

# Micropower, Regulated 5V Charge Pump DC/DC Converter

## FEATURES

- **Ultralow Power: Typical Operating  $I_{CC} = 6\mu\text{A}$**
- **Short-Circuit/Thermal Protected**
- **Regulated  $5\text{V} \pm 4\%$  Output Voltage**
- 2.7V to 5V Input Range
- **No Inductors**
- Very Low  $I_{CC}$  in Shutdown:  $< 1\mu\text{A}$
- **Output Current:  $10\text{mA}$  ( $V_{IN} \geq 2.7\text{V}$ )  
 $20\text{mA}$  ( $V_{IN} \geq 3\text{V}$ )**
- Shutdown Disconnects Load from  $V_{IN}$
- Internal Oscillator: 700kHz
- Compact Application Circuit ( $< 0.1 \text{ in}^2$ )
- 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

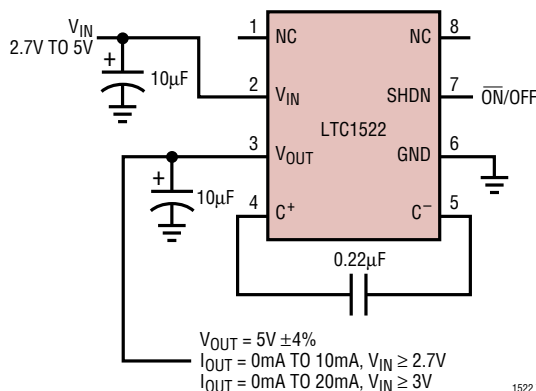
The LTC<sup>®</sup>1522 is a micropower charge pump DC/DC converter that produces a regulated 5V output from a 2.7V to 5V input supply. Extremely low supply current ( $6\mu\text{A}$  typical with no load,  $< 1\mu\text{A}$  in shutdown) and low external parts count (one  $0.22\mu\text{F}$  flying capacitor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

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  $V_{IN} \geq 2.7\text{V}$  and  $I_{OUT} \leq 20\text{mA}$ .

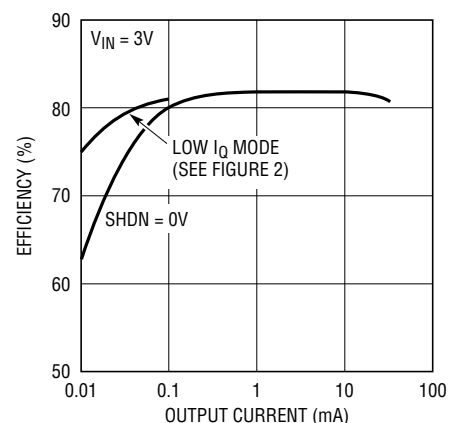
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## TYPICAL APPLICATION

**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	Commercial Temperature Range .....	0°C to 70°C
$V_{OUT}$ to GND .....	-0.3V to 6V	Extended Commercial Operating	
SHDN to GND .....	-0.3V to 6V	Temperature Range (Note 2) .....	-40°C to 85°C
$V_{OUT}$ Short-Circuit Duration .....	Indefinite	Storage Temperature Range .....	-65°C to 150°C
		Lead Temperature (Soldering, 10 sec) .....	300°C

## PACKAGE/ORDER INFORMATION

<p>MS8 PACKAGE 8-LEAD PLASTIC MSOP</p> <p><math>T_{JMAX} = 125^{\circ}C</math>, <math>\theta_{JA} = 160^{\circ}C/W</math></p>	ORDER PART NUMBER	<p>S8 PACKAGE 8-LEAD PLASTIC SO</p> <p><math>T_{JMAX} = 125^{\circ}C</math>, <math>\theta_{JA} = 150^{\circ}C/W</math></p>	ORDER PART NUMBER
	LTC1522CMS8		LTC1522CS8
	MS8 PART MARKING		S8 PART MARKING
	LTCG		1522

Consult factory for Industrial and Military grade parts.

## ELECTRICAL CHARACTERISTICS

$V_{IN} = 2.7V$  to  $5V$ ,  $C_{FLY} = 0.22\mu F$ ,  $C_{IN} = C_{OUT} = 10\mu F$ ,  $T_{MIN}$  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	$2.7V \leq V_{IN} \leq 5V$ , $I_{OUT} \leq 10mA$	4.8	5.0	5.2	V
		$3V \leq V_{IN} \leq 5V$ , $I_{OUT} \leq 20mA$	4.8	5.0	5.2	V
$I_{CC}$	Operating Supply Current	$2.7V \leq V_{IN} \leq 5V$ , $I_{OUT} = 0mA$ , SHDN = 0V		6	15	$\mu A$
	Shutdown Supply Current	$2.7V \leq V_{IN} \leq 3.6V$ , $I_{OUT} = 0mA$ , SHDN = $V_{IN}$		0.005	1	$\mu A$
		$3.6V < V_{IN} \leq 5V$ , $I_{OUT} = 0mA$ , SHDN = $V_{IN}$				2.5
	Output Ripple	$V_{IN} = 3V$ , $I_{OUT} = 10mA$		70		mV <sub>P-P</sub>
	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	$\mu A$
$I_{IL}$		$V_{SHDN} = 0V$	-1		1	$\mu A$
$t_{ON}$	$V_{OUT}$ Turn-On Time	$V_{IN} = 3V$ , $I_{OUT} = 0mA$		1		ms

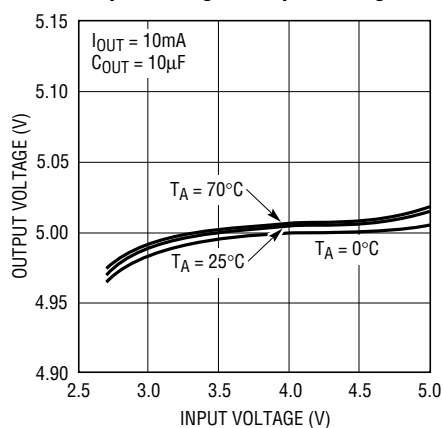
The ● denotes specifications which apply over the specified temperature range.

**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.

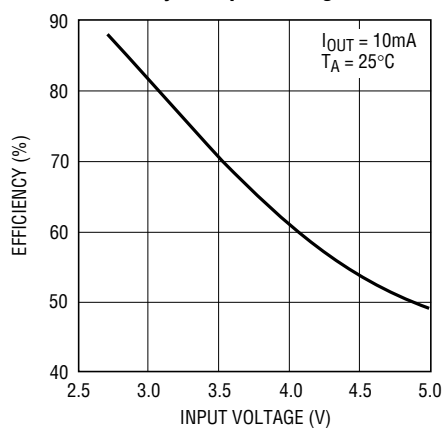
## TYPICAL PERFORMANCE CHARACTERISTICS

### Output Voltage vs Input Voltage



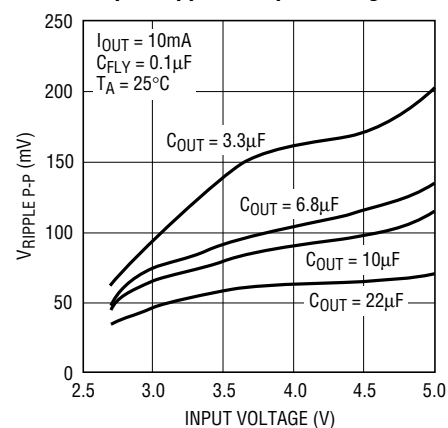
1522 G01

### Efficiency vs Input Voltage



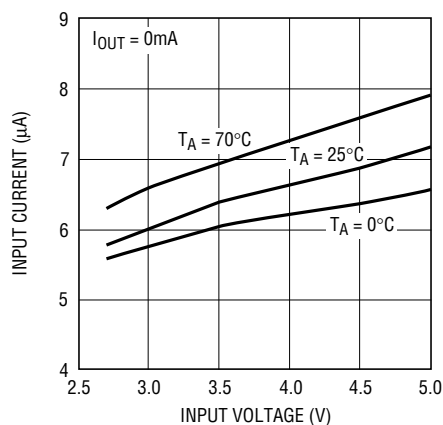
1522 G02

### Output Ripple vs Input Voltage



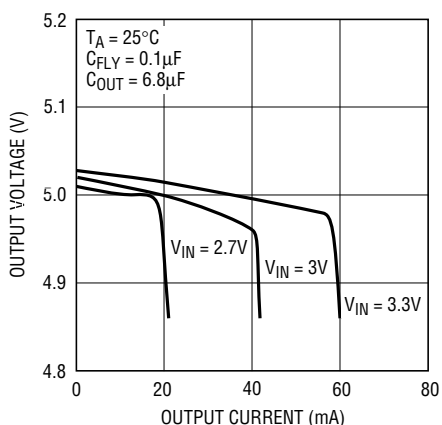
1522 G03

### No Load Input Current vs Input Voltage



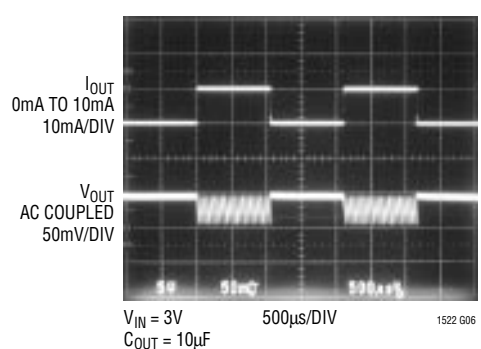
1522 G04

### Typical Output Voltage vs Output Current



1522 G05

### Load Transient Response



1522 G06

## PIN FUNCTIONS

**NC (Pin 1):** No Connect.

**$V_{IN}$  (Pin 2):** Input Supply Voltage. Bypass  $V_{IN}$  with a  $\geq 3.3\mu\text{F}$  low ESR capacitor.

**$V_{OUT}$  (Pin 3):** 5V Output Voltage ( $V_{OUT} = 0\text{V}$  in Shutdown). Bypass  $V_{OUT}$  with a  $\geq 3.3\mu\text{F}$  low ESR capacitor.

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

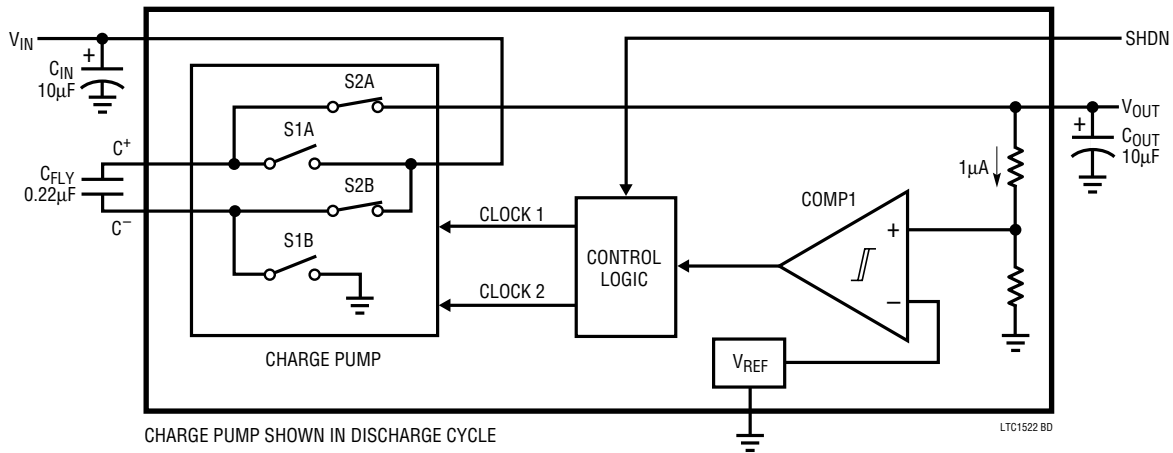
**$C^-$  (Pin 5):** Flying Capacitor, Negative Terminal.

**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



## APPLICATIONS INFORMATION

### Operation

The LTC1522 uses a switched capacitor charge pump to boost  $V_{IN}$  to a regulated  $5V \pm 4\%$  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  $4\mu A$  (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  $\approx 160^\circ C$ , and reenables the charge pump once the junction temperature falls back to  $\approx 145^\circ C$ . 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 ( $< 0.5\Omega$ ) 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  $3.3\mu F$  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  $10\mu F$  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  $0.1\mu\text{F}$  to  $0.22\mu\text{F}$ . Note that a large value flying cap ( $> 0.22\mu\text{F}$ ) will increase output ripple unless  $C_{\text{OUT}}$  is also increased. For very low load applications,  $C_{\text{FLY}}$  may be reduced to  $0.01\mu\text{F}$  to  $0.047\mu\text{F}$ . This will reduce output ripple at the expense of efficiency and maximum output current.

### Output Ripple

Normal LTC1522 operation produces voltage ripple on the  $V_{\text{OUT}}$  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  $50\text{mV}_{\text{P-P}}$  with a low ESR  $10\mu\text{F}$  output capacitor.

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

There are several ways to reduce the output voltage ripple. A larger  $C_{\text{OUT}}$  capacitor ( $22\mu\text{F}$  or greater) will reduce both the low and high frequency ripple due to the lower  $C_{\text{OUT}}$  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  $10\mu\text{F}$  to  $22\mu\text{F}$  tantalum capacitor in parallel with a  $1\mu\text{F}$  to  $3.3\mu\text{F}$  ceramic capacitor on  $V_{\text{OUT}}$  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).

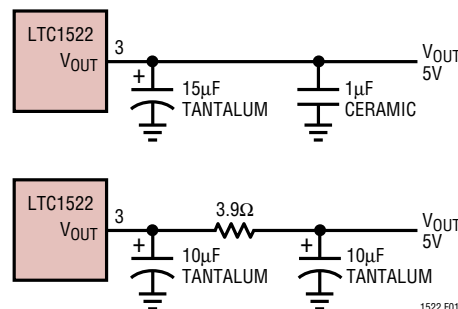


Figure 1. Output Ripple Reduction Techniques

In low load or high  $V_{\text{IN}}$  applications, smaller values for  $C_{\text{FLY}}$  may be used to reduce output ripple. A smaller flying capacitor ( $0.01\mu\text{F}$  to  $0.047\mu\text{F}$ ) 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  $I_{\text{OUT}}$  capability as well as efficiency.

### Inrush Currents

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

### Ultralow Quiescent Current ( $I_{\text{Q}} = 2.1\mu\text{A}$ ) Regulated Supply

The LTC1522 contains an internal resistor divider (refer to the Block Diagram) that draws only  $1\mu\text{A}$  (typ) from  $V_{\text{OUT}}$ . During no-load conditions, the internal load causes a droop rate of only  $100\text{mV}$  per second on  $V_{\text{OUT}}$  with  $C_{\text{OUT}} = 10\mu\text{F}$ . Applying a  $2\text{Hz}$  to  $100\text{Hz}$ ,  $95\%$  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  $(V_{\text{OUT}})(1\mu\text{A})/(V_{\text{IN}})(\text{Efficiency})$ .

APPLICATIONS INFORMATION

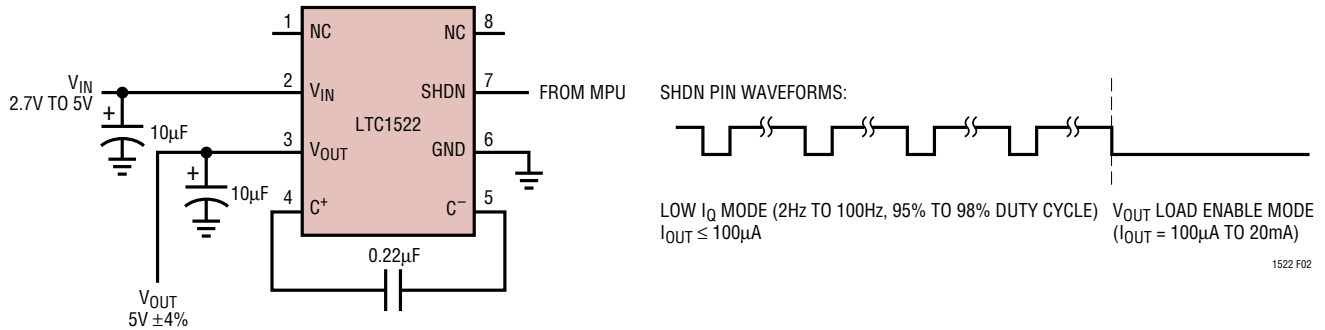


Figure 2. Ultralow Quiescent Current (<2.1µA) Regulated Supply

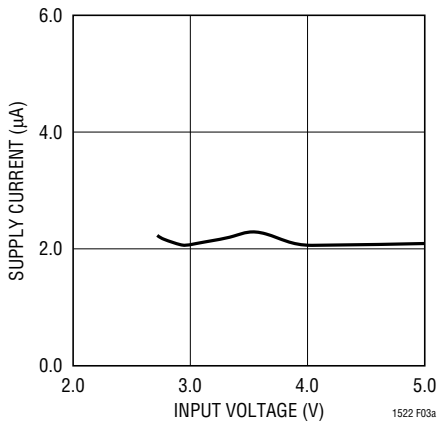


Figure 3a. No-Load ICC vs Input Voltage for Circuit in Figure 3

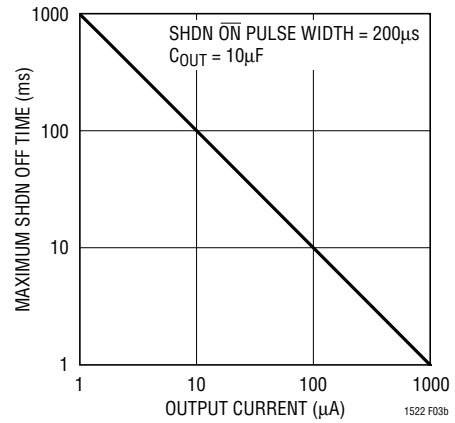


Figure 3b. Maximum SHDN OFF Time vs Output Load Current for Ultralow IQ Operation

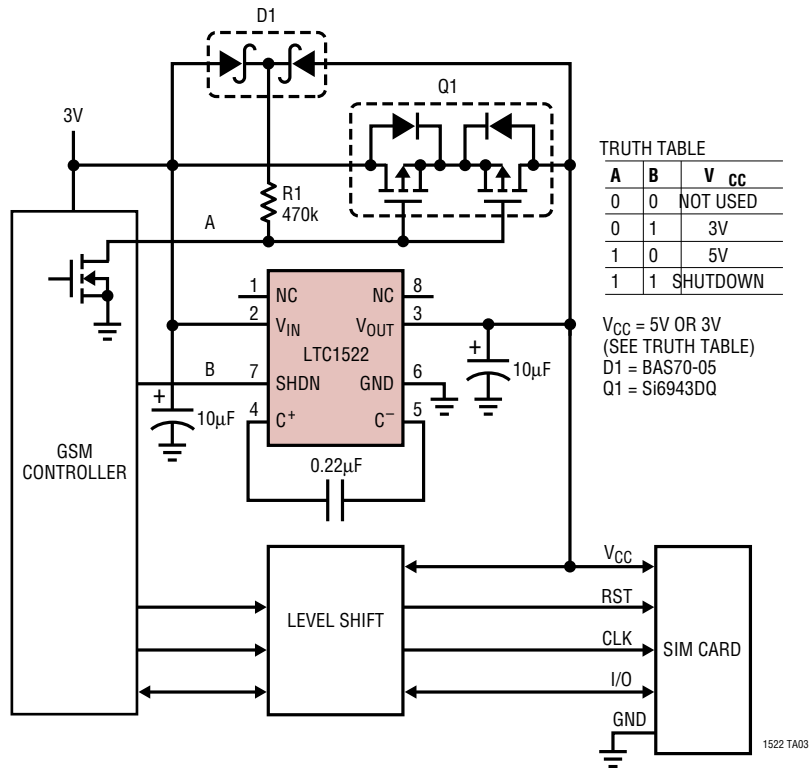
The LTC1522 must be out of shutdown for a minimum duration of 200µs to allow enough time to sense the output and keep it in regulation. A 2Hz, 98% duty cycle signal will keep VOUT in regulation under no-load conditions. As the VOUT load current increases, the frequency with which the part is taken out of shutdown must also be increased to prevent VOUT 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 VIN = 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 VIN (>3.3V) and/or low IOU (<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, VOUT will slowly drift positive and may even go out of regulation. To avoid this potential problem in the low IQ 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.



**TYPICAL APPLICATION**

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



**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 <sub>IN</sub> 2V to 10V, V <sub>OUT</sub> is Fixed or Adjustable, I <sub>OUT</sub> to 50mA
LTC1516	Micropower, Regulated 5V Charge Pump DC/DC Converter	I <sub>OUT</sub> = 20mA (V <sub>IN</sub> ≥ 2V), I <sub>OUT</sub> = 50mA (V <sub>IN</sub> ≥ 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