LTC1516

Micropower, Regulated 5V Charge Pump DC/DC Converter

May 1996

FEATURES

- **Ultralow Power: Typical Operating I_{CC} = 12μA**
- **Short Circuit/Thermal Protection**
- Regulated 5V ±4% Output
- 2V to 5V Input Range
- **No Inductors**
- I_{CC} in Shutdown: <1μA
- **Output Current: 20mA (V_{IN} > 2V)**
  50mA (V_{IN} > 3V)
- Shutdown Disconnects Load from V_{IN}
- Internal Oscillator: 600kHz
- Compact Application Circuit (0.1 in^2)
- 8-Pin SO Package

APPLICATIONS

- 2-Cell to 5V Conversion
- Li-Ion Battery Backup Supplies
- Local 3V to 5V Conversion
- 5V Flash Memory Programmer
- Smart Card Readers

DESCRIPTION

The LTC®1516 is a micropower charge pump DC/DC converter that produces a regulated 5V output from a 2V to 5V supply. Extremely low supply current (12μA typical with no load, <1μA in shutdown) and low external parts count (two 0.22μF flying capacitors and two 10μF capacitors at V_{IN} and V_{OUT}) make the LTC1516 ideally suited for small, low-load battery-powered applications. Typical efficiency (V_{IN} = 3V) exceeds 70% with load currents between 50μA and 50mA. Modulating the SHDN pin keeps the typical efficiency above 70% with load currents all the way down to 10μA.

The LTC1516 operates as either a doubler or a tripler depending on V_{IN} and output load conditions to improve overall efficiency. The part has thermal shutdown and can survive a continuous short from V_{OUT} to GND. In shutdown the load is disconnected from V_{IN}.

The LTC1516 is available in an 8-pin SO package in both commercial and industrial temperature grades.

TYPICAL APPLICATION

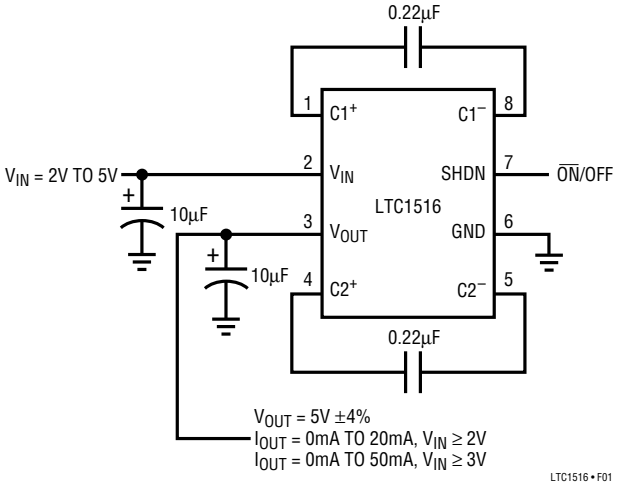
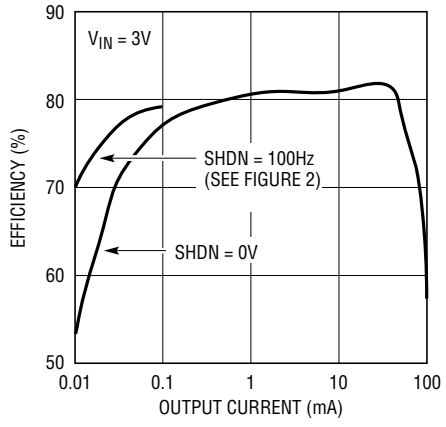


Figure 1. Regulated 5V Output from a 2V to 5V Input

Efficiency vs Output Current

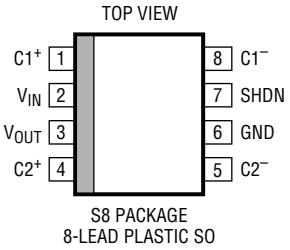


ABSOLUTE MAXIMUM RATINGS

(Note 1)

V_{IN} to GND ..... –0.3V to 6V
V_{OUT} to GND ..... –0.3V to 6V
SHDN to GND ..... –0.3V to 6V
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

PACKAGE/ORDER INFORMATION



S8 PACKAGE
8-LEAD PLASTIC SO

T_{JMAX} = 125°C, θ_{JA} = 150°C/W

ORDER PART NUMBER
LTC1516CS8 LTC1516IS8
S8 PART MARKING
1516 1516I

Consult factory for Military grade parts.

ELECTRICAL CHARACTERISTICS

V_{IN} = 2V to 5V, C1 = C2 = 0.22µF, C_{IN} = C_{OUT} = 10µF, T_{MIN} to T_{MAX} unless otherwise specified (Note 3).

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{IN}	Input Voltage		●	2		5	V
V_{OUT}	Output Voltage	2V ≤ V_{IN} ≤ 5V, I_{OUT} ≤ 20mA	●	4.8		5.2	V
		3V ≤ V_{IN} ≤ 3.6V, I_{OUT} ≤ 50mA	●	4.8		5.2	V
		3.6V ≤ V_{IN} ≤ 5V, I_{OUT} ≤ 50mA, T_A = 25°C (Note 2)		4.8		5.2	V
I_{CC}	Supply Current	2V ≤ V_{IN} ≤ 5V, I_{OUT} = 0mA, SHDN = 0V	●		12	20	µA
		2V ≤ V_{IN} ≤ 5V, I_{OUT} = 0mA, SHDN = V_{IN}	●		0.005	1	µA
	Output Ripple	Full Load			100		mV
	Efficiency	V_{IN} = 3V, I_{OUT} = 20mA			82		%
f_{OSC}	Switching Frequency	Full Load			600		kHz
V_{IH}	SHDN Input Threshold		●	(0.7)(V_{IN})			V
V_{IL}			●			0.4	V
I_{IH}	SHDN Input Current	V_{SHDN} = V_{IN}	●	–1		1	µA
I_{IL}		V_{SHDN} = 0V	●	–1		1	µA
t_{ON}	Turn-On Time	V_{IN} = 3V, I_{OUT} = 0mA (Note 3)			500		µs

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

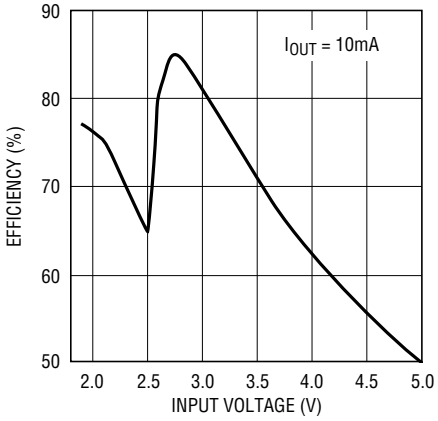
Note 1: Absolute Maximum Ratings are those values beyond which the life of the device may be impaired

Note 2: At input voltages >3.6V and ambient temperatures >70°C, continuous power dissipation must be derated to maintain junction temperatures below 125°C. Derate 6mW/°C above 70°C in SO-8.

Note 3: The LTC1516 is tested with the capacitors shown in Figure 1.

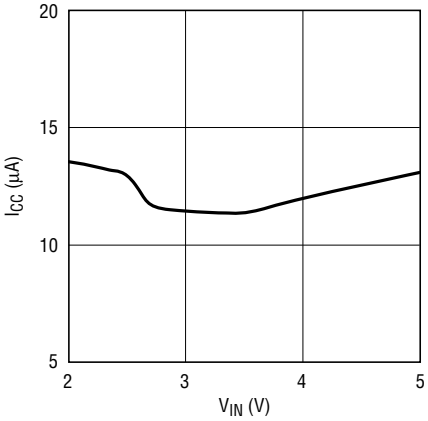
TYPICAL PERFORMANCE CHARACTERISTICS

Efficiency vs Input Voltage



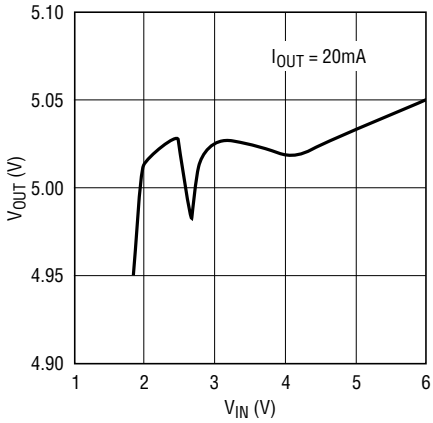
LTC1516 • TPC01

No-Load Supply Current vs Input Voltage



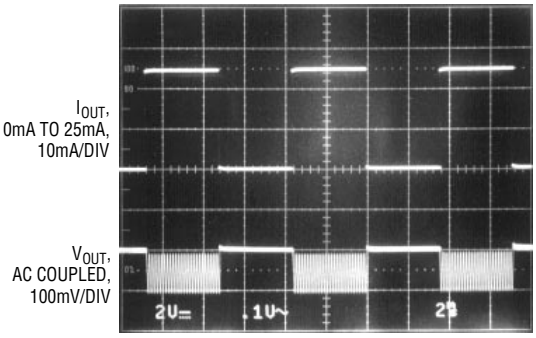
LTC1516 • TPC02

Output Voltage vs Input Voltage



LTC1516 • TPC03

Load-Transient Response, V_{IN} = 3V



LTC1516 • TPC04

PIN FUNCTIONS

C1+ (Pin 1): Flying Capacitor 1, Positive Terminal.

V_{IN} (Pin 2): Input Supply Voltage.

V_{OUT} (Pin 3): 5V Output Voltage (V_{OUT} = 0V in Shutdown).

C2+ (Pin 4): Flying Capacitor 2, Positive Terminal.

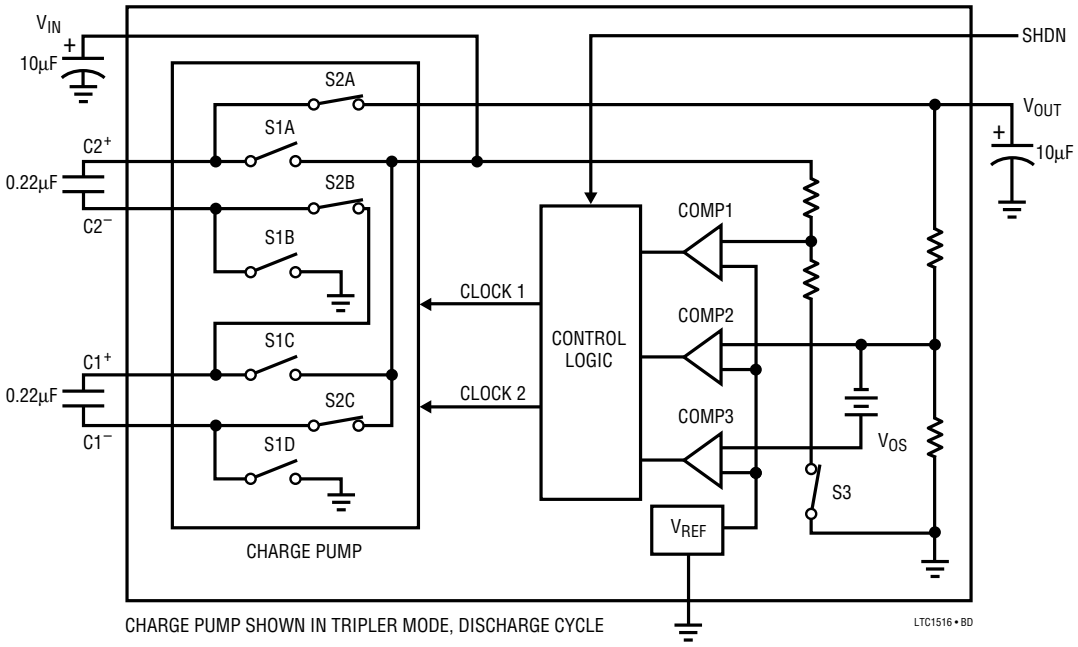
C2– (Pin 5): Flying Capacitor 2, Negative Terminal.

GND (Pin 6): Ground.

SHDN (Pin 7): Active High CMOS Logic-Level Shutdown Input.

C1– (Pin 8): Flying Capacitor 1, Negative Terminal.

BLOCK DIAGRAM



APPLICATIONS INFORMATION

Operation

The LTC1516 uses a switched capacitor charge pump to boost V_{IN} from 2V to 5V to a regulated 5V ±4% output voltage. Regulation is achieved by sensing the output voltage through an internal resistor divider and enabling the charge pump when the output voltage droops below the lower trip point of COMP2. When the charge pump is enabled, a 2-phase, nonoverlapping clock controls the charge pump switches. Clock 1 closes the S1 switches which enable the flying capacitors, C1 and C2, to charge up to the V_{IN} voltage. Clock 2 closes the S2 switches which stack C1 and C2 in series with V_{IN} and connect the top plate of C2 to the output capacitor at V_{OUT}. This sequence of charging and discharging continues at a free-running frequency of 600kHz (typ) until the output has risen to the upper trip point of COMP2 and the charge pump is disabled. When the charge pump is disabled, the LTC1516 draws only 8µA (typ) from V_{IN} which provides high efficiency at low load conditions.

To achieve the highest efficiency over the entire V_{IN} range, the LTC1516 operates as either a doubler or a tripler depending on V_{IN} and output load conditions. COMP1 and COMP2 determine whether the charge pump is in doubler mode or tripler mode. COMP1 forces the part into tripler mode if V_{IN} is < 2.55V, regardless of output load. When V_{IN} is > 2.55V, the part will be in doubler mode using only C2 as a flying capacitor. In doubler mode, if the output droops by 50mV under heavy loads, COMP3 will force the charge pump into tripler mode until V_{OUT} climbs above the upper trip point of COMP3. Under these V_{IN} and load conditions, the nominal V_{OUT} will be approximately 50mV lower than the no load nominal V_{OUT}. This method of sensing V_{IN} and output load results in efficiency greater than 80% with V_{IN} between 2.5V and 3V.

APPLICATIONS INFORMATION

In shutdown mode, all circuitry is turned off and the part draws only leakage current (<1μA) from the V_{IN} supply. V_{OUT} is also disconnected from V_{IN}. The SHDN pin is a CMOS input with a threshold of approximately $V_{IN}/2$; however, the SHDN pin can be driven by logic levels that exceed the V_{IN} voltage. The part enters shutdown mode when a logic-high is applied to the SHDN pin. The SHDN pin cannot float; it must be driven with a logic high or low.

Short Circuit/Thermal Protection

During short circuit conditions, the LTC1516 will draw between 200mA and 400mA from V_{IN} causing a rise in the junction temperature. On-chip thermal shutdown circuitry disables the charge pump once the junction temperature exceeds 135°C, and reenables the charge pump once the junction temperature falls back to 115°C. The LTC1516 will cycle in and out of thermal shutdown indefinitely without latchup or damage until the V_{OUT} short is removed.

Capacitor Selection

For best performance, it is recommended that low ESR capacitors be used for both C_{IN} and C_{OUT} to reduce noise and ripple. The C_{IN} and C_{OUT} capacitors should be either ceramic or tantalum and should be 10μF or greater. If the input source impedance is very low, C_{IN} may not be needed. Increasing the size of C_{OUT} to 22μF or greater will reduce output voltage ripple.

Ceramic or tantalum capacitors are recommended for the flying caps C1 and C2 with values in the range of 0.1μF to 1μF. Note that large value flying caps (>0.22μF) will increase output ripple unless C_{OUT} is also increased. For very low load applications, C1 and C2 may be reduced to 0.01μF to 0.047μF. This will reduce output ripple at the expense of efficiency and maximum output current.

Inrush Currents

During normal operation, V_{IN} will experience current transients in the 100mA to 200mA range whenever the charge pump is enabled. During start-up, these inrush currents may approach 500mA. For this reason, it is important to minimize the source resistance between the input supply and the V_{IN} pin to prevent start-up problems and large input voltage transients.

Ultralow Quiescent Current (I_Q < 5μA) Regulated Supply

The LTC1516 contains an internal resistor divider (refer to Block Diagram) which draws only 1.5μA (typ) from V_{OUT}. During no-load conditions, the internal load causes a droop rate of only 150mV per second on V_{OUT} with C_{OUT} = 10μF. Applying a 5Hz to 100Hz, 95% to 98% duty cycle signal to the SHDN pin ensures that the circuit of Figure 2 comes out of shutdown frequently enough to maintain regulation during no-load or low-load conditions. Since the part spends nearly all of its time in

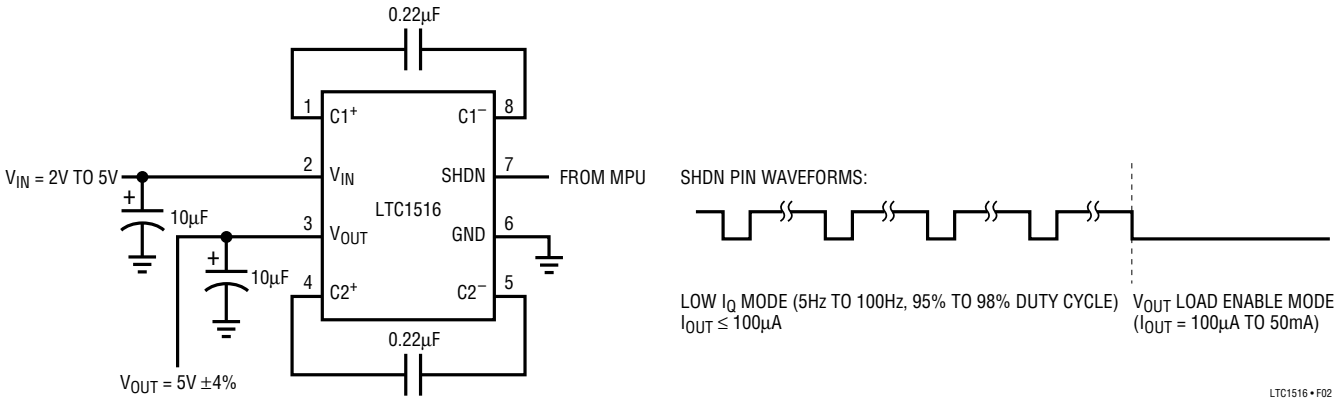


Figure 2. Ultralow Quiescent Current (<5μA) Regulated Supply

APPLICATIONS INFORMATION

shutdown, the no-load quiescent current (see Figure 3a) is approximately equal to $(V_{OUT})(1.5\mu A)/(V_{IN})$(Efficiency).

The LTC1516 must be out of shutdown for a minimum duration of 200µs to allow enough time to sense the output and keep it in regulation. As the V_{OUT} load current increases, the frequency with which the part is taken out of shutdown must also be increased to prevent V_{OUT} from drooping below 4.8V during the OFF phase (see Figure 3b). A 100Hz 98% duty cycle signal on the SHDN pin ensures proper regulation with load currents as high as 100µA. When load current greater than 100µA is needed, the SHDN pin must be forced low as in normal operation. The typical no-load supply current for this circuit with V_{IN} = 3V is only **3.2µA**.

Paralleling Devices

Two or more LTC1516's may be connected in parallel to provide higher output currents. The V_{IN}, V_{OUT}, GND and SHDN pins may be tied together, but the C1 and C2 pins must be kept separate (see Figure 4). Separate C_{IN} and C_{OUT} capacitors may be required to reduce output noise and ripple if the paralleled devices cannot be kept close together. Otherwise, single C_{IN} and C_{OUT} capacitors may be used with each being 2× (or 3× if three parts are paralleled, etc.) in value.

General Layout Considerations

Due to the high switching frequency and high transient currents produced by the LTC1516, careful board layout is a must. For best performance, use very short connections to all capacitors (refer to Figure 5).

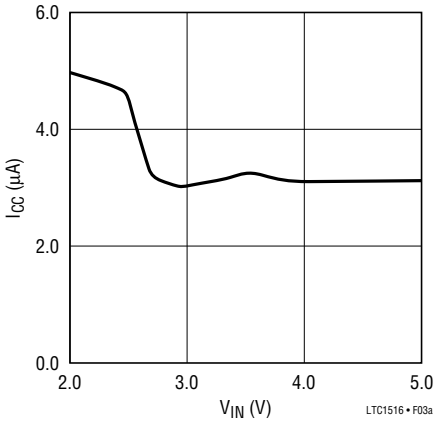


Figure 3a. No-Load I_{CC} vs Input Voltage for Circuit in Figure 2

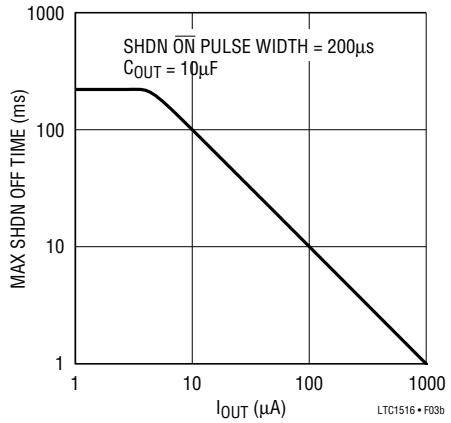


Figure 3b. Maximum SHDN OFF Time vs Output Load Current for Ultralow I_Q Operation

APPLICATIONS INFORMATION

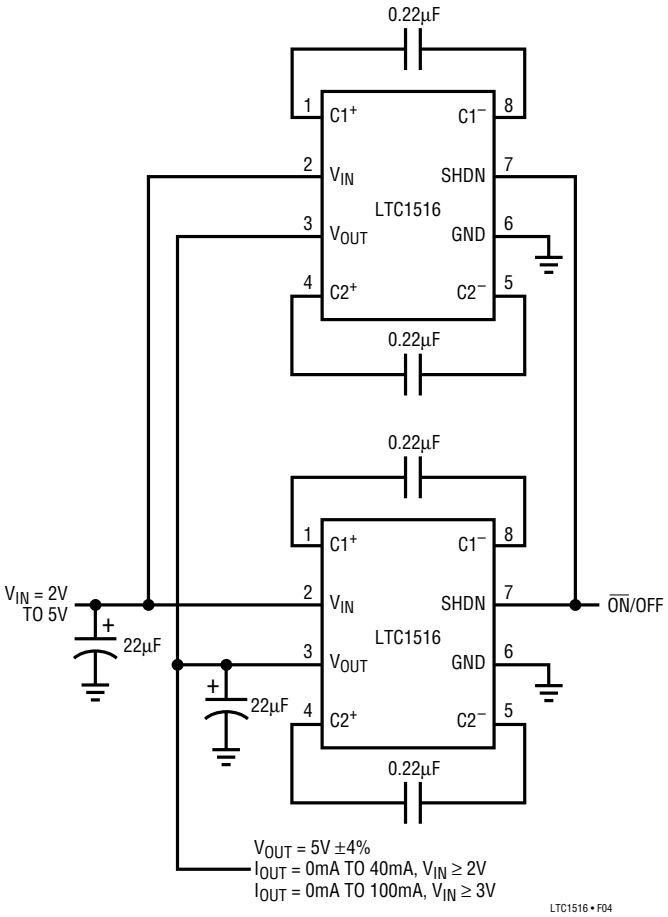


Figure 4. Paralleling Devices

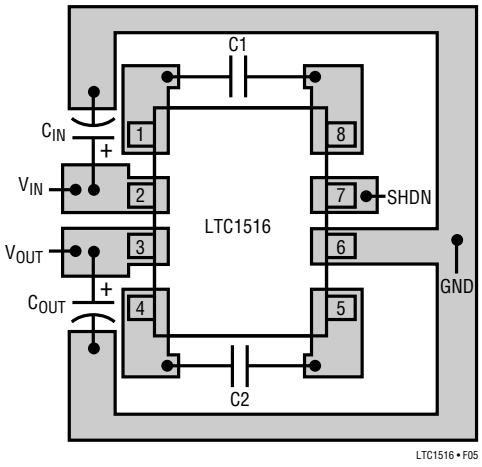
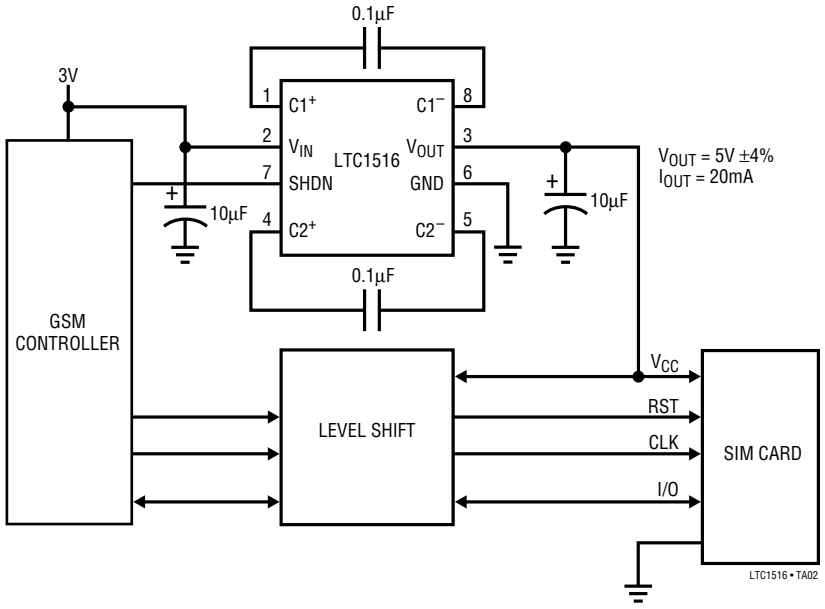


Figure 5. Suggested Component Placement for LTC1516

TYPICAL APPLICATION

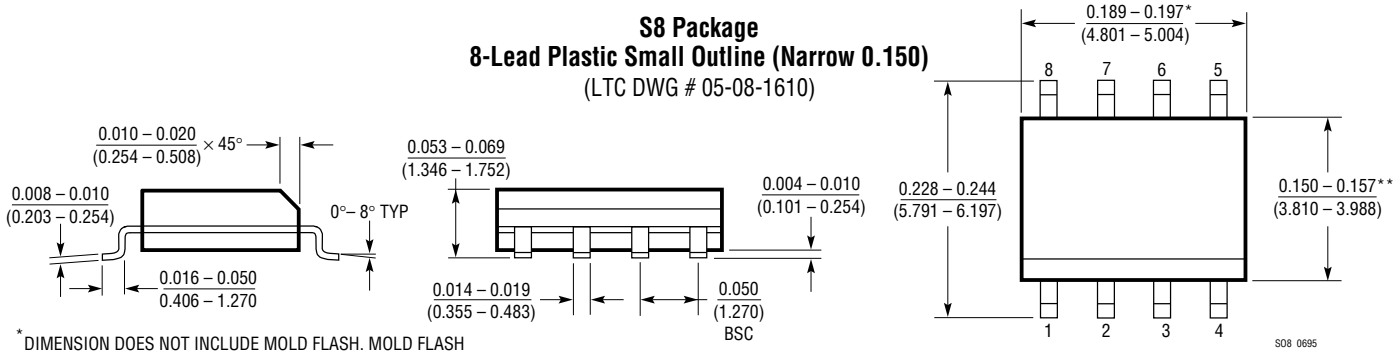
Fault-Protected SIM Interface Supply for GSM Cellular Phones



PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

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



*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1054	100mA Switched Capacitor Converter	Includes Reference and Amplifier for Regulation
LTC1144	20mA Switched Capacitor Converter for Up to 20V Inputs	Includes Micropower Shutdown (8µA)
LTC1261	Positive to Negative Regulated Switched Capacitor Converter	Low Noise (5mV) Output for Up to 10mA Loads
LTC1262	5V to 12V Regulated Switched Capacitor Converter	Up to 30mA at Regulated Output
LTC1550/51	Low Noise Switched Capacitor Regulated Converter	Provides –4.1V at 20mA with <1mV Ripple

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