LTC1514-3.3/LTC1514-5
Step-Up/Step-Down Switched Capacitor DC/DC Converters with Low-Battery Comparator

FEATURES

- 3.3V or 5V Output Voltages
- 2V to 10V Input Voltage Range
- Up to 50mA Output Current
- Only Three External Capacitors Required
- Soft Start Limits Inrush Current at Turn-On
- Low Operating Current: 60µA
- Low Shutdown Current: 10µA
- Shutdown Disconnects Load from VIN
- Short-Circuit and Overtemperature Protected
- 650kHz Switching Frequency
- Low-Battery Comparator Active in Shutdown
- Available in SO-8 Package

DESCRIPTION

The LTC®1514-3.3/LTC1514-5 are micropower switched capacitor DC/DC converters that produce a regulated output voltage by either stepping up or stepping down the input voltage. Output voltage is fixed at either 3.3V (LTC1514-3.3) or 5V (LTC1514-5) by an internal resistor divider.

A unique architecture allows the parts to accommodate a wide input voltage range (2V to 10V) while maintaining ±4% regulation. Additional circuitry prevents excessive inrush current and output voltage ripple when large VIN to VOUT differentials are present.

An internal uncommitted comparator is kept active in shutdown. The comparator has an open-drain output for flexible interfacing.

The parts are short-circuit and overtemperature protected. Battery life is maximized by very low operating currents (ICC = 60µA typ, 10µA in shutdown). Both parts are available in an SO-8 package.

APPLICATIONS

- Battery-Operated Equipment
- Smart Card Readers
- Local Power Supplies
- Handheld Instruments
- Battery Backup Supplies

TYPICAL APPLICATION

5V Step-Up/Step-Down Power Supply with Low-Battery Detect

LTC1514-5 Output Voltage vs Input Voltage
**LTC1514-3.3/LTC1514-5**

**ABSOLUTE MAXIMUM RATINGS**

(Note 1)
- $V_{IN}$ to GND ........................................... $-0.3V$ to $12V$
- $V_{OUT}$ to GND ........................................... $-0.3V$ to $12V$
- SHDN, LBI, LBO to GND ................................. $-0.3V$ to $12V$
- $V_{OUT}$ Short-Circuit Duration ..................... Indefinite

Operating Temperature Range
- Commercial ............................................. $0°C$ to $70°C$
- Industrial .............................................. $-40°C$ to $85°C$

Storage Temperature Range ...................... $-65°C$ to $150°C$

Lead Temperature (Soldering, 10 sec) ......... $300°C$

Note 1: Absolute Maximum Ratings are those values beyond which the life of the device may be impaired.

**ELECTRICAL CHARACTERISTICS**

$V_{IN} = 2V$ to $10V$, SHDN = 3V, C1 = 0.22µF, $C_{IN} = C_{OUT} = 10µF$, unless otherwise noted (Note 2).

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNITS</th>
</tr>
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<tbody>
<tr>
<td>$V_{IN}$ Operating Voltage</td>
<td>LTC1514-3.3</td>
<td>2.0</td>
<td>8</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>LTC1514-5</td>
<td>2.7</td>
<td>10</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_{OUT}$ (LTC1514-3.3)</td>
<td>$2V \leq V_{IN} \leq 8V, I_{OUT} \leq 15mA$</td>
<td>3.17</td>
<td>3.3</td>
<td>3.43</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>$3V \leq V_{IN} \leq 8V, I_{OUT} \leq 50mA$</td>
<td>3.17</td>
<td>3.3</td>
<td>3.43</td>
<td>V</td>
</tr>
<tr>
<td>$V_{OUT}$ (LTC1514-5)</td>
<td>$2.7V \leq V_{IN} \leq 10V, I_{OUT} \leq 15mA$</td>
<td>4.8</td>
<td>5</td>
<td>5.2</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>$3.3V \leq V_{IN} \leq 10V, I_{OUT} \leq 50mA$</td>
<td>4.8</td>
<td>5</td>
<td>5.2</td>
<td>V</td>
</tr>
<tr>
<td>$V_{IN}$ Operating Current</td>
<td>$V_{IN} \leq 5V, I_{OUT} = 0, SHDN = 3V$</td>
<td>60</td>
<td>100</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td>$V_{IN} &gt; 5V, I_{OUT} = 0, SHDN = 3V$</td>
<td>75</td>
<td>120</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>$V_{IN}$ Shutdown Current</td>
<td>SHDN = 0V, $V_{IN} \leq 5V$</td>
<td>10</td>
<td>20</td>
<td></td>
<td>µA</td>
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<tr>
<td></td>
<td>SHDN = 0V, $V_{IN} &gt; 5V$</td>
<td>35</td>
<td></td>
<td></td>
<td>µA</td>
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<tr>
<td>Output Ripple</td>
<td>Full Load (Note 2)</td>
<td>100</td>
<td></td>
<td></td>
<td>mV_{P-P}</td>
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<tr>
<td>Switching Frequency</td>
<td></td>
<td>500</td>
<td>650</td>
<td>800</td>
<td>kHz</td>
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<tr>
<td>LBI Trip Point</td>
<td>LBI Ramping Negative</td>
<td>1.10</td>
<td>1.145</td>
<td>1.180</td>
<td>V</td>
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<tr>
<td>LBI Trip Point Hysteresis</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>%</td>
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<tr>
<td>LBI Input Current</td>
<td>LBI = 1.145V</td>
<td>-50</td>
<td>50</td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>LBO $V_{OL}$</td>
<td>$I_{SINK} = 100µA, V_{IN} = 3V$</td>
<td>0.025</td>
<td>0.4</td>
<td></td>
<td>V</td>
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<tr>
<td>LBO Leakage Current</td>
<td>$V_{LBO} = 5V, LBI = V_{IN}$</td>
<td>-1</td>
<td></td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>SHDN Input Threshold</td>
<td>$V_{IL}$</td>
<td>0.4</td>
<td>1</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>$V_{IH}$</td>
<td>1</td>
<td>1.6</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>SHDN Input Current</td>
<td>SHDN = $V_{IN}$</td>
<td>-1</td>
<td>1</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td>SHDN = 0V</td>
<td>-1</td>
<td>1</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>$I_{OUT}$ Short-Circuit Current</td>
<td>$V_{OUT} = 0V$</td>
<td>12</td>
<td>40</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$t_{ON}$ Soft Start Turn-On Time</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td>ms</td>
</tr>
</tbody>
</table>

Note 2: For $V_{IN} \geq 8V$, $C_{OUT} = 22µF$.

The ● denotes specifications which apply over the full operating temperature range.

Note 1: Absolute Maximum Ratings are those values beyond which the life of the device may be impaired.
TYPICAL PERFORMANCE CHARACTERISTICS

LTC1514-5 Step-Down Mode Load Transient Response

\[ V_{IN} = 8V, V_{OUT} = 5V, C_{OUT} = 10\mu F, T_A = 25^\circ C \]

\[ V_{OUT} \text{ AC COUPLED} 100mV/\text{DIV} \]
\[ I_{OUT} 50mA/\text{DIV} \]

LTC1514-5 Step-Up Mode Load Transient Response

\[ V_{IN} = 3.3V, V_{OUT} = 5V, C_{OUT} = 10\mu F, T_A = 25^\circ C \]

\[ V_{OUT} \text{ AC COUPLED} 100mV/\text{DIV} \]
\[ I_{OUT} 50mA/\text{DIV} \]

BLOCK DIAGRAM

PIN FUNCTIONS

**SHDN (Pin 1):** Shutdown Input. A logic low on the SHDN pin puts the part into shutdown mode. A logic high (\( V_{\text{SHDN}} \geq 1.6V \)) enables the charge pump regulator. At high \( V_{IN} \) voltages, the SHDN pin may still be controlled with 3V logic without causing a large rise in \( V_{IN} \) quiescent current. The SHDN pin may not float; connect to \( V_{IN} \) if unused.

**LBO (Pin 2):** Open-Drain, Low-Battery Comparator Output. This pin will pull low whenever the voltage on the LBI pin is less than the internal reference voltage (1.145V typ).

**LBI (Pin 3):** Low-Battery Comparator Input. The voltage on this pin is compared to the internal reference voltage (1.145V). The LBO output will sink current when the voltage on the LBI pin is less than 1.145V typ. The low-
**PIN FUNCTIONS**

battery comparator and 1.145V reference are kept alive in shutdown.

**GND (Pin 4):** Ground. Should be tied to a ground plane for best performance.

**C1⁻ (Pin 5):** Charge Pump Flying Capacitor, Negative Terminal.

**C1⁺ (Pin 6):** Charge Pump Flying Capacitor, Positive Terminal.

**V_IN (Pin 7):** Charge Pump Input Voltage. May be between 2V and 8V (LTC1514-3.3) or between 2.7V and 10V (LTC1514-5). \( V_{\text{IN}} \) should be bypassed with a \( \geq 10 \mu F \) low ESR capacitor as close as possible to the pin for best performance.

**V_OUT (Pin 8):** Regulated Output Voltage. The output voltage is internally set to either 3.3V (LTC1514-3.3) or to 5V (LTC1514-5) using an internal resistor divider. \( V_{\text{OUT}} \) should be bypassed with a \( \geq 10 \mu F \) low ESR capacitor as close as possible to the pin for best performance.

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**APPLICATIONS INFORMATION**

**Regulator Operation**

The regulator section of the LTC1514-3.3/LTC1514-5 consists of a charge pump, reference, comparator and some logic. The divided down output voltage is compared to the internal reference voltage. When the divided output drops below the reference voltage, the charge pump is enabled, which boosts the output back into regulation. Hysteresis in the comparator forces the regulator to burst on and off and causes approximately 100mV of peak-to-peak ripple to appear at the output. By enabling the charge pump only when needed, the LTC1514-3.3 and LTC1514-5 are able to achieve high efficiencies with low output load currents.

Each part’s charge pump has a unique architecture that allows the input voltage to be either stepped up or stepped down to produce a regulated output. Internal circuitry senses the \( V_{\text{IN}} \) to \( V_{\text{OUT}} \) differential voltage and controls the charge pump operating mode. In addition, the effective output impedance of the charge pump is internally adjusted to prevent large inrush currents and allow for a wide input voltage range. When the input voltage is lower than the output voltage, the charge pump operates as a step-up voltage doubler. When the input voltage is greater than the output, the charge pump operates as a step-down gated switch.

**Capacitor Selection**

For best performance, low ESR capacitors are recommended for both \( C_{\text{IN}} \) and \( C_{\text{OUT}} \) to reduce noise and ripple. The \( C_{\text{IN}} \) and \( C_{\text{OUT}} \) capacitors should be either ceramic or tantalum and should be 10\( \mu F \) or greater. If the input source impedance is very low (<0.5\( \Omega \)), \( C_{\text{IN}} \) may not be needed. Increasing the size of \( C_{\text{OUT}} \) to 22\( \mu F \) or greater will reduce output voltage ripple—particularly with high \( V_{\text{IN}} \) voltages (8V or greater). A ceramic capacitor is recommended for the flying capacitor \( C_1 \) with a value of 0.1\( \mu F \) or 0.22\( \mu F \). Smaller value flying capacitors may be used in low output current applications.

**Output Ripple**

Normal LTC1514-3.3/LTC1514-5 operation produces voltage ripple on the \( V_{\text{OUT}} \) pin. Output voltage ripple is required for the parts to regulate. Low frequency ripple exists due to the hysteresis in the sense comparator and propagation delays in the charge pump enable/disable circuits. High frequency ripple is also present mainly from the ESR (equivalent series resistance) in the output capacitor. Typical output ripple (\( V_{\text{IN}} < 8V \)) under maximum load is 100mV peak-to-peak with a low ESR (<0.5\( \Omega \)) 10\( \mu F \) output capacitor. For applications requiring \( V_{\text{IN}} \) to exceed 8V, a 22\( \mu F \) or larger \( C_{\text{OUT}} \) capacitor is recommended to maintain max ripple in the 100mV range.

The magnitude of the ripple voltage depends on several factors. High input voltages increase the output ripple since more charge is delivered to \( C_{\text{OUT}} \) per charging cycle. A large \( C_1 \) flying capacitor (>0.22\( \mu F \)) also increases ripple in step-up mode for the same reason. Large output current load and/or a small output capacitor (<10\( \mu F \)) results in higher ripple due to higher output voltage dV/dt. High ESR capacitors (ESR > 0.5\( \Omega \)) on the
APPLICATIONS INFORMATION

output pin cause high frequency voltage spikes on VOUT with every clock cycle. There are several ways to reduce the output voltage ripple. A larger COUT capacitor (22µF or greater) will reduce both the low and high frequency ripple due to the lower COUT charging and discharging dV/dt and the lower ESR typically found with higher value (larger case size) capacitors. A low ESR ceramic output capacitor will minimize the high frequency ripple, but will not reduce the low frequency ripple unless a high capacitance value is chosen. A reasonable compromise is to use a 10µF to 22µF tantalum capacitor in parallel with a 1µF to 3.3µF ceramic capacitor on VOUT to reduce both the low and high frequency ripple. An RC or LC filter may also be used to reduce high frequency voltage spikes (see Figure 1).

Internal soft start circuitry controls the rate at which VOUT may be charged from 0V to its final regulated value. The typical start-up time from VOUT = 0V to 5V is 4ms. This corresponds to an effective VOUT charging current of only 12.5mA for a 10µF output capacitor (27.5mA for 22µF, etc). Note that any output current load present during start-up will add directly to the charging currents mentioned above. The soft start circuitry limits start-up current both at initial power-up and when coming out of shutdown.

As the VIN (or boosted VIN) to VOUT voltage differential grows, the effective output impedance of the charge pump is automatically increased by internal voltage sensing circuitry. This feature minimizes the current spikes pulled from VIN whenever the charge pump is enabled and helps to reduce both input and output ripple.

Protection Features

The LTC1514-X contain thermal shutdown and short-circuit protection features. The parts will shut down when the junction temperature reaches approximately 150°C and will resume operation once the junction temperature has dropped back to approximately 140°C. The parts will limit output current to 12mA (typ) when a short-circuit condition (VOUT < 100mV) exists. The parts can survive an indefinite short to GND. The LTC1514-X devices use a low thermal resistance SO-8 package (110°C/W vs 150°C/W for standard SO-8). This permits full output current, even at high input supply voltages.

Inrush Currents

A common problem with switched capacitor regulators is inrush current—particularly during power-up and coming out of shutdown mode. Whenever large VIN (or boosted VIN) to VOUT voltage differentials are present, most charge pumps will pull large current spikes from the input supply. Only the effective charge pump output impedance limits the current while the charge pump is enabled. This may disrupt input supply regulation, especially if the input supply is a low power DC/DC converter or linear regulator. The LTC1514-3.3/LTC1514-5 minimize inrush currents both at start-up and under normal high VIN to VOUT operation.

Low-Battery Comparator

The internal low-battery comparator trips at 1.145 ±3% (LBI ramping negative). Programming the comparator to trip at a higher voltage can easily be done with an external

Figure 1. Output Ripple Reduction Techniques

Figure 2. Programming the Low-Battery Comparator Trip Voltage
resistor divider (see Figure 2). Since the low-battery comparator is kept alive in shutdown, it may be used to protect batteries against deep discharge by shutting down the power supply when the battery voltage gets too low. The open-drain comparator output allows for flexible interfacing between the LBO output and external logic. LBO pull-up resistors in the 50k to 1M range are recommended.

### TYPICAL APPLICATIONS

#### 3.3V Step-Up/Step-Down Supply with Power Good Output

![Circuit Diagram for 3.3V Step-Up/Step-Down Supply with Power Good Output]

- **VOUT** = 3.3V ± 4%
- **IOUT** = 15mA, **VIN** > 2V
- **IOUT** = 50mA, **VIN** > 3V

#### Low Power Battery Backup Supply with Autoswitchover and No Reverse Current

![Circuit Diagram for Low Power Battery Backup Supply with Autoswitchover and No Reverse Current]

#### Battery/External Power Autoswitch Regulator

![Circuit Diagram for Battery/External Power Autoswitch Regulator]
TYPICAL APPLICATIONS

Low Power Dual Output Supply (Maximum Combined I_{OUT} = 50mA)

Step-Up/Step-Down Power Supply with Input Autoswitching

PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

S8 Package
8-Lead Plastic Small Outline (Narrow 0.150)
(LTC DWG # 05-08-1610)

RELATED PARTS

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTC1515 Series</td>
<td>Step-Up/Step-Down Switched Capacitor DC/DC Converters with Reset</td>
<td>V_{IN} 2V to 10V, 3.3V, 5V and ADJ Versions, I_{OUT} to 50mA</td>
</tr>
<tr>
<td>LTC1516</td>
<td>Micropower, Regulated 5V Charge Pump DC/DC Converter</td>
<td>I_{OUT} = 20mA (V_{IN} ≥ 2V), I_{OUT} = 50mA (V_{IN} ≥ 3V)</td>
</tr>
<tr>
<td>LTC1517-5</td>
<td>Micropower, Regulated 5V Charge Pump DC/DC Converter</td>
<td>LTC1522 Without Shutdown and Packaged in SOT-23</td>
</tr>
<tr>
<td>LTC1522</td>
<td>Micropower, Regulated 5V Charge Pump DC/DC Converter</td>
<td>Available in 8-Pin MSOP, 6μA Quiescent Current, I_{OUT} = 20mA</td>
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<tr>
<td>LTC1555/LTC1556</td>
<td>SIM Power Supply and Level Translators</td>
<td>Step-Up/Step-Down SIM Power Supply and Level Translators</td>
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<tr>
<td>LTC660</td>
<td>100mA CMOS Voltage Converter</td>
<td>5V to –5V Conversion with Low Voltage Loss</td>
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</table>