1 Features

- Up to 95% Efficiency at Typical Operating Conditions
- 5.5 μA Quiescent Current
- Startup Into Load at 0.7 V Input Voltage
- Operating Input Voltage from 0.7 V to 5.5 V
- Pass-Through Function during Shutdown
- Minimum Switching Current 200 mA
- Protections:
  - Output Overvoltage
  - Overtemperature
  - Input Undervoltage Lockout
- Adjustable Output Voltage from 1.8 V to 6 V
- Fixed Output Voltage Versions
- Small 6-pin SC-70 Package

2 Applications

- Battery Powered Applications
  - 1 to 3 Cell Alkaline, NiCd or NiMH
  - 1 cell Li-Ion or Li-Primary
- Solar or Fuel Cell Powered Applications
- Consumer and Portable Medical Products
- Personal Care Products
- White or Status LEDs
- Smartphones

3 Description

The TPS6122x family devices provide a power-supply solution for products powered by either a single-cell, two-cell, or three-cell alkaline, NiCd or NiMH, or one-cell Li-Ion or Li-polymer battery. Possible output currents depend on the input-to-output voltage ratio. The boost converter is based on a hysteretic controller topology using synchronous rectification to obtain maximum efficiency at minimal quiescent currents. The output voltage of the adjustable version can be programmed by an external resistor divider, or is set internally to a fixed output voltage. The converter can be switched off by a featured enable pin. While being switched off, battery drain is minimized. The device is offered in a 6-pin SC-70 package (DCK) measuring 2 mm x 2 mm to enable small circuit layout size.

4 Simplified Schematic

![Simplified Schematic](image)

Table: Device Information

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE (NOM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS6120</td>
<td>SC-70 (6)</td>
<td>2.00mm x 1.25mm</td>
</tr>
<tr>
<td>TPS61221</td>
<td>SC-70 (6)</td>
<td>2.00mm x 1.25mm</td>
</tr>
<tr>
<td>TPS61222</td>
<td>SC-70 (6)</td>
<td>2.00mm x 1.25mm</td>
</tr>
</tbody>
</table>

(1) For all available packages, see the orderable addendum at the end of this document.
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5 Revision History

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

Changes from Revision A (April 2014) to Revision B Page
- Changed format of Handling Ratings table. ................................................................. 3
- Added new note to Application and Implementation section ........................................ 13
- Renamed "Thermal Information" section to "Thermal Considerations" section. .................. 18

Changes from Original (August 2009) to Revision A Page
- Updated data sheet format ........................................................................ 1
- Changed the data sheet title From: LOW INPUT VOLTAGE STEP-UP CONVERTER IN 6 PIN SC-70 PACKAGE To: TPS6122x LOW INPUT VOLTAGE, 0.7V BOOST CONVERTER WITH 5.5μA QUIESCENT CURRENT .......... 1
- Changed Feature bullet and Simplified Schematic text from "....1.8 V to 5.5 V" to "....1.8 V to 6 V" ................................. 1
- Deleted "machine model" ESD rating because JEDEC discontinued its use in 2012. ................ 3
- Changed Overvoltage protect threshold min and V\textsubscript{OUT} max levels from 5.5V to 6V .................................................. 4
- Changed Adjustable output voltage version description text string from "....voltage is 5.5 V" to "....voltage is 6.0 V" ....... 16
- Changed Layout diagram to correct typo in resistor numbers. ........................................ 18

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Product Folder Links: TPS61220 TPS61221 TPS61222
6 Device Comparison (1)

<table>
<thead>
<tr>
<th>$T_A$</th>
<th>OUTPUT VOLTAGE DC/DC</th>
<th>PACKAGE MARKING</th>
<th>PACKAGE (1)</th>
<th>PART NUMBER (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-40^\circ$ to $85^\circ$C</td>
<td>Adjustable</td>
<td>CKR</td>
<td>6-pin SC-70</td>
<td>TPS61220DCK</td>
</tr>
<tr>
<td></td>
<td>3.3 V</td>
<td>CKS</td>
<td></td>
<td>TPS61221DCK</td>
</tr>
<tr>
<td></td>
<td>5.0 V</td>
<td>CKT</td>
<td></td>
<td>TPS61222DCK</td>
</tr>
</tbody>
</table>

(1) Contact the factory to check availability of other fixed output voltage versions.
(2) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.

7 Pin Configuration and Functions

Pin Functions

<table>
<thead>
<tr>
<th>PIN NAME</th>
<th>NO.</th>
<th>I/O</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN</td>
<td>6</td>
<td>I</td>
<td>Enable input (1: enabled, 0: disabled). Must be actively tied high or low. Do not leave floating.</td>
</tr>
<tr>
<td>FB</td>
<td>2</td>
<td>I</td>
<td>Voltage feedback of adjustable version. Must be connected to $V_{OUT}$ at fixed output voltage versions.</td>
</tr>
<tr>
<td>GND</td>
<td>3</td>
<td></td>
<td>Control / logic and power ground</td>
</tr>
<tr>
<td>L</td>
<td>5</td>
<td>I</td>
<td>Connection for Inductor</td>
</tr>
<tr>
<td>VIN</td>
<td>1</td>
<td>I</td>
<td>Boost converter input voltage</td>
</tr>
<tr>
<td>VOUT</td>
<td>4</td>
<td>O</td>
<td>Boost converter output voltage</td>
</tr>
</tbody>
</table>

8 Specifications

8.1 Absolute Maximum Ratings

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

| $V_{IN}$ Input voltage on VIN, L, VOUT, EN, FB | TPS6122x | UNIT |
| $T_J$ Operating junction temperature | $-0.3$ to $7.5$ | V |
| $-40$ to $150$ | °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.

8.2 Handling Ratings

| $T_{stg}$ Storage temperature range | MIN | MAX | UNIT |
| $V_{(ESD)}$ Electrostatic discharge | | | |
| Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins (1) | $-2$ | $2$ | kV |
| Charged device model (CDM), per JEDEC specification JESD22-C101, all pins (2) | $-1.5$ | $1.5$ | kV |

(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.
8.3 Recommended Operating Conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>NOM</th>
<th>MAX</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{IN} )</td>
<td></td>
<td>0.7</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>( T_J )</td>
<td>–40</td>
<td>125</td>
<td></td>
<td>°C</td>
</tr>
</tbody>
</table>

8.4 Thermal Information

<table>
<thead>
<tr>
<th>Thermal Metric(1)</th>
<th>TPS6122x DCK</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction-to-ambient thermal resistance</td>
<td>231.2</td>
<td>°C/W</td>
</tr>
<tr>
<td>Junction-to-case (top) thermal resistance</td>
<td>61.8</td>
<td></td>
</tr>
<tr>
<td>Junction-to-board thermal resistance</td>
<td>78.8</td>
<td></td>
</tr>
<tr>
<td>Junction-to-top characterization parameter</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Junction-to-board characterization parameter</td>
<td>78.0</td>
<td></td>
</tr>
<tr>
<td>Junction-to-case (bottom) thermal resistance</td>
<td>n/a</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.

8.5 Electrical Characteristics

over recommended free-air temperature range and over recommended input voltage range (typical at an ambient temperature range of 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>DC/DC STAGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{IN} ) Input voltage</td>
<td></td>
<td>0.7</td>
<td>5.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( V_{IN} ) Minimum input voltage at startup</td>
<td>( R_{LOAD} \geq 150 \Omega )</td>
<td>0.7</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{OUT} ) TPS61220 output voltage</td>
<td>( V_{IN} &lt; V_{OUT} )</td>
<td>1.8</td>
<td>6.0</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>( V_{FB} ) TPS61220 feedback voltage</td>
<td></td>
<td>483</td>
<td>500</td>
<td>513</td>
<td>mV</td>
</tr>
<tr>
<td>( V_{OUT} ) TPS61221 output voltage (3.3 V)</td>
<td>( V_{IN} &lt; V_{OUT} )</td>
<td>3.20</td>
<td>3.30</td>
<td>3.41</td>
<td>V</td>
</tr>
<tr>
<td>( V_{OUT} ) TPS61222 output voltage (5 V)</td>
<td>( V_{IN} &lt; V_{OUT} )</td>
<td>4.82</td>
<td>5.00</td>
<td>5.13</td>
<td>V</td>
</tr>
<tr>
<td>( I_{IH} ) Inductor current ripple</td>
<td></td>
<td>200</td>
<td></td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>( I_{SW} ) switch current limit</td>
<td>( V_{OUT} = 3.3 , \text{V}, , V_{IN} = 1.2 , \text{V}, , T_A = 25^\circ\text{C} )</td>
<td>240</td>
<td>400</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>( R_{DSon_HSD} ) Rectifying switch on resistance</td>
<td>( V_{OUT} = 3.3 , \text{V} )</td>
<td>1000</td>
<td>mΩ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( R_{DSon_LSD} ) Main switch on resistance</td>
<td>( V_{OUT} = 5.0 , \text{V} )</td>
<td>700</td>
<td>mΩ</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CONTROL STAGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( I_{Q} ) Quiescent current</td>
<td>( V_{IN} )</td>
<td>0.5</td>
<td>0.9</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>( I_{SD} ) Shutdown current</td>
<td>( V_{IN} )</td>
<td>5</td>
<td>7.5</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>( I_{LKG_VOUT} ) Leakage current into ( V_{OUT} )</td>
<td>( V_{EN} = 0 , \text{V}, , V_{IN} = 1.2 , \text{V}, , V_{OUT} \geq V_{IN} )</td>
<td>0.2</td>
<td>0.5</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>( I_{LKG_L} ) Leakage current into ( L )</td>
<td>( V_{EN} = 0 , \text{V}, , V_{IN} = 1.2 , \text{V}, , V_{L} = 1.2 , \text{V}, , V_{OUT} \geq V_{IN} )</td>
<td>0.01</td>
<td>0.2</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>( I_{FB} ) TPS61220 Feedback input current</td>
<td>( V_{FB} = 0.5 , \text{V} )</td>
<td>0.01</td>
<td>0.1</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>( I_{EN} ) EN input current</td>
<td></td>
<td>0.005</td>
<td>0.1</td>
<td>μA</td>
<td></td>
</tr>
</tbody>
</table>

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Product Folder Links: TPS61220  TPS61221  TPS61222
Electrical Characteristics (continued)

over recommended free-air temperature range and over recommended input voltage range (typical at an ambient temperature range of 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>( V_{UVLO} )</td>
<td>Undervoltage lockout threshold for turn off</td>
<td>0.5</td>
<td>0.7</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Overvoltage protection threshold</td>
<td></td>
<td>6.0</td>
<td>7.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Overtemperature protection</td>
<td></td>
<td>140</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Overtemperature hysteresis</td>
<td></td>
<td>20</td>
<td></td>
<td></td>
<td>°C</td>
</tr>
</tbody>
</table>

8.6 Typical Characteristics

<table>
<thead>
<tr>
<th>TABLE OF GRAPHS</th>
<th>FIGURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Output Current</td>
<td>versus Input Voltage (TPS61220, TPS61221, TPS61222)</td>
</tr>
<tr>
<td>Efficiency</td>
<td>versus Output Current, ( V_{OUT} = 1.8 \text{ V}, V_{IN} = [0.7 \text{ V}; 1.2 \text{ V}; 1.5 \text{ V}] ) (TPS61220)</td>
</tr>
<tr>
<td></td>
<td>versus Output Current, ( V_{IN} = [0.7 \text{ V}; 1.2 \text{ V}; 2.4 \text{ V}; 3 \text{ V}] ) (TPS61221)</td>
</tr>
<tr>
<td></td>
<td>versus Output Current, ( V_{IN} = [0.7 \text{ V}; 1.2 \text{ V}; 2.4 \text{ V}; 3.6 \text{ V}; 4.2 \text{ V}] ) (TPS61222)</td>
</tr>
<tr>
<td></td>
<td>versus Input Voltage, ( V_{OUT} = 1.8 \text{ V}, I_{OUT} = [100 \mu \text{ A}; 1 \text{ mA}; 10 \text{ mA}; 50 \text{ mA}] ) (TPS61220)</td>
</tr>
<tr>
<td></td>
<td>versus Input Voltage, ( I_{OUT} = [100 \mu \text{ A}; 1 \text{ mA}; 10 \text{ mA}; 50 \text{ mA}] ) (TPS61221)</td>
</tr>
<tr>
<td></td>
<td>versus Input Voltage, ( I_{OUT} = [100 \mu \text{ A}; 1 \text{ mA}; 10 \text{ mA}; 50 \text{ mA}] ) (TPS61222)</td>
</tr>
<tr>
<td>Input Current</td>
<td>at No Output Load, Device Enabled (TPS61220, TPS61221, TPS61222)</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>versus Output Current, ( V_{OUT} = 1.8 \text{ V}, V_{IN} = [0.7 \text{ V}; 1.2 \text{ V}] ) (TPS61220)</td>
</tr>
<tr>
<td></td>
<td>versus Output Current, ( V_{IN} = [0.7 \text{ V}; 1.2 \text{ V}; 2.4 \text{ V}] ) (TPS61221)</td>
</tr>
<tr>
<td></td>
<td>versus Output Current, ( V_{IN} = [0.7 \text{ V}; 1.2 \text{ V}; 2.4 \text{ V}; 3.6 \text{ V}] ) (TPS61222)</td>
</tr>
<tr>
<td></td>
<td>versus Input Voltage, Device Disabled, ( R_{LOAD} = [1 \text{ k}; 10 \text{ k}] ) (TPS6122x)</td>
</tr>
<tr>
<td>Waveforms</td>
<td>Output Voltage Ripple, ( V_{IN} = 0.8 \text{ V}, V_{OUT} = 1.8 \text{ V}, I_{OUT} = 20 \text{ mA} ) (TPS61220)</td>
</tr>
<tr>
<td></td>
<td>Output Voltage Ripple ( V_{IN} = 1.8 \text{ V}, I_{OUT} = 50 \text{ mA} ) (TPS61221)</td>
</tr>
<tr>
<td></td>
<td>Load Transient Response, ( V_{IN} = 1.2 \text{ V}, I_{OUT} = 6 \text{ mA} ) to ( 50 \text{ mA} ) (TPS61221)</td>
</tr>
<tr>
<td></td>
<td>Load Transient Response, ( V_{IN} = 2.4 \text{ V}, I_{OUT} = 14 \text{ mA} ) to ( 126 \text{ mA} ) (TPS61222)</td>
</tr>
<tr>
<td></td>
<td>Line Transient Response, ( V_{IN} = 1.8 \text{ V} ) to ( 2.4 \text{ V}, R_{LOAD} = 100 \Omega ) (TPS61221)</td>
</tr>
<tr>
<td></td>
<td>Line Transient Response, ( V_{IN} = 2.8 \text{ V} ) to ( 3.6 \text{ V}, R_{LOAD} = 100 \Omega ) (TPS61222)</td>
</tr>
<tr>
<td></td>
<td>Startup after Enable, ( V_{IN} = 0.7 \text{ V}, V_{OUT} = 1.8 \text{ V}, R_{LOAD} = 150 \Omega ) (TPS61220)</td>
</tr>
<tr>
<td></td>
<td>Startup after Enable, ( V_{IN} = 0.7 \text{ V}, R_{LOAD} = 150 \Omega ) (TPS61222)</td>
</tr>
<tr>
<td></td>
<td>Continuous Current Operation, ( V_{IN} = 1.2 \text{ V}, V_{OUT} = 1.8 \text{ V}, I_{OUT} = 50 \text{ mA} ) (TPS61220)</td>
</tr>
<tr>
<td></td>
<td>Discontinuous Current Operation, ( V_{IN} = 1.2 \text{ V}, V_{OUT} = 1.8 \text{ V}, I_{OUT} = 10 \text{ mA} ) (TPS61220)</td>
</tr>
</tbody>
</table>
Figure 1. Maximum Output Current versus Input Voltage (TPS61220, TPS61221, TPS61222)

Figure 2. Efficiency versus Output Current and Input Voltage (TPS61220)

Figure 3. Efficiency versus Output Current and Input Voltage (TPS61221)

Figure 4. Efficiency versus Output Current and Input Voltage (TPS61222)

Figure 5. Efficiency versus Input Voltage and Output Current (TPS61220)

Figure 6. Efficiency versus Input Voltage and Output Current (TPS61221)
Figure 7. Efficiency versus Input Voltage and Output Current (TPS61222)

Figure 8. No Load Input Current versus Input Voltage, Device Enabled (TPS61220, TPS61221, TPS61222)

Figure 9. Output Voltage versus Output Current and Input Voltage (TPS61220)

Figure 10. Output Voltage versus Output Current and Input Voltage (TPS61221)

Figure 11. Output Voltage versus Output Current and Input Voltage (TPS61222)

Figure 12. Output Voltage versus Input Voltage, Device Disabled (TPS61220)
Figure 13. Output Voltage Ripple (TPS61220)

Figure 14. Output Voltage Ripple (TPS61221)

Figure 15. Load Transient Response (TPS61221)

Figure 16. Load Transient Response (TPS61222)

Figure 17. Line Transient Response (TPS61221)

Figure 18. Line Transient Response (TPS61222)
## 9 Parameter Measurement Information

![Diagram of TPS6122x schematic](image)

### Table 1. List Of Components:

<table>
<thead>
<tr>
<th>COMPONENT REFERENCE</th>
<th>PART NUMBER</th>
<th>MANUFACTURER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₁</td>
<td>GRM188R60J106ME84D</td>
<td>Murata</td>
<td>10 μF, 6.3V. X5R Ceramic</td>
</tr>
<tr>
<td>C₂</td>
<td>GRM188R60J106ME84D</td>
<td>Murata</td>
<td>10 μF, 6.3V. X5R Ceramic</td>
</tr>
<tr>
<td>L₁</td>
<td>EPL3015-472MLB</td>
<td>Coilcraft</td>
<td>4.7 μH</td>
</tr>
<tr>
<td>R₁, R₂</td>
<td></td>
<td></td>
<td>adjustable version: Values depending on the programmed output voltage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>fixed version: R₁= 0 Ω, R₂ not used</td>
</tr>
</tbody>
</table>
10 Detailed Description

10.1 Overview

The TPS6122x is a high performance, high efficient family of switching boost converters. To achieve high efficiency, the power stage is realized as a synchronous-boost topology. For the power switching, two actively-controlled low-$R_{D\text{son}}$ power MOSFETs are implemented.

10.2 Functional Block Diagrams

![Functional Block Diagram (Adjustable Version)](image1)

![Functional Block Diagram (Fixed Output Voltage Version)](image2)

Figure 24. Functional Block Diagram (Fixed Output Voltage Version)

10.3 Feature Description

10.3.1 Controller Circuit

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 200 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 current, the inductor current becomes discontinuous to keep the efficiency high under low-load conditions.

![Figure 25. Hysteretic Current Operation](image3)

The output voltage $V_{\text{OUT}}$ is monitored via the 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. In fixed output voltage devices, an internal feedback network is used to program the output voltage. In adjustable versions an external resistor divider is required.

The self-oscillating hysteretic current mode architecture is inherently stable and allows fast response to load variations. This architecture also allows using a wide range of inductor and capacitor values.
Feature Description (continued)

10.3.2 Device Enable And Shutdown Mode

The device is enabled when EN is driven high, and shut down when EN is low. During shutdown, the converter stops switching and all internal control circuitry is turned off. During shutdown, the input voltage is connected to the output through the back-gate diode of the rectifying MOSFET. This means that voltage is always present at the output, which can be as high as the input voltage or lower depending on the load.

10.3.3 Startup

After the EN pin is tied high, the device begins to operate. If the input voltage is not high enough to supply the control circuit properly, a startup oscillator operates the switches. During this phase, the switching frequency is controlled by the oscillator, and the maximum switch current is limited. When the device has built up the output voltage to approximately 1.8V, high enough to supply the control circuit, the device switches to its normal hysteretic current mode operation. The startup time depends on input voltage and load current.

10.3.4 Operation At Output Overload

If, in normal boost operation, the inductor current reaches the internal switch current limit threshold, the main switch is turned off to stop further increase of the input current. In this case the output voltage will decrease because 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 becomes forward biased, and current starts to flow through it. This diode cannot be turned off, so the current finally is only limited by the remaining DC resistances. As soon as the overload condition is removed, the converter resumes providing the set output voltage.

10.3.5 Undervoltage Lockout

An undervoltage lockout function stops the operation of the converter if the input voltage drops below the typical undervoltage lockout threshold. This function is implemented in order to prevent converter malfunction.

10.3.6 Overvoltage Protection

If, for any reason, the output voltage is not fed back properly to the input of the voltage amplifier, control of the output voltage is lost. Therefore an overvoltage protection is implemented to avoid the output voltage exceeding critical values for the device and possibly for the system it is supplying. For this protection, the TPS6122x output voltage is also monitored internally. If it reaches the internally programmed threshold of 6.5 V, typically the voltage amplifier regulates (limits) the output voltage to this value.

If the TPS6122x is used to drive LEDs, this feature protects the circuit if the LED fails.

10.3.7 Overtemperature Protection

The device has a built-in temperature sensor which monitors the internal IC junction temperature. If the temperature exceeds the programmed threshold (see electrical characteristics table), the device stops operating. As soon as the IC temperature has decreased below the programmed threshold, it starts operating again. To prevent unstable operation close to the region of overtemperature threshold, a built-in hysteresis is implemented.

10.4 Device Functional Modes

- Enabled or disabled
- Continuous or discontinuous current operation
- Protective mechanisms
  - Output Overload
  - Undervoltage
  - Overvoltage
  - Overtemperature
11 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.

11.1 Application Information
The TPS6122x family devices provide a power-supply solution for products powered by either a single-cell, two-cell, or three-cell alkaline, NiCd or NiMH, or one-cell Li-Ion or Li-polymer battery. Use the following design procedure to select component values for the TPS61220 device and the TPS61222 device. Alternatively, use the SwitcherPro™ tool. This section presents a simplified discussion of the design process.

11.2 Typical Applications

11.2.1 Specific Application, Fixed Output Voltage Supply

11.2.1.1 Design Requirements
• Single 5 V output at up to 60 mA
• Power source, two AA alkaline cells
• Greater than 90% conversion efficiency

11.2.1.2 Detailed Design Procedure

11.2.1.2.1 Device Choice
The TPS61222 DC/DC converter is intended for systems powered by anything from a single cell through up to three Alkaline, NiCd or NiMH cells with a total typical pin voltage between 0.7 V and 5.5 V. They can also be used in systems powered by one-cell Li-Ion or Li-Polymer batteries with a typical voltage between 2.5 V and 4.2 V. Additionally, any other voltage source with a typical output voltage between 0.7 V and 5.5 V can be used with the TPS61222.

11.2.1.2.2 Programming The Output Voltage
In the fixed-voltage version used for this example, the output voltage is set by an internal resistor divider. The FB pin is used to sense the output voltage. To configure the device properly, connect the FB pin directly to VOUT as shown in Figure 26.

11.2.1.2.3 Inductor Selection
To make sure that the device can operate, a suitable inductor must be connected between pin VIN and pin L. Inductor values of 4.7 μH show good performance over the whole input and output voltage range.

Choosing other inductance values affects the switching frequency \( f \) proportional to \( 1/L \) as shown in Equation 1.
Typical Applications (continued)

\[
L = \frac{1}{f \times 200 \text{ mA}} \times \frac{V_{IN} \times (V_{OUT} - V_{IN})}{V_{OUT}}
\]  

Equation 1

Choosing inductor values higher than 4.7 \( \mu \)H can improve efficiency due to reduced switching frequency and therefore with reduced switching losses. Using inductor values below 2.2 \( \mu \)H is not recommended.

Having selected an inductance value, the peak current for the inductor in steady-state operation can be calculated. **Equation 2** gives the peak-current estimate.

\[
I_{L,\text{MAX}} = \begin{cases} 
V_{OUT} \times I_{OUT} & + 100 \text{ mA}; \quad \text{continuous current operation} \\
0.8 \times V_{IN} & 200 \text{ mA}; \quad \text{discontinuous current operation}
\end{cases}
\]

Equation 2

**Equation 2** provides a suitable inductor current rating. However, remember that load transients and error conditions may cause higher inductor currents.

**Equation 3** provides an easy way to estimate whether the device will work in continuous or discontinuous operation depending on the operating points. As long as the **Equation 3** is true, continuous operation is typically established. If **Equation 3** becomes false, discontinuous operation is typically established.

\[
\frac{V_{OUT} \times I_{OUT}}{V_{IN}} > 0.8 \times 100 \text{ mA}
\]

Equation 3

The following inductor series from different suppliers have been used with TPS6122x converters:

<table>
<thead>
<tr>
<th>VENDOR</th>
<th>INDUCTOR SERIES</th>
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<tr>
<td>Coilcraft</td>
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<tr>
<td>Wurth Elektronik</td>
<td>WE-TPC Typ S</td>
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</tbody>
</table>

11.2.1.2.4 Capacitor Selection

11.2.1.2.4.1 Input Capacitor

An input capacitor value of at least 10 \( \mu \)F is 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.

11.2.1.2.4.2 Output Capacitor

For the output capacitor \( C_2 \), 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 around 2.2\( \mu \)F 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.

A minimum capacitance value of 4.7 \( \mu \)F should be used, 10 \( \mu \)F is recommended. If the inductor value exceeds 4.7 \( \mu \)H, the value of the output capacitance value needs to be half the inductance value or higher for stability reasons, see **Equation 4**.

\[
C_2 \geq \frac{L}{2} \times \frac{\mu \text{F}}{\mu \text{H}}
\]

Equation 4
The TPS6122x is not sensitive to the ESR in terms of stability. However, low ESR capacitors, such as ceramic capacitors, are recommended anyway to minimize output voltage ripple. If heavy load changes are expected, increase the output capacitor value to avoid output voltage drops during fast load transients.

11.2.1.3 Application Curves

Figure 27 shows the excellent efficiency of the converter, which remains above 80% even with heavily discharged cells.

11.2.2 Specific Application, Variable Output Voltage Supply

11.2.2.1 Design Requirements

- Single 4.2 V output at up to 50 mA
- Power source, two AA alkaline cells
- Greater than 80% conversion efficiency

11.2.2.2 Detailed Design Procedure

The design procedure for this application is identical to that for the fixed-output supply except for programming the output voltage.

11.2.2.2.1 Device Selection

This application example uses the TPS61220 so that the output voltage can be set at 4.2 V.
11.2.2.2 Programming The Output Voltage

In the adjustable output versions, an external resistor divider is used to adjust the output voltage. The resistor divider must be connected between VOUT, FB and GND as shown in Figure 28. When the output voltage is regulated properly, the typical voltage value at the FB pin is 500 mV for the adjustable devices. The maximum recommended value for the output voltage is 6.0 V. The current through the resistor divider should be about 100 times greater than the current into the FB pin. The typical current into the FB pin is 0.01 μA, and the voltage across the resistor between FB and GND, R2, is typically 500 mV. Based on those two values, the recommended value for R2 should be lower than 500 kΩ, in order to set the divider current to 1 μA or higher. The value of the resistor connected between VOUT and FB, R1, depending on the needed output voltage (VOUT), can be calculated using Equation 5:

\[
R_1 = R_2 \times \left( \frac{V_{OUT}}{V_{FB}} - 1 \right)
\]  

(5)

For this example, if an output voltage of 4.2 V is needed, a 1.2-MΩ resistor is calculated for R1 when 160 kΩ is selected for R2. This would yield an output voltage of 4.25 V, neglecting resistor tolerances.

11.2.2.3 Inductor Selection

See Inductor Selection for a discussion on inductor choice.

11.2.2.4 Capacitor Selection

The procedure for selecting capacitors is the same as for the fixed output voltage circuit. See Capacitor Selection.

11.2.2.3 Application Curves

Figure 29 shows the excellent efficiency of the converter, which remains above 80% with heavily discharged cells.
12 Power Supply Recommendations

12.1 Typical Power Sources
The high conversion efficiency of this device encourages the use of a wide range of battery types. Photovoltaic cells and large capacitors ('supercapacitors') may also serve as power sources within the limits specified in Recommended Operating Conditions.

12.2 Input Voltage Effects On Output Current and Efficiency
The TPS6122x devices have a wide input-voltage range, and deliver enough current to be applicable to many portable applications. However, at lower extremes of input voltage, less output current is available, and efficiency is somewhat less. Figure 1 - Figure 11 show the tradeoffs between input voltage, output current capacity and conversion efficiency, and allow the designer to plan how far to discharge a battery array before system shutdown occurs.

12.3 Behavior While Disabled
When the device is disabled, the output voltage follows the power-source voltage as shown in Figure 12.

12.4 Startup
See the description of the Startup sequence for more information.
13 Layout

13.1 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.

The feedback divider in an application using the TPS61220 should be placed as close as possible to the control ground pin of the IC. To route the ground path from the resistor divider, use short traces as well, separated from the power ground traces. This avoids ground shift problems, which can occur due to superimposition of power ground current and control ground current. Assure that the ground traces are connected close to the device GND pin.

13.2 Layout Example

![PCB Layout Suggestion For Adjustable Output Voltage Options](image)

13.3 Thermal Considerations

Implementation of integrated circuits in low-profile and fine-pitch surface-mount packages typically requires special attention to power dissipation. Many system-dependent issues such as thermal coupling, airflow, added heat sinks and convection surfaces, and the presence of other heat-generating components affect the power-dissipation limits of a given component.

Three basic approaches for enhancing thermal performance are listed below.

- Improving the power-dissipation capability of the PCB design
- Improving the thermal coupling of the component to the PCB
- Introducing airflow in the system

For more details on how to use the thermal parameters in the dissipation ratings table please check the Thermal Characteristics Application Note (SZZA017) and the IC Package Thermal Metrics Application Note (SPRA953).
14 Device and Documentation Support

14.1 Device Support

14.1.1 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.

14.1.2 Development Support
TPS61220EVM-319 Evaluation Module
SwitcherPro Switching Power Supply Design Tool (Circuit Design & Simulation)

14.2 Documentation Support

14.2.1 Related Documentation
Gas Sensor Platform Reference Design
Wireless Heart Monitor with Bluetooth Low Energy

14.3 Related Links
The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

<table>
<thead>
<tr>
<th>PARTS</th>
<th>PRODUCT FOLDER</th>
<th>SAMPLE &amp; BUY</th>
<th>TECHNICAL DOCUMENTS</th>
<th>TOOLS &amp; SOFTWARE</th>
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14.4 Trademarks
SwitcherPro is a trademark of Texas Instruments. All other trademarks are the property of their respective owners.

14.5 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.

14.6 Glossary
SLYZ022 — *TI Glossary.*
This glossary lists and explains terms, acronyms, and definitions.
15 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>
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<th>Package Type</th>
<th>Package Drawing</th>
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<th>Package Qty</th>
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<th>Lead/Ball Finish</th>
<th>MSL Peak Temp (3)</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
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(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substances do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

**OTHER QUALIFIED VERSIONS OF TPS61222 :**

- **Enhanced Product:** TPS61222-EP

**NOTE:** Qualified Version Definitions:

- **Enhanced Product - Supports Defense, Aerospace and Medical Applications**
**TAPE AND REEL INFORMATION**

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*All dimensions are nominal.

**TAPE DIMENSIONS**

- **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 FOR PIN 1 ORIENTATION IN TAPE**

- **Pocket Quadrants**: Positions for component orientation
- **Sprocket Holes**: Points for reel feeding
- **User Direction of Feed**: Direction of component feed
**TAPE AND REEL BOX DIMENSIONS**

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*All dimensions are nominal*

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<th>Pins</th>
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</table>
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Falls within JEDEC MO-203 variation AB.
NOTES:  
A. All linear dimensions are in millimeters.  
B. This drawing is subject to change without notice.  
C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.  
D. Publication IPC-7351 is recommended for alternate designs.  
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
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