FEATURES

- 1.5V to 12V Operating Supply Voltage Range
- 13V Absolute Maximum Rating
- 200µA Maximum No Load Supply Current at 5V
- Boost Pin (Pin 1) for Higher Switching Frequency
- 97% Minimum Open Circuit Voltage Conversion Efficiency
- 95% Minimum Power Conversion Efficiency
- I_S = 1.5µA with 5V Supply When OSC Pin = 0V or V+
- High Voltage Upgrade to ICL7660/LTC1044

APPLICATIONS

- Conversion of 10V to ±10V Supplies
- Conversion of 5V to ±5V Supplies
- Precise Voltage Division: V_OUT = V_IN/2 ±20ppm
- Voltage Multiplication: V_OUT = ±nV_IN
- Supply Splitter: V_OUT = ±V_S/2
- Automotive Applications
- Battery Systems with 9V Wall Adapters/Chargers

DESCRIPTION

The LTC®1044A is a monolithic CMOS switched-capacitor voltage converter. It plugs in for ICL7660/LTC1044 in applications where higher input voltage (up to 12V) is needed. The LTC1044A provides several conversion functions without using inductors. The input voltage can be inverted (V_OUT = –V_IN), doubled (V_OUT = 2V_IN), divided (V_OUT = V_IN/2) or multiplied (V_OUT = ±nV_IN).

To optimize performance in specific applications, a boost function is available to raise the internal oscillator frequency by a factor of seven. Smaller external capacitors can be used in higher frequency operation to save board space. The internal oscillator can also be disabled to save power. The supply current drops to 1.5µA at 5V input when the OSC pin is tied to GND or V+.

CONVERSION OF 10V TO ±10V SUPPLIES
CONVERSION OF 5V TO ±5V SUPPLIES
PRECISE VOLTAGE DIVISION: V_OUT = V_IN/2 ±20ppm
VOLTAGE MULTIPLICATION: V_OUT = ±nV_IN
SUPPLY SPLITTER: V_OUT = ±V_S/2
AUTOMOTIVE APPLICATIONS
BATTERY SYSTEMS WITH 9V WALL ADAPTERS/CHARGERS

TYPICAL APPLICATION

Generating –10V from 10V

Output Voltage vs Load Current, V+ = 10V

For more information www.linear.com/LTC1044A
LTC1044A

**ABSOLUTE MAXIMUM RATINGS**

(Note 1)

Supply Voltage .................................................. 13V

Input Voltage on Pins 1, 6 and 7 (Note 2) .................. –0.3V < VIN < V+ + 0.3V

Current into Pin 6 ............................................. 20µA

Output Short-Circuit Duration

V+ ≤ 6.5V .................................................. Continuous

Operating Temperature Range

LTC1044AC .................................................. 0°C to 70°C

LTC1044AI .................................................. –40°C to 85°C

Storage Temperature Range .................. –65°C to 150°C

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

**PIN CONFIGURATION**

![PIN CONFIGURATION Diagram](image)

Consult factory for military grade parts

**ORDER INFORMATION**

<table>
<thead>
<tr>
<th>LEAD FREE FINISH</th>
<th>TAPE AND REEL</th>
<th>PART MARKING</th>
<th>PACKAGE DESCRIPTION</th>
<th>TEMPERATURE RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTC1044ACN8#PBF</td>
<td>LTC1044ACN8#TRPBF</td>
<td>LTC1044 ACN8</td>
<td>8-Lead Plastic DIP</td>
<td>0°C to 70°C</td>
</tr>
<tr>
<td>LTC1044AIN8#PBF</td>
<td>LTC1044AIN8#TRPBF</td>
<td>LTC1044 AIN8</td>
<td>8-Lead Plastic DIP</td>
<td>–40°C to 85°C</td>
</tr>
<tr>
<td>LTC1044ACS8#PBF</td>
<td>LTC1044ACS8#TRPBF</td>
<td>1044A</td>
<td>8-Lead Plastic SO</td>
<td>0°C to 70°C</td>
</tr>
<tr>
<td>LTC1044AIS8#PBF</td>
<td>LTC1044AIS8#TRPBF</td>
<td>1044AI</td>
<td>8-Lead Plastic SO</td>
<td>–40°C to 85°C</td>
</tr>
</tbody>
</table>

Consult LTC Marketing for parts specified with wider operating temperature ranges.
Consult LTC Marketing for information on nonstandard lead based finish parts.

For more information on lead free part marking, go to: [http://www.linear.com/leadfree/](http://www.linear.com/leadfree/)
For more information on tape and reel specifications, go to: [http://www.linear.com/tapeandreel/]
## ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at $T_A = 25^\circ C$. $V^+ = 5V$, $C_{OSC} = 0pF$, unless otherwise noted.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>LTC1044AC</th>
<th>LTC1044AI</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_S$</td>
<td>Supply Current</td>
<td>$R_L = \infty$, Pins 1 and 7, No Connection $V^+ = 3V$</td>
<td>60</td>
<td>15</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Minimum Supply Voltage</td>
<td>$R_L = 10k$</td>
<td>●</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Maximum Supply Voltage</td>
<td>$R_L = 10k$</td>
<td>●</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>$R_{OUT}$</td>
<td>Output Resistance</td>
<td>$I_L = 20mA$, $f_{OSC} = 5kHz$, $V^+ = 2V$, $I_L = 3mA$, $f_{OSC} = 1kHz$</td>
<td>100</td>
<td>310</td>
<td>100</td>
</tr>
<tr>
<td>$f_{OSC}$</td>
<td>Oscillator Frequency</td>
<td>$V^+ = 5V$, (Note 3)</td>
<td>5</td>
<td>●</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Voltage Conversion Efficiency</td>
<td>$RL = 5k$, $f_{OSC} = 5kHz$</td>
<td>95</td>
<td>98</td>
<td>95</td>
</tr>
<tr>
<td>$P_{EFF}$</td>
<td>Power Efficiency</td>
<td>$R_L = \infty$</td>
<td>97</td>
<td>99.9</td>
<td>97</td>
</tr>
<tr>
<td>$\text{Oscillator Sink or Source Current}$</td>
<td>$V_{OSC} = 0V$ or $V^+$</td>
<td>●</td>
<td>3</td>
<td>3</td>
<td>$\mu A$</td>
</tr>
<tr>
<td></td>
<td>Pin 1 (BOOST) = 0V</td>
<td>●</td>
<td>20</td>
<td>20</td>
<td>$\mu A$</td>
</tr>
<tr>
<td></td>
<td>Pin 1 (BOOST) = $V^+$</td>
<td>●</td>
<td></td>
<td></td>
<td>$\mu A$</td>
</tr>
</tbody>
</table>

**Note 1:** Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

**Note 2:** Connecting any input terminal to voltages greater than $V^+$ or less than ground may cause destructive latchup. It is recommended that no inputs from sources operating from external supplies be applied prior to power-up of the LTC1044A.

**Note 3:** $f_{OSC}$ is tested with $C_{OSC} = 100pF$ to minimize the effects of test fixture capacitance loading. The 0pF frequency is correlated to this 100pF test point, and is intended to simulate the capacitance at pin 7 when the device is plugged into a test socket and no external capacitor is used.
TYPICAL PERFORMANCE CHARACTERISTICS

Operating Voltage Range vs Temperature

Power Efficiency vs Oscillator Frequency, $V^+ = 5V$

Power Efficiency vs Oscillator Frequency, $V^+ = 10V$

Output Resistance vs Oscillator Frequency, $V^+ = 5V$

Output Resistance vs Oscillator Frequency, $V^+ = 10V$

Power Conversion Efficiency vs Load Current, $V^+ = 2V$

Power Conversion Efficiency vs Load Current, $V^+ = 5V$

Power Conversion Efficiency vs Load Current, $V^+ = 10V$

Operating Voltage Range vs Temperature

Power Efficiency vs Load Current, $V^+ = 5V$

Power Efficiency vs Load Current, $V^+ = 10V$

For more information www.linear.com/LTC1044A
TYPICAL PERFORMANCE CHARACTERISTICS

Output Resistance vs Supply Voltage

Output Voltage vs Load Current, $V^+ = 2V$

Output Voltage vs Load Current, $V^+ = 5V$

Output Voltage vs Load Current, $V^+ = 10V$

Output Resistance vs Temperature

Oscillator Frequency as a Function of $C_{OSC}$, $V^+ = 5V$

Oscillator Frequency as a Function of $C_{OSC}$, $V^+ = 10V$

Oscillator Frequency vs Supply Voltage

Oscillator Frequency vs Temperature

For more information www.linear.com/LTC1044A
Theory of Operation

To understand the theory of operation of the LTC1044A, a review of a basic switched-capacitor building block is helpful.

In Figure 1, when the switch is in the left position, capacitor C1 will charge to voltage V1. The total charge on C1 will be $q_1 = C_1 V_1$. The switch then moves to the right, discharging C1 to voltage V2. After this discharge time, the charge on C1 is $q_2 = C_1 V_2$. Note that charge has been transferred from the source, V1, to the output, V2. The amount of charge transferred is:

$$ \Delta q = q_1 - q_2 = C_1 (V_1 - V_2) $$

If the switch is cycled f times per second, the charge transfer per unit time (i.e., current) is:

$$ I = f \cdot \Delta q = f \cdot C_1 (V_1 - V_2) $$

Rewriting in terms of voltage and impedance equivalence,

$$ I = \frac{V_1 - V_2}{\frac{1}{f \cdot C_1}} = \frac{V_1 - V_2}{R_{\text{EQUIV}}} $$

A new variable, $R_{\text{EQUIV}}$, has been defined such that $R_{\text{EQUIV}} = 1/(f \cdot C_1)$. Thus, the equivalent circuit for the switched-capacitor network is as shown in Figure 2.

Examination of Figure 3 shows that the LTC1044A has the same switching action as the basic switched-capacitor building block. With the addition of finite switch-on resistance and output voltage ripple, the simple theory although not exact, provides an intuitive feel for how the device works.

For example, if you examine power conversion efficiency as a function of frequency (see typical curve), this simple theory will explain how the LTC1044A behaves. The loss, and hence the efficiency, is set by the output impedance. As frequency is decreased, the output impedance will eventually be dominated by the $1/(f \cdot C_1)$ term, and power efficiency will drop. The typical curves for Power Efficiency vs Frequency show this effect for various capacitor values.

Note also that power efficiency decreases as frequency goes up. This is caused by internal switching losses which occur due to some finite charge being lost on each switching cycle. This charge loss per unit cycle, when multiplied by the switching frequency, becomes a current loss. At high frequency this loss becomes significant and the power efficiency starts to decrease.
LV (Pin 6)
The internal logic of the LTC1044A runs between \( V^+ \) and \( LV \) (pin 6). For \( V^+ \) greater than or equal to 3V, an internal switch shorts \( LV \) to GND (pin 3). For \( V^+ \) less than 3V, the \( LV \) pin should be tied to GND. For \( V^+ \) greater than or equal to 3V, the \( LV \) pin can be tied to GND or left floating.

OSC (Pin 7) and Boost (Pin 1)
The switching frequency can be raised, lowered, or driven from an external source. Figure 4 shows a functional diagram of the oscillator circuit.

Loading pin 7 with more capacitance will lower the frequency. Using the boost (pin 1) in conjunction with external capacitance on pin 7 allows user selection of the frequency over a wide range.

Driving the LTC1044A from an external frequency source can be easily achieved by driving pin 7 and leaving the boost pin open as shown in Figure 5. The output current from pin 7 is small (typically 0.5µA) so a logic gate is capable of driving this current. The choice of using a CMOS logic gate is best because it can operate over a wide supply voltage range (3V to 15V) and has enough voltage swing to drive the internal Schmitt trigger shown in Figure 4. For 5V applications, a TTL logic gate can be used by simply adding an external pull-up resistor (see Figure 5).

By connecting the boost pin (pin 1) to \( V^+ \), the charge and discharge current is increased and hence, the frequency is increased by approximately seven times. Increasing the frequency will decrease output impedance and ripple for higher load currents.
Applications Information

Capacitor Selection

External capacitors C1 and C2 are not critical. Matching is not required, nor do they have to be high quality or tight tolerance. Aluminum or tantalum electrolytics are excellent choices with cost and size being the only consideration.

Negative Voltage Converter

Figure 6 shows a typical connection which will provide a negative supply from an available positive supply. This circuit operates over full temperature and power supply ranges without the need of any external diodes. The LV pin (pin 6) is shown grounded, but for V+ ≥ 3V it may be floated, since LV is internally switched to ground (pin 3) for V+ ≥ 3V.

The output voltage (pin 5) characteristics of the circuit are those of a nearly ideal voltage source in series with an 80Ω resistor. The 80Ω output impedance is composed of two terms:

1. The equivalent switched-capacitor resistance (see Theory of Operation).

2. A term related to the on-resistance of the MOS switches.

At an oscillator frequency of 10kHz and C1 = 10µF, the first term is:

\[ \text{REQUIV} = \frac{1}{(f_{OSC}/2) \cdot C1} \]
\[ = \frac{1}{5 \cdot 10^3 \cdot 10 \cdot 10^{-6}} = 20\Omega \]

Notice that the above equation for REQUIV is not a capacitive reactance equation \((X_C = 1/\omega C)\) and does not contain a \(2\pi\) term.

Voltage Doubling

Figure 7 shows a two-diode capacitive voltage doubler. With a 5V input, the output is 9.93V with no load and 9.13V with a 10mA load. With a 10V input, the output is 19.93V with no load and 19.28V with a 10mA load.

Ultra-Precision Voltage Divider

An ultra-precision voltage divider is shown in Figure 8. To achieve the 0.002% accuracy indicated, the load current should be kept below 100nA. However, with a slight loss in accuracy the load current can be increased.

For more information www.linear.com/LTC1044A
Battery Splitter
A common need in many systems is to obtain (+) and (–) supplies from a single battery or single power supply system. Where current requirements are small, the circuit shown in Figure 9 is a simple solution. It provides symmetrical ± output voltages, both equal to one half input voltage. The output voltages are both referenced to pin 3 (output common). If the input voltage between pin 8 and pin 5 is less than 6V, pin 6 should also be connected to pin 3 as shown by the dashed line.

Paralleling for Lower Output Resistance
Additional flexibility of the LTC1044A is shown in Figures 10 and 11.
Figure 10 shows two LTC1044As connected in parallel to provide a lower effective output resistance. If, however, the output resistance is dominated by 1/(f • C1), increasing the capacitor size (C1) or increasing the frequency will be of more benefit than the paralleling circuit shown.
Figure 11 makes use of stacking two LTC1044As to provide even higher voltages. A negative voltage doubler or tripler can be achieved, depending upon how pin 8 of the second LTC1044A is connected, as shown schematically by the switch. The available output current will be dictated/decreased by the product of the individual power conversion efficiencies and the voltage step-up ratio.
LTC 1044A

TYPICAL APPLICATIONS

Low Output Impedance Voltage Converter

![Circuit Diagram]

* \( V_{IN} \geq |V_{OUT}| + 0.5V \)
LOAD REGULATION ±0.02%, 0mA TO 15mA

Single 5V Strain Gauge Bridge Signal Conditioner

![Circuit Diagram]

*1% FILM RESISTOR
PRESSURE TRANSDUCER BLH/DHF-350
(CIRCLED LETTER IS PIN NUMBER)

For more information [www.linear.com/LTC1044A](http://www.linear.com/LTC1044A)
TYPICAL APPLICATIONS

Regulated Output 3V to 5V Converter

Low Dropout 5V Regulator

For more information www.linear.com/LTC1044A
**PACKAGE DESCRIPTION**


### N Package

8-Lead PDIP (Narrow .300 Inch)
(Reference LTC DWG # 05-08-1510 Rev I)

**S8 Package**

8-Lead Plastic Small Outline (Narrow .150 Inch)
(Reference LTC DWG # 05-08-1610 Rev G)
## REVISION HISTORY

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<td>4/14</td>
<td>Changed 0.0002% to 0.002% in the Ultra-Precision Voltage Divider section</td>
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</table>
LTC1044A

TYPICAL APPLICATION

Two-Diode Capacitive Voltage Doubler

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<tr>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>COMMENTS</th>
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<tr>
<td>LTC3240-3.3/</td>
<td>3.3V/2.5V Step-Up/Step-Down Charge Pump DC/DC Converter</td>
<td>$V_{IN}$: 1.8V to 5.5V, $V_{OUT(MAX)} = 3.3V/2.5V$, $I_Q = 65\mu A$, $I_{SD} &lt; 1\mu A$, (2mm x 2mm) DFN Package</td>
</tr>
<tr>
<td>LTC3240-2.5</td>
<td></td>
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</tr>
<tr>
<td>LTC3245</td>
<td>Wide $V_{IN}$ Range Low Noise 250mA Buck-Boost Charge Pump</td>
<td>$V_{IN}$: 2.7V to 38V, $V_{OUT(MAX)} = 5V$, $I_Q = 20\mu A$, $I_{SD} = 4\mu A$, 12-Lead MS and (3mm x 4mm) DFN Packages</td>
</tr>
<tr>
<td>LTC3255</td>
<td>Wide $V_{IN}$ Range 50mA Buck (Step-Down) Charge Pump</td>
<td>$V_{IN}$: 4V to 48V, $V_{OUT(MAX)} = 12.5V$, $I_Q = 16\mu A$, 10-Lead MSOP and (3mm x 3mm) DFN Packages</td>
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