{V}, \, T_J = 25^\circ\text{C}$, unless otherwise noted

Figure 1. Load Efficiency with Different Input Voltage

Figure 2. Load Efficiency with Different Output Voltage

Figure 3. Switching Peak Current Limit Setting

Figure 4. Switching Frequency Setting

Figure 5. Reference Voltage vs Temperature

Figure 6. Quiescent Current vs Temperature
Typical Characteristics (continued)

\( V_{\text{IN}} = 3.6 \, \text{V}, \ V_{\text{OUT}} = 9 \, \text{V}, \ T_{\text{J}} = 25^\circ \text{C}, \) unless otherwise noted

![Graph showing Shutdown Current vs Temperature](image)

Figure 7. Shutdown Current vs Temperature
8 Detailed Description

8.1 Overview

The TPS61089x is a synchronous boost converter integrating a 19-mΩ main power switch and a 27-mΩ rectifier switch with adjustable switch current up to 10A. It is capable to output continuous power more than 18W from input of a single cell Lithium-ion battery or two-cell Lithium-ion batteries in series. The TPS61089x operates at a quasi-constant frequency pulse-width modulation (PWM) at moderate to heavy load currents. At light load current, the TPS61089 operates in PFM mode and the TPS610891 operates in forced PWM (FPWM) mode. The PFM mode brings high efficiency over the entire load range, and the FPWM mode can avoid the acoustic noise and switching frequency interference at light load. The converter uses the constant off-time peak current mode control scheme, which provides excellent line and load transient response with minimal output capacitance. The external loop compensation brings flexibility to use different inductors and output capacitors. The TPS61089x supports adjustable switching frequency ranging from 200 kHz to 2.2 MHz. The device implements cycle-by-cycle current limit to protect the device from overload conditions during boost switching. The current limit is set by an external resistor.

8.2 Functional Block Diagram
8.3 Feature Description

8.3.1 Undervoltage Lockout (UVLO)
An under-voltage lockout (UVLO) circuit stops the operation of the converter when the input voltage drops below the typical UVLO threshold of 2.5 V. A hysteresis of 200 mV is added so that the device cannot be enabled again until the input voltage goes up to 2.7 V. This function is implemented in order to prevent malfunctioning of the device when the input voltage is between 2.5 V and 2.7 V.

8.3.2 Enable and Disable
When the input voltage is above maximal UVLO rising threshold of 2.7 V and the EN pin is pulled above the high threshold, the TPS61089x is enabled. When the EN pin is pulled below the low threshold, the TPS61089x goes into shutdown mode. The device stops switching in the shutdown mode and consumes less than 3-µA current. Because of the body diode of the high side rectifier FET, the input voltage goes through the body diode and appears at the VOUT pin at the shutdown mode.

8.3.3 Soft Start
The TPS61089x implements the soft start function to reduce the inrush current during startup. The TPS61089x begins soft start when the EN pin is pulled to logic high voltage. The soft start time is typically 4 ms.

8.3.4 Adjustable Switching Frequency
The TPS61089x features a wide adjustable switching frequency ranging from 200 kHz to 2.2 MHz. The switching frequency is set by a resistor connected between the FSW pin and the SW pin of the TPS61089x. Do not leave the FSW pin open. Use Equation 1 to calculate the resistor value required for a desired frequency.

\[
R_{\text{FREQ}} = \frac{4 \times \left( \frac{1}{f_{\text{SW}}} - t_{\text{DELAY}} \times \frac{V_{\text{OUT}}}{V_{\text{IN}}} \right)}{C_{\text{FREQ}}}
\]

where
- \( R_{\text{FREQ}} \) is the resistance connected between the FSW pin and the SW pin.
- \( C_{\text{FREQ}} = 24 \, \text{pF} \)
- \( f_{\text{SW}} \) is the desired switching frequency.
- \( t_{\text{DELAY}} = 86 \, \text{ns} \)
- \( V_{\text{IN}} \) is the input voltage.
- \( V_{\text{OUT}} \) is the output voltage.

8.3.5 Adjustable Peak Current Limit
To avoid an accidental large peak current, an internal cycle-by-cycle current limit is adopted. The low-side switch turns off immediately as long as the peak switch current touches the limit. The peak inductor current can be set by selecting the correct external resistor value correlating with the required current limit. Use Equation 2 to calculate the correct resistor value for the TPS61089.

\[
I_{\text{LIM}} = \frac{1030000}{R_{\text{ILIM}}}
\]

where
- \( R_{\text{ILIM}} \) is the resistance connected between the ILIM pin and ground.
- \( I_{\text{LIM}} \) is the switch peak current limit.

For a typical current limit of 8 A, the resistor value is 127 k\( \Omega \) for the TPS61089.

8.3.6 Overvoltage Protection
If the output voltage at the VOUT pin is detected above over-voltage protection threshold of 13.2 V (typical value), the TPS61089x stops switching immediately until the voltage at the VOUT pin drops the hysteresis voltage lower than the output over-voltage protection threshold. This function prevents over-voltage on the output and secures the circuits connected to the output from excessive overvoltage.
Feature Description (continued)

8.3.7 Thermal Shutdown

A thermal shutdown is implemented to prevent damage due to excessive heat and power dissipation. Typically, the thermal shutdown happens at the junction temperature of 150°C. When the thermal shutdown is triggered, the device stops switching until the junction temperature falls below typically 130°C, then the device starts switching again.

8.4 Device Functional Modes

8.4.1 Operation

The synchronous boost converter TPS61089x operates at a quasi-constant frequency pulse width modulation (PWM) in moderate to heavy load condition. Based on the $V_{IN}$ to $V_{OUT}$ ratio, a circuit predicts the required off-time of the switching cycle. At the beginning of each switching cycle, the low-side N-MOSFET switch, shown in Functional Block Diagram, is turned on, and the inductor current ramps up to a peak current that is determined by the output of the internal error amplifier. After the peak current is reached, the current comparator trips, and it turns off the low-side N-MOSFET switch and the inductor current goes through the body diode of the high-side N-MOSFET in a dead-time duration. After the dead-time duration, the high-side N-MOSFET switch is turned on. Because the output voltage is higher than the input voltage, the inductor current decreases. The high-side switch is not turned off until the fixed off-time is reached. After a short dead-time duration, the low-side switch is turned on again and the switching cycle is repeated.

In light load condition, the TPS61089 implements PFM mode for applications requiring high efficiency at light load. And the TPS610891 implements forced PWM mode for applications requiring fixed switching frequency to avoid unexpected switching noise interference.

8.4.1.1 Forced PWM Mode

In the forced PWM mode, the TPS610891 keeps the switching frequency unchanged in light load condition. When the load current decreases, the output of the internal error amplifier decreases as well to keep the inductor peak current down, delivering less power from input to output. When the output current further reduces, the current through the inductor will decrease to zero during the off-time. The high-side N-MOSFET is not turned off even if the current through the MOSFET is zero. Thus, the inductor current changes its direction after it runs to zero. The power flow is from output side to input side. The efficiency will be low in this mode. But with the fixed switching frequency, there is no audible noise and other problems which might be caused by low switching frequency in light load condition.

8.4.1.2 PFM Mode

The TPS61089 improves the efficiency at light load with the PFM mode. When the converter operates in light load condition, the output of the internal error amplifier decreases to make the inductor peak current down, delivering less power to the load. When the output current further reduces, the current through the inductor will decrease to zero during the off-time. Once the current through the high side N-MOSFET is zero, the high-side MOSFET is turned off until the beginning of the next switching cycle. When the output of the error amplifier continuously goes down and reaches a threshold with respect to the peak current of $I_{LIM}/10$, the output of the error amplifier is clamped at this value and does not decrease any more. If the load current is smaller than what the TPS61089 delivers, the output voltage increases above the nominal setting output voltage. The TPS61089 extends its off time of the switching period to deliver less energy to the output and regulate the output voltage to 1.0% higher than the nominal setting voltage. With the PFM operation mode, the TPS61089 keeps the efficiency above 70% even when the load current decreases to 1 mA. At light load, the output voltage ripple is much smaller due to low peak inductor current. Refer to Figure 8.
Device Functional Modes (continued)

![Graph showing Output Voltage in PWM Mode and PFM Mode](image)

**Figure 8.** Output Voltage in PWM Mode and PFM Mode
9 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.

9.1 Application Information
The TPS61089x is designed for outputting voltage up to 12.6 V with 7-A continuous switch current capability to deliver more than 18-W power. The TPS61089x operates at a quasi-constant frequency pulse-width modulation (PWM) in moderate to heavy load condition. In light load condition, the TPS61089 operates in the PFM mode and the TPS610891 operates in the forced PWM mode. The PFM mode brings high efficiency over entire load range, while the PWM mode can avoid the acoustic noise as the switching frequency is fixed. In PWM mode, the TPS61089x converter uses the adaptive constant off-time peak current control scheme, which provides excellent transient line and load response with minimal output capacitance. The TPS61089x can work with different inductor and output capacitor combination by external loop compensation. It also supports adjustable switching frequency ranging from 200 kHz to 2.2 MHz.

9.2 Typical Application

Figure 9. TPS61089x Single Cell Li-ion Battery to 9-V/2-A Output Converter

9.2.1 Design Requirements

Table 1. Design Parameters

<table>
<thead>
<tr>
<th>DESIGN PARAMETERS</th>
<th>EXAMPLE VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage range</td>
<td>3.0 to 4.35 V</td>
</tr>
<tr>
<td>Output voltage</td>
<td>9 V</td>
</tr>
<tr>
<td>Output voltage ripple</td>
<td>100 mV peak to peak</td>
</tr>
<tr>
<td>Output current rating</td>
<td>2 A</td>
</tr>
<tr>
<td>Operating frequency</td>
<td>500 kHz</td>
</tr>
<tr>
<td>Operation mode at light load</td>
<td>PFM</td>
</tr>
</tbody>
</table>
9.2.2 Detailed Design Procedure

9.2.2.1 Setting Switching Frequency

The switching frequency is set by a resistor connected between the FSW pin and the SW pin of the TPS61089x. The resistor value required for a desired frequency can be calculated using Equation 3.

\[
R_{\text{FREQ}} = \frac{4 \times (1 - t_{\text{DELAY}} \times \frac{V_{\text{OUT}}}{V_{\text{IN}}})}{C_{\text{FREQ}}}
\]

where
- \(R_{\text{FREQ}}\) is the resistance connected between the FSW pin and the SW pin.
- \(C_{\text{FREQ}} = 24 \ \text{pF}\)
- \(f_{\text{SW}}\) is the desired switching frequency.
- \(t_{\text{DELAY}} = 86 \ \text{ns}\)
- \(V_{\text{IN}}\) is the input voltage.
- \(V_{\text{OUT}}\) is the output voltage. (3)

9.2.2.2 Setting Peak Current Limit

The peak input current is set by selecting the correct external resistor value correlating to the required current limit. Use Equation 4 to calculate the correct resistor value:

\[
I_{\text{ILIM}} = \frac{1030000}{R_{\text{ILIM}}}
\]

where
- \(R_{\text{ILIM}}\) is the resistance connected between the ILIM pin and ground.
- \(I_{\text{ILIM}}\) is the switching peak current limit. (4)

For a typical current limit of 8 A, the resistor value is 127 k\(\Omega\). Considering the device variation and the tolerance over temperature, the minimum current limit at the worst case can be 0.8 A lower than the value calculated by Equation 4. The minimum current limit must be higher than the required peak switch current at the lowest input voltage and the highest output power to make sure the TPS61089x does not hit the current limit and still can regulate the output voltage in these conditions.

9.2.2.3 Setting Output Voltage

The output voltage is set by an external resistor divider (R1, R2 in the Figure 9). Typically, a minimum current of 10 \(\mu\)A flowing through the feedback divider gives good accuracy and noise covering. A resistor of less than 120 k\(\Omega\) is typically selected for low-side resistor R2.

When the output voltage is regulated, the typical voltage at the FB pin is \(V_{\text{REF}}\). Thus the value of R1 is calculated as:

\[
R_1 = \frac{(V_{\text{OUT}} - V_{\text{REF}}) \times R_2}{V_{\text{REF}}}
\]

9.2.2.4 Inductor Selection

Because the selection of the inductor affects the power supply’s steady state operation, transient behavior, loop stability, and boost converter efficiency, the inductor is the most important component in switching power regulator design. Three most important specifications to the performance of the inductor are the inductor value, DC resistance, and saturation current.

The TPS61089x is designed to work with inductor values between 0.47 \(\mu\)H and 10 \(\mu\)H. A 0.47-\(\mu\)H inductor is typically available in a smaller or lower-profile package, while a 10-\(\mu\)H inductor produces lower inductor current ripple. If the boost output current is limited by the peak current protection of the IC, using a 10-\(\mu\)H inductor can maximize the controller’s output current capability.
Inductor values can have ±20% or even ±30% tolerance with no current bias. When the inductor current approaches saturation level, its inductance can decrease 20% to 35% from the value at 0-A current depending on how the inductor vendor defines saturation. When selecting an inductor, make sure its rated current, especially the saturation current, is larger than its peak current during the operation.

Follow Equation 6 to Equation 8 to calculate the peak current of the inductor. To calculate the current in the worst case, use the minimum input voltage, maximum output voltage, and maximum load current of the application. To leave enough design margin, TI recommends using the minimum switching frequency, the inductor value with −30% tolerance, and a low-power conversion efficiency for the calculation.

In a boost regulator, calculate the inductor DC current as in Equation 6.

\[ I_{DC} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times \eta} \]

where

- \( V_{OUT} \) is the output voltage of the boost regulator.
- \( I_{OUT} \) is the output current of the boost regulator.
- \( V_{IN} \) is the input voltage of the boost regulator.
- \( \eta \) is the power conversion efficiency.

Calculate the inductor current peak-to-peak ripple as in Equation 7.

\[ I_{PP} = \frac{1}{L \times \left( \frac{1}{V_{OUT} - V_{IN}} + \frac{1}{V_{IN}} \right) \times f_{SW}} \]

where

- \( I_{PP} \) is the inductor peak-to-peak ripple.
- \( L \) is the inductor value.
- \( f_{SW} \) is the switching frequency.
- \( V_{OUT} \) is the output voltage.
- \( V_{IN} \) is the input voltage.

Therefore, the peak current, \( I_{Lpeak} \), seen by the inductor is calculated with Equation 8.

\[ I_{Lpeak} = I_{DC} + \frac{I_{PP}}{2} \]

Set the current limit of the TPS61089x higher than the peak current \( I_{Lpeak} \). Then select the inductor with saturation current higher than the setting current limit.

Boost converter efficiency is dependent on the resistance of its current path, the switching loss associated with the switching MOSFETs, and the inductor’s core loss. The TPS61089x has optimized the internal switch resistance. However, the overall efficiency is affected significantly by the inductor’s DC resistance (DCR), equivalent series resistance (ESR) at the switching frequency, and the core loss. Core loss is related to the core material and different inductors have different core loss. For a certain inductor, larger current ripple generates higher DCR and ESR conduction losses and higher core loss. Usually, a data sheet of an inductor does not provide the ESR and core loss information. If needed, consult the inductor vendor for detailed information. Generally, TI would recommend an inductor with lower DCR and ESR. However, there is a tradeoff among the inductor’s inductance, DCR and ESR resistance, and its footprint. Furthermore, shielded inductors typically have higher DCR than unshielded inductors. Table 2 lists recommended inductors for the TPS61089x. Verify whether the recommended inductor can support the user’s target application with the previous calculations and bench evaluation. In this application, the Sumida’s inductor CDMC8D28NP-1R8MC is selected for its small size and low DCR.
Table 2. Recommended Inductors

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>L (µH)</th>
<th>DCR MAX (mΩ)</th>
<th>SATURATION CURRENT / HEAT RATING CURRENT (A)</th>
<th>SIZE MAX (L × W × H mm)</th>
<th>VENDOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDMC8D28NP-1R8MC</td>
<td>1.8</td>
<td>12.6</td>
<td>9.4 / 9.3</td>
<td>9.5 × 8.7 × 3.0</td>
<td>Sumida</td>
</tr>
<tr>
<td>744311150</td>
<td>1.5</td>
<td>7.2</td>
<td>14.0 / 11.0</td>
<td>7.3 × 7.2 × 4.0</td>
<td>Wurth-Elektronik</td>
</tr>
<tr>
<td>744311220</td>
<td>2.2</td>
<td>12.5</td>
<td>13.0 / 9.0</td>
<td>7.3 × 7.2 × 4.0</td>
<td>Wurth-Elektronik</td>
</tr>
<tr>
<td>PIMB03T-2R2MS</td>
<td>2.2</td>
<td>9.0</td>
<td>16 / 13</td>
<td>11.2 × 10.3 × 3.0</td>
<td>Cyntec</td>
</tr>
<tr>
<td>PIMB065T-2R2MS</td>
<td>2.2</td>
<td>12.5</td>
<td>12 / 10.5</td>
<td>7.4 × 6.8 × 5.0</td>
<td>Cyntec</td>
</tr>
</tbody>
</table>

### 9.2.2.5 Input Capacitor Selection

For good input voltage filtering, TI recommends low-ESR ceramic capacitors. The VIN pin is the power supply for the TPS61089x. A 0.1-µF ceramic bypass capacitor is recommended as close as possible to the VIN pin of the TPS61089x. The VCC pin is the output of the internal LDO. A ceramic capacitor of more than 1.0 µF is required at the VCC pin to get a stable operation of the LDO.

For the power stage, because of the inductor current ripple, the input voltage changes if there is parasitic inductance and resistance between the power supply and the inductor. It is recommended to have enough input capacitance to make the input voltage ripple less than 100mV. Generally, 10-µF input capacitance is sufficient for most applications.

**NOTE**

DC bias effect: High-capacitance ceramic capacitors have a DC bias effect, which has a strong influence on the final effective capacitance. Therefore, the right capacitor value must be chosen carefully. The differences between the rated capacitor value and the effective capacitance result from package size and voltage rating in combination with material. A 10-V rated 0805 capacitor with 10 µF can have an effective capacitance of less 5 µF at an output voltage of 5 V.

### 9.2.2.6 Output Capacitor Selection

For small output voltage ripple, TI recommends a low-ESR output capacitor like a ceramic capacitor. Typically, three 22-µF ceramic output capacitors work for most applications. Higher capacitor values can be used to improve the load transient response. Take care when evaluating a capacitor’s derating under DC bias. The bias can significantly reduce capacitance. Ceramic capacitors can lose most of their capacitance at rated voltage. Therefore, leave margin on the voltage rating to ensure adequate effective capacitance. From the required output voltage ripple, use the following equations to calculate the minimum required effective capacitance \( C_O \):

\[
V_{\text{ripple\_dis}} = \frac{(V_{\text{OUT}} - V_{\text{IN\_MIN}}) \times I_{\text{OUT}}}{V_{\text{OUT}} \times f_{\text{SW}} \times C_O}
\]

\[
V_{\text{ripple\_ESR}} = I_{\text{Lpeak}} \times R_{\text{ESR}}
\]

where

- \( V_{\text{ripple\_dis}} \) is output voltage ripple caused by charging and discharging of the output capacitor.
- \( V_{\text{ripple\_ESR}} \) is output voltage ripple caused by ESR of the output capacitor.
- \( V_{\text{IN\_MIN}} \) is the minimum input voltage of boost converter.
- \( V_{\text{OUT}} \) is the output voltage.
- \( I_{\text{OUT}} \) is the output current.
- \( I_{\text{Lpeak}} \) is the peak current of the inductor.
- \( f_{\text{SW}} \) is the converter’s switching frequency.
- \( R_{\text{ESR}} \) is the ESR of the output capacitors.

### 9.2.2.7 Loop Stability

The TPS61089x requires external compensation, which allows the loop response to be optimized for each application. The COMP pin is the output of the internal error amplifier. An external compensation network comprised of resister R5, ceramic capacitors C5 and C6 is connected to the COMP pin.
The power stage small signal loop response of constant off time (COT) with peak current control can be modeled by Equation 11.

\[ G_{PS}(S) = \frac{R_O \times (1 - D)}{2 \times R_{\text{sense}}} \times \left( \frac{1 + \frac{S}{2 \times \pi \times f_{\text{ESRZ}}}}{1 + \frac{S}{2 \times \pi \times f_{\text{RHPZ}}}} \right) \left( \frac{1 - \frac{S}{2 \times \pi \times f_p}}{1 + \frac{S}{2 \times \pi \times f_p}} \right) \]

where
- \( D \) is the switching duty cycle
- \( R_O \) is the output load resistance.
- \( R_{\text{sense}} \) is the equivalent internal current sense resistor, which is 0.08 \( \Omega \).
- \( f_p \) is the pole’s frequency
- \( f_{\text{ESRZ}} \) is the zero’s frequency
- \( f_{\text{RHPZ}} \) is the right-half-plane-zero’s frequency

(11)

The, \( f_P \), \( f_{\text{ESRZ}} \) and \( f_{\text{RHPZ}} \) can be calculated by following equations:

\[ D = 1 - \frac{V_{\text{IN}} \times \eta}{V_{\text{OUT}}} \]

where
- \( \eta \) is the power conversion efficiency

(12)

\[ f_P = \frac{2}{2\pi \times R_O \times C_O} \]

where
- \( C_O \) is effective capacitance of the output capacitor.

(13)

\[ f_{\text{ESRZ}} = \frac{1}{2\pi \times R_{\text{ESR}} \times C_O} \]

where
- \( R_{\text{ESR}} \) is the equivalent series resistance of the output capacitor.

(14)

\[ f_{\text{RHPZ}} = \frac{R_O \times (1 - D)^2}{2\pi \times L} \]

(15)

The COMP pin is the output of the internal transconductance amplifier. Equation 16 shows the small signal transfer function of compensation network.

\[ G_c(S) = G_{\text{EA}} \times R_{\text{EA}} \times \frac{V_{\text{REF}}}{V_{\text{OUT}}} \times \left( \frac{1 + \frac{S}{2 \times \pi \times f_{\text{COMZ}}}}{1 + \frac{S}{2 \times \pi \times f_{\text{COMP1}}}} \right) \left( \frac{1 + \frac{S}{2 \times \pi \times f_{\text{COMP2}}}}{1 + \frac{S}{2 \times \pi \times f_{\text{COMP2}}}} \right) \]

where
- \( G_{\text{EA}} \) is the amplifier’s transconductance
- \( R_{\text{EA}} \) is the amplifier’s output resistance
- \( V_{\text{REF}} \) is the reference voltage at the FB pin
- \( V_{\text{OUT}} \) is the output voltage
- \( f_{\text{COMP1}}, f_{\text{COMP2}} \) are the poles’ frequency of the compensation network.
- \( f_{\text{COMZ}} \) is the zero’s frequency of the compensation network.

(16)

The next step is to choose the loop crossover frequency, \( f_C \). The higher in frequency that the loop gain stays above zero before crossing over, the faster the loop response is. It is generally accepted that the loop gain cross over no higher than the lower of either 1/10 of the switching frequency, \( f_{\text{SW}} \), or 1/5 of the RHPZ frequency, \( f_{\text{RHPZ}} \).
At the crossover frequency, the loop gain is 1. Thus the value of R5 can be calculated by Equation 17. Then set the values of C5 and C6 (in Figure 9) by Equation 18 and Equation 19.

\[ R5 = \frac{2\pi \times V_{OUT} \times R_{sense} \times f_c \times C_O}{(1 - D) \times V_{REF} \times G_{EA}} \]

where

- \( f_c \) is the selected crossover frequency.  

The value of C5 can be set by Equation 18.

\[ C5 = \frac{R_O \times C_O}{2R5} \]

The value of C6 can be set by Equation 19.

\[ C6 = \frac{R_{ESR} \times C_O}{R5} \]

If the calculated value of C6 is less than 10 pF, it can be left open.

Designing the loop for greater than 45° of phase margin and greater than 10-dB gain margin eliminates output voltage ringing during the line and load transient.

### 9.2.3 Application Curves

#### Figure 10. Switching Waveforms in CCM

- \( V_{IN} = 3.6 \, V \)
- \( V_{OUT} = 9 \, V \)
- \( I_{OUT} = 2 \, A \)

#### Figure 11. Switching Waveforms in DCM

- \( V_{IN} = 3.6 \, V \)
- \( V_{OUT} = 9 \, V \)
- \( I_{OUT} = 200 \, mA \)

#### Figure 12. Switching Waveforms in PFM Mode

- \( V_{IN} = 3.6 \, V \)
- \( V_{OUT} = 9 \, V \)
- \( I_{OUT} = 20 \, mA \)

#### Figure 13. Startup Waveforms
Figure 14. Shutdown Waveforms

Figure 15. Load Transient

Figure 16. Line Transient
10 Power Supply Recommendations

The device is designed to operate from an input voltage supply range between 2.7 V to 12 V. This input supply must be well regulated. If the input supply is located more than a few inches from the converter, additional bulk capacitance may be required in addition to the ceramic bypass capacitors. A typical choice is an electrolytic or tantalum capacitor with a value of 47 \( \mu \text{F} \).

11 Layout

11.1 Layout Guidelines

As for all switching power supplies, especially those running at high switching frequency and high currents, layout is an important design step. If layout is not carefully done, the regulator could suffer from instability and noise problems. To maximize efficiency, switching rise time and fall time are very fast. To prevent radiation of high-frequency noise (for example, EMI), proper layout of the high-frequency switching path is essential. Minimize the length and area of all traces connected to the SW pin, and always use a ground plane under the switching regulator to minimize interplane coupling. The input capacitor needs to be close to the VIN pin and GND pin in order to reduce the input supply current ripple.

The most critical current path for all boost converters is from the switching FET, through the rectifier FET, then the output capacitors, and back to ground of the switching FET. This high current path contains nanosecond rise time and fall time, and should be kept as short as possible. Therefore, the output capacitor needs not only to be close to the VOUT pin, but also to the GND pin to reduce the overshoot at the SW pin and VOUT pin.

11.2 Layout Example

Figure 17. Layout Example
11.3 Thermal Considerations

The maximum IC junction temperature should be restricted to 125°C under normal operating conditions. Calculate the maximum allowable dissipation, $P_{D(max)}$, and keep the actual power dissipation less than or equal to $P_{D(max)}$. The maximum-power-dissipation limit is determined using Equation 20.

$$P_{D(max)} = \frac{125 - T_A}{R_{iUA}}$$

where

- $T_A$ is the maximum ambient temperature for the application.
- $R_{iUA}$ is the junction-to-ambient thermal resistance given in the Thermal Information table. (20)

The TPS61089x comes in a thermally-enhanced VQFN package. The pads underneath the package improve the thermal capabilities of the package. The real junction-to-ambient thermal resistance of the package greatly depends on the PCB type, layout, and pad connection. Using thick PCB copper and soldering the SW pin, VOUT pin and GND pin to large copper plate enhance the thermal performance. Using more vias connects the ground plate on the top layer and bottom layer around the IC without solder mask also improves the thermal capability.
12 Device and Documentation Support

12.1 Device Support

12.1.1 Third-Party Products Disclaimer
TI’S PUBLICATION OF INFORMATION REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE AN ENDORSEMENT REGARDING THE SUITABILITY OF SUCH PRODUCTS OR SERVICES OR A WARRANTY, REPRESENTATION OR ENDORSEMENT OF SUCH PRODUCTS OR SERVICES, EITHER ALONE OR IN COMBINATION WITH ANY TI PRODUCT OR SERVICE.

12.2 Receiving Notification of Documentation Updates
To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on Alert me to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

12.3 Community Resources
The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

Ti E2E™ Online Community Ti’s Engineer-to-Engineer (E2E) Community. Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support Ti's Design Support Quickly find helpful E2E forums along with design support tools and contact information for technical support.

12.4 Trademarks
E2E is a trademark of Texas Instruments.
Bluetooth is a trademark of Bluetooth SIG.
All other trademarks are the property of their respective owners.

12.5 Electrostatic Discharge Caution
These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

12.6 Glossary
SLYZ022 — Ti Glossary.
This glossary lists and explains terms, acronyms, and definitions.

13 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

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status (1)</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan (2)</th>
<th>Lead/Ball Finish</th>
<th>MSL Peak Temp (3)</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS61089RNRR</td>
<td>ACTIVE</td>
<td>VQFN-HR</td>
<td>RNR</td>
<td>11</td>
<td>3000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 85</td>
<td>ZGOI</td>
<td>Samples</td>
</tr>
<tr>
<td>TPS61089RNRT</td>
<td>ACTIVE</td>
<td>VQFN-HR</td>
<td>RNR</td>
<td>11</td>
<td>250</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 85</td>
<td>ZGOI</td>
<td>Samples</td>
</tr>
</tbody>
</table>

---

(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](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.

---

**Important Information and Disclaimer:** The information provided on this page represents TI’s knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.
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.
## TAPE AND REEL INFORMATION

**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**
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---
TPS61089RNRR | VQFN-HR | RNR | 11 | 3000 | 180.0 | 8.4 | 2.25 | 2.8 | 1.1 | 4.0 | 8.0 | Q2
TPS61089RNRT | VQFN-HR | RNR | 11 | 250 | 180.0 | 8.4 | 2.25 | 2.8 | 1.1 | 4.0 | 8.0 | Q2

*All dimensions are nominal.*

---

[Reel Dimensions Diagram]

[TAPE DIMENSIONS Diagram]

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

[Quadrant Assignments Diagram]
### TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal*

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS61089RNRR</td>
<td>VQFN-HR</td>
<td>RNR</td>
<td>11</td>
<td>3000</td>
<td>210.0</td>
<td>185.0</td>
<td>35.0</td>
</tr>
<tr>
<td>TPS61089RNRT</td>
<td>VQFN-HR</td>
<td>RNR</td>
<td>11</td>
<td>250</td>
<td>210.0</td>
<td>185.0</td>
<td>35.0</td>
</tr>
</tbody>
</table>
NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
NOTES: (continued)

3. 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).

4. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
NOTES: (continued)

5. For alternate stencil design recommendations, see IPC-7525 or board assembly site preference.
IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that TI is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to additional restrictions.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have not been so designated is solely at the Buyer’s risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products

Audio: www.ti.com/audio
Amplifiers: amplifier.ti.com
Data Converters: dataconverter.ti.com
DLP® Products: www.dlp.com
DSP: dsp.ti.com
Clocks and Timers: www.ti.com/clocks
Interface: interface.ti.com
Logic: logic.ti.com
Power Mgmt: power.ti.com
Microcontrollers: microcontroller.ti.com
RFID: www.ti-rfid.com
OMAP Applications Processors: www.ti.com/omap
Wireless Connectivity: www.ti.com/wirelessconnectivity

Applications

Automotive and Transportation: www.ti.com/automotive
Communications and Telecom: www.ti.com/communications
Computers and Peripherals: www.ti.com/computers
Consumer Electronics: www.ti.com/consumer-apps
Energy and Lighting: www.ti.com/energy
Industrial: www.ti.com/industrial
Medical: www.ti.com/medical
Security: www.ti.com/security
Space, Avionics and Defense: www.ti.com/space-avionics-defense
Video and Imaging: www.ti.com/video

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2016, Texas Instruments Incorporated