# TPS61099x 静态电流极低的同步升压转换器

## 1 特性

- 600 nA 超低 $I_Q$ 流入 $V_{OUT}$ 引脚
- 400 nA 超低 $I_Q$ 流入 $V_{IN}$ 引脚
- 工作输入电压范围为 0.7V 至 5.5V
- 可调节输出电压范围为 1.8V 至 5.5V
- 提供固定输出电压版本
- 最小开关峰值电流限值为 0.8A
- 降压模式下的稳压输出电压
- 关断期间真正实现断开
- 使用固定输出电压版本时，10μA 负载条件下的效率高达 75%
- 在 10mA 至 300mA 负载条件下，效率高达 93%
- 6 焊球 1.23 mm x 0.88 mm 晶圆级芯片封装 (WCSP) 封装

## 2 应用

- 存储器液晶显示屏 (LCD) 偏置
- 光学心率监测发光二极管 (LED) 偏置
- 可穿戴 设备
- 低功耗无线 应用
- 便携式产品
- 电池供电系统

## 3 说明

TPS61099x 是一款超低静态电流为 1μA 的同步升压转换器。该器件设计用于由碱性电池、NiMH 充电电池、Li-Mn 电池或锂离子充电电池供电的产品，其在轻载条件下的高效运行对于延长电池使用寿命至关重要。

TPS61099x 升压转换器采用迟滞控制拓扑，可在静态电流最低的情况下实现最高效率。该器件在轻载条件下仅消耗 1μA 静态电流；当负载为 10μA 时，使用固定输出电压版本可实现高达 75% 的效率。该器件在 3.3V 至 5V 转换过程中的输出电流高达 300mA，在 200mA 负载条件下可实现高达 93% 的效率。

TPS61099x 还可为不同应用 提供降压模式和直通模式。在降压模式下，即使输入电压高于输出电压，输出电压仍可调节为目标值。在直通模式下，输出电压随着输入电压发生变化。当 $V_{IN} > V_{OUT}$ + 0.3V 时，TPS61099x 退出降压模式并转入直通模式。

TPS61099x 在禁用状态下能够将负载与输入电源断开，真正实现关断，从而降低电流消耗。

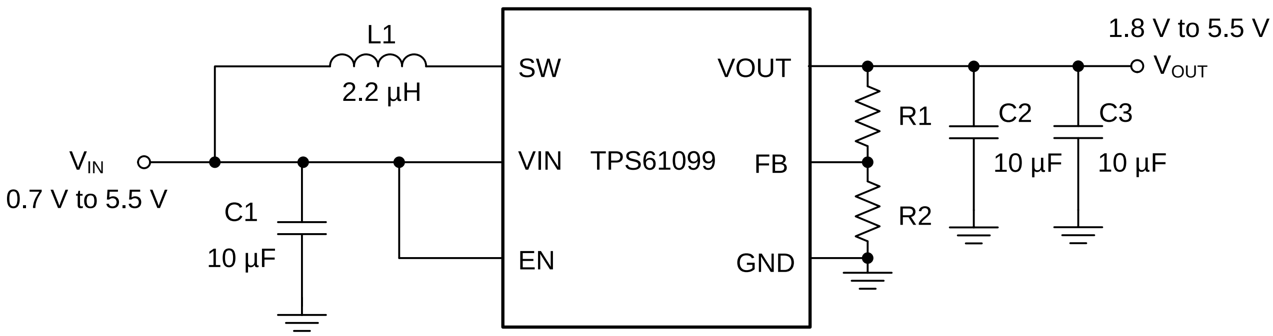
TPS61099x 具有可调节输出电压版本和固定输出电压版本。该器件采用 6 焊球 1.23mm x 0.88mm WCSP 封装。

器件信息(1)

| 器件型号 | 封装 | 封装尺寸（标称值） |
|---|---|---|
| TPS61099 | WCSP (6) | 1.23mm x 0.88mm |
| TPS61099x | WCSP (6) | 1.23mm x 0.88mm |

(1) 要了解所有可用封装，请参见本文档末尾的可订购产品附录。

典型应用电路



目录

1 特性 ... 1
2 应用 ... 1
3 说明 ... 1
4 修订历史记录 ... 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 Diagrams ... 8
8.3 Feature Description ... 8
8.4 Device Functional Modes ... 11
9 **Applications and Implementation** ... 12
9.1 Application Information ... 12
9.2 Typical Application - 5 V Output Boost Converter ... 12
10 **Power Supply Recommendations** ... 16
11 **Layout** ... 17
11.1 Layout Guidelines ... 17
11.2 Layout Example ... 17
12 器件和文档支持 ... 18
12.1 器件支持 ... 18
12.2 文档支持 ... 18
12.3 接收文档更新通知 ... 18
12.4 社区资源 ... 18
12.5 商标 ... 18
12.6 静电放电警告 ... 18
12.7 Glossary ... 18
13 机械、封装和可订购信息 ... 18

## 4 修订历史记录

| **Changes from Original (June 2016) to Revision A** | **Page** |
|---|---|
| • 已添加 完整数据表 - 全局 | 1 |

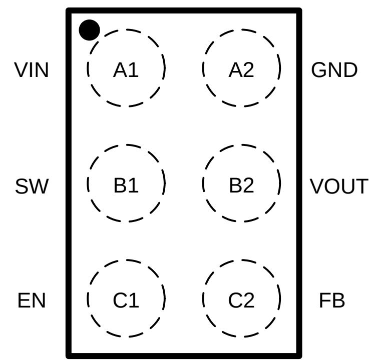
# 5 Device Comparison Table

| PART NUMBER | OUTPUT VOLTAGE |
|---|---|
| TPS61099 | Adjustable |
| TPS610997 (1) | 5.0 V |

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

# 6 Pin Configuration and Functions

**YFF Package**
**6-Pin YFF**
**Top View**




**Pin Functions**

| PIN | | TYPE | DESCRIPTION |
|---|---|---|---|
| NO. | NAME | | |
| A1 | VIN | I | IC power supply input |
| B1 | SW | PWR | Switch pin of the converter. It is connected to the inductor |
| C1 | EN | I | Enable logic input. Logic high voltage enables the device; logic low voltage disables the device. Do not leave it floating. |
| A2 | GND | PWR | Ground |
| B2 | VOUT | PWR | Boost converter output |
| C2 | FB | I | Voltage feedback of adjustable output voltage. Connect to the center tap of a resistor divider to program the output voltage. Connect to VOUT pin for fixed output voltage versions. |

# 7 Specifications

## 7.1 Absolute Maximum Ratings

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

| | | MIN | MAX | UNIT |
|---|---|---|---|---|
| Voltage range at terminals(2) | VIN, SW, VOUT, FB, EN | -0.3 | 6.0 | V |
| Operating junction temperature, $T_J$ | | –40 | 150 | °C |
| Storage temperature range, $T_{stg}$ | | –65 | 150 | °C |

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to network ground terminal.

## 7.2 ESD Ratings

| | | | VALUE | UNIT |
|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human Body Model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(1) | ±2000 | V |
| | | Charged Device Model (CDM), per JEDEC specification JESD22-C101, all pins(2) | ±500 | |

(1) JEDEC document JEP155 states that 500V HBM rating allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250V CDM rating allows safe manufacturing with a standard ESD control process.

## 7.3 Recommended Operating Conditions

| | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{IN}$ | Input voltage range | 0.7 | | 5.5 | V |
| $V_{OUT}$ | Output voltage range | 1.8 | | 5.5 | V |
| L | Inductor | 0.7 | 2.2 | 2.86 | µH |
| $C_{IN}$ | Input capacitor | 1.0 | 10 | | µF |
| $C_{OUT}$ | Output capacitor | 10 | 20 | 100 | µF |
| $T_J$ | Operating virtual junction temperature | –40 | | 125 | °C |

## 7.4 Thermal Information

| THERMAL METRIC(1) | | TPS61099 | UNIT |
|---|---|---|---|
| | | YFF (6 BALLS, WCSP) | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 134.4 | °C/W |
| $R_{\theta JCtop}$ | Junction-to-case (top) thermal resistance | 0.9 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 36.1 | °C/W |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 0.1 | °C/W |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 36.2 | °C/W |
| $R_{\theta JCbot}$ | Junction-to-case (bottom) thermal resistance | N/A | °C/W |

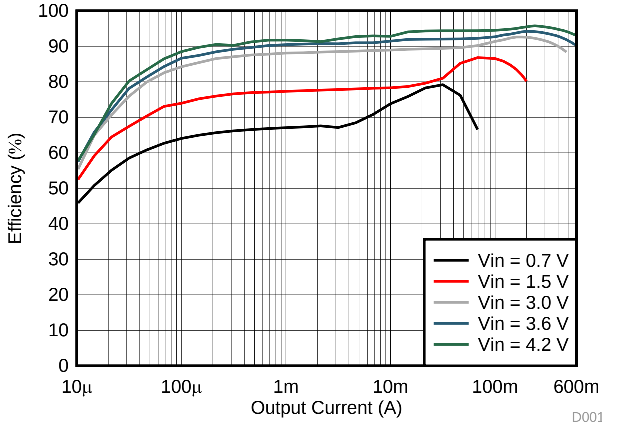
(1) For more information about traditional and new thermal metrics, see the IC Package Thermal Metrics application report, SPRA953.

## 7.5 Electrical Characteristics

$T_J$ = -40°C to 125°C and $V_{IN}$ = 0.7 V to 5.5 V. Typical values are at $V_{IN}$ = 3.7 V, $T_J$ = 25°C, unless otherwise noted.

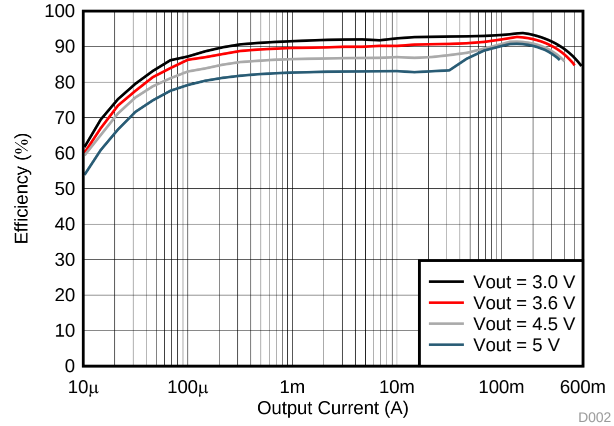
| PARAMETER | | Version | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| **Power Supply** | | | | | | | |
| $V_{IN}$ | Input voltage range | TPS61099x | | 0.7 | | 5.5 | V |
| $V_{UVLO}$ | Input under voltage lockout threshold | TPS61099x | $V_{IN}$ rising | | 0.6 | 0.7 | V |
| | UVLO hysteresis | TPS61099x | | | 200 | | mV |
| $I_Q$ | Quiescent current into VIN pin | TPS61099x | IC enabled, no Load, no Switching<br>$T_J$ = -40 °C to 85 °C | | 0.4 | 1.1 | µA |
| | Quiescent current into VOUT pin | TPS61099x | IC enabled, no Load, no Switching,<br>Boost or Down Mode<br>$T_J$ = -40 °C to 85 °C | | 0.6 | 1.5 | µA |
| $I_{SD}$ | Shutdown current into VIN pin | TPS61099x | IC disabled, $V_{IN}$ = 3.7 V, $V_{OUT}$ = 0 V<br>$T_J$ = -40 °C to 85 °C | | 0.5 | 1.6 | µA |
| **Output** | | | | | | | |
| $V_{OUT}$ | Output voltage range | TPS61099x | | 1.8 | | 5.5 | V |
| $V_{REF}$ | Feedback reference voltage | TPS61099 | $V_{IN}$ < $V_{OUT}$, PWM mode | 0.98 | 1.00 | 1.02 | V |
| | | TPS61099 | $V_{IN}$ < $V_{OUT}$, PFM mode | | 1.03 | | V |
| $V_{OVP}$ | Output overvoltage protection threshold | TPS61099x | $V_{OUT}$ rising | 5.6 | 5.8 | 6.0 | V |
| | OVP hysteresis | TPS61099x | | | 100 | 200 | mV |
| $I_{FB\_LKG}$ | Leakage current into FB pin | TPS61099x | $V_{FB}$ = 1.0 V | | 10 | 50 | nA |
| **Power Switch** | | | | | | | |
| $R_{DS(on)\_LS}$ | Low side switch on resistance | TPS61099x | $V_{OUT}$ = 5.0 V | | 250 | | mΩ |
| | | | $V_{OUT}$ = 3.3 V | | 300 | | mΩ |
| | | | $V_{OUT}$ = 1.8 V | | 400 | | mΩ |
| $R_{DS(on)\_HS}$ | Rectifier on resistance | TPS61099x | $V_{OUT}$ = 5.0 V | | 300 | 350 | mΩ |
| | | | $V_{OUT}$ = 3.3 V | | 350 | 450 | mΩ |
| | | | $V_{OUT}$ = 1.8 V | | 500 | 750 | mΩ |
| $I_{LH}$ | Inductor current ripple | TPS61099x | $V_{OUT}$ = 5.0 V | | 350 | | mA |
| | | | $V_{OUT}$ = 3.3 V | | 300 | | mA |
| | | | $V_{OUT}$ = 1.8 V | | 250 | | mA |
| $I_{LIM}$ | Current limit threshold | TPS61099x | $V_{OUT}$ ≥ 2.5 V, boost operation | 0.8 | 1 | 1.25 | A |
| | | | $V_{OUT}$ < 2.5 V, boost operation | 0.5 | 0.75 | | A |
| $I_{SW\_LKG}$ | Leakage current into SW pin (from SW pin to GND) | TPS61099x | $V_{SW}$ = 5.0 V, no switch, $T_J$ = -40 °C to 85 °C | | | 200 | nA |
| **Control Logic** | | | | | | | |
| $V_{IL}$ | EN input low voltage threshold | TPS61099x | $V_{IN}$ ≤ 1.5 V | 0.2 x VIN | | | V |
| $V_{IH}$ | EN input high voltage threshold | TPS61099x | $V_{IN}$ ≤ 1.5 V | | | 0.8 x VIN | V |
| $V_{IL}$ | EN input low voltage threshold | TPS61099x | $V_{IN}$ > 1.5 V | 0.4 | | | V |
| $V_{IH}$ | EN input high voltage threshold | TPS61099x | $V_{IN}$ > 1.5 V | | | 1.2 | V |
| $I_{EN\_LKG}$ | Leakage current into EN pin | TPS61099x | $V_{EN}$ = 5.0 V | | | 50 | nA |
| | Overtemperature protection | TPS61099x | | | 150 | | °C |
| | Overtemperature hysteresis | TPS61099x | | | 25 | | °C |

## 7.6 Typical Characteristics



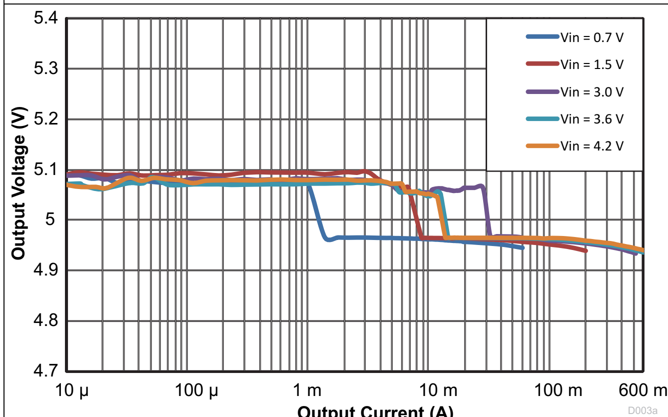

TPS61099, $V_{IN}$ = 0.7 V, 1.5 V, 3.0 V, 3.6 V, 4.2 V, $V_{OUT}$ = 5.0 V

**图 1. Load Efficiency with Different Inputs**



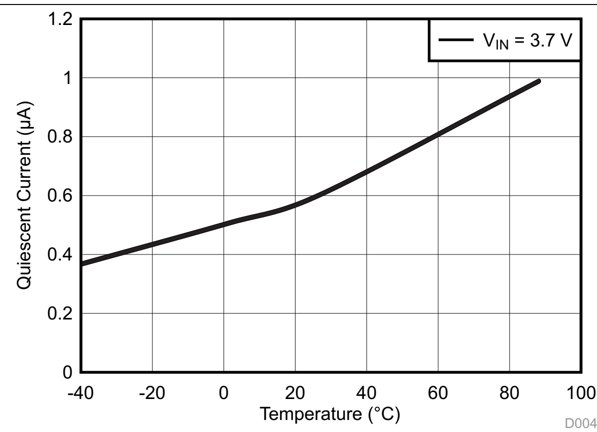

TPS61099, $V_{IN}$ = 2.4 V, $V_{OUT}$ = 3.0 V, 3.6 V, 4.5 V, 5.0 V

**图 2. Load Efficiency with Different Outputs**



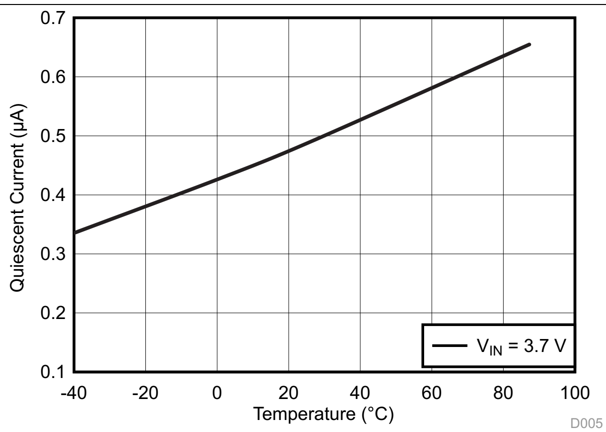

TPS61099, $V_{IN}$ = 0.7 V, 1.5 V, 3.0 V, 3.6 V, 4.2 V, $V_{OUT}$ = 5.0 V

**图 3. Load Regulation**



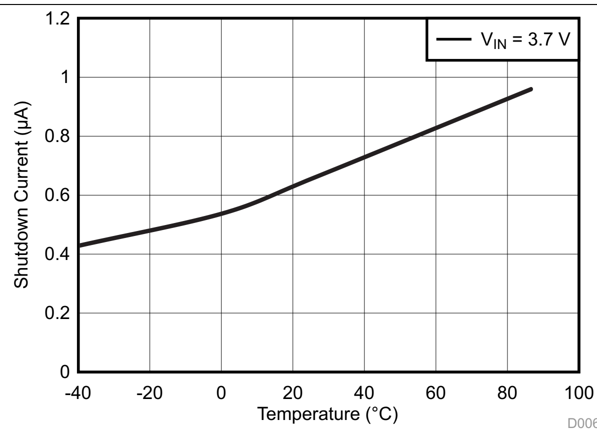

$V_{IN}$ = 3.7 V No Switching

**图 4. Quiescent Current into $V_{OUT}$ vs Temperature**




$V_{IN}$ = 3.7 V No Switching

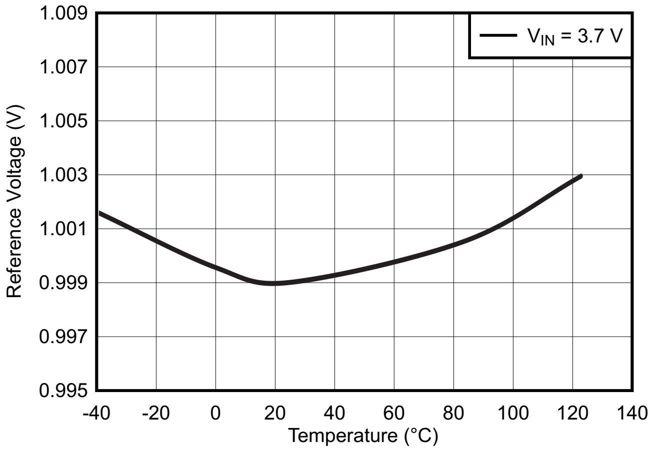
**图 5. Quiescent Current into $V_{IN}$ vs Temperature**




$V_{IN}$ = 3.7 V, Into $V_{IN}$ and SW

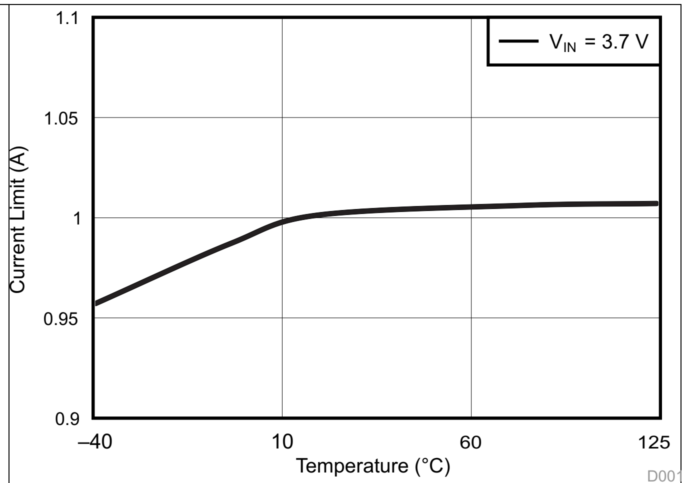
**图 6. Shutdown Current vs Temperature**

## Typical Characteristics (接下页)




TPS61099, $V_{IN}$ = 3.7 V    $T_J$ = –40°C to 125°C

**图 7. Reference Voltage vs Temperature**




$V_{IN}$ = 3.7 V    $T_J$ = –40°C to 125°C

**图 8. Current Limit vs Temperature**

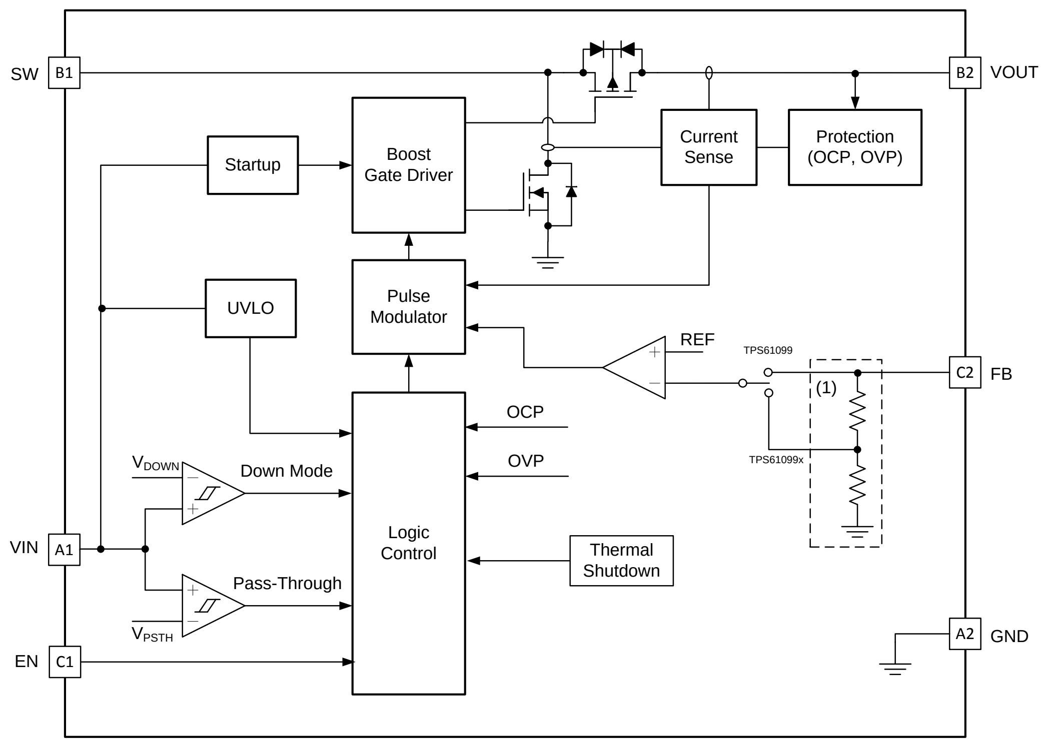
# 8 Detailed Description

## 8.1 Overview

The TPS61099x synchronous step-up converter is designed for alkaline battery, coin-cell battery, Li-ion or Li-polymer battery powered systems, which requires long battery running time and tiny solution size. The TPS61099x can operate with a wide input voltage from 0.7 V to 5.5 V. It only consumes 1 µA quiescent current and can achieve high efficiency under light load condition.

The TPS61099x operates in a hysteretic control scheme with typical 1-A peak switch current limit. The TPS61099x provides the true shutdown function and the load is completely disconnected from the input so as to minimize the leakage current. It also adopts Down Mode and Pass-Through operation when input voltage is close to or higher than the regulated output voltage. The TPS61099x family is available in both adjustable and fixed output voltage versions. Adjustable version offers programmable output voltage for flexible applications while fixed versions offer minimal solution size and achieve up to 75% high efficiency under 10-µA load.

## 8.2 Functional Block Diagrams






(1) Internal FB resistor divider is implemented in fixed output voltage versions.

**图 9. Functional Block Diagram**

## 8.3 Feature Description

### 8.3.1 Boost Controller Operation

The TPS61099x boost converter is controlled by a hysteretic current mode controller. This controller regulates the output voltage by keeping the inductor ripple current constant in the range of 300 mA and adjusting the offset of this inductor current depending on the output load. Since the input voltage, output voltage and inductor value all affect the rising and falling slopes of inductor ripple current, the switching frequency is not fixed and is determined by the operation condition. If the required average input current is lower than the average inductor current defined by this constant ripple, the inductor current goes discontinuously to keep the efficiency high under light load condition. 图 10 illustrates the hysteretic current operation. If the load current is reduced further, the

## Feature Description (接下页)

boost converter enters into Burst mode. In Burst mode, the boost converter ramps up the output voltage with several switching cycles. Once the output voltage exceeds a setting threshold, the device stops switching and goes into a sleep status. In sleep status, the device consumes less quiescent current. It resumes switching when the output voltage is below the setting threshold. It exits the Burst mode when the output current can no longer be supported in this mode. Refer to 图 11 for Burst mode operation details.

To achieve high efficiency, the power stage is realized as a synchronous boost topology. The output voltage $V_{OUT}$ is monitored via an external or internal feedback network which is connected to the voltage error amplifier. To regulate the output voltage, the voltage error amplifier compares this feedback voltage to the internal voltage reference and adjusts the required offset of the inductor current accordingly.

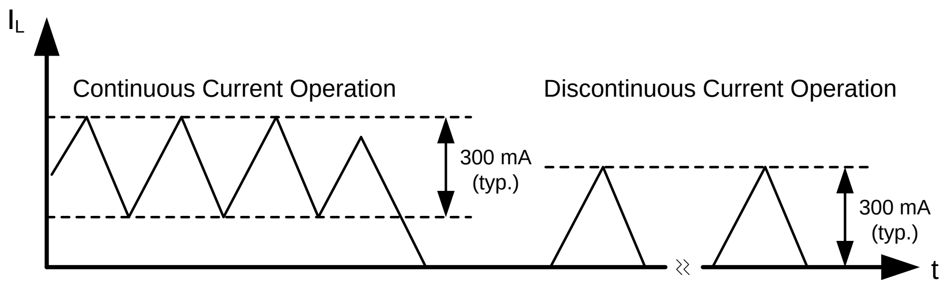



**图 10. Hysteretic Current Operation**

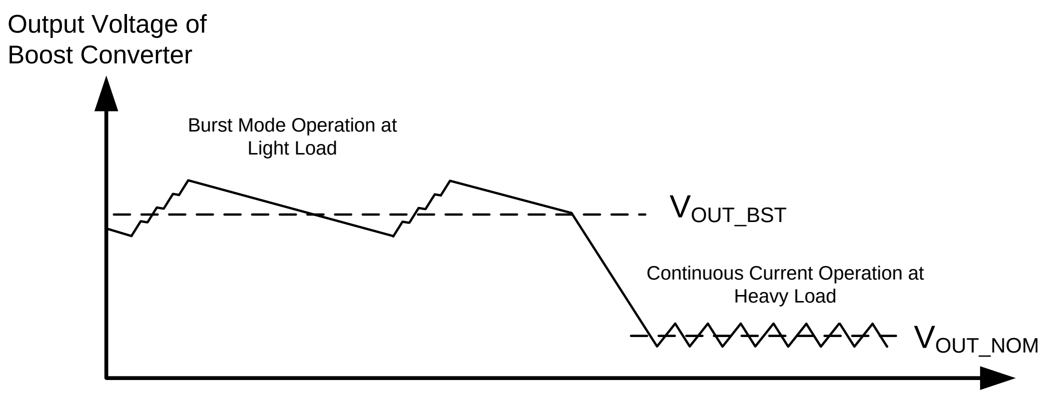



**图 11. Burst Mode Operation**

### 8.3.2 Under-Voltage Lockout

An under-voltage lockout (UVLO) circuit stops the operation of the converter when the input voltage drops below the typical UVLO threshold of 0.4 V. A hysteresis of 200 mV is added so that the device cannot be enabled again until the input voltage goes up to 0.6 V. This function is implemented in order to prevent malfunctioning of the device when the input voltage is between 0.4 V and 0.6 V.

### 8.3.3 Enable and Disable

When the input voltage is above UVLO rising threshold and the EN pin is pulled to high voltage, the TPS61099x is enabled. When the EN pin is pulled to low voltage, the TPS61099x goes into shutdown mode. In shutdown mode, the device stops switching and the rectifying PMOS fully turns off, providing the completed disconnection between input and output. Less than 0.5-µA input current is consumed in shutdown mode.

## Feature Description (接下页)

### 8.3.4 Soft Start

After the EN pin is tied to high voltage, the TPS61099x begins to startup. At the beginning, the device operates at the boundary of Discontinuous Conduction Mode (DCM) and Continuous Conduction Mode (CCM), and the inductor peak current is limited to around 200 mA during this stage. When the output voltage is charged above approximately 1.6 V, the device starts the hysteretic current mode operation. The current limit threshold is gradually increasing to 0.7× $I_{LIM}$ within 500 µs. In this way, the soft start function reduces the inrush current during startup. After $V_{OUT}$ reaches the target value, soft start stage ends and the peak current is now determined by the output of an internal error amplifier which compares the feedback of the output voltage and the internal reference voltage.

The TPS61099x is able to start up with 0.7-V input voltage with larger than 3-kΩ load. However, if the load during startup is so heavy that the TPS61099x fails to charge the output voltage above 1.6 V, the TPS61099x can't start up successfully until the input voltage is increased or the load current is reduced. The startup time depends on input voltage and load current.

### 8.3.5 Current Limit Operation

The TPS61099x employs cycle-by-cycle over-current protection (OCP) function. If the inductor peak current reaches the current limit threshold $I_{LIM}$, the main switch turns off so as to stop further increase of the input current. In this case the output voltage will decrease until the power balance between input and output is achieved. If the output drops below the input voltage, the TPS61099x enters into Down Mode. The peak current is still limited by $I_{LIM}$ cycle-by-cycle in Down Mode. If the output drops below 1.6 V, the TPS61099 enters into startup process again. In Pass-Through operation, current limit function is not enabled.

### 8.3.6 Output Short-to-Ground Protection

The TPS61099x starts to limit the switch current to 200 mA when the output voltage is below 1.6 V. If short-to-ground condition occurs, switch current is limited at 200 mA. Once the short circuit is released, the TPS61099x goes back to soft start again and regulates the output voltage.

### 8.3.7 Over Voltage Protection

TPS61099x has an output over-voltage protection (OVP) to protect the device in case that the external feedback resistor divider is wrongly populated. When the output voltage of the TPS61099 exceeds the OVP threshold of 5.8 V, the device stops switching. Once the output voltage falls 0.1 V below the OVP threshold, the device starts operating again.

### 8.3.8 Down Mode Regulation and Pass-Through Operation

The TPS61099x features Down Mode and Pass-Through operation when input voltage is close to or higher than output voltage.

In the Down Mode, output voltage is regulated at target value even when $V_{IN} > V_{OUT}$. The control circuit changes the behavior of the rectifying PMOS by pulling its gate to input voltage instead of to ground. In this way, the voltage drop across the PMOS is increasing as high as to regulate the output voltage. The power loss also increases in this mode, which needs to be taken into account for thermal consideration.

In the Pass-Through operation, the boost converter stops switching. The rectifying PMOS constantly turns on and low side switch constantly turns off. The output voltage is the input voltage minus the voltage drop across the dc resistance (DCR) of the inductor and the on-resistance of the rectifying PMOS.

With $V_{IN}$ ramping up, the TPS61099x goes into Down Mode first when $V_{IN} > V_{OUT}$ – 50mV. It stays in Down Mode until $V_{IN} > V_{OUT}$ + 0.3V and then goes automatically into Pass-Through operation. In the Pass-Through operation, output voltage follows input voltage. The TPS61099x exits Pass-Through Mode and goes back to Down Mode when $V_{IN}$ ramps down to 103% of the target output voltage. It stays in Down Mode until input voltage falls 100mV below the output voltage, returning to Boost operation.

**Feature Description (接下页)**

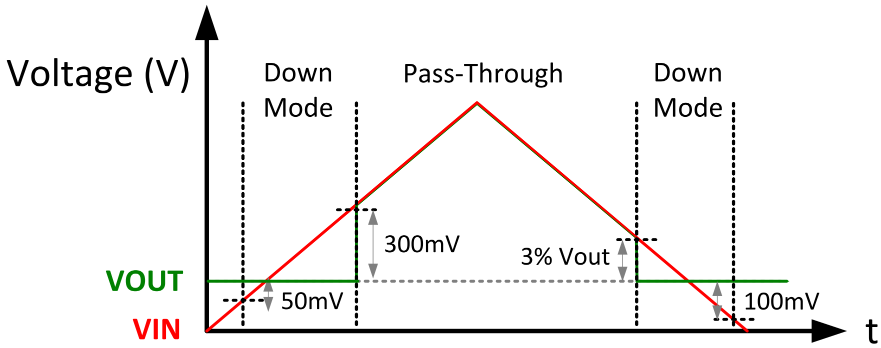



**图 12. Down Mode and Pass-Through Operation**

### 8.3.9 Thermal Shutdown

The TPS61099x has a built-in temperature sensor which monitors the internal junction temperature in boost mode operation. If the junction temperature exceeds the threshold 150°C, the device stops operating. As soon as the junction temperature drops below the shutdown temperature minus the hysteresis, typically 125°C, it starts operating again.

## 8.4 Device Functional Modes

### 8.4.1 Burst Mode Operation under Light Load Condition

The boost converter of TPS61099x enters into Burst Mode operation under light load condition. Refer to *Boost Controller Operation* for details.

### 8.4.2 Down Mode Regulation and Pass-Through Mode Operation

The boost converter of TPS61099x automatically enters into Down Mode or pass-through mode operation when input voltage is higher than the target output voltage. Refer to *Down Mode Regulation and Pass-Through Operation* for details.

# 9 Applications and Implementation

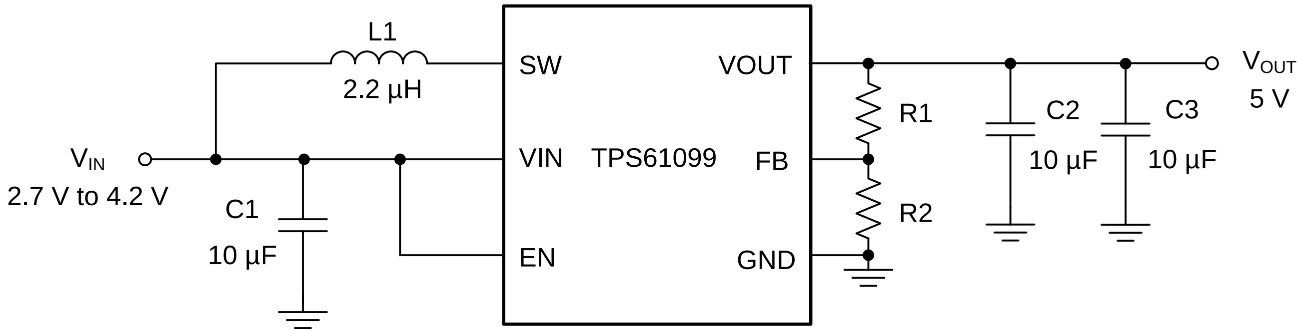
注

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 TPS61099x is a synchronous boost converter designed to operate at a wide input voltage from 0.7 V to 5.5 V with 1-A peak switch current limit. The device adopts a hysteretic control scheme so the operating frequency is not a constant value, which varies with different input/output voltages and inductor values. It only consumes 1-µA quiescent current under light load condition. It also supports true shutdown to disconnect the load from the input in order to minimize the leakage current. Therefore, it is very suitable for alkaline battery, coin-cell battery, Li-ion or Li-polymer battery powered systems to extend the battery running time.

## 9.2 Typical Application - 5 V Output Boost Converter






### 9.2.1 Design Requirements

A typical application example is the memory LCD, which normally requires 5-V output as its bias voltage and only consumes less than 1 mA current. The following design procedure can be used to select external component values for the TPS61099x.

**表 1. Design Requirements**

| PARAMETERS | VALUES |
|---|---|
| Input Voltage | 2.7 V ~ 4.2 V |
| Output Voltage | 5 V |
| Output Current | 1 mA |
| Output Voltage Ripple | ± 50 mV |

#### *9.2.1.1 Detailed Design Procedure*

##### 9.2.1.1.1 Programming the Output Voltage

There are two ways to set the output voltage of the TPS61099x. For adjustable output voltage version, select the external resistor divider R1 and R2, as shown in 公式 1, the output voltage is programmed to the desired value. When the output voltage is regulated, the typical voltage at the FB pin is $V_{REF}$ of 1.0 V.

$$V_{OUT} = V_{REF} \cdot \frac{R1+R2}{R2} \tag{1}$$

For fixed output voltage versions, the FB pin should be connected to the $V_{OUT}$ pin directly. The TPS61099x offers diverse fixed voltage versions, refer to *Device Comparison Table* for version details.

In this example, 5-V output is required to bias the memory LCD. For the best accuracy, the current following through R2 should be 100 times larger than FB pin leakage current. Changing R2 towards a lower value increases the robustness against noise injection. Changing R2 towards higher values reduces the FB divider current for achieving the highest efficiency at low load currents. 1-MΩ and 249-kΩ resistors are selected for R1 and R2 in this example. High accuracy resistors are recommended for better output voltage accuracy.

#### 9.2.1.1.2 Maximum Output Current

The maximum output capability of the TPS61099x is determined by the input to output ratio and the current limit of the boost converter. It can be estimated by 公式 2.

$$I_{OUT(max)} = \frac{V_{IN} \cdot (I_{LIM} - \frac{I_{LH}}{2}) \cdot \eta}{V_{OUT}}$$

where

- $\eta$ is the conversion efficiency, use 85% for estimation
- $I_{LH}$ is the current ripple value
- $I_{LIM}$ is the switch current limit (2)

Minimum input voltage, maximum boost output voltage and minimum current limit $I_{LIM}$ should be used as the worst case condition for the estimation.

#### 9.2.1.1.3 Inductor Selection

Because the selection of the inductor affects steady state operation, transient behavior, and loop stability, the inductor is the most important component in power regulator design. There are three important inductor specifications, inductor value, saturation current, and dc resistance (DCR).

The TPS61099x is optimized to work with inductor values between 1 µH and 2.2 µH. For best stability consideration, a 2.2-µH inductor is recommended under Vout > 3.0V condition while choosing a 1-µH inductor for applications under Vout ≤ 3.0V condition. Follow 公式 3 and 公式 4 to calculate the inductor's peak current for the application. Depending on different load conditions, the TPS61099x works in continuous current mode or discontinuous mode. In different modes, the peak currents of the inductor are also different. 公式 3 provides an easy way to estimate whether the device works in CCM or DCM. As long as the 公式 3 is true, continuous current mode is typically established. Otherwise, discontinuous current mode is typically established.

$$\frac{V_{OUT} \cdot I_{OUT}}{V_{IN} \times \eta} > \frac{I_{LH}}{2} \tag{3}$$

The inductor current ripple $I_{LH}$ is fixed by design. Therefore, the peak inductor current is calculated with 公式 4.

$$I_{L,peak} = \frac{V_{OUT} \cdot I_{OUT}}{V_{IN} \times \eta} + \frac{I_{LH}}{2}; \quad \text{continuous current mode operation}$$

$$I_{L,peak} = I_{LH}; \quad \text{discontinuous current mode operation}$$

where

- $I_{L,peak}$ is the peak inductor current. (4)

The inductor's saturation current must be higher than the calculated peak inductor current. 表 2 lists the recommended inductors for TPS61099x device.

After choosing the inductor, the estimated switching frequency *f* in continuous current mode can be calculated by 公式 5. The switching frequency is not a constant value, which is determined by L, $V_{IN}$ and $V_{OUT}$.

$$f = \frac{V_{IN} \cdot (V_{OUT} - V_{IN} \cdot \eta)}{L \cdot I_{LH} \cdot V_{OUT}} \tag{5}$$

表 2. List of Inductors[1]

| VOUT [V] | INDUCTANCE [µH] | SATURATION CURRENT [A] | DC RESISTANCE [mΩ] | SIZE (LxWxH) | PART NUMBER | MANUFACTURER |
|---|---|---|---|---|---|---|
| > 3.0 | 2.2 | 1.95 | 80 | 2.5 x 2.0 x 1.2 | 74404024022 | Würth Elektronik |
| | 2.2 | 1.7 | 92 | 2.5 x 2.0 x 1.1 | LQH2HPN2R2MJR | muRata |
| | 2.2 | 1.45 | 163 | 2.0 x 1.6 x 1.0 | VLS201610CX-2R2M | TDK |
| ≤ 3.0 | 1.0 | 2.6 | 37 | 2.5 x 2.0 x 1.2 | 74404024010 | Würth Elektronik |
| | 1.0 | 2.3 | 48 | 2.5 x 2.0 x 1.0 | MLP2520W1R0MT0S1 | TDK |
| | 1.0 | 1.5 | 80 | 2.0 x 1.2 x 1.0 | LQM21PN1R0MGH | muRata |

(1) See *Third-Party Products* disclaimer

#### 9.2.1.1.4 Capacitor Selection

For best output and input voltage filtering, low ESR X5R or X7R ceramic capacitors are recommended.

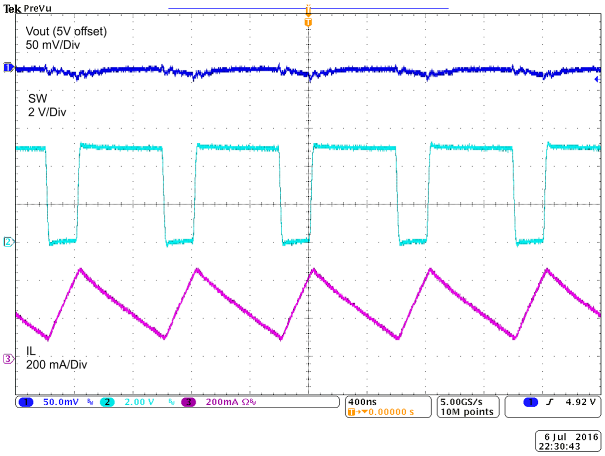
The input capacitor minimizes input voltage ripple, suppresses input voltage spikes and provides a stable system rail for the device. An input capacitor value of 10 µF is normally recommended to improve transient behavior of the regulator and EMI behavior of the total power supply circuit. A ceramic capacitor placed as close as possible to the VIN and GND pins of the IC is recommended.

For the output capacitor of VOUT pin, small ceramic capacitors are recommended, placed as close as possible to the VOUT and GND pins of the IC. If, for any reason, the application requires the use of large capacitors which cannot be placed close to the IC, the use of a small ceramic capacitor with a capacitance value of 1 µF in parallel to the large one is recommended. This small capacitor should be placed as close as possible to the VOUT and GND pins of the IC.

From the power stage point of view, the output capacitor sets the corner frequency of the converter while the inductor creates a Right-Half-Plane-Zero. Consequently, with a larger inductor, a larger output capacitor must be used. The TPS61099x is optimized to work with the inductor from 1 µH to 2.2 µH, so the minimal output capacitor value is 20 µF (nominal value). Increasing the output capacitor makes the output ripple smaller in PWM mode.

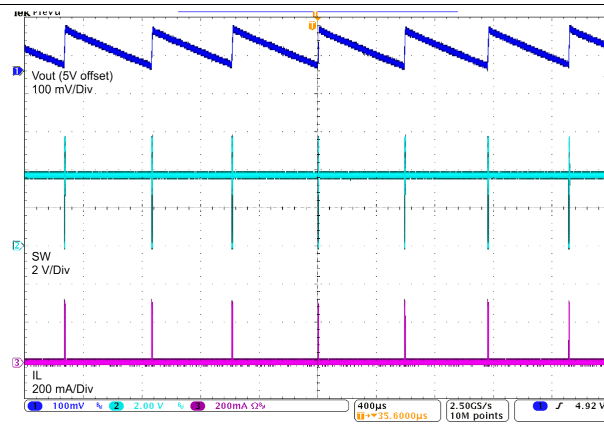
When selecting capacitors, ceramic capacitor’s derating effect under bias should be considered. Choose the right nominal capacitance by checking capacitor's DC bias characteristics. In this example, GRM188R60J106ME84D, which is a 10-µF ceramic capacitor with high effective capacitance value at DC biased condition, is selected for $V_{OUT}$ rail. The performance of TPS61099x is shown in *Application Curves* section.

### *9.2.1.2 Application Curves*



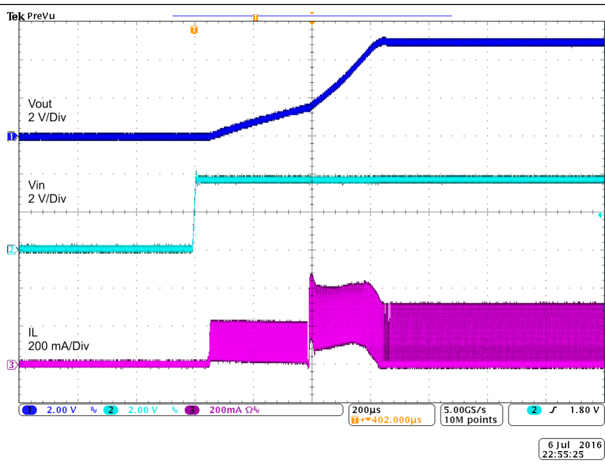

$V_{IN}$ = 3.7 V　$V_{OUT}$ = 5 V　$I_{OUT}$ = 200 mA

**图 13. Switching Waveform at Heavy Load**



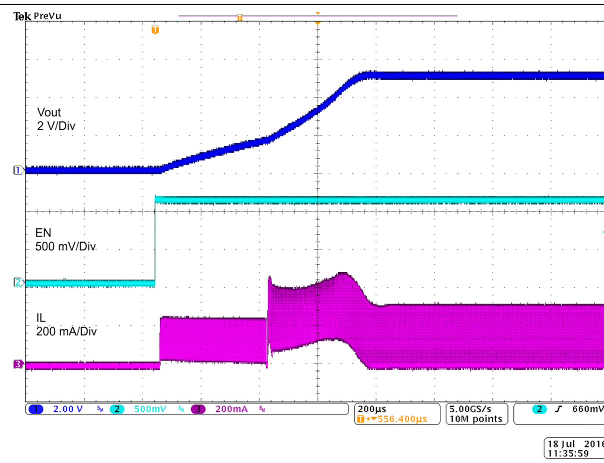

$V_{IN}$ = 3.7 V　$V_{OUT}$ = 5 V　$I_{OUT}$ = 10 mA

**图 14. Switching Waveform at Light Load**



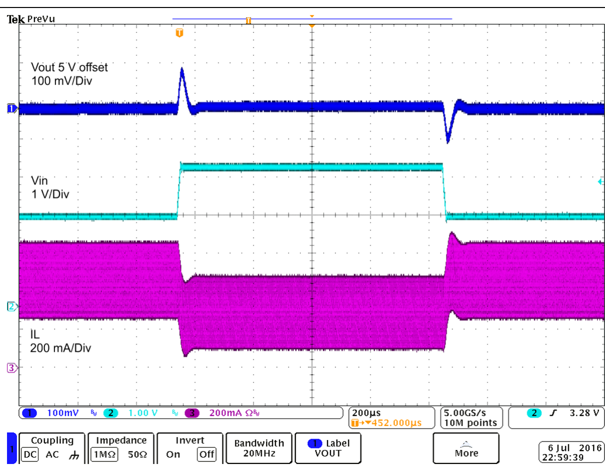

$V_{IN}$ = 3.7 V　$V_{OUT}$ = 5 V　$I_{OUT}$ = 50 mA

**图 15. Startup by $V_{IN}$**



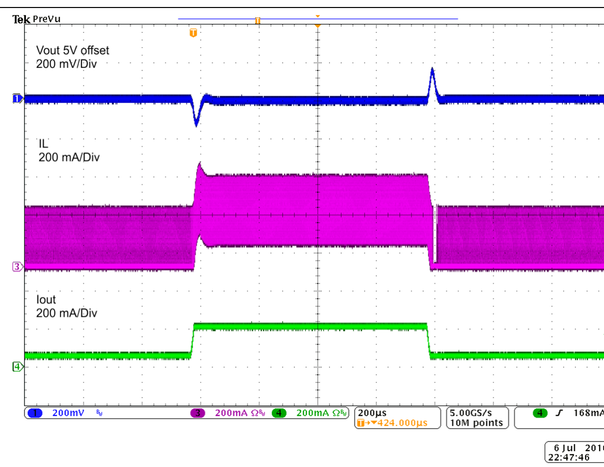

$V_{IN}$ = 3.7 V　$V_{OUT}$ = 5 V　$I_{OUT}$ = 100 mA

**图 16. Startup by EN**



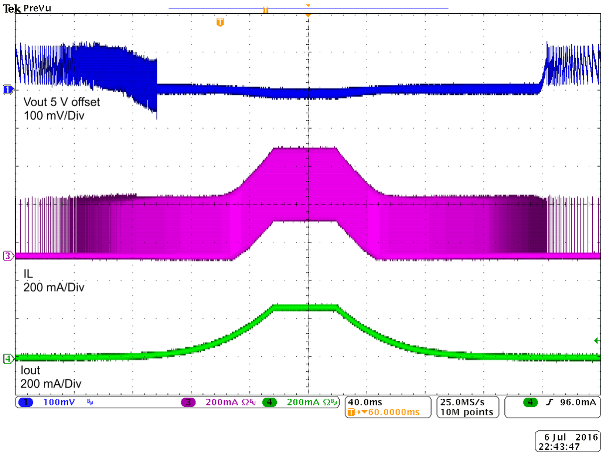

$V_{IN}$ = 2.4 V to 3.7 V　$V_{OUT}$ = 5 V　$I_{OUT}$ = 200 mA

**图 17. Line Transient**



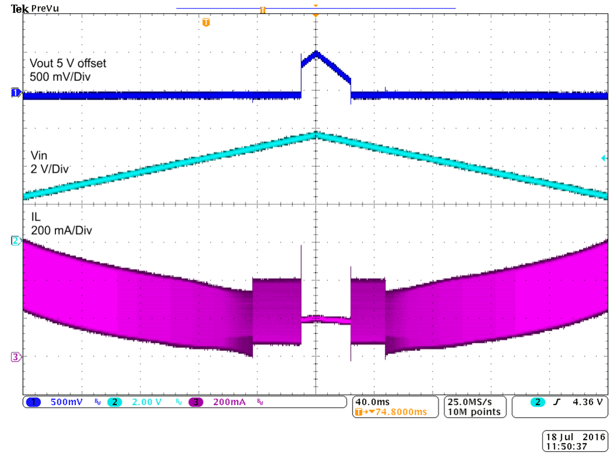

$V_{IN}$ = 3.7 V　$V_{OUT}$ = 5 V　$I_{OUT}$ = 50 mA to 200 mA

**图 18. Load Transient**




$V_{IN}$ = 3.7 V $V_{OUT}$ = 5 V $I_{OUT}$ = 0 mA to 250 mA

**图 19. Load Regulation**




$V_{IN}$ = 2.4 to 5.5 V $V_{OUT}$ = 5 V $I_{OUT}$ = 200 mA

**图 20. Line Regulation**

## 10 Power Supply Recommendations

The TPS61099x family is designed to operate from an input voltage supply range between 0.7 V to 5.5 V. The power supply can be alkaline battery, NiMH rechargeable battery, Li-Mn battery or rechargeable Li-Ion battery. The input supply should be well regulated with the rating of TPS61099x.

# 11 Layout

## 11.1 Layout Guidelines

As for all switching power supplies, the layout is an important step in the design, especially at high peak currents and high switching frequencies. If the layout is not carefully done, the regulator could show stability problems as well as EMI problems. Therefore, use wide and short traces for the main current path and for the power ground paths. The input and output capacitor, as well as the inductor should be placed as close as possible to the IC.

## 11.2 Layout Example

The bottom layer is a large GND plane connected by vias.

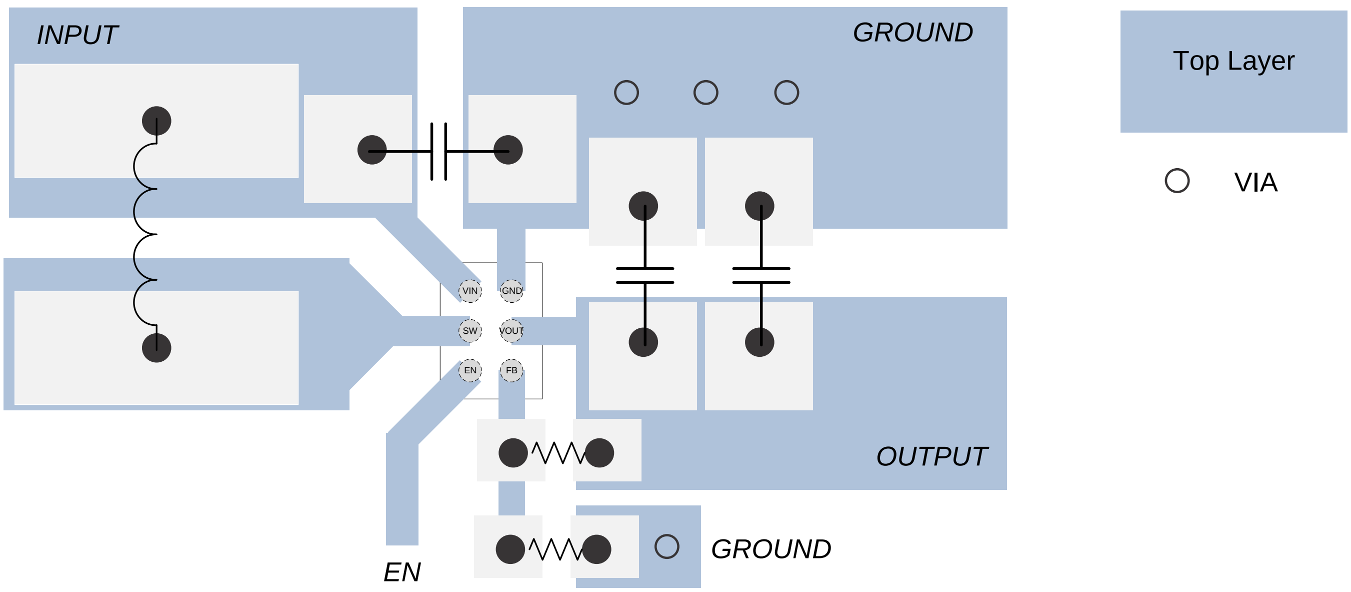



**图 21. Layout**

# 12 器件和文档支持

## 12.1 器件支持

### 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 文档支持

### 12.2.1 相关文档

相关文档请参见以下部分：

- *《执行精确的 PFM 模式效率测量》*，SLVA236
- *《精确测量超低 IQ 器件的效率》*，SLYT558
- *《IQ：它是什么、不是什么以及如何使用》*，SLYT412

## 12.3 接收文档更新通知

如需接收文档更新通知，请访问 www.ti.com.cn 网站上的器件产品文件夹。点击右上角的*提醒我* (Alert me) 注册后，即可每周定期收到已更改的产品信息。有关更改的详细信息，请查阅已修订文档中包含的修订历史记录。

## 12.4 社区资源

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.

## 12.5 商标

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

## 12.6 静电放电警告

这些装置包含有限的内置 ESD 保护。 存储或装卸时，应将导线一起截短或将装置放置于导电泡棉中，以防止 MOS 门极遭受静电损伤。

## 12.7 Glossary

SLYZ022 — *TI Glossary*.

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

# 13 机械、封装和可订购信息

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

# 重要声明



| | 产品 | | 应用 |
|---|---|---|---|
| 数字音频 | www.ti.com.cn/audio | 通信与电信 | www.ti.com.cn/telecom |
| 放大器和线性器件 | www.ti.com.cn/amplifiers | 计算机及周边 | www.ti.com.cn/computer |
| 数据转换器 | www.ti.com.cn/dataconverters | 消费电子 | www.ti.com/consumer-apps |
| DLP® 产品 | www.dlp.com | 能源 | www.ti.com/energy |
| DSP - 数字信号处理器 | www.ti.com.cn/dsp | 工业应用 | www.ti.com.cn/industrial |
| 时钟和计时器 | www.ti.com.cn/clockandtimers | 医疗电子 | www.ti.com.cn/medical |
| 接口 | www.ti.com.cn/interface | 安防应用 | www.ti.com.cn/security |
| 逻辑 | www.ti.com.cn/logic | 汽车电子 | www.ti.com.cn/automotive |
| 电源管理 | www.ti.com.cn/power | 视频和影像 | www.ti.com.cn/video |
| 微控制器 (MCU) | www.ti.com.cn/microcontrollers | | |
| RFID 系统 | www.ti.com.cn/rfidsys | | |
| OMAP应用处理器 | www.ti.com/omap | | |
| 无线连通性 | www.ti.com.cn/wirelessconnectivity | 德州仪器在线技术支持社区 | www.deyisupport.com |

邮寄地址： 上海市浦东新区世纪大道1568 号，中建大厦32 楼邮政编码： 200122

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TPS610994YFFR | PREVIEW | DSBGA | YFF | 6 | 3000 | TBD | Call TI | Call TI | -40 to 85 | | |
| TPS610994YFFT | PREVIEW | DSBGA | YFF | 6 | 250 | TBD | Call TI | Call TI | -40 to 85 | | |
| TPS610997YFFR | ACTIVE | DSBGA | YFF | 6 | 3000 | Green (RoHS & no Sb/Br) | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | 14K | Samples |
| TPS610997YFFT | ACTIVE | DSBGA | YFF | 6 | 250 | Green (RoHS & no Sb/Br) | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | 14K | Samples |
| TPS61099YFFR | ACTIVE | DSBGA | YFF | 6 | 3000 | Green (RoHS & no Sb/Br) | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | 12G | Samples |
| TPS61099YFFT | ACTIVE | DSBGA | YFF | 6 | 250 | Green (RoHS & no Sb/Br) | SNAGCU | Level-1-260C-UNLIM | -40 to 85 | 12G | Samples |

(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.

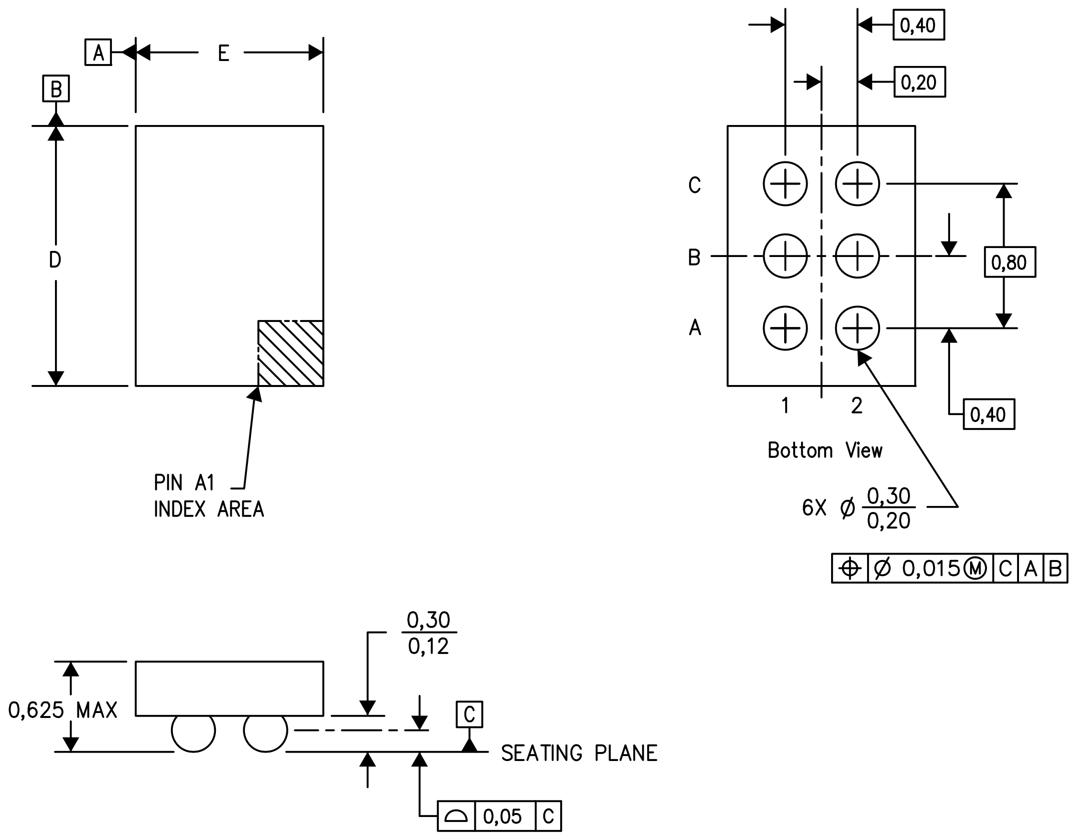
(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(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.

**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.

YFF (R–XBGA–N6) DIE–SIZE BALL GRID ARRAY




D: Max = 1.256 mm, Min =1.196 mm

E: Max = 0.914 mm, Min =0.854 mm

4207625–4/A0 12/13

NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
- B. This drawing is subject to change without notice.
- C. NanoFree™ package configuration.

NanoFree is a trademark of Texas Instruments.

# 重要声明

德州仪器(TI) 及其下属子公司有权根据 JESD46 最新标准, 对所提供的产品和服务进行更正、修改、增强、改进或其它更改， 并有权根据 JESD48 最新标准中止提供任何产品和服务。客户在下订单前应获取最新的相关信息, 并验证这些信息是否完整且是最新的。所有产品的销售都遵循在订单确认时所提供的TI 销售条款与条件。

TI 保证其所销售的组件的性能符合产品销售时 TI 半导体产品销售条件与条款的适用规范。仅在 TI 保证的范围内，且 TI 认为 有必要时才会使用测试或其它质量控制技术。除非适用法律做出了硬性规定，否则没有必要对每种组件的所有参数进行测试。

TI 对应用帮助或客户产品设计不承担任何义务。客户应对其使用 TI 组件的产品和应用自行负责。为尽量减小与客户产品和应 用相关的风险，客户应提供充分的设计与操作安全措施。

TI 不对任何 TI 专利权、版权、屏蔽作品权或其它与使用了 TI 组件或服务的组合设备、机器或流程相关的 TI 知识产权中授予 的直接或隐含权限作出任何保证或解释。TI 所发布的与第三方产品或服务有关的信息，不能构成从 TI 获得使用这些产品或服 务的许可、授权、或认可。使用此类信息可能需要获得第三方的专利权或其它知识产权方面的许可，或是 TI 的专利权或其它 知识产权方面的许可。

对于 TI 的产品手册或数据表中 TI 信息的重要部分，仅在没有对内容进行任何篡改且带有相关授权、条件、限制和声明的情况 下才允许进行复制。TI 对此类篡改过的文件不承担任何责任或义务。复制第三方的信息可能需要服从额外的限制条件。

在转售 TI 组件或服务时，如果对该组件或服务参数的陈述与 TI 标明的参数相比存在差异或虚假成分，则会失去相关 TI 组件 或服务的所有明示或暗示授权，且这是不正当的、欺诈性商业行为。TI 对任何此类虚假陈述均不承担任何责任或义务。

客户认可并同意，尽管任何应用相关信息或支持仍可能由 TI 提供，但他们将独力负责满足与其产品及在其应用中使用 TI 产品 相关的所有法律、法规和安全相关要求。客户声明并同意，他们具备制定与实施安全措施所需的全部专业技术和知识，可预见 故障的危险后果、监测故障及其后果、降低有可能造成人身伤害的故障的发生机率并采取适当的补救措施。客户将全额赔偿因 在此类安全关键应用中使用任何 TI 组件而对 TI 及其代理造成的任何损失。

在某些场合中，为了推进安全相关应用有可能对 TI 组件进行特别的促销。TI 的目标是利用此类组件帮助客户设计和创立其特 有的可满足适用的功能安全性标准和要求的终端产品解决方案。尽管如此，此类组件仍然服从这些条款。

TI 组件未获得用于 FDA Class III（或类似的生命攸关医疗设备）的授权许可，除非各方授权官员已经达成了专门管控此类使 用的特别协议。

只有那些 TI 特别注明属于军用等级或“增强型塑料”的 TI 组件才是设计或专门用于军事/航空应用或环境的。购买者认可并同 意，对并非指定面向军事或航空航天用途的 TI 组件进行军事或航空航天方面的应用，其风险由客户单独承担，并且由客户独 力负责满足与此类使用相关的所有法律和法规要求。

TI 已明确指定符合 ISO/TS16949 要求的产品，这些产品主要用于汽车。在任何情况下，因使用非指定产品而无法达到 ISO/TS16949 要求，TI不承担任何责任。

| | 产品 | | 应用 |
|---|---|---|---|
| 数字音频 | www.ti.com.cn/audio | 通信与电信 | www.ti.com.cn/telecom |
| 放大器和线性器件 | www.ti.com.cn/amplifiers | 计算机及周边 | www.ti.com.cn/computer |
| 数据转换器 | www.ti.com.cn/dataconverters | 消费电子 | www.ti.com/consumer-apps |
| DLP® 产品 | www.dlp.com | 能源 | www.ti.com/energy |
| DSP - 数字信号处理器 | www.ti.com.cn/dsp | 工业应用 | www.ti.com.cn/industrial |
| 时钟和计时器 | www.ti.com.cn/clockandtimers | 医疗电子 | www.ti.com.cn/medical |
| 接口 | www.ti.com.cn/interface | 安防应用 | www.ti.com.cn/security |
| 逻辑 | www.ti.com.cn/logic | 汽车电子 | www.ti.com.cn/automotive |
| 电源管理 | www.ti.com.cn/power | 视频和影像 | www.ti.com.cn/video |
| 微控制器 (MCU) | www.ti.com.cn/microcontrollers | | |
| RFID 系统 | www.ti.com.cn/rfidsys | | |
| OMAP应用处理器 | www.ti.com/omap | | |
| 无线连通性 | www.ti.com.cn/wirelessconnectivity | 德州仪器在线技术支持社区 | www.deyisupport.com |

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265