Micropower, Regulated 5V Charge Pump DC/DC Converter

FEATURES

- **Ultralow Power: Typical Operating I_{CC} = 6μA**
- **Short-Circuit/Thermal Protected**
- **Regulated 5V ±4% Output Voltage**
- 2.7V to 5V Input Range
- **No Inductors**
- Very Low I_{CC} in Shutdown: <1μA
- **Output Current: 10mA (V_{IN} ≥ 2.7V)**
  20mA (V_{IN} ≥ 3V)
- Shutdown Disconnects Load from V_{IN}
- Internal Oscillator: 700kHz
- Compact Application Circuit (<0.1 in^2)
- 8-Pin MSOP and SO Packages

APPLICATIONS

- SIM Interface Supplies for GSM Cellular Telephones
- Li-Ion Battery Backup Supplies
- Local 3V to 5V Conversion
- Smart Card Readers
- PCMCIA Local 5V Supplies

DESCRIPTION

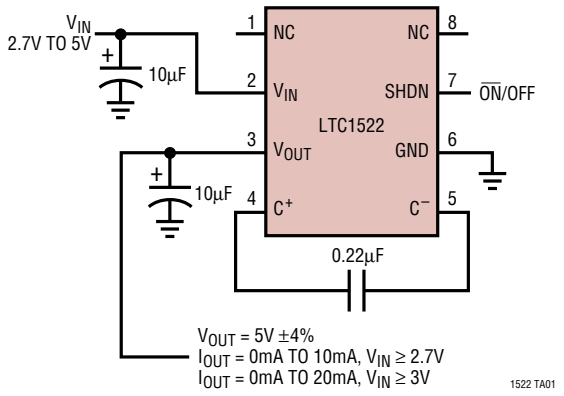
The LTC®1522 is a micropower charge pump DC/DC converter that produces a regulated 5V output from a 2.7V to 5V input supply. Extremely low supply current (6μA typical with no load, <1μA in shutdown) and low external parts count (one 0.22μF flying capacitor and two 10μF capacitors at V_{IN} and V_{OUT}) make the LTC1522 ideally suited for small, light load battery-powered applications. Typical efficiency (V_{IN} = 3V) exceeds 75% with load currents between 50μA and 20mA. Modulating the SHDN pin keeps the typical efficiency above 75% with load currents all the way down to 10μA.

The LTC1522 has thermal shutdown and can survive a continuous short from V_{OUT} to GND. In shutdown the load is disconnected from V_{IN}. The part is available in 8-pin MSOP and SO packages. The LTC1522 is pin compatible with the LTC1516 in applications where V_{IN} ≥ 2.7V and I_{OUT} ≤ 20mA.

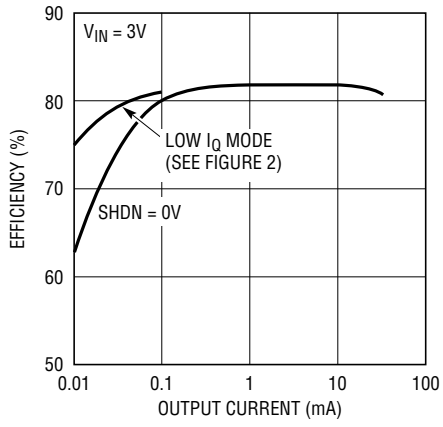
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TYPICAL APPLICATION

Regulated 5V Output from a 2.7V to 5V Input



Efficiency vs Output Current



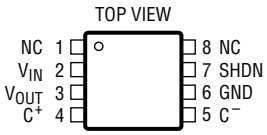
ABSOLUTE MAXIMUM RATINGS

(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

Commercial Temperature Range ..... 0°C to 70°C
Extended Commercial Operating
Temperature Range (Note 2) ..... –40°C to 85°C
Storage Temperature Range ..... –65°C to 150°C
Lead Temperature (Soldering, 10 sec) ..... 300°C

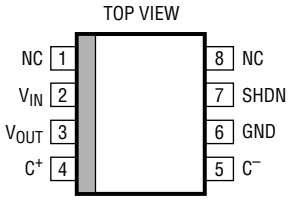
PACKAGE/ORDER INFORMATION



MS8 PACKAGE
8-LEAD PLASTIC MSOP

T_{JMAX} = 125°C, θ_{JA} = 160°C/W

ORDER PART NUMBER
LTC1522CMS8
MS8 PART MARKING
LTCG



S8 PACKAGE
8-LEAD PLASTIC SO

T_{JMAX} = 125°C, θ_{JA} = 150°C/W

ORDER PART NUMBER
LTC1522CS8
S8 PART MARKING
1522

Consult factory for Industrial and Military grade parts.

ELECTRICAL CHARACTERISTICS

V_{IN} = 2.7V to 5V, C_{FLY} = 0.22µF, C_{IN} = C_{OUT} = 10µF, T_{MIN} to T_{MAX} unless otherwise specified. (Note 2)

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{IN}	Input Voltage		●	2.7		5	V
V_{OUT}	Output Voltage	2.7V ≤ V_{IN} ≤ 5V, I_{OUT} ≤ 10mA	●	4.8	5.0	5.2	V
		3V ≤ V_{IN} ≤ 5V, I_{OUT} ≤ 20mA	●	4.8	5.0	5.2	V
I_{CC}	Operating Supply Current	2.7V ≤ V_{IN} ≤ 5V, I_{OUT} = 0mA, SHDN = 0V	●		6	15	µA
	Shutdown Supply Current	2.7V ≤ V_{IN} ≤ 3.6V, I_{OUT} = 0mA, SHDN = V_{IN}	●		0.005	1	µA
		3.6V < V_{IN} ≤ 5V, I_{OUT} = 0mA, SHDN = V_{IN}	●			2.5	µA
	Output Ripple	V_{IN} = 3V, I_{OUT} = 10mA			70		mV_{P-P}
	Efficiency	V_{IN} = 3V, I_{OUT} = 10mA			82		%
f_{OSC}	Switching Frequency	Oscillator Free Running			700		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}	V_{OUT} Turn-On Time	V_{IN} = 3V, I_{OUT} = 0mA			1		ms

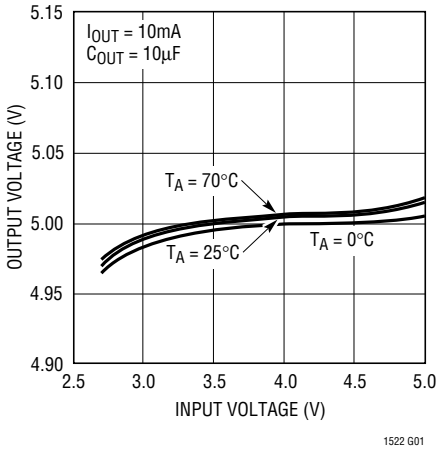
The ● denotes specifications which apply over the specified temperature range.

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

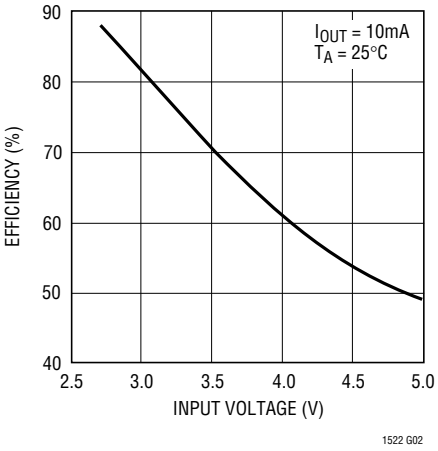
Note 2: C grade device specifications are guaranteed over the 0°C to 70°C temperature range. In addition, C grade device specifications are assured over the –40°C to 85°C temperature range by design or correlation, but are not production tested.

TYPICAL PERFORMANCE CHARACTERISTICS

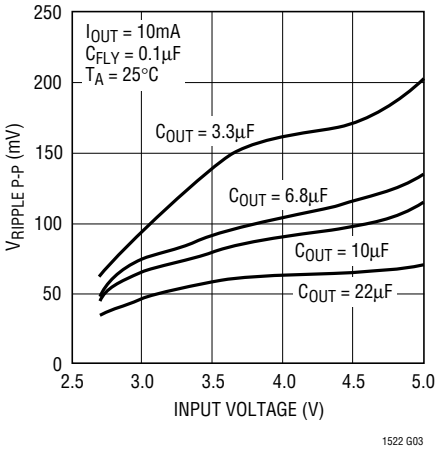
Output Voltage vs Input Voltage



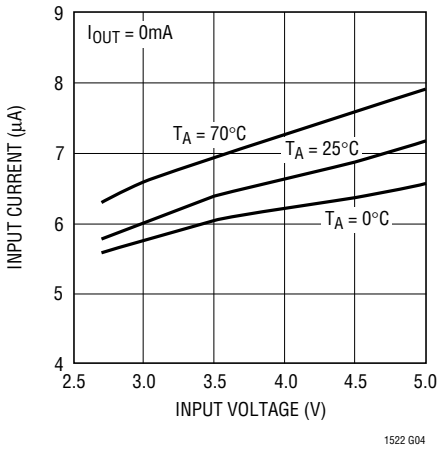
Efficiency vs Input Voltage



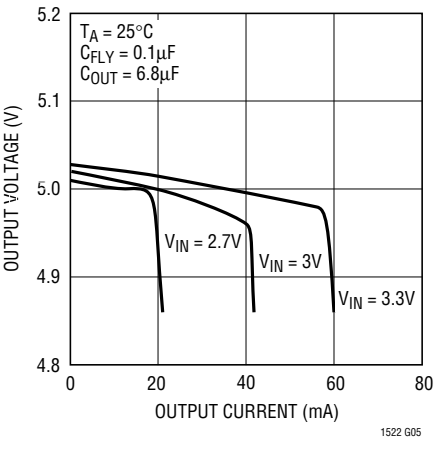
Output Ripple vs Input Voltage



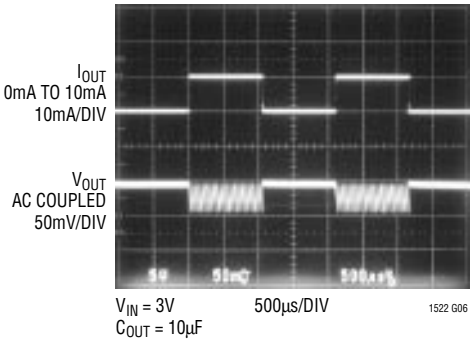
No Load Input Current vs Input Voltage



Typical Output Voltage vs Output Current



Load Transient Response



PIN FUNCTIONS

NC (Pin 1): No Connect.

V_{IN} (Pin 2): Input Supply Voltage. Bypass V_{IN} with a ≥3.3µF low ESR capacitor.

V_{OUT} (Pin 3): 5V Output Voltage (V_{OUT} = 0V in Shutdown). Bypass V_{OUT} with a ≥3.3µF low ESR capacitor.

C^+ (Pin 4): Flying Capacitor, Positive Terminal.

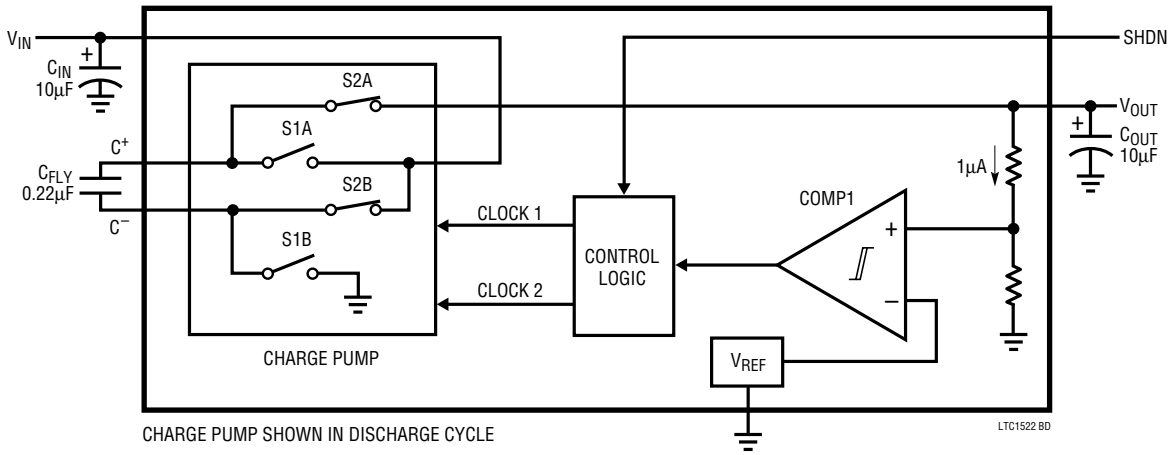
C^- (Pin 5): Flying Capacitor, Negative Terminal.

GND (Pin 6): Ground.

SHDN (Pin 7): Active High CMOS Logic-Level Shutdown Input. Drive SHDN low to enable the DC/DC converter. Do not float.

NC (Pin 8): No Connect.

BLOCK DIAGRAM



CHARGE PUMP SHOWN IN DISCHARGE CYCLE

APPLICATIONS INFORMATION

Operation

The LTC1522 uses a switched capacitor charge pump to boost V_{IN} 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 COMP1. When the charge pump is enabled, a 2-phase, nonoverlapping clock controls the charge pump switches. Clock 1 closes the S1 switches which enables the flying capacitor to charge up to the V_{IN} voltage. Clock 2 closes the S2 switches that stack C_{FLY} in series with V_{IN} and connect the top plate of C_{FLY} to the output capacitor at V_{OUT}. This sequence of charging and discharging continues at a free-running frequency of 700kHz (typ) until the output has risen to the upper trip point of COMP1 and the charge pump is disabled. When the charge pump is disabled, the LTC1522 draws only 4µA (typ) from V_{IN} which provides high efficiency at low load conditions.

In shutdown mode, all circuitry is turned off and the part draws only leakage current 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 should not be floated; it must be driven with a logic high or low.

Short-Circuit/Thermal Protection

During short-circuit conditions, the LTC1522 will draw between 100mA and 200mA from V_{IN} causing a rise in the junction temperature. On-chip thermal shutdown circuitry disables the charge pump once the junction temperature exceeds ≈160°C, and reenables the charge pump once the junction temperature falls back to ≈145°C. The LTC1522 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 (<0.5Ω) 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 3.3µF or greater (aluminum capacitors are not recommended because of their high ESR). If the input source impedance is very low, C_{IN} may not be needed. Increasing the size of C_{OUT} to 10µF or greater will reduce output voltage ripple.

APPLICATIONS INFORMATION

A ceramic capacitor is recommended for the flying capacitor with a value in the range of 0.1µF to 0.22µF. Note that a large value flying cap (>0.22µF) will increase output ripple unless C_{OUT} is also increased. For very low load applications, C_{FLY} may be reduced to 0.01µF to 0.047µF. This will reduce output ripple at the expense of efficiency and maximum output current.

Output Ripple

Normal LTC1522 operation produces voltage ripple on the V_{OUT} pin. Output voltage ripple is required for the LTC1522 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 due to ESR (Equivalent Series Resistance) in the output capacitor. Typical output ripple under maximum load is 50mV_{P-P} with a low ESR 10µF output capacitor.

The magnitude of the ripple voltage depends on several factors. High input voltages (V_{IN} > 3.3V) increase the output ripple since more charge is delivered to C_{OUT} per clock cycle. A large flying capacitor (>0.22µF) also increases ripple for the same reason. Large output current load and/or a small output capacitor (<10µF) results in higher ripple due to higher output voltage dV/dt. High ESR capacitors (ESR > 0.5Ω) on the output pin cause high frequency voltage spikes on V_{OUT} with every clock cycle.

There are several ways to reduce the output voltage ripple. A larger C_{OUT} capacitor (22µF or greater) will reduce both the low and high frequency ripple due to the lower C_{OUT} 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 V_{OUT} to reduce both the low and high frequency ripple. An RC filter may also be used to reduce high frequency voltage spikes (see Figure 1).

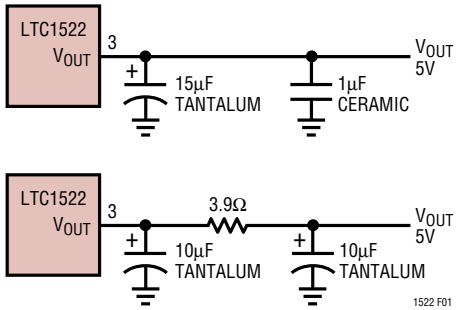


Figure 1. Output Ripple Reduction Techniques

In low load or high V_{IN} applications, smaller values for C_{FLY} may be used to reduce output ripple. A smaller flying capacitor (0.01µF to 0.047µF) delivers less charge per clock cycle to the output capacitor resulting in lower output ripple. However, the smaller value flying caps also reduce the maximum I_{OUT} capability as well as efficiency.

Inrush Currents

During normal operation, V_{IN} will experience current transients in the 50mA to 100mA range whenever the charge pump is enabled. During start-up, these inrush currents may approach 250mA. For this reason, it is important to minimize the source resistance between the input supply and the V_{IN} pin. Too much source resistance may result in regulation problems or even prevent start-up.

Ultralow Quiescent Current (I_Q = 2.1µA) Regulated Supply

The LTC1522 contains an internal resistor divider (refer to the Block Diagram) that draws only 1µA (typ) from V_{OUT}. During no-load conditions, the internal load causes a droop rate of only 100mV per second on V_{OUT} with C_{OUT} = 10µF. Applying a 2Hz 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 shutdown, the no-load quiescent current (see Figure 3a) is approximately equal to (V_{OUT})(1µA)/(V_{IN})(Efficiency).

APPLICATIONS INFORMATION

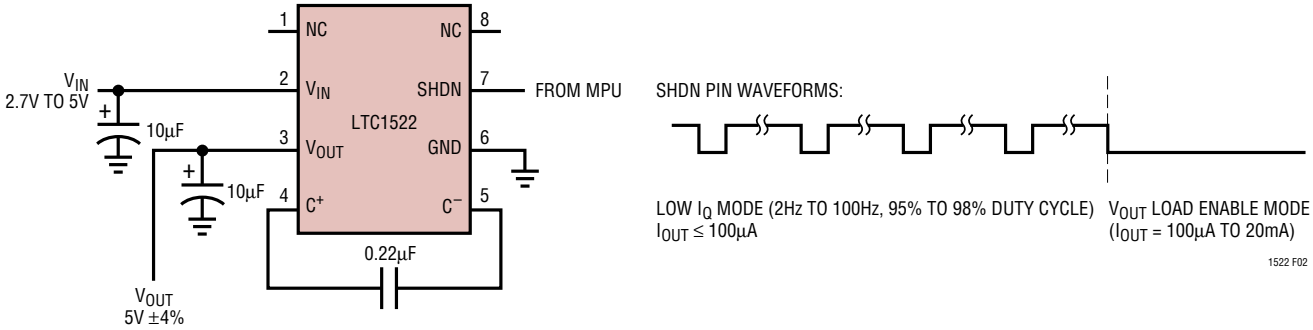


Figure 2. Ultralow Quiescent Current (<2.1µA) Regulated Supply

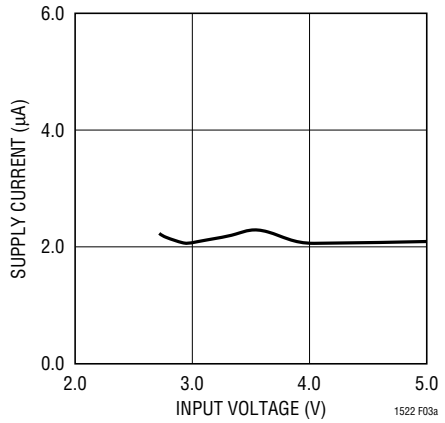


Figure 3a. No-Load I_{CC} vs Input Voltage for Circuit in Figure 3

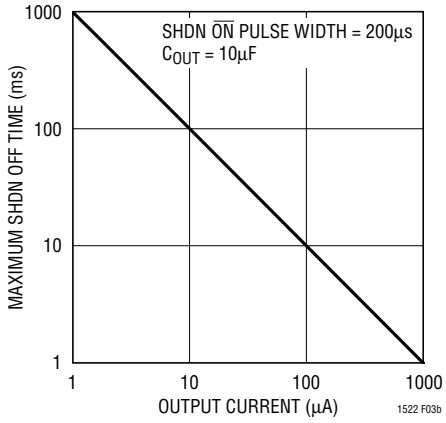


Figure 3b. Maximum SHDN OFF Time vs Output Load Current for Ultralow I_Q Operation

The LTC1522 must be out of shutdown for a minimum duration of 200µs to allow enough time to sense the output and keep it in regulation. A 2Hz, 98% duty cycle signal will keep V_{OUT} in regulation under no-load conditions. 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 **2.1µA**.

Each time the LTC1522 comes out of shutdown, the part delivers a minimum of one clock cycle worth of charge to the output. Under high V_{IN} (>3.3V) and/or low I_{OUT} (<10µA) conditions, this behavior may cause a net excess of charge to be delivered to the output capacitor if a high frequency signal is used on the SHDN pin (e.g., 50Hz to 100Hz). Under such conditions, V_{OUT} will slowly drift positive and may even go out of regulation. To avoid this potential problem in the low I_Q mode, it is necessary to switch the part in and out of shutdown at the minimum allowable frequency (refer to Figure 3b) for a given output load.

APPLICATIONS INFORMATION

General Layout Considerations

Due to the high switching frequency and high transient currents produced by the LTC1522, careful board layout is a must. A clean board layout using a ground plane and short connections to all capacitors will improve performance and ensure proper regulation under all conditions (refer to Figure 4).

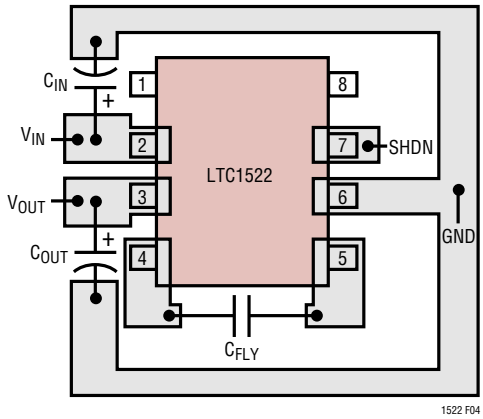
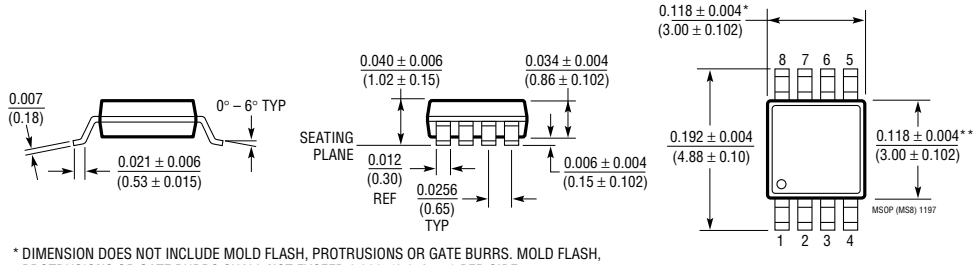


Figure 4. Suggested Component Placement for LTC1522

PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

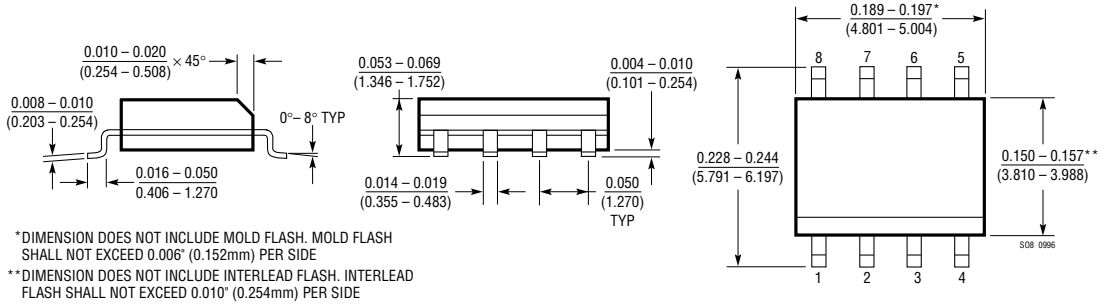
MS8 Package
8-Lead Plastic MSOP
(LTC DWG # 05-08-1660)



* DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

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

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

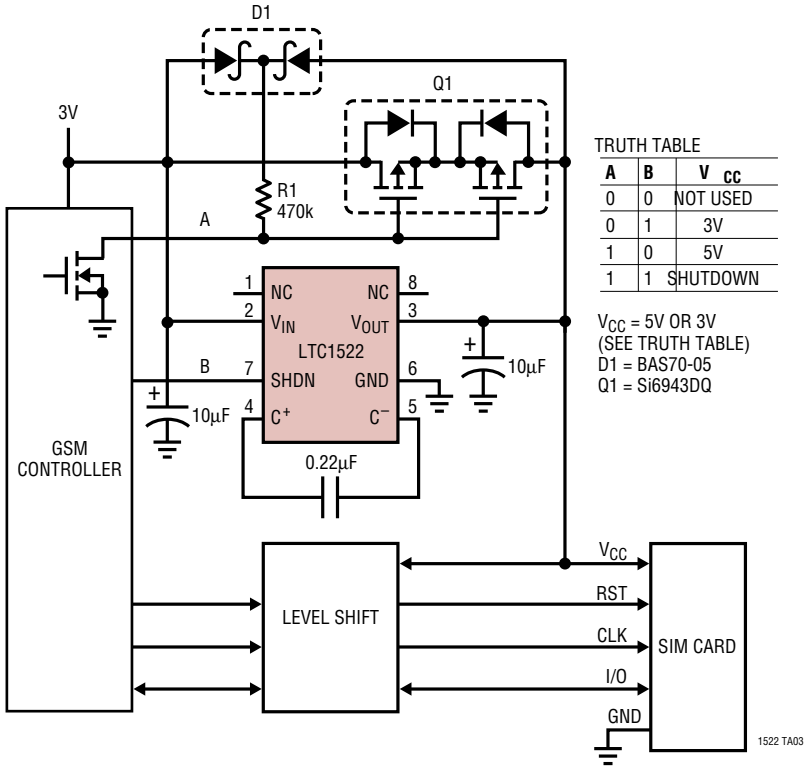
**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

LINEAR TECHNOLOGY

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TYPICAL APPLICATION

Programmable 5V/3V SIM Interface Supply for GSM Cellular Phones



TRUTH TABLE

A	B	V_{CC}
0	0	NOT USED
0	1	3V
1	0	5V
1	1	SHUTDOWN

V_{CC} = 5V OR 3V
(SEE TRUTH TABLE)
D1 = BAS70-05
Q1 = Si6943DQ

RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LTC1144	20mA Switched Capacitor Converter for Up to 20V Inputs	Includes Micropower Shutdown (8µA)
LTC1262	5V to 12V Regulated Switched Capacitor Converter	Up to 30mA at Regulated Output
LTC1514/15	Step-Up/Step-Down Switched Capacitor DC/DC Converters	V_{IN} 2V to 10V, V_{OUT} is Fixed or Adjustable, I_{OUT} to 50mA
LTC1516	Micropower, Regulated 5V Charge Pump DC/DC Converter	I_{OUT} = 20mA ($V_{IN} \geq$ 2V), I_{OUT} = 50mA ($V_{IN} \geq$ 3V)
LTC1517-5	Micropower, Regulated 5V Charge Pump DC/DC Converter	LTC1522 Without Shutdown and Packaged in SOT-23
LTC1555/56	SIM Power Supply and Level Translator	Step-Up/Step-Down SIM Power Supply and Level Translators
LTC660	100mA CMOS Voltage Converter	5V to –5V Conversion with Low Voltage Loss

Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7417• (408)432-1900
FAX: (408) 434-0507•TELEX: 499-3977 • www.linear-tech.com
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