

# 10V Micropower Synchronous Boost Converter in ThinSOT

## FEATURES

- **Small Solution Size**
- **>85% Efficiency over Wide Load Range**
- **Internal Synchronous Rectifier**
- $V_{IN}$  Range: 1.5V to 5.5V
- 5V at 30mA from 3.3V Input
- 3.3V at 20mA from 2 AA Cell Input
- Programmable Output Voltages Up to 10V
- Burst Mode<sup>®</sup> Operation
- Inrush Current Limiting
- Output Disconnect in Shutdown
- Ultralow Quiescent (10 $\mu$ A) and Shutdown (<1 $\mu$ A) Currents
- Low Profile (1mm) SOT-23 Package

## APPLICATIONS

- General Purpose Micropower Boost
- Digital Cameras
- PDAs
- LCD Bias
- Small OLED Displays
- Supercap Charging

## DESCRIPTION

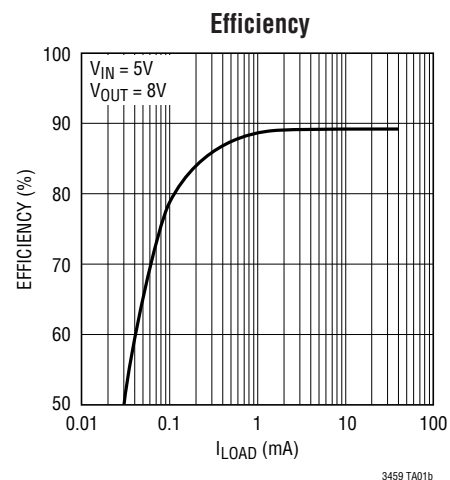
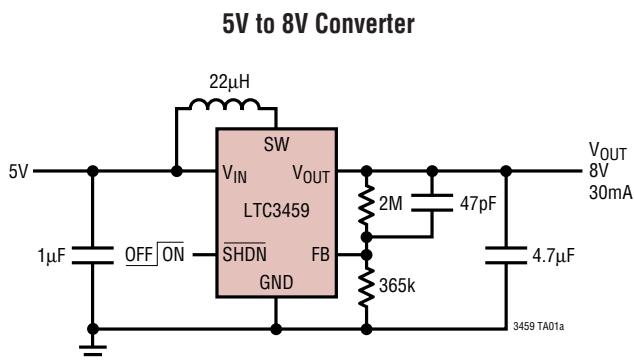
The LTC<sup>®</sup>3459 is a low current, high efficiency synchronous boost converter intended for low power, size constrained portable applications. The LTC3459 can be powered from a single lithium ion battery, a 2- to 3-cell stack of Alkaline or Nickel batteries, or any low impedance voltage source between 1.5V and 5.5V. The output is programmable via an external divider between 2.5V and 10V. Although the part is primarily intended for boost applications,  $V_{OUT}$  will maintain regulation below  $V_{IN}$  (at reduced efficiency).

The LTC3459 offers Burst Mode operation with a fixed peak current, providing high conversion efficiency over a wide range of load currents. During start-up, inductor current is controlled preventing the inrush surge current found in many boost converters. In shutdown the output is disconnected from the input and quiescent current is reduced to <1 $\mu$ A.

The LTC3459 is offered in a low profile (1mm) 6-pin SOT-23 (ThinSOT<sup>™</sup>) package allowing a tiny footprint for the total solution.

LT, LTC and LT are registered trademarks of Linear Technology Corporation. Burst Mode is a registered trademark of Linear Technology Corporation. ThinSOT is trademark of Linear Technology Corporation.

## TYPICAL APPLICATION

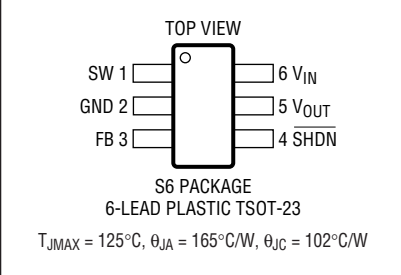


## ABSOLUTE MAXIMUM RATINGS

Referred to GND (Note 1)

$V_{IN}$ , FB Voltage .....	-0.3V to 7V
$V_{OUT}$ , SHDN Voltage .....	-0.3V to 10V
SW Voltage .....	-0.3V to 12V
Operating Temperature Range (Notes 2, 3) .....	-40°C to 85°C
Storage Temperature Range .....	-65°C to 150°C
Lead Temperature (Soldering, 10 sec).....	300°C

## PACKAGE/ORDER INFORMATION

	ORDER PART NUMBER
	LTC3459ES6
	S6 PART MARKING
	LTAHA

Consult LTC Marketing for parts specified with wider operating temperature ranges.

## ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at  $T_A = 25^\circ\text{C}$ .  $V_{IN} = 3.3\text{V}$ ,  $V_{OUT} = 5\text{V}$ , unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
<b><math>V_{IN}</math></b>					
Input Voltage Range		● 1.5		5.5	V
$V_{IN}$ Quiescent Current	$\overline{\text{SHDN}} = V_{CC}$		10	20	$\mu\text{A}$
$V_{IN}$ Shutdown Current	$\overline{\text{SHDN}} = \text{GND}$		0.1	1	$\mu\text{A}$
<b><math>V_{OUT}</math></b>					
Programmable Voltage Range		● 2.5		10	V
$V_{OUT}$ Quiescent Supply Current	$\overline{\text{SHDN}} = V_{CC}$		2	4	$\mu\text{A}$
$V_{OUT}$ Shutdown Current	$\overline{\text{SHDN}} = \text{GND}$		0.1	1	$\mu\text{A}$
<b>Reference</b>					
Feedback Voltage	$V_{IN} = 3.3\text{V}$ , $V_{OUT} = 7.5\text{V}$	● 1.19	1.22	1.25	V
FB Input Leakage Current	Measured on FB		10	50	nA
<b>Converter Performance</b>					
Peak Switch Current ( $V_{IN} = 3.3\text{V}$ )	$L = 22\mu\text{H}$	● 60	75	90	mA
$t_{OFF}$ Timer ( $V_{IN} = 3.3\text{V}$ , $V_{OUT} = 5\text{V}$ )	Varies by $1/(V_{OUT} - V_{IN})$	225	400	550	ns
Zero Current Comparator Threshold	$L = 22\mu\text{H}$		0		mA
<b>Main NMOS Switch</b>					
On Resistance	$V_{OUT} = 5\text{V}$		2.8		$\Omega$
Leakage Current	$V_{SWITCH} = 10\text{V}$ , $V_{OUT} = 10\text{V}$		0.01	1	$\mu\text{A}$
<b>Main PMOS Switch</b>					
On Resistance	$V_{OUT} = 5\text{V}$		4.2		$\Omega$
Leakage Current	$V_{IN} = 5\text{V}$ , $V_{SWITCH} = 5\text{V}$ , $V_{OUT} = 0\text{V}$		0.02	2	$\mu\text{A}$
<b>Logic Inputs</b>					
SHDN Threshold (Rising Edge)		0.3		1	V
SHDN Hysteresis			80		mV
SHDN Input Leakage Current			0	50	nA

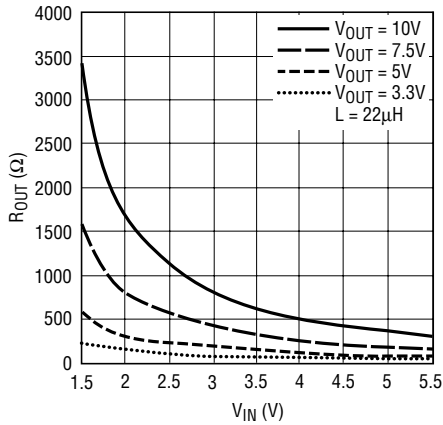
**Note 1:** Absolute Maximum Ratings are those values beyond which the life of a device may be impaired.

**Note 2:** The LTC3459E is guaranteed to meet performance specifications from 0°C to 70°C. Specifications over the -40°C to 85°C operating temperature range are assured by design, characterization and correlation with statistical process controls.

**Note 3:** This IC includes overtemperature protection that is intended to protect the device during momentary overload conditions. Junction temperature will exceed 125°C when overtemperature protection is active. Continuous operation above the specified maximum operating junction temperature may impair device reliability.

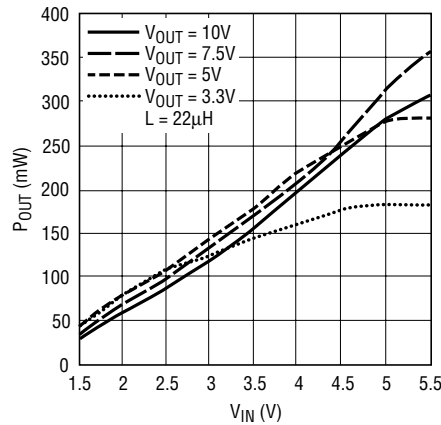
**TYPICAL PERFORMANCE CHARACTERISTICS** ( $T_A = 25^\circ\text{C}$  unless otherwise noted.)

**Minimum  $R_{OUT}$  vs  $V_{IN}$**



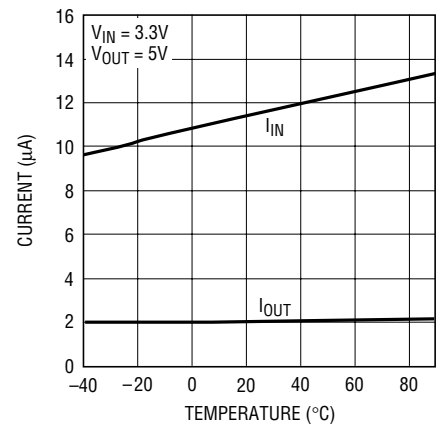
3459 G01

**Minimum  $P_{OUT}$  vs  $V_{IN}$**



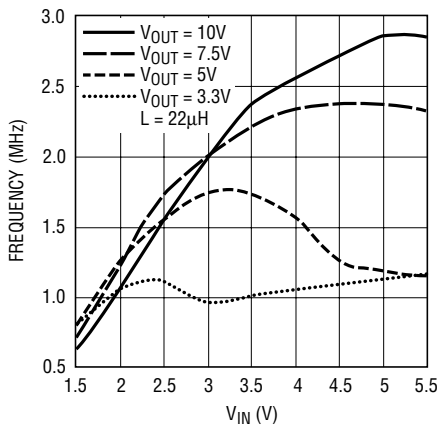
3459 G02

**$V_{IN}$  and  $V_{OUT}$  Quiescent Current vs Temperature**



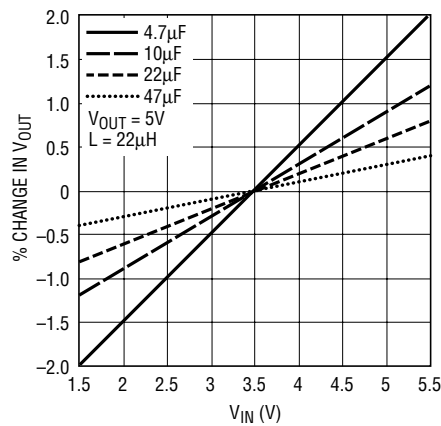
3459 G03

**Switching Frequency vs  $V_{IN}$  at Various  $V_{OUT}$ s**



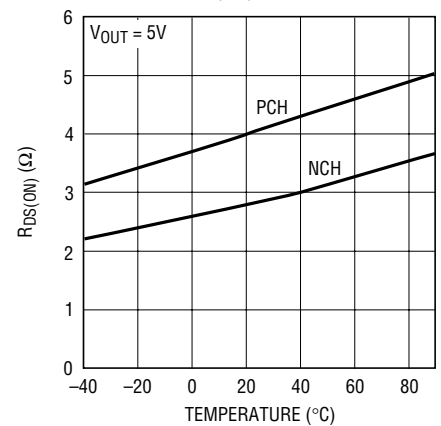
3459 G04

**$V_{OUT}$  Regulation vs  $V_{IN}$  and  $C_{OUT}$**



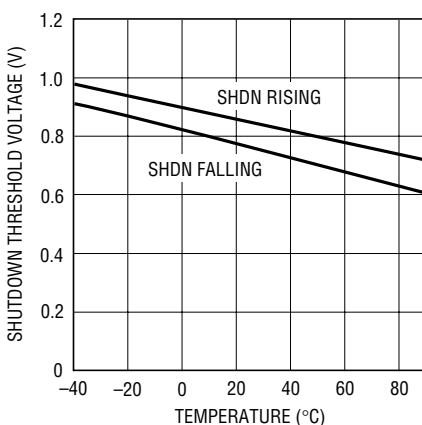
3459 G05

**N-Channel and P-Channel MOSFET  $R_{DS(ON)}$  vs Temperature**



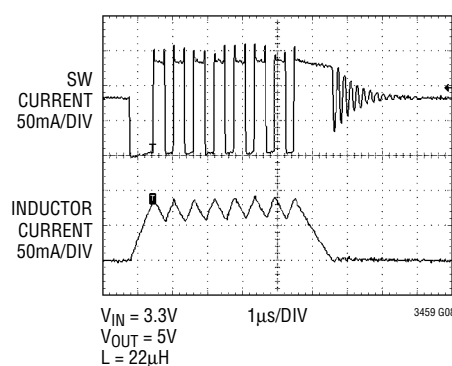
3459 G06

**Shutdown Threshold Voltage vs Temperature**



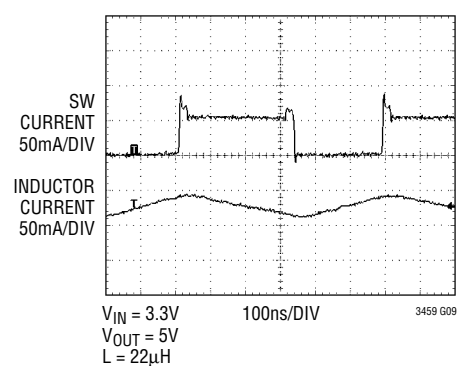
3459 G07

**Burst Cycle**



3459 G08

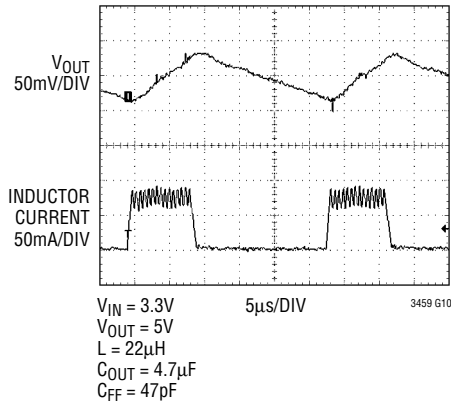
**Switch Pin Waveform**



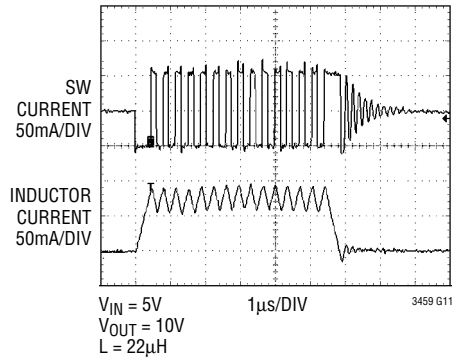
3459 G09

## TYPICAL PERFORMANCE CHARACTERISTICS ( $T_A = 25^\circ\text{C}$ unless otherwise noted.)

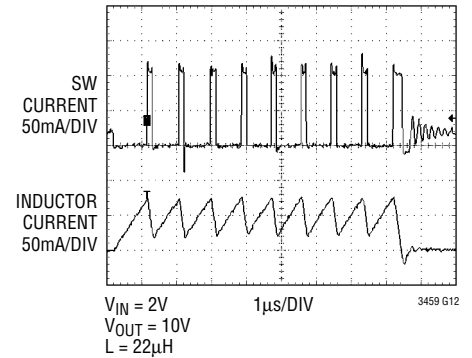
### $V_{OUT}$ AC Ripple



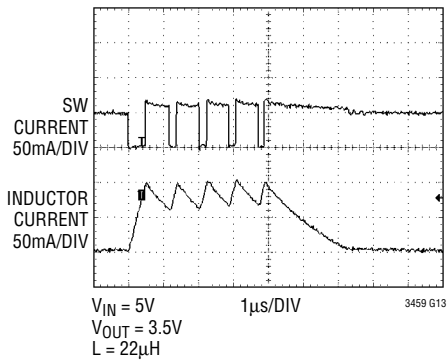
### Burst Cycle



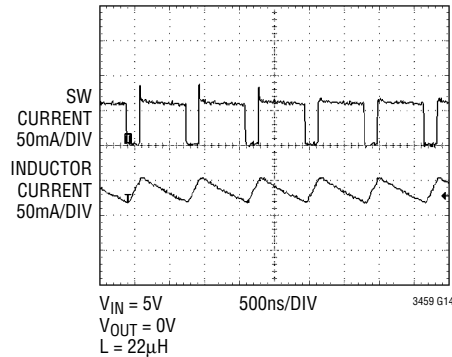
### Burst Cycle



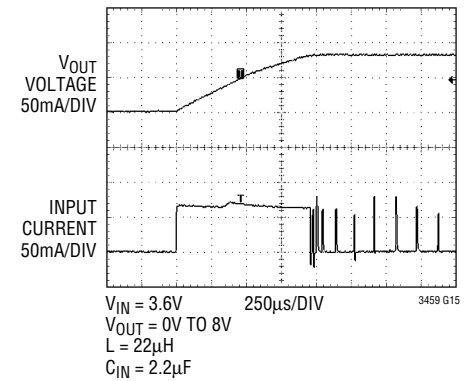
### $V_{OUT}$ Regulated Below $V_{IN}$ Burst Cycle



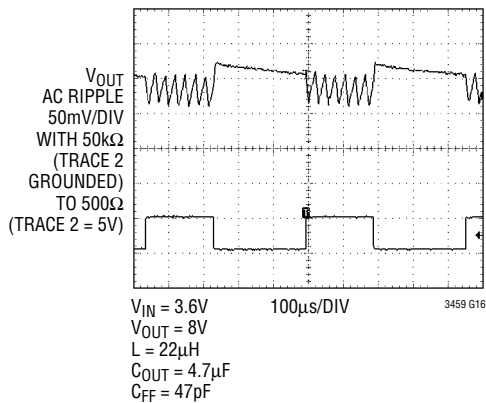
### Shorted Output



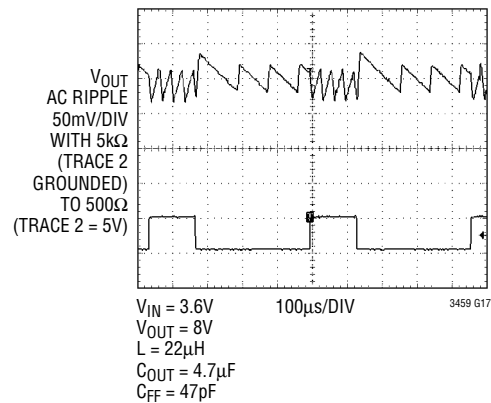
### Start-Up



### Load Steps



### Load Steps



## PIN FUNCTIONS

**SW (Pin 1):** Switch Pin. Connect a 15 $\mu$ H to 33 $\mu$ H inductor between SW and  $V_{IN}$ . Keep PCB trace lengths as short and wide as possible to reduce EMI and voltage overshoot. If the inductor current falls to zero, the internal P-channel MOSFET synchronous rectifier is turned off to prevent reverse charging of the inductor.

**GND (Pin 2):** Signal and Power Ground. Provide a short, direct PCB path between GND and the (–) side of the filter capacitors on  $V_{IN}$  and  $V_{OUT}$ .

**FB (Pin 3):** Input to the Burst Mode Comparator. An external resistor divider connected between  $V_{OUT}$ , GND and this pin sets the output voltage to:

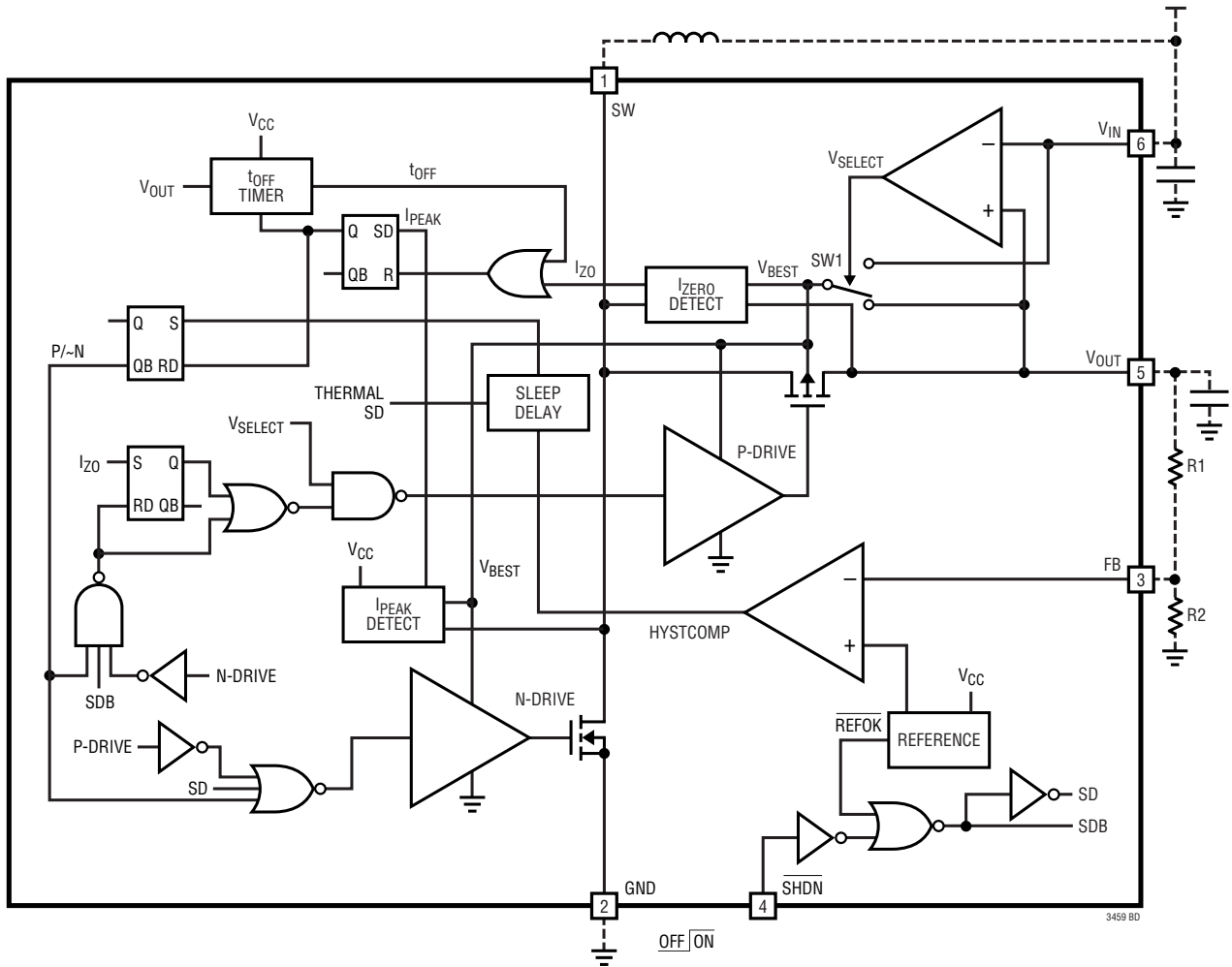
$$V_{OUT} = 1.22(1 + R1/R2)$$

**$\overline{\text{SHDN}}$  (Pin 4):** Master Shutdown Input. Driving  $\overline{\text{SHDN}}$  low disables all IC functions and reduces quiescent current from the battery to less than 2 $\mu$ A. This pin must be pulled above 1V to enable the IC.

**$V_{OUT}$  (Pin 5):** Regulated Output Voltage of the Boost Regulator. Bypass  $V_{OUT}$  with a low ESR, ESL ceramic capacitor between 2.2 $\mu$ F and 10 $\mu$ F.  $V_{OUT}$  ripple increases with smaller capacitors.

**$V_{IN}$  (Pin 6):** Input Supply Pin. Bypass  $V_{IN}$  with a low ESR, ESL ceramic capacitor of at least 1 $\mu$ F.

**BLOCK DIAGRAM**



# OPERATION

## Operation

The LTC3459 synchronous boost converter utilizes a Burst Mode control technique to achieve high efficiency over a wide dynamic range. A 2.5% accurate comparator is used to monitor the output voltage ( $V_{OUT}$ ), if  $V_{OUT}$  is above the comparator threshold no switching occurs and only quiescent current ( $10\mu A$ ) is drawn from the power source. When  $V_{OUT}$  drops below the comparator threshold, switching commences and the output capacitor is charged. During the on time of the switching period, inductor current is ramped through an internal N-channel MOSFET to GND until a peak current ( $75mA$ ) is detected. A P-channel MOSFET connects the inductor to  $V_{OUT}$  during the off time delivering energy to the load. The off time is controlled by an internal timer which is proportional to  $1/(V_{OUT} - V_{IN})$ . Anticross conduction circuitry ensures the N- and P-channel switches are never on simultaneously.

Only three power components and two feedback resistors are required to complete the design of the boost converter, an external Schottky diode is not required. The high operating frequency allows the use of low value, low profile inductors and tiny external ceramic capacitors. The

boost converter disconnects  $V_{OUT}$  from  $V_{IN}$  during shut-down to avoid loading the input power source.

## Peak Current Overshoot

The LTC3459's peak current comparator has a delay of approximately 100ns from the time inductor current reaches current limit until the internal N-channel MOSFET turns off. This delay causes the peak current to overshoot based on the inductor value and  $V_{IN}$  as follows (Figure 2 is based on a 65mA initial  $I_{LIMIT}$ ).

$$I_{PEAK} = I_{LIMIT} + (100ns) \frac{V_{IN}}{L}$$

## $t_{OFF}$ Timer

The LTC3459's  $t_{OFF}$  timer is designed to keep the inductor current continuous during a Burst Mode switching packet, thereby increasing current capability at the output. A larger inductor value will have lower peak to peak current ripple, increasing the available current to the load. This improvement is offset somewhat by the reduced  $I_{PEAK}$

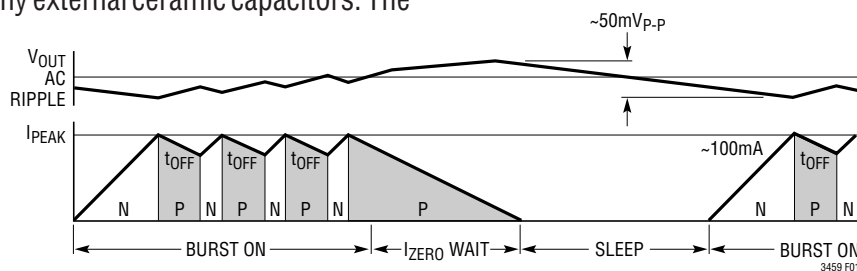


Figure 1. Inductor Current and  $V_{OUT}$  Ripple Waveforms

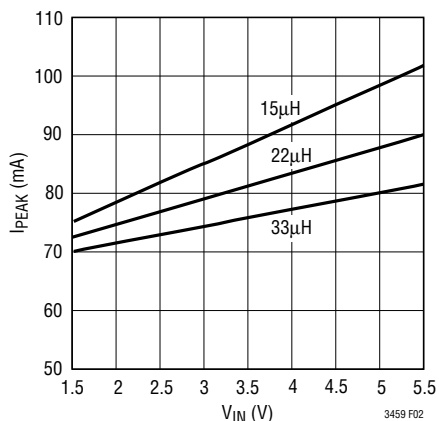


Figure 2. Typical  $I_{PEAK}$  Values

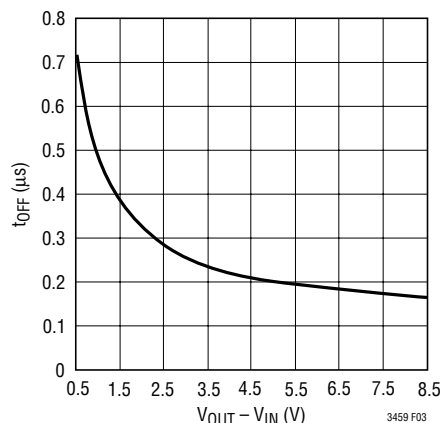


Figure 3.  $t_{OFF}$  Times

## OPERATION

overshoot. The  $t_{OFF}$  timer is designed to maintain a relatively constant peak-to-peak current in the inductor despite  $V_{IN}$  changes. This is accomplished by varying the  $t_{OFF}$  period by approximately  $1/(V_{OUT} - V_{IN})$ . Due to propagation delays and a  $0.6\mu A$  bias current in the timer, the  $t_{OFF}$  time can be more accurately predicted as follows:

$$t_{OFF} \approx 100ns + \frac{0.8pF \cdot 1.25V}{0.6\mu A + \frac{V_{OUT} - V_{IN}}{500k}}$$

If  $V_{OUT}$  is less than  $V_{IN}$ , the  $t_{OFF}$  delay is fixed at approximately 750ns.

## APPLICATIONS INFORMATION

### Inductor Selection

An inductor with a minimum value of  $15\mu H$  is recommended for use with the LTC3459. Values larger than  $15\mu H$  will result in lower ripple current and switching frequency. High frequency Ferrite core materials are strongly recommended. Some inductors meeting these requirements are listed in Table 2.

**Table 2. Example Inductors**

VENDOR/PART	L ( $\mu H$ )	DCR ( $\Omega$ )/ $I_{MAX}$ (mA)	DIMENSIONS (mm)	CONTACT INFORMATION
<b>Chip Inductors</b>				
Murata LQH31C	22	3/160	$3.2 \times 1.6 \times 1.8$	www.murata.com
LQH32C-Low Profile	22	0.7/250	$3.2 \times 2.5 \times 1.6$	
Taiyo Yuden LB2016	15 22 33	0.7/130 1/105 1.7/85	$2.0 \times 1.6 \times 1.6$	www.t-yuden.com (408) 573-4150
Toko LLB2520	15 22 33	1.7/180 2.5/160 3.8/130	$2.5 \times 2.0 \times 1.6$	www.tokoam.com (847) 297-0070
Coilcraft DO3314	15 22	0.86/650 1.2/500	$3.3 \times 3.3 \times 1.4$	www.coilcraft.com (847) 639-6400
DO1606T	15 22 33	0.4/700 0.5/500 0.74/450	$6.5 \times 5.3 \times 2.0$	
Sumida CMD4D06	15 22 33	0.5/400 0.8/300 1.3/240	$6.6 \times 5.8 \times 0.8$	www.sumida.com (847) 956-0666
CDRJ2D18LD	15 22 33	0.175/350 0.255/300 0.37/240	$3.2 \times 3.2 \times 2.0$	

### Capacitor Selection

The boost converter requires two capacitors. The input capacitor should be an X5R type of at least  $1.0\mu F$ . The  $V_{OUT}$

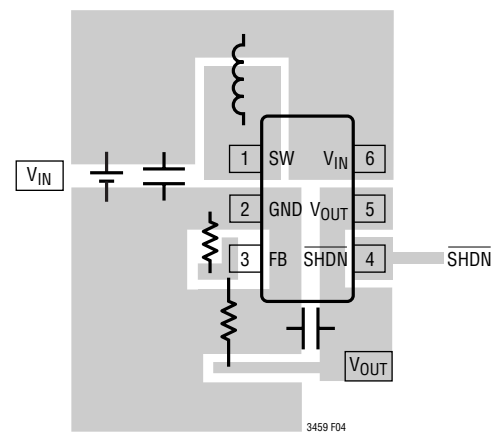
capacitor should also be an X5R type between  $2.2\mu F$  and  $10\mu F$ . A larger capacitor should be used if lower peak-to-peak output ripple and better line regulation is desired.

**Table 2. Capacitor Vendor Information**

SUPPLIER	PHONE	WEBSITE
AVX	(803) 448-9411	www.avxcorp.com
Murata	(714) 852-2001	www.murata.com
Taiyo Yuden	(408) 573-4150	www.t-yuden.com
TDK	(847) 803-6100	www.component.tdk.com

### PCB Layout Guidelines

The high speed operation of the LTC3459 demands careful attention to board layout. You will not get advertised performance with careless layout. Figure 4 shows the recommended component placement. A large ground pin copper area will help to lower the chip temperature.



RECOMMENDED COMPONENT PLACEMENT. TRACES CARRYING CURRENT ARE DIRECT. TRACE AREA AT FB PIN IS SMALL. LEAD LENGTH TO BATTERY IS SHORT

**Figure 4. Recommended Component Placement for Single Layer Board**

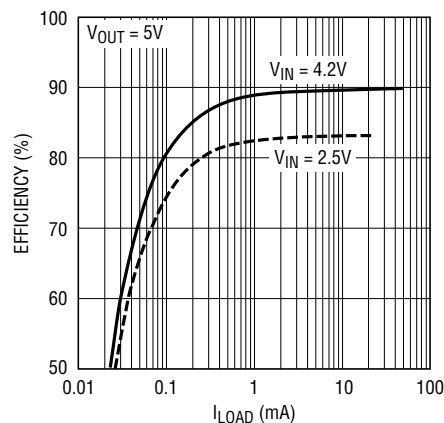
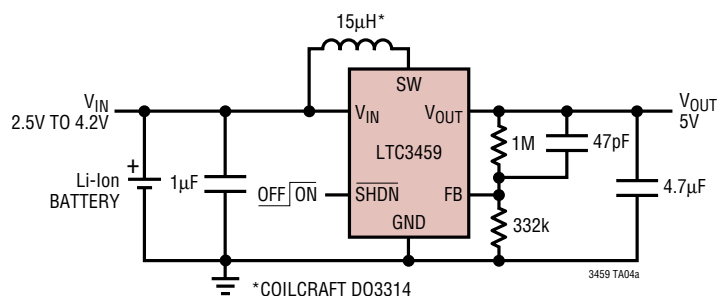


## TYPICAL APPLICATIONS

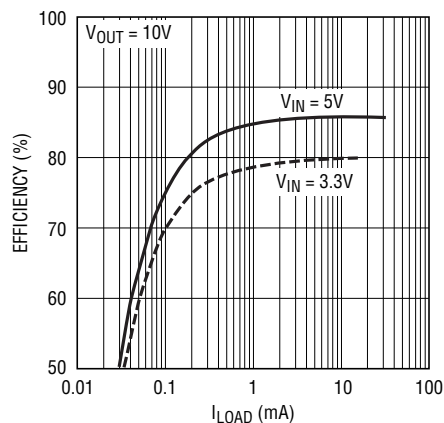
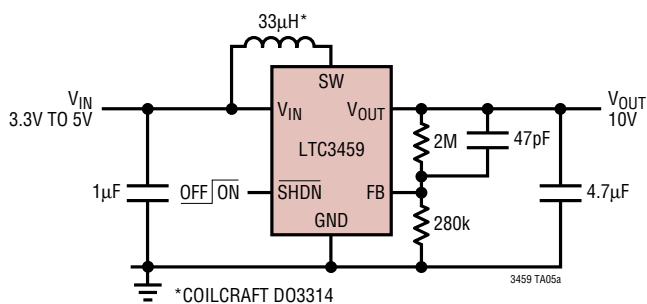
Very low operating quiescent current and synchronous operation allow for greater than 85% conversion efficiency in many applications. Lower output voltages will result in lower efficiencies since the N- and P-channel

$R_{DS(ON)}$ 's will increase. The switching frequency and output power capability of the LTC3459 are also dependant on input and output voltages.

### 5V from Li-Ion Input



### 10V from 3.3V or 5V Input



## TYPICAL APPLICATIONS

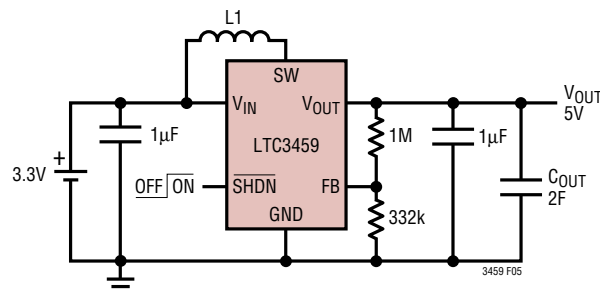
### Charging a SuperCap<sup>®</sup>

SuperCaps have become a popular alternative to NiCd batteries as backup power sources in portable equipment. Capacitance values of one Farad and higher are achievable in small package sizes with leakage currents in the low microamps. SuperCaps are typically charged at low currents for several minutes until they reach the required back-up voltage.

The LTC3459 is designed to control peak inductor current when  $V_{IN}$  is greater than or less than  $V_{OUT}$ . This allows current to be controlled during start-up in a boost application, for example, or  $V_{OUT}$  to be regulated below  $V_{IN}$  when powered from a fresh battery. Peak current control makes the LTC3459 an ideal candidate for charging a back-up source such as a SuperCap. Figure 5 shows an application where the LTC3459 is used to charge a two Farad, 5V supercap from a 3.3V input. A NiCd battery could be charged by the LTC3459 as well, but that application may require additional circuitry for proper charge termination.

When  $V_{OUT}$  is less than  $\sim 3.5V$ , the body of the internal synchronous P-channel MOSFET rectifier is connected to  $V_{IN}$  and the SW pin rises a diode above  $V_{IN}$  when current is delivered to the load. While efficiency is compromised in this mode of operation, current to the SuperCap is controlled, preventing any damaging effects of inrush current. Proper heat sinking of the SOT package is required in this application as the die may dissipate 100mW to 200mW during initial charging. When  $V_{OUT}$  is greater than  $\sim 3.5V$  normal boost mode operation and efficiency begin, with the P-channel MOSFET acting as a synchronous switch. Average input current is a constant 50mA during charging, where the current delivered to the SuperCap varies somewhat with duty cycle. Once the supercap is charged to 5V, the LTC3459 begins to regulate and the input current is reduced to the amount required to support the load and/or self discharge of the SuperCap.

SuperCap is a registered trademark of Baknor Industries.

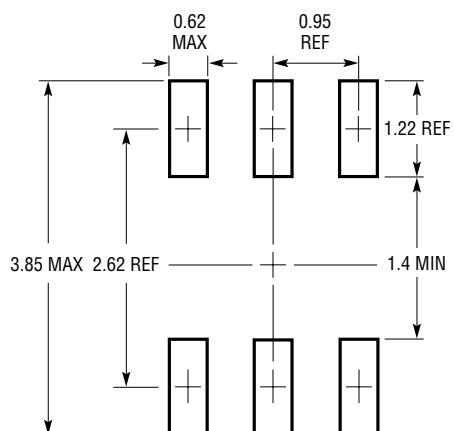


$C_{OUT}$ : MAXWELL TECHNOLOGIES ULTRACAP PC5-5, 2F, 5V  
 L1: 33µH, 1.7Ω TAIYO YUDEN LB2016

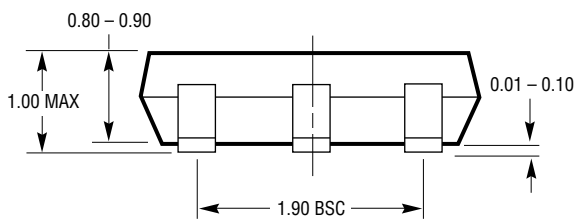
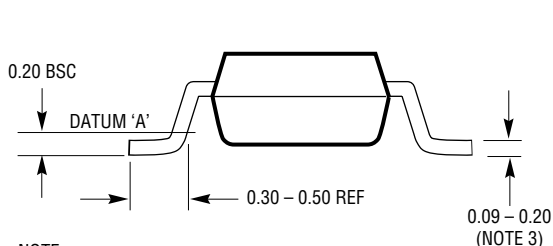
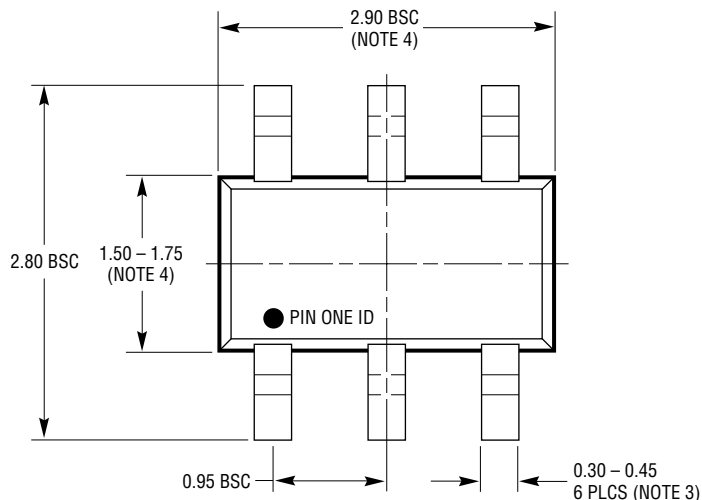
Figure 5. Charging a SuperCap from a 3.3V Source

# PACKAGE DESCRIPTION

## S6 Package 6-Lead Plastic TSOT-23 (Reference LTC DWG # 05-08-1636)



RECOMMENDED SOLDER PAD LAYOUT  
PER IPC CALCULATOR

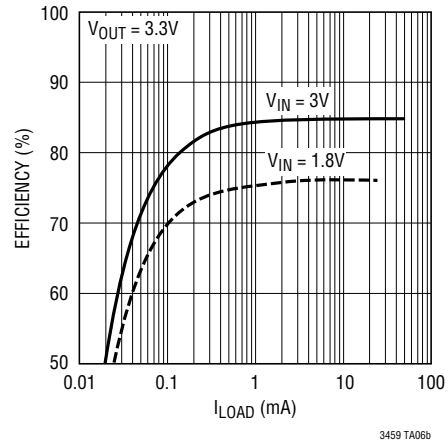
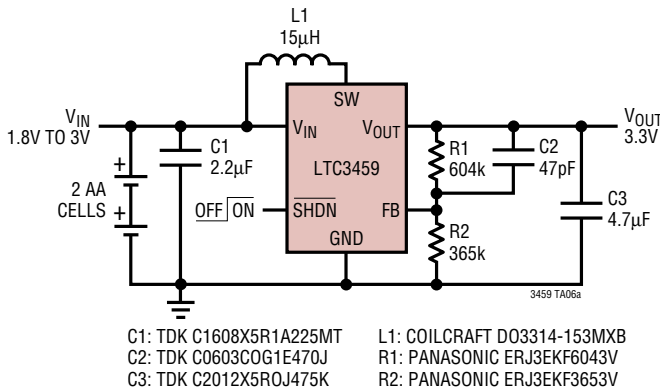


S6 TSOT-23 0302

- NOTE:
1. DIMENSIONS ARE IN MILLIMETERS
  2. DRAWING NOT TO SCALE
  3. DIMENSIONS ARE INCLUSIVE OF PLATING
  4. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH AND METAL BURR
  5. MOLD FLASH SHALL NOT EXCEED 0.254mm
  6. JEDEC PACKAGE REFERENCE IS MO-193

## TYPICAL APPLICATION

### 3.3V from 2 AA Alkaline Input



## RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1310	1.5A $I_{SW}$ , 4.5MHz, High Efficiency Step-Up DC/DC Converter	$V_{IN}$ : 2.75V to 18V, $V_{OUT(MAX)}$ = 35V, $I_Q$ = 12mA, $I_{SD}$ < 1µA, MS10E
LT1613	550mA $I_{SW}$ , 1.4MHz, High Efficiency Step-Up DC/DC Converter	$V_{IN}$ : 0.9V to 10V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 3mA, $I_{SD}$ < 1µA, ThinSOT
LT1615/LT1615-1	300mA/80mA $I_{SW}$ , Constant Off-Time, High Efficiency Step-Up DC/DC Converter	$V_{IN}$ : 1.2V to 15V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 20µA, $I_{SD}$ < 1µA, ThinSOT
LT1618	1.5A $I_{SW}$ , 1.4MHz, High Efficiency Step-Up DC/DC Converter	$V_{IN}$ : 1.6V to 18V, $V_{OUT(MAX)}$ = 35V, $I_Q$ = 1.8mA, $I_{SD}$ < 1µA, MS10
LT1944 (Dual)	Dual Output 350mA $I_{SW}$ , Constant Off-Time, High Efficiency Step-Up DC/DC Converter	$V_{IN}$ : 1.2V to 15V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 20µA, $I_{SD}$ < 1µA, MS10
LT1945 (Dual)	Dual Output Pos/Neg 350mA $I_{SW}$ , Constant Off-Time, High Efficiency Step-Up DC/DC Converter	$V_{IN}$ : 1.2V to 15V, $V_{OUT(MAX)}$ = ±34V, $I_Q$ = 20µA, $I_{SD}$ < 1µA, MS10
LT1946/LT1946A	1.5A $I_{SW}$ , 1.2MHz/2.7MHz, High Efficiency Step-Up DC/DC Converter	$V_{IN}$ : 2.45V to 16V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 3.2mA, $I_{SD}$ < 1µA, MS8
LT1949/LT1949-1	550mA $I_{SW}$ , 600kHz/1.1MHz, High Efficiency Step-Up DC/DC Converter	$V_{IN}$ : 1.5V to 12V, $V_{OUT(MAX)}$ = 28V, $I_Q$ = 4.5mA, $I_{SD}$ < 25µA, SO-8, MS8
LT1961	1.5A $I_{SW}$ , 1.25MHz, High Efficiency Step-Up DC/DC Converter	$V_{IN}$ : 3V to 25V, $V_{OUT(MAX)}$ = 35V, $I_Q$ = 0.9mA, $I_{SD}$ < 6µA, MS8E
LTC3400/LTC3400B	600mA $I_{SW}$ , 1.2MHz, Synchronous Step-Up DC/DC Converter	$V_{IN}$ : 0.5V to 5V, $V_{OUT(MAX)}$ = 5V, $I_Q$ = 19µA/300µA $I_{SD}$ < 1µA, ThinSOT
LTC3401	1A $I_{SW}$ , 3MHz, Synchronous Step-Up DC/DC Converter	$V_{IN}$ : 0.5V to 5V, $V_{OUT(MAX)}$ = 6V, $I_Q$ = 38µA $I_{SD}$ < 1µA, MS10
LTC3402	2A $I_{SW}$ , 3MHz, Synchronous Step-Up DC/DC Converter	$V_{IN}$ : 0.5V to 5V, $V_{OUT(MAX)}$ = 6V, $I_Q$ = 38µA $I_{SD}$ < 1µA, MS10
LTC3425	5A $I_{SW}$ , 8MHz, 4-Phase Synchronous Step-Up DC/DC Converter QFN32	$V_{IN}$ : 0.5V to 4.5V, $V_{OUT(MAX)}$ = 5.25V, $I_Q$ = 12µA, $I_{SD}$ < 1µA,
LTC3429	600mA, 500kHz, Synchronous Step-Up DC/DC Converter with Output Disconnect and Soft-Start	$V_{IN}$ : 0.5V to 5V, $V_{OUT(MAX)}$ = 5V, $I_Q$ = 20µA/300µA $I_{SD}$ < 1µA, ThinSOT
LT3460	320mA $I_{SW}$ , 1.3MHz, High Efficiency Step-Up DC/DC Converter	$V_{IN}$ : 2.5V to 16V, $V_{OUT(MAX)}$ = 36V, $I_Q$ = 2mA, $I_{SD}$ < 1µA, SC70, ThinSOT
LT3464	85mA $I_{SW}$ , Constant Off-Time, High Efficiency Step-Up DC/DC Converter with Integrated Schottky/Output Disconnect	$V_{IN}$ : 2.3V to 10V, $V_{OUT(MAX)}$ = 34V, $I_Q$ = 25µA, $I_{SD}$ < 1µA, ThinSOT

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