TPS61291 Low Iq Boost Converter with Bypass Operation

1 Features

- Input Voltage Range 0.9V to 5V
- Startup Voltage 1.5V at 20mA Load
- Pin Selectable Output Voltages: 3.3V, 3V, 2.5V
- 15nA typical Quiescent Current in Bypass Mode
- 5.7μA typical Quiescent Current in Boost Mode
- Bypass Switch from VIN to VOUT
- I\textsubscript{OUT} > 200mA at 3.3V V\textsubscript{OUT}, V\textsubscript{IN} = 1.8V
- Internal Feedback Divider Disconnect (Bypass Mode)
- Controlled Bypass Transition Prevents Reverse Current into Battery
- Power-Save Mode at Light Loads
- Overtemperature Protection
- Redundant Overvoltage Protection
- Small 2mm x 2mm SON 6-pin package

2 Applications

- Metering (Gas, Water, Smart Meters)
- Remote Controls
- Home Security / Home Automation
- Single 3V Li-MnO\textsubscript{2} or 2 x 1.5V Alkaline Cell
- Powered Applications

3 Description

The TPS61291 is a boost converter with pin selectable output voltages and an integrated bypass mode. In bypass operation, the device provides a direct path from the input to the system and allows a low power micro controller (MCU) such as the MSP430 to operate directly from a single 3V Li-MnO\textsubscript{2} battery or dual alkaline battery cells.

In bypass mode the integrated feedback divider network for boost mode operation is disconnected from the output and the quiescent current consumption drops down to only 15nA (typical).

In boost mode the device provides a minimum output current of 200mA at 3.3V V\textsubscript{OUT} from 1.8V V\textsubscript{IN}. The boost mode is used for system components which require a regulated supply voltage and cannot directly operate from the input source. The boost converter is based on a current-mode controller using synchronous rectification to obtain maximum efficiency and consumes typically 5.7μA from the output. During startup of the boost converter, the VSEL pin is read out and the integrated feedback network sets the output voltage to 2.5V, 3V or 3.3V.

Bypass mode or boost mode operation is controlled by the system via the EN/BYP pin.

The device integrates an enhanced bypass mode control to prevent charge, stored in the output capacitor during boost mode operation, from flowing back to the input and charging the battery.

The device is packaged in a small 6-pin SON package (DRV) measuring 2.0mm x 2.00mm x 0.75mm.

Device Information(1)

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE (NOM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS61291</td>
<td>SON (6)</td>
<td>2.00 mm x 2.00 mm</td>
</tr>
</tbody>
</table>

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

Simplified Schematic and Efficiency Curves
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4 Revision History

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

Changes from Original (September 2014) to Revision A

<table>
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<th>Page</th>
</tr>
</thead>
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<tr>
<td>• Changed &quot;Bypass Mode Operation&quot; description</td>
<td>9</td>
</tr>
<tr>
<td>• Added sub-section &quot;Controlled Transition into Bypass Mode&quot;</td>
<td>9</td>
</tr>
<tr>
<td>• Added NOTE to the &quot;Application and Implementation&quot; section.</td>
<td>10</td>
</tr>
<tr>
<td>• Changed &quot;List of Inductors&quot; table</td>
<td>11</td>
</tr>
</tbody>
</table>
5 Pin Configuration and Functions

<table>
<thead>
<tr>
<th>PIN NAME</th>
<th>I/O</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW</td>
<td>I</td>
<td>Switch node of the converter. Connect the inductor between this pin and the input capacitor ( C_{IN} ).</td>
</tr>
<tr>
<td>VOUT</td>
<td>O</td>
<td>Boost converter output. Connect the output capacitor ( C_{OUT} ) between this pin and GND close to the device.</td>
</tr>
<tr>
<td>VIN</td>
<td>PWR</td>
<td>Input voltage supply pin for the boost converter. Connect the input capacitor ( C_{IN} ) between this pin and GND as close as possible to the device.</td>
</tr>
<tr>
<td>EN/BYP</td>
<td>I</td>
<td>Control pin of the device. A high level enables the boost mode operation. A low level disables the boost converter and enables bypass mode operation. EN/BYP must be actively terminated high or low. Usually, this pin is controlled by the MCU in the system.</td>
</tr>
<tr>
<td>VSEL</td>
<td>I</td>
<td>Output voltage selection pin. The logic level of this pin is read out during startup and internally latched. Connect this pin only to GND, VOUT, or leave it floating.</td>
</tr>
<tr>
<td>GND</td>
<td>PWR</td>
<td>Ground pin of the device.</td>
</tr>
<tr>
<td>EXPOSED THERMAL PAD</td>
<td>NC</td>
<td>Not electrically connected to the IC, but must be soldered to achieve specified thermal performance. Connect this pad to the GND pin and use it as a central GND plane.</td>
</tr>
</tbody>
</table>

Output Voltage Setting

<table>
<thead>
<tr>
<th>EN/BYP Pin</th>
<th>VSEL Pin at Startup</th>
<th>( V_{OUT} )</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>high</td>
<td>GND</td>
<td>3.3V</td>
<td>Boost Mode Operation</td>
</tr>
<tr>
<td>high</td>
<td>VOUT</td>
<td>3.0V</td>
<td>Boost Mode Operation</td>
</tr>
<tr>
<td>high</td>
<td>floating</td>
<td>2.5V</td>
<td>Bypass Mode Operation</td>
</tr>
<tr>
<td>low</td>
<td>GND / VOUT / floating</td>
<td>( V_{OUT} = V_{IN} ) (Bypass Mode)</td>
<td>Bypass Mode Operation</td>
</tr>
</tbody>
</table>
6 Specifications

6.1 Absolute Maximum Ratings
over operating free-air temperature range (unless otherwise noted) \(^{(1)}\)

<table>
<thead>
<tr>
<th>Pin Voltage Range</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIN</td>
<td>-0.3</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>SW</td>
<td>-0.3</td>
<td>7</td>
<td>V</td>
</tr>
<tr>
<td>EN/BYP, VOUT</td>
<td>-0.3</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>VSEL</td>
<td>-0.3</td>
<td>VOUT + 0.3 V</td>
<td></td>
</tr>
<tr>
<td>Output Current</td>
<td></td>
<td>250 mA</td>
<td></td>
</tr>
<tr>
<td>TJ</td>
<td></td>
<td>-40 150 °C</td>
<td></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.

All voltage values are with respect to network ground terminal GND.

6.2 Handling Ratings

<table>
<thead>
<tr>
<th>T_{stg} Storage temperature range</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_{(ESD)} Electrostatic discharge</td>
<td></td>
<td></td>
<td></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.

6.3 Recommended Operating Conditions
over operating free-air temperature range (unless otherwise noted)

<table>
<thead>
<tr>
<th>V_{IN} Supply voltage for startup</th>
<th>MIN</th>
<th>NOM</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage range (once device has started)</td>
<td>0.9</td>
<td>5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Supply voltage range for step up conversion (once device has started)</td>
<td>0.9</td>
<td>V_{OUT}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T_A Operating ambient temperature</td>
<td>-40</td>
<td>85</td>
<td>°C</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>

6.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC(^{(1)})</th>
<th>TPS61291</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>R_{JA} Junction-to-ambient thermal resistance</td>
<td>71.2</td>
<td>°C/W</td>
</tr>
<tr>
<td>R_{JCTop} Junction-to-case (top) thermal resistance</td>
<td>93.5</td>
<td></td>
</tr>
<tr>
<td>R_{JB} Junction-to-board thermal resistance</td>
<td>46.7</td>
<td></td>
</tr>
<tr>
<td>( \psi_{JT} ) Junction-to-top characterization parameter</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>( \psi_{JB} ) Junction-to-board characterization parameter</td>
<td>41.1</td>
<td></td>
</tr>
<tr>
<td>R_{JCbott} Junction-to-case (bottom) thermal resistance</td>
<td>11.1</td>
<td></td>
</tr>
</tbody>
</table>

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

$T_A = -40°C$ to $85°C$. Typical values are at $T_A = 25°C$ (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>SUPPLY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{IN}$</td>
<td>Startup voltage</td>
<td>$V_{OUT} = 3.3V, I_{OUT} = 20mA$</td>
<td></td>
<td>1.5</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Input voltage range</td>
<td>Operating voltage range</td>
<td>0.9</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>$I_Q$</td>
<td>Quiescent current in boost mode</td>
<td>$V_{IN}$</td>
<td>$I_{OUT} = 0 mA, V_{EN/BYP} = V_{IN} = 1.8V, V_{OUT} = 3.3V, device not switching$</td>
<td>0.4</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Quiescent current in bypass mode</td>
<td>$V_{IN}$</td>
<td>$V_{EN/BYP} = low, V_{IN} = 3V, I_{OUT} = 0mA$</td>
<td>5.7</td>
<td>9</td>
</tr>
<tr>
<td>$I_{LSW}$</td>
<td>Leakage current into SW</td>
<td>$V_{EN/BYP} = low, V_{IN} = 1.2V, V_{SW} = 1.2V$</td>
<td>0.01</td>
<td>0.5</td>
<td>μA</td>
</tr>
<tr>
<td>$V_{UVLO}$</td>
<td>Undervoltage lockout threshold</td>
<td>$V_{IN}$ decreasing</td>
<td>0.65</td>
<td>0.9</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Overtemperature protection</td>
<td>$T_J$ rising</td>
<td>140</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td></td>
<td>Overtemperature hysteresis</td>
<td></td>
<td>20</td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td><strong>INPUTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{IN}$</td>
<td>EN/BYP, input current</td>
<td>EN/BYP = low or EN/BYP = $V_{IN}$</td>
<td>0.01</td>
<td>0.1</td>
<td>μA</td>
</tr>
<tr>
<td>$V_{IL}$</td>
<td>EN/BYP, input low voltage</td>
<td>$V_{IN} \leq 1.5V$</td>
<td>0.2 $\times V_{IN}$</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$5V &gt; V_{IN} &gt; 1.5V$</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{IH}$</td>
<td>EN/BYP, input high voltage</td>
<td>$V_{IN} \leq 1.5V$</td>
<td>0.8 $\times V_{IN}$</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$5V &gt; V_{IN} &gt; 1.5V$</td>
<td>1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{IL}$</td>
<td>VSEL, input low voltage</td>
<td>$V_{EN/BYP} = high$</td>
<td>0.3</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{IH}$</td>
<td>VSEL, input high voltage</td>
<td>$V_{EN/BYP} = high$</td>
<td>$V_{OUT} - 0.3$</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$I_{IN}$</td>
<td>VSEL, input current</td>
<td>$V_{EN/BYP} = high, VSEL = VOUT = 3V$</td>
<td>0.01</td>
<td>0.1</td>
<td>μA</td>
</tr>
<tr>
<td><strong>POWER SWITCHES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_{DS(ON)}$</td>
<td>Rectifying switch on resistance</td>
<td>$V_{OUT} = 3.3V$</td>
<td>0.6</td>
<td>Ω</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Main switch on resistance</td>
<td>$V_{OUT} = 3.3V$</td>
<td>0.4</td>
<td>Ω</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bypass switch on resistance</td>
<td>$V_{IN} = 1.8V, I_{OUT} = 50mA, EN/BYP = low$</td>
<td>1.2</td>
<td>Ω</td>
<td></td>
</tr>
<tr>
<td>$I_{SW}$</td>
<td>Switch current limit</td>
<td>$V_{OUT} = 3.3V$</td>
<td>700</td>
<td>1000</td>
<td>1300</td>
</tr>
<tr>
<td><strong>OUTPUT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{OUT}$</td>
<td>Output voltage accuracy</td>
<td>$V_{IN} = 1.8V, I_{OUT} = 10mA, V_{OUT} = 3.3V, 3.0V, 2.5V, EN/BYP = high$</td>
<td>-2</td>
<td>+1</td>
<td>+4</td>
</tr>
<tr>
<td></td>
<td>Line regulation</td>
<td>$V_{OUT} = 3.3V, V_{IN} = 2V$ to $3.0V, I_{OUT} = 50mA, EN/BYP = high$</td>
<td>+0.15</td>
<td></td>
<td>%/V</td>
</tr>
<tr>
<td></td>
<td>Load regulation</td>
<td>$V_{IN} = 2V, V_{OUT} = 3.3V, I_{OUT} = 1mA$ to $200mA, EN/BYP = high$</td>
<td>-0.007</td>
<td></td>
<td>%/mA</td>
</tr>
<tr>
<td>$V_{OVP}$</td>
<td>Output overvoltage protection</td>
<td>$V_{OUT}$ rising, EN/BYP = high</td>
<td>5.4</td>
<td>V</td>
<td></td>
</tr>
</tbody>
</table>
6.6 Typical Characteristics

Figure 1. Quiescent Current $I_Q$ into VIN Pin in Bypass Mode

Figure 2. Quiescent Current $I_Q$ into VIN Pin in Boost Mode

Figure 3. Quiescent Current $I_Q$ into VOUT Pin in Boost Mode

Figure 4. $R_{DS(on)}$ Bypass Switch

Figure 5. $R_{DS(on)}$ Main Switch

Figure 6. $R_{DS(on)}$ Rectifier Switch

EN/BYP = low  VSEL = low  IOUT = 0mA

EN/BYP = high  Boost mode operation  Device not switching

VIN = 1.8V  VIN = 2.5V  VIN = 3.3V

VOUT = 2.6V  VOUT = 3.1V  VOUT = 3.4V

VOUT = 3.3V  VOUT = 3.3V

VOUT = 3.3V
7 Detailed Description

7.1 Overview
The TPS61291 provides two operating modes: high efficiency boost mode to generate an output voltage higher than the input voltage and bypass mode, which connects the output of the device directly to the input.

7.2 Functional Block Diagram

7.3 Feature Description

7.3.1 Bypass / Boost Mode Operation EN/BYP
The EN/BYP pin selects the operating mode of the device. With the EN/BYP pin pulled low, the device operates in bypass mode. With a high level on the EN/BYP pin, the device operates as a boost converter. The EN/BYP pin is usually controlled by an I/O pin of a MCU, powered from the output of the TPS61291 and should not be left floating. See Figure 8. See also sections Boost Mode Operation and Bypass Mode Operation for more detailed descriptions.
Feature Description (continued)

7.3.2 Output Voltage Selection VSEL
In boost mode operation, the device supports three internally set output voltages: 2.5V, 3V and 3.3V. Leaving the VSEL pin open sets the output voltage to 2.5V, VSEL = VOUT to 3.0V and VSEL = GND to 3.3V. The VSEL pin condition is detected during the startup of the boost converter and internally latched. For proper operation, it must be connected to either GND, VOUT or left floating. Depending on the VSEL condition, an integrated feedback divider network is selected. Changing the VSEL pin condition during operation does not change the output voltage.

7.3.3 Feedback Divider Disconnect
In boost mode operation, the integrated feedback divider network, which is required for regulation, is connected to the VOUT pin. To achieve the low quiescent current in bypass mode, the integrated feedback divider network is disconnected from the output pin VOUT.

7.3.4 Undervoltage Lockout
An undervoltage lockout function stops the operation of the boost converter if the input voltage drops below the undervoltage lockout threshold. This function is implemented in order to prevent malfunction of the boost converter. The undervoltage lockout function has no control of the bypass switch.

7.3.5 Overtemperature Protection
The device has a built-in temperature sensor which monitors the internal junction temperature in boost mode operation. If the junction temperature exceeds the threshold (140 °C typical), the device stops operating. As soon as the junction temperature has decreased below the programmed threshold, it starts operating again. There is a built-in hysteresis to avoid unstable operation at IC temperatures at the overtemperature threshold. The overtemperature protection is not active in bypass mode operation.

7.3.6 Overvoltage Protection
In boost mode operation (EB/BYP = high), the device features a redundant over voltage protection circuit (OVP), which is independent from the reference, the regulation loop and feedback divider network. The redundant over voltage protection circuit limits the output voltage to typically 5.4V. The over voltage protection can only limit the output voltage in boost mode operation, when the input voltage $V_{IN}$ is smaller than the output voltage $V_{OUT}$.

7.4 Device Functional Modes

7.4.1 Boost Mode Operation
The device is enabled and operates in boost mode operation when the EN/BYP pin is set high. The bypass switch is turned off once the boost converter has started switching.

In boost mode operation, the device 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. If the required average input current is lower than the average inductor current defined by this constant ripple, the inductor current goes discontinuous to keep the efficiency high at low load conditions. To achieve high efficiency, the power stage is realized as a synchronous boost topology.

![Figure 7. Hysteretic Current Operation](image)
Device Functional Modes (continued)

The output voltage $V_{\text{OUT}}$ is monitored via the integrated 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.

The hysteretic current mode architecture allows fast response to load variations.

### 7.4.2 Bypass Mode Operation

The TPS61291 includes a P-channel MOSFET (Bypass Switch) between the VIN and VOUT pins. When the IC is disabled (EN/BYP = low), bypass mode is activated to provide a direct, low impedance connection from the input voltage (at the VIN pin) to the load ($V_{\text{OUT}}$). The bypass switch is not impacted by undervoltage lockout, or thermal shutdown. The bypass switch is not current-limit controlled. In bypass operation, the OVP circuit is disabled.

### 7.4.3 Controlled Transition into Bypass Mode

When changing from boost mode into bypass mode, the output capacitor is usually charged up to a higher voltage than the battery voltage $V_{\text{BAT}}$. In order to prevent current flowing from the output capacitor $C_{\text{OUT}}$ via the bypass switch into the battery (reverse battery current), the internal bypass control circuit delays the bypass switch activation until the output voltage $V_{\text{OUT}}$ has decreased to the input voltage level.

### 7.4.4 Operation at Output Overload

If the peak inductor current reaches the internal switch current limit threshold in boost mode operation, the main switch is turned off to stop a further increase of the input current. In this case the output voltage will decrease since the device cannot provide sufficient power to maintain the set output voltage. If the output voltage drops below the input voltage, the backgate diode of the rectifying switch gets forward biased and current starts to flow through it. Because this diode cannot be turned off, the load current is only limited by the remaining DC resistance. As soon as the overload condition is removed, the converter automatically resumes normal operation and enters the appropriate soft start mode depending on the operating conditions.

### 7.4.5 Startup

After the EN/BYP pin is tied high, the device starts to operate. If the input voltage is not high enough to supply the control circuit properly, a startup oscillator starts to operate the switches. During this phase, the switching frequency is controlled by the oscillator and the switch current is limited. As soon as the device has built up the output voltage to about 1.8 V, high enough for supplying the control circuit, the device switches to its normal hysteretic current mode operation.
8 Applications and Implementation

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

8.1 Application Information

The TPS61291 is a boost converter with pin selectable output voltages and an integrated bypass mode. In bypass operation, the device provides a direct path from the input to the system and allows a low power micro controller (MCU) to operate directly from a single 3V Li-MnO2 battery or dual alkaline battery cells. In bypass mode, the quiescent current consumption is typically only 15nA and supports low power modes of MCUs such as the MSP430. In boost mode operation, the device provides a regulated output voltage (e.g. 3.3V) to supply circuits which require a higher voltage than provided by the battery. See Figure 8.

The device also extends battery life in applications which can run partially directly from the battery, but need a boost conversion to maintain sufficient system voltage when the battery voltage drops due to discharge. In this case, the system runs off the battery in bypass mode operation until the battery voltage trips the minimum system operating voltage. Then the system turns on the boost converter, providing a sufficient output voltage down to the cut off voltage of the battery. See Figure 9 and Figure 26.

8.2 Typical Application

8.2.1 Design Requirements

The TPS61291 is a highly integrated boost converter. The output voltage is set internally via a VSEL pin without any additional components. For operation, only an input capacitor, output capacitor, and an inductor are required. Table 1 shows the components used for the application characteristic curves.
Typical Application (continued)

Table 1. Components for Application Characteristic Curves(1)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Description</th>
<th>Value</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS61291</td>
<td>Low Iq Boost Converter with Bypass Operation</td>
<td></td>
<td>Texas Instruments</td>
</tr>
<tr>
<td>C_IN</td>
<td>Input capacitor</td>
<td>10µF</td>
<td>Murata</td>
</tr>
<tr>
<td>C_OUT</td>
<td>Output capacitor</td>
<td>22µF</td>
<td>Murata</td>
</tr>
<tr>
<td>L</td>
<td>Inductor</td>
<td>3.3µH</td>
<td>Coilcraft</td>
</tr>
</tbody>
</table>

(1) See the Third-Party Products Disclaimer in the Device Support section.

8.2.2 Detailed Design Procedure

The external components have to fulfill the needs of the application but also the stability criteria of the device's control loop. The TPS61291 is optimized to work within a range of L and C combinations. The LC output filter inductance and capacitance must be considered together. The output capacitor sets the corner frequency of the converter while the inductor creates a Right-Half-Plane-Zero degrading the stability of the converter. Consequently with a larger inductor a bigger capacitor has to be used to guarantee a stable loop. Table 2 shows the output filter component selection.

Table 2. Recommended LC Output Filter Combinations

<table>
<thead>
<tr>
<th>Output voltage [V]</th>
<th>Inductor value <a href="1">µH</a></th>
<th>Output capacitor value <a href="2">µF</a></th>
<th>22</th>
<th>22 + 10</th>
<th>2 x 22</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3 / 3.0</td>
<td>3.3</td>
<td>√(3)</td>
<td>√</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>2.2</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Inductor tolerance and current de-rating is anticipated. The effective inductance can vary by 20% and -30%.
(2) Capacitance tolerance and bias voltage de-rating is anticipated. The effective capacitance can vary by 20% and -50%.
(3) This LC combination is the standard value and recommended for most applications.

8.2.2.1 Inductor Selection

The device is optimized to operate with a 3.3µH inductor value. Other inductor values can be used, per Table 2. The maximum inductor current can be approximated by the $L_{\text{MAX}}$ from Equation 1. For proper operation, the inductor needs to be rated for a saturation current which is higher than the switch current limit of typically 1A. Table 3 lists inductors that have been tested with the TPS61291.

$$L_{\text{MAX}} = \frac{V_{\text{OUT}} \times I_{\text{OUT}}}{0.8 \times V_{\text{IN}}} + 150 \text{ mA} \quad \text{continuous current operation}$$

$$L_{\text{MAX}} = 300 \text{ mA} \quad \text{discontinuous current operation}$$

(1)

Table 3. List of Inductors(1)

<table>
<thead>
<tr>
<th>INDUCTANCE</th>
<th>DIMENSIONS [mm³]</th>
<th>TYPE</th>
<th>SUPPLIER</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3</td>
<td>3.3 x 3.3 x 1.3</td>
<td>LPS3314</td>
<td>Coilcraft</td>
</tr>
<tr>
<td>3.3</td>
<td>2.95 x 2.95 x 1.4</td>
<td>LPS3015</td>
<td></td>
</tr>
<tr>
<td>3.3</td>
<td>3 x 2.5 x 1.5</td>
<td>VLF302515</td>
<td>TDK</td>
</tr>
<tr>
<td>3.3</td>
<td>2 x 2 x 1.2</td>
<td>MDMK2020T3R3M</td>
<td>Taiyo Yuden</td>
</tr>
<tr>
<td>3.3</td>
<td>2.5 x 2.0 x 1.2</td>
<td>DFE252012</td>
<td>Toko</td>
</tr>
<tr>
<td>3.3</td>
<td>3.0 x 3.0 x 1.5</td>
<td>74438335033</td>
<td>Würth</td>
</tr>
</tbody>
</table>

(1) See the Third-Party Products Disclaimer in the Device Support section.
8.2.2.2 Input and Output 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. At least a 10μF or larger input capacitor is recommended for operation. In applications in which the power source (e.g. certain battery chemistries) shows an internal resistance characteristic, a larger input capacitor might be used to buffer the supply voltage for the TPS61291. The recommended typical output capacitor value is 22 μF and can vary as outlined in the output filter selection Table 2.
8.2.3 Application Curves

**Figure 10. Efficiency vs I\textsubscript{OUT}, V\textsubscript{OUT} = 3.3V**

**Figure 11. Efficiency vs I\textsubscript{OUT}, V\textsubscript{OUT} = 3.0V**

**Figure 12. Efficiency vs I\textsubscript{OUT}, V\textsubscript{OUT} = 2.5V**

**Figure 13. Output Voltage vs Output Current V\textsubscript{OUT} = 3.3V**

**Figure 14. Output Voltage vs Output Current V\textsubscript{OUT} = 3.0V**

**Figure 15. Output Voltage vs Output Current V\textsubscript{OUT} = 2.5V**
EN/BYP = high

\[ I_{SW} = 1000 \text{mA (typical)} \]

Boost mode operation

**Figure 16. Maximum Output Current**

\[ V_{OUT} = 3.3 \text{V} \]
\[ L = 3.3 \mu\text{H} \]
\[ C_{OUT} = 22 \mu\text{F} \]

Device switching

\[ I_{OUT} = 0 \text{mA} \]

**Figure 17. Supply Current vs. \( V_{IN} \), \( V_{OUT} = 3.3\text{V}, I_{OUT} = 0\text{mA} \)**

\[ V_{OUT} = 3.0 \text{V} \]
\[ L = 3.3 \mu\text{H} \]
\[ C_{OUT} = 22 \mu\text{F} \]

Device switching

\[ I_{OUT} = 0 \text{mA} \]

**Figure 18. Supply Current vs. \( V_{IN} \), \( V_{OUT} = 3.0\text{V}, I_{OUT} = 0\text{mA} \)**

\[ V_{IN} = 2.0 \text{V} \]
\[ V_{OUT} = 3.3 \text{V} \]
\[ L = 3.3 \mu\text{H} \]
\[ C_{OUT} = 22 \mu\text{F} \]

\[ I_{OUT} = 15\text{mA} \]

VSEL = GND

EN/BYP = high

**Figure 20. Discontinuous Conduction Mode Operation, \( V_{OUT} = 3.3\text{V} \)**

\[ V_{IN} = 1.8 \text{V} \]
\[ V_{OUT} = 3.3 \text{V} \]
\[ L = 3.3 \mu\text{H} \]
\[ C_{OUT} = 22 \mu\text{F} \]

\[ I_{OUT} = 150 \text{mA} \]

VSEL = GND

EN/BYP = high

**Figure 21. Continuous Conduction Mode Operation, \( V_{OUT} = 3.3\text{V} \)**
EN/BYP control

VIN < 2.2V

VOUT = 2.5V

VOUT tracks VIN

Boost operation

Bypass switch activation when V is discharged to V level

Bypass mode

V IN = 1.8V

L = 3.3µH

C OUT = 22 µF

VSEL = GND

ILOAD 20mA / 150mA

V IN = 2.5V / 3V

L = 3.3µH

C OUT = 22 µF

VSEL = GND

Load = 100Ω

V IN = 2.0V

L = 3.3µH

C OUT = 22 µF

VSEL = GND

R LOAD = 1kΩ

V IN = 0.9V to 3V

VSEL = Open

ILOAD = 5mA

Bypass / Boost mode operation

V IN = 2.0V

L = 3.3µH

C OUT = 22 µF

VSEL = GND

R LOAD = 100Ω

Figure 22. Load Transient Response

Figure 23. AC Load Sweep

Figure 24. Line Transient Response

Figure 25. Boost Mode / Bypass Mode Transition

Figure 26. Bypass / Boost Mode Operation

Figure 27. Startup in Boost Mode
9 Power Supply Recommendations

The input power supply needs to have a current rating according to the supply voltage, output voltage and output current of the TPS61291.

10 Layout

10.1 Layout Guidelines

As for all switching power supplies, the layout is an important step in the design. Care must be taken in board layout to get the specified performance. If the layout is not carefully done, the regulator could show poor line and/or load regulation, stability issues as well as EMI problems. It is critical to provide a low inductance, low impedance ground path. Therefore, use wide and short traces for the main current paths. In a boost converter, the ripple current on the output is larger than the ripple current on the input. The output capacitor needs to be placed as close as possible between the VOUT and the GND pins. The input capacitor should be placed as close as possible to the VIN and GND pins. Place the inductor close by the IC and connect it with short and thick traces to the IC. Avoid current loops to minimize radiated noise and stray fields. The exposed thermal pad of the package and the GND pin must be connected. See Figure 28 for the recommended PCB layout.

10.2 Layout Example
11 Device and Documentation Support

11.1 Device Support

11.1.1 Third-Party Products Disclaimer
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OR A WARRANTY, REPRESENTATION OR ENDORSEMENT OF SUCH PRODUCTS OR SERVICES, EITHER
ALONE OR IN COMBINATION WITH ANY TI PRODUCT OR SERVICE.

11.2 Documentation Support

11.2.1 Related Documentation
TPS61291EVM-569 User's Guide, SLVUA29

11.3 Trademarks

11.4 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.

11.5 Glossary
SLYZ022 — TI Glossary.
This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

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

<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</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS61291DRVR</td>
<td>ACTIVE</td>
<td>WSON</td>
<td>DRV</td>
<td>6</td>
<td>3000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-2-260C-1 YEAR</td>
<td>-40 to 85</td>
<td>PC4I</td>
<td></td>
</tr>
<tr>
<td>TPS61291DRVT</td>
<td>ACTIVE</td>
<td>WSON</td>
<td>DRV</td>
<td>6</td>
<td>250</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-2-260C-1 YEAR</td>
<td>-40 to 85</td>
<td>PC4I</td>
<td></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.

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## TAPE AND REEL INFORMATION

### TAPE DIMENSIONS

<table>
<thead>
<tr>
<th>A0</th>
<th>Dimension designed to accommodate the component width</th>
</tr>
</thead>
<tbody>
<tr>
<td>B0</td>
<td>Dimension designed to accommodate the component length</td>
</tr>
<tr>
<td>K0</td>
<td>Dimension designed to accommodate the component thickness</td>
</tr>
<tr>
<td>W</td>
<td>Overall width of the carrier tape</td>
</tr>
<tr>
<td>P1</td>
<td>Pitch between successive cavity centers</td>
</tr>
</tbody>
</table>

### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

- **Q1**
- **Q2**
- **Q3**
- **Q4**

*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>Reel Diameter (mm)</th>
<th>Reel Width W1 (mm)</th>
<th>A0  (mm)</th>
<th>B0  (mm)</th>
<th>K0  (mm)</th>
<th>P1  (mm)</th>
<th>W  (mm)</th>
<th>Pin1 Quadrant</th>
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<tbody>
<tr>
<td>TPS61291DRVR</td>
<td>WSON</td>
<td>DRV</td>
<td>6</td>
<td>3000</td>
<td>180.0</td>
<td>8.4</td>
<td>2.3</td>
<td>2.3</td>
<td>1.15</td>
<td>4.0</td>
<td>8.0</td>
<td>Q2</td>
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<tr>
<td>TPS61291DRVT</td>
<td>WSON</td>
<td>DRV</td>
<td>6</td>
<td>250</td>
<td>180.0</td>
<td>8.4</td>
<td>2.3</td>
<td>2.3</td>
<td>1.15</td>
<td>4.0</td>
<td>8.0</td>
<td>Q2</td>
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</table>
### TAPE AND REEL BOX DIMENSIONS

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<th>Pins</th>
<th>SPQ</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
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<tr>
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<td>DRV</td>
<td>6</td>
<td>3000</td>
<td>210.0</td>
<td>185.0</td>
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<tr>
<td>TPS61291DRVT</td>
<td>WSON</td>
<td>DRV</td>
<td>6</td>
<td>250</td>
<td>210.0</td>
<td>185.0</td>
<td>35.0</td>
</tr>
</tbody>
</table>

*All dimensions are nominal*
Images above are just a representation of the package family, actual package may vary. Refer to the product data sheet for package details.
NOTES:

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

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).

5. Vias are optional depending on application, refer to device data sheet. If some or all are implemented, recommended via locations are shown.
NOTES: (continued)

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