

High Current, Micropower Single Cell, 600kHz DC/DC Converters

August 1999

FEATURES

- 5V at 1A from a Single Li-Ion Cell
- 5V at 800mA in SEPIC Mode from Four NiCd Cells
- Fixed Frequency Operation: 600kHz
- Boost Converter Outputs up to 34V
- Starts into Heavy Loads
- Automatic Burst Mode™ Operation at Light Load (LT1308A)
- Continuous Switching at Light Loads (LT1308B)
- Low V_{CESAT} Switch: 300mV at 2A
- Pin-for-Pin Upgrade Compatible with LT1308
- Lower Quiescent Current in Shutdown: 1 μ A (Max)
- Improved Accuracy Low-Battery Detector Reference: 200mV \pm 2%

APPLICATIONS

- GSM/CDMA Phones
- Digital Cameras
- LCD Bias Supplies
- Answer-Back Pagers
- GPS Receivers
- Battery Backup Supplies
- Handheld Computers

DESCRIPTION

The LT[®]1308A/LT1308B are micropower, fixed frequency step-up DC/DC converters that operate over a 1V to 10V input voltage range. They are improved versions of the LT1308 and are recommended for use in new designs. The LT1308A features automatic shifting to power saving Burst Mode operation at light loads and consumes just 140 μ A at no load. The LT1308B features continuous switching at light loads and operates at a quiescent current of 2.5mA. Both devices consume less than 1 μ A in shutdown.

Low-battery detector accuracy is significantly tighter than the LT1308. The 200mV reference is specified at \pm 2% at room and \pm 3% over temperature. The shutdown pin enables the device when it is tied to a 1V or higher source and does not need to be tied to V_{IN} as on the LT1308. An internal V_C clamp results in improved transient response and the switch voltage rating has been increased to 36V, enabling higher output voltage applications.

The LT1308A/LT1308B are available in the 8-lead SO and 14-lead TSSOP packages.

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TYPICAL APPLICATION

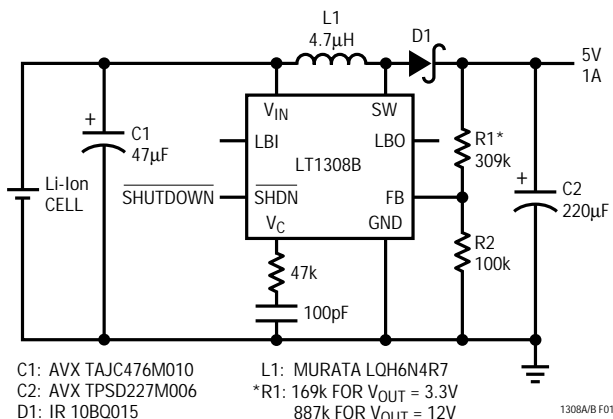
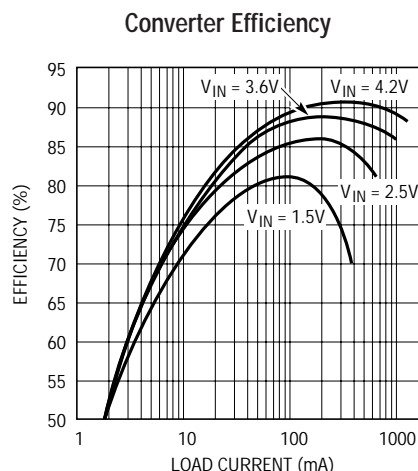


Figure 1. LT1308B Single Li-Ion Cell to 5V/1A DC/DC Converter



LT1308A/LT1308B

ABSOLUTE MAXIMUM RATINGS (Note 1)

V_{IN} , SHDN, LBO Voltage	10V	Operating Temperature Range	
SW Voltage	-0.4V to 36V	Commercial	0°C to 70°C
FB Voltage	$V_{IN} + 1V$	Extended Commercial (Note 2)	-40°C to 85°C
V_C Voltage	2V	Industrial	-40°C to 85°C
LBI Voltage	-0.1V to 1V	Storage Temperature Range	-65°C to 150°C
Current into FB Pin	$\pm 1mA$	Lead Temperature (Soldering, 10 sec)	300°C

PACKAGE/ORDER INFORMATION

<p>F PACKAGE 14-LEAD PLASTIC TSSOP</p> <p>(Note 6) $T_{JMAX} = 125^{\circ}C, \theta_{JA} = 80^{\circ}C/W$</p>	ORDER PART NUMBER	<p>S8 PACKAGE 8-LEAD PLASTIC SO</p> <p>$T_{JMAX} = 125^{\circ}C, \theta_{JA} = 80^{\circ}C/W$</p>	ORDER PART NUMBER
	LT1308ACF LT1308BCF		LT1308ACS8 LT1308AIS8 LT1308BCS8 LT1308BIS8
			1308A 1308B 1308AI 1308BI

Consult factory for Military grade parts.

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are $T_A = 25^{\circ}C$. Commercial Grade 0°C to 70°C. $V_{IN} = 1.1V$, $V_{SHDN} = V_{IN}$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	
I_Q	Quiescent Current	Not Switching, LT1308A Switching, LT1308B $V_{SHDN} = 0V$ (LT1308A/LT1308B)		140 2.5 0.01	240 4 1	μA mA μA	
V_{FB}	Feedback Voltage		● 1.20	1.22	1.24	V	
I_B	FB Pin Bias Current	(Note 3)	●	27	80	nA	
	Reference Line Regulation	$1.1V \leq V_{IN} \leq 2V$ $2V \leq V_{IN} \leq 10V$	●	0.03 0.01	0.4 0.2	%/V %/V	
	Minimum Input Voltage			0.92	1	V	
g_m	Error Amp Transconductance	$\Delta I = 5\mu A$		60		$\mu mhos$	
A_V	Error Amp Voltage Gain			100		V/V	
f_{OSC}	Switching Frequency	$V_{IN} = 1.2V$	●	500	600	700	kHz
	Maximum Duty Cycle		●	82	90	%	
	Switch Current Limit	Duty Cycle = 30% (Note 4)		2	3	4.5	A
	Switch V_{CESAT}	$I_{SW} = 2A$ (25°C, 0°C), $V_{IN} = 1.5V$ $I_{SW} = 2A$ (70°C), $V_{IN} = 1.5V$		290 330	350 400	mV mV	
	Burst Mode Operation Switch Current Limit (LT1308A)	$V_{IN} = 2.5V$, Circuit of Figure 1		400		mA	

ELECTRICAL CHARACTERISTICS

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are $T_A = 25^\circ\text{C}$. Commercial Grade 0°C to 70°C . $V_{IN} = 1.1\text{V}$, $V_{SHDN} = V_{IN}$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
	Shutdown Pin Current	$V_{SHDN} = 1.1\text{V}$	●	2	5	μA
		$V_{SHDN} = 6\text{V}$	●	20	35	μA
		$V_{SHDN} = 0\text{V}$	●	0.01	0.1	μA
	LBI Threshold Voltage		●	196	204	mV
			●	194	206	mV
	LBO Output Low	$I_{SINK} = 50\mu\text{A}$	●	0.1	0.25	V
	LBO Leakage Current	$V_{LBI} = 250\text{mV}$, $V_{LBO} = 5\text{V}$	●	0.01	0.1	μA
	LBI Input Bias Current (Note 5)	$V_{LBI} = 150\text{mV}$		33	100	nA
	Low-Battery Detector Gain			3000		V/V
	Switch Leakage Current	$V_{SW} = 5\text{V}$	●	0.01	10	μA

The ● denotes specifications which apply over the full operating temperature range, otherwise specifications are $T_A = 25^\circ\text{C}$. Industrial Grade -40°C to 85°C . $V_{IN} = 1.2\text{V}$, $V_{SHDN} = V_{IN}$, unless otherwise noted.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
I_Q	Quiescent Current	Not Switching, LT1308A	●	140	240	μA
		Switching, LT1308B	●	2.5	4	mA
		$V_{SHDN} = 0\text{V}$ (LT1308A/LT1308B)	●	0.01	1	μA
V_{FB}	Feedback Voltage		●	1.19	1.25	V
I_B	FB Pin Bias Current	(Note 3)	●	27	80	nA
	Reference Line Regulation	$1.1\text{V} \leq V_{IN} \leq 2\text{V}$	●	0.05	0.4	%/V
		$2\text{V} \leq V_{IN} \leq 10\text{V}$	●	0.01	0.2	%/V
	Minimum Input Voltage			0.92	1	V
g_m	Error Amp Transconductance	$\Delta I = 5\mu\text{A}$		60		μmhos
A_V	Error Amp Voltage Gain			100		V/V
f_{OSC}	Switching Frequency		●	500	750	kHz
	Maximum Duty Cycle		●	82	90	%
	Switch Current Limit	Duty Cycle = 30% (Note 4)		2	4.5	A
	Switch V_{CESAT}	$I_{SW} = 2\text{A}$ (25°C , -40°C), $V_{IN} = 1.5\text{V}$		290	350	mV
		$I_{SW} = 2\text{A}$ (85°C), $V_{IN} = 1.5\text{V}$		330	400	mV
	Burst Mode Operation Switch Current Limit (LT1308A)	$V_{IN} = 2.5\text{V}$, Circuit of Figure 1		400		mA
	Shutdown Pin Current	$V_{SHDN} = 1.1\text{V}$	●	2	5	μA
		$V_{SHDN} = 6\text{V}$	●	20	35	μA
		$V_{SHDN} = 0\text{V}$		0.01	0.1	μA
	LBI Threshold Voltage		●	196	204	mV
			●	193	207	mV
	LBO Output Low	$I_{SINK} = 50\mu\text{A}$	●	0.1	0.25	V
	LBO Leakage Current	$V_{LBI} = 250\text{mV}$, $V_{LBO} = 5\text{V}$	●	0.01	0.1	μA
	LBI Input Bias Current (Note 5)	$V_{LBI} = 150\text{mV}$		33	100	nA
	Low-Battery Detector Gain			3000		V/V
	Switch Leakage Current	$V_{SW} = 5\text{V}$	●	0.01	10	μA

ELECTRICAL CHARACTERISTICS

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

Note 2: The LT1308ACS8 and LT1308BCS8 are designed, characterized and expected to meet the industrial temperature limits, but are not tested at -40°C and 85°C . I grade devices are guaranteed.

Note 3: Bias current flows into FB pin.

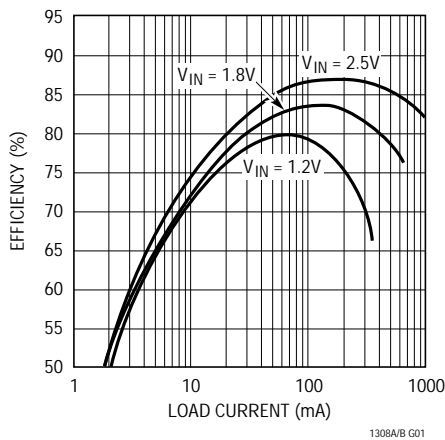
Note 4: Switch current limit guaranteed by design and/or correlation to static tests. Duty cycle affects current limit due to ramp generator (see Block Diagram).

Note 5: Bias current flows out of LBI pin.

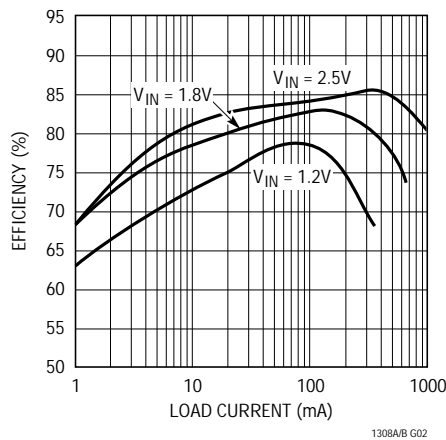
Note 6: Connect the four GND pins (Pins 4–7) together at the device. Similarly, connect the three SW pins (Pins 8–10) together and the two V_{IN} pins (Pins 11, 12) together at the device.

TYPICAL PERFORMANCE CHARACTERISTICS

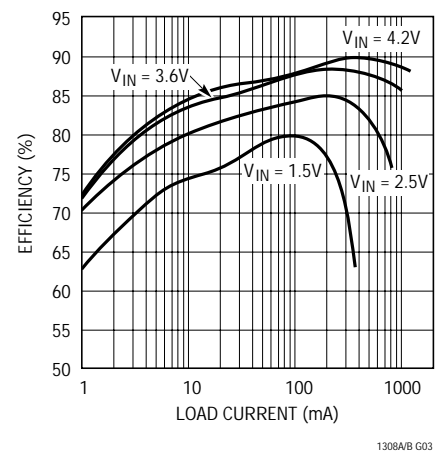
LT1308B
3.3V Output Efficiency



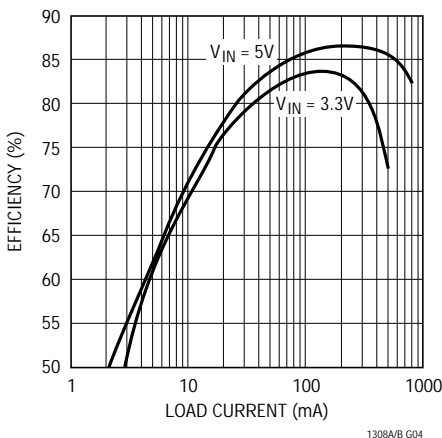
LT1308A
3.3V Output Efficiency



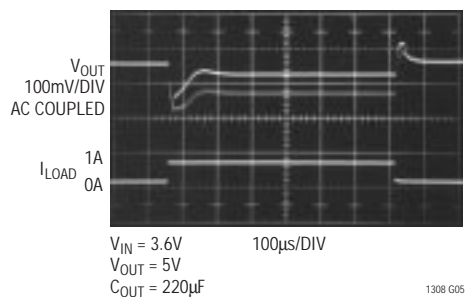
LT1308A
5V Output Efficiency



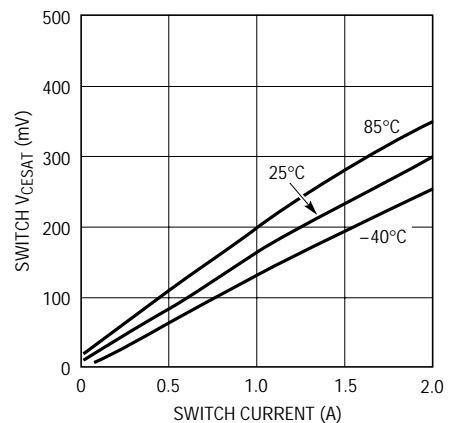
LT1308B
12V Output Efficiency



LT1308A Transient Response
Circuit of Figure 1



Switch Saturation Voltage vs Current



PIN FUNCTIONS

V_C (Pin 1): Compensation Pin for Error Amplifier. Connect a series RC from this pin to ground. Typical values are 47kΩ and 100pF. Minimize trace area at V_C.

FB (Pin 2): Feedback Pin. Reference voltage is 1.22V. Connect resistive divider tap here. Minimize trace area at FB. Set V_{OUT} according to: $V_{OUT} = 1.22V(1 + R1/R2)$.

SHDN (Pin 3): Shutdown. Ground this pin to turn off switcher. To enable, tie to 1V or more. SHDN does not need to be at V_{IN} to enable the device.

GND (Pin 4): Ground. Connect directly to local ground plane. Ground plane should enclose all components associated with the LT1308. PCB copper connected to Pin 4 also functions as a heat sink. Maximize this area to keep chip heating to a minimum.

SW (Pin 5): Switch Pin. Connect inductor/diode here. Minimize trace area at this pin to keep EMI down.

V_{IN} (Pin 6): Supply Pin. Must have local bypass capacitor right at the pin, connected directly to ground.

LBI (Pin 7): Low-Battery Detector Input. 200mV reference. Voltage on LBI must stay between -100mV and 1V. Low-battery detector does not function with SHDN pin grounded. If not used, float LBI pin.

LBO (Pin 8): Low-Battery Detector Output. Open collector, can sink 50μA. A 1MΩ pull-up is recommended. LBO is high impedance when SHDN is grounded.

BLOCK DIAGRAM

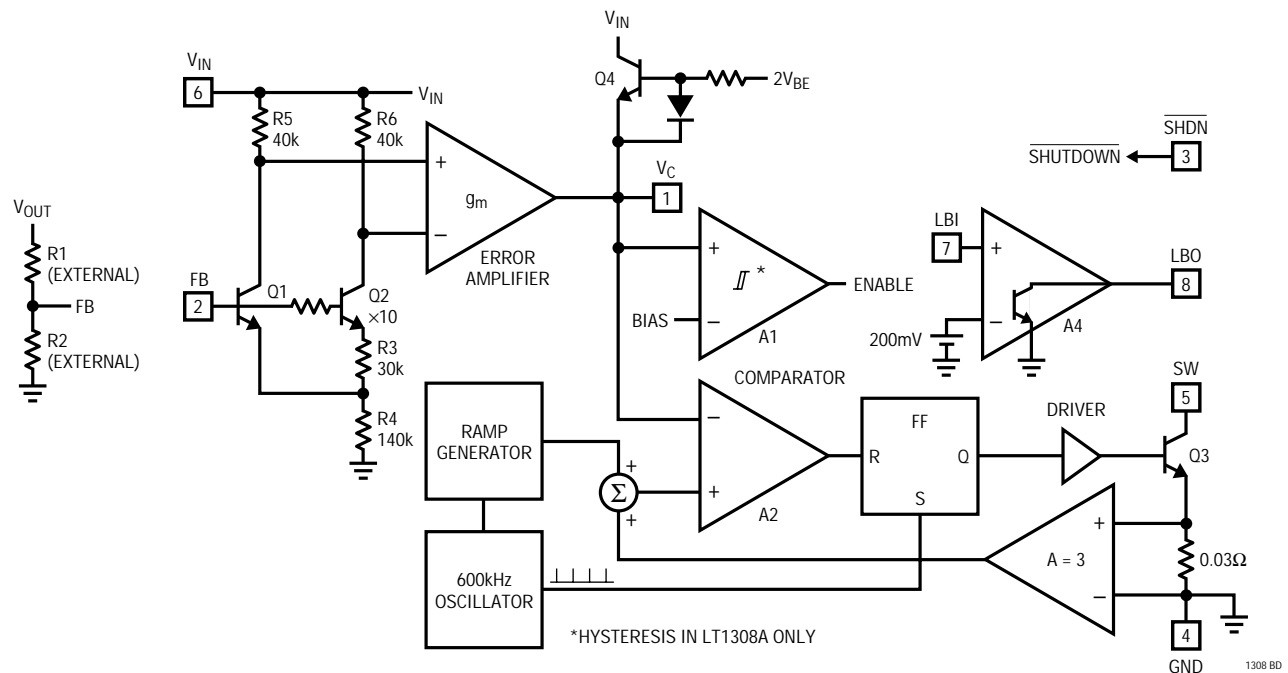


Figure 2. LT1308A/LT1308B Block Diagram

APPLICATIONS INFORMATION

OPERATION

The LT1308A combines a current mode, fixed frequency PWM architecture with Burst Mode micropower operation to maintain high efficiency at light loads. Operation can be best understood by referring to the block diagram in Figure 2. Q1 and Q2 form a bandgap reference core whose loop is closed around the output of the converter. When V_{IN} is 1V, the feedback voltage of 1.22V, along with an 80mV drop across R5 and R6, forward biases Q1 and Q2's base collector junctions to 300mV. Because this is not enough to saturate either transistor, FB can be at a higher voltage than V_{IN} . When there is no load, FB rises slightly above 1.22V, causing V_C (the error amplifier's output) to decrease. When V_C reaches the bias voltage on hysteretic comparator A1, A1's output goes low, turning off all circuitry except the input stage, error amplifier and low-battery detector. Total current consumption in this state is 120 μ A. As output loading causes the FB voltage to decrease, A1's output goes high, enabling the rest of the IC. Switch current is limited to approximately 400mA initially after A1's output goes high. If the load is light, the output voltage (and FB voltage) will increase until A1's output goes low, turning off the rest of the LT1308A. Low frequency ripple voltage appears at the output. The ripple frequency is dependent on load current and output capacitance. This Burst Mode operation keeps the output regulated and reduces average current into the IC, resulting in high efficiency even at load currents of 1mA or less.

If the output load increases sufficiently, A1's output remains high, resulting in continuous operation. When the LT1308A is running continuously, peak switch current is controlled by V_C to regulate the output voltage. The switch is turned on at the beginning of each switch cycle. When the summation of a signal representing switch current and a ramp generator (introduced to avoid subharmonic oscillations at duty factors greater than 50%) exceeds the V_C signal, comparator A2 changes state, resetting the flip-flop and turning off the switch. Output voltage increases as switch current is increased. The output, attenuated by a resistor divider, appears at the FB pin, closing the overall loop. Frequency compensation is provided by an external series RC network connected between the V_C pin and ground.

Low-battery detector A4's open-collector output (LBO) pulls low when the LBI pin voltage drops below 200mV. There is no hysteresis in A4, allowing it to be used as an amplifier in some applications. The entire device is disabled when the $\overline{\text{SHDN}}$ pin is brought low. To enable the converter, $\overline{\text{SHDN}}$ must be at 1V or greater. It need not be tied to V_{IN} as on the LT1308.

The LT1308B differs from the LT1308A in that there is no hysteresis in comparator A1. Also, the bias point on A1 is set lower than on the LT1308B so that switching can occur at inductor current less than 100mA. Because A1 has no hysteresis, there is no Burst Mode operation at light loads and the device continues switching at constant frequency. This results in the absence of low frequency output voltage ripple at the expense of efficiency.

The difference between the two devices is clearly illustrated in Figure 3. The top two traces in Figure 3 shows an LT1308A/LT1308B circuit, using the components indicated in Figure 1, set to a 5V output. Input voltage is 3V. Load current is stepped from 50mA to 800mA for both circuits. Low frequency Burst Mode operation voltage ripple is observed on Trace A, while none is observed on Trace B.

At light loads, the LT1308B will begin to skip alternate cycles. The load point at which this occurs can be decreased by increasing the inductor value. However, output ripple will continue to be significantly less than the LT1308A output ripple. Further, the LT1308B can be forced into micropower mode, where I_Q falls from 3mA to 200 μ A by sinking 40 μ A or more out of the V_C pin. This stops switching by causing A1's output to go low.

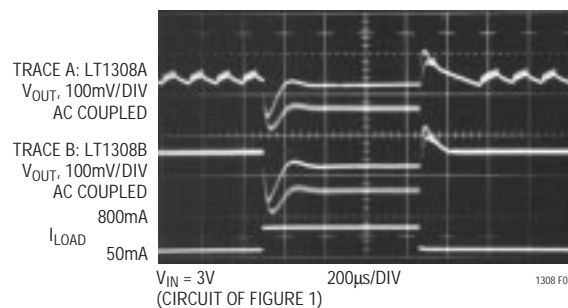


Figure 3. LT1308A Exhibits Burst Mode Operation Output Voltage Ripple at 50mA Load, LT1308B Does Not

APPLICATIONS INFORMATION

LAYOUT HINTS

The LT1308A/LT1308B switch current at high speed, mandating careful attention to layout for proper performance. *You will not get advertised performance with careless layouts.* Figure 4 shows recommended component placement for a boost (step-up) converter. Follow this closely in your PC layout. Note the direct path of the switching loops. Input capacitor C1 *must* be placed close (< 5mm) to the IC package. As little as 10mm of wire or PC trace from C_{IN} to V_{IN} will cause problems such as inability to regulate or oscillation.

The negative terminal of output capacitor C2 should tie close to Pin 4 of the LT1308A/LT1308B. Doing this reduces di/dt in the ground copper which keeps high frequency spikes to a minimum. The DC/DC converter ground should tie to the PC board ground plane at one place only, to avoid introducing di/dt in the ground plane.

A SEPIC (Single-Ended Primary Inductance Converter) schematic is shown in Figure 5. This converter topology produces a regulated output over an input voltage range that spans (i.e., can be higher or lower than) the output. Recommended component placement for a SEPIC is shown in Figure 6.

COMPONENT SELECTION

Inductors

Suitable inductors for use with the LT1308A/LT1308B must fulfill two requirements. First, the inductor must be able to handle current of 2A steady-state, as well as support transient and start-up current over 3A without inductance decreasing by more than 50% to 60%. Second, the DCR of the inductor should have low DCR, under 0.05Ω so that copper loss is minimized. Acceptable inductance values range between 2μH and 20μH, with 4.7μH best for most applications. Lower value inductors are physically smaller than higher value inductors for the same current capability.

Table 1 lists some inductors we have found to perform well in LT1308A/LT1308B application circuits. This is not an exclusive list.

Table 1

VENDOR	PART NO.	VALUE	PHONE NO.
Murata	LQH6C4R7	4.7μH	770-436-1300
Sumida	CDRH734R7	4.7μH	847-956-0666
Coiltronics	CTX5-1	5μH	561-241-7876

Capacitors

Equivalent Series Resistance (ESR) is the main issue regarding selection of capacitors, especially the output capacitors.

The output capacitors specified for use with the LT1308A/LT1308B circuits have low ESR and are specifically designed for power supply applications. Output voltage ripple of a boost converter is equal to ESR multiplied by switch current. The performance of the AVX TPSD227M006 220μF tantalum can be evaluated by referring to Figure 4. When the load is 800mA, the peak switch current is approximately 2A. Output voltage ripple is about 60mV_{p-p}, so the ESR of the output capacitor is 60mV/2A or 0.03Ω. Ripple can be further reduced by paralleling ceramic units.

Table 2 lists some capacitors we have found to perform well in the LT1308A/LT1308B application circuits. This is not an exclusive list.

Table 2

VENDOR	SERIES	PART NO.	VALUE	PHONE NO.
AVX	TPS	TPSD227M006	220μF, 6V	803-448-9411
AVX	TPS	TPSD107M010	100μF, 10V	803-448-9411
Taiyo Yuden	X5R	LMK432BJ226	22μF, 10V	408-573-4150
Taiyo Yuden	X5R	TMK432BJ106	10μF, 25V	408-573-4150

Diodes

We have found Motorola MBR5130 and International Rectifier 10BQ015 to perform well. For applications where V_{OUT} exceeds 30V, use 40V diodes such as MBR5140 or 10BQ040.

APPLICATIONS INFORMATION

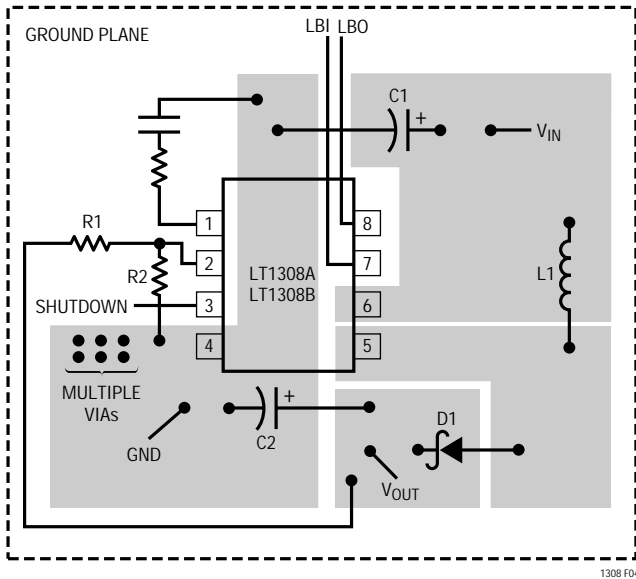


Figure 4. Recommended Component Placement for Boost Converter. Note Direct High Current Paths Using Wide PC Traces. Minimize Trace Area at Pin 1 (V_C) and Pin 2 (FB). Use Multiple Vias to Tie Pin 4 Copper to Ground Plane. Use Vias at One Location Only to Avoid Introducing Switching Currents into the Ground Plane

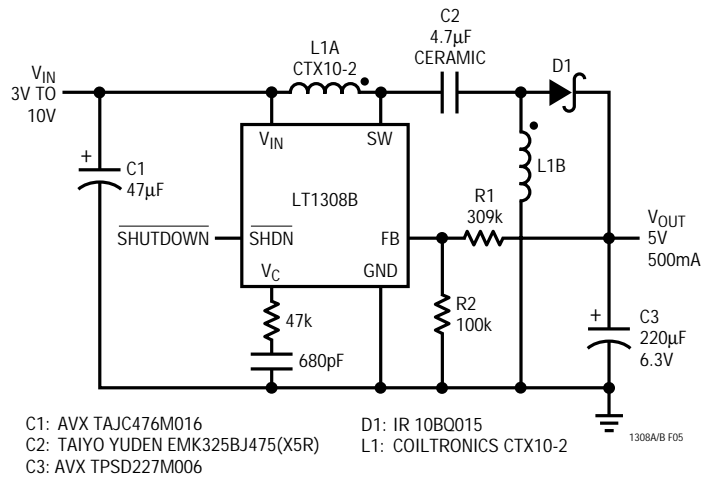


Figure 5. SEPIC (Single-Ended Primary Inductance Converter) Converts 3V to 10V Input to a 5V/500mA Regulated Output

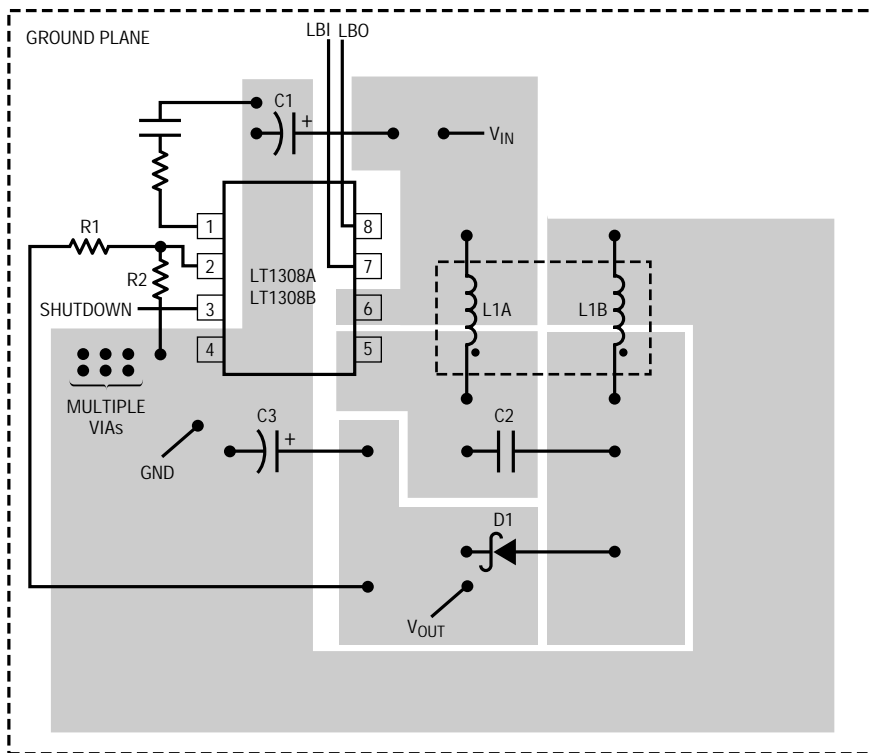


Figure 6. Recommended Component Placement for SEPIC

APPLICATIONS INFORMATION

SHDN PIN

The LT1308A/LT1308B $\overline{\text{SHDN}}$ pin is improved over the LT1308. The pin does not require tying to V_{IN} to enable the device, but needs only a logic level signal. The voltage on the $\overline{\text{SHDN}}$ pin can vary from 1V to 10V independent of V_{IN} . Further, floating this pin has the same effect as grounding, which is to shut the device down, reducing current drain to 1 μA or less.

LOW-BATTERY DETECTOR

The low-battery detector on the LT1308A/LT1308B features improved accuracy and drive capability compared to the LT1308. The 200mV reference has an accuracy of $\pm 2\%$ and the open-collector output can sink 50 μA . The LT1308A/LT1308B low-battery detector is a simple PNP input gain stage with an open-collector NPN output. The negative input of the gain stage is tied internally to a 200mV reference. The positive input is the LBI pin. Arrangement as a low-battery detector is straightforward. Figure 7 details hookup. R1 and R2 need only be low enough in value so that the bias current of the LBI pin doesn't cause large errors. For R2, 100k is adequate. The 200mV reference can also be accessed as shown in Figure 8.

A cross plot of the low-battery detector is shown in Figure 9. The LBI pin is swept with an input which varies from 195mV to 205mV, and LBO with a 100k pull-up resistor, is displayed.

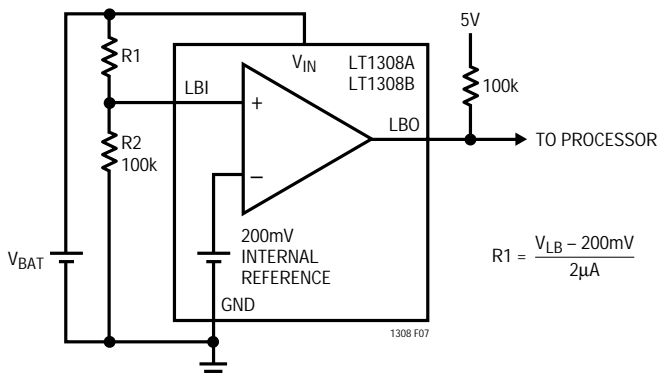


Figure 7. Setting Low-Battery Detector Trip Point

START-UP

The LT1308A/LT1308B can start up into heavy loads, unlike many CMOS DC/DC converters that derive operating voltage from the output (a technique known as “bootstrapping”). Figure 10 details start-up waveforms of Figure 1’s circuit with a 20 Ω load and V_{IN} of 1.5V. Inductor current rises to 3.5A as the output capacitor is charged. After the output reaches 5V, inductor current is about 1A. In Figure 11, the load is 5 Ω and input voltage is 3V. Output voltage reaches 5V 500 μs after the device is enabled. Figure 12 shows start-up behavior of Figure 5’s SEPIC circuit, driven from a 9V input with a 10 Ω load. The output reaches 5V in about 1ms after the device is enabled.

GSM AND CDMA PHONES

The LT1308A/LT1308B are suitable for converting a single Li-Ion cell to 5V for powering RF power stages in GSM or CDMA phones. Improvements in the LT1308A/LT1308B error amplifiers allow external compensation values to be reduced, resulting in faster transient response compared to the LT1308. The circuit of Figure 13 (same as Figure 1, printed again for convenience) provides a 5V, 1A output from a Li-Ion cell. Figure 14 details transient response at the LT1308A operating at a V_{IN} of 4.2V, 3.6V and 3V. Ripple voltage in Burst Mode operation can be seen at 10mA load. Figure 15 shows transient response of the LT1308B under the same conditions. Note the lack of Burst Mode ripple at 10mA load.

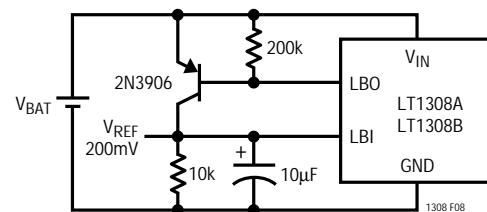


Figure 8. Accessing 200mV Reference

APPLICATIONS INFORMATION

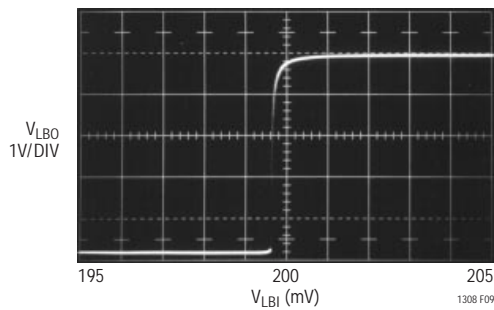


Figure 9. Low-Battery Detector Input/Output Characteristic

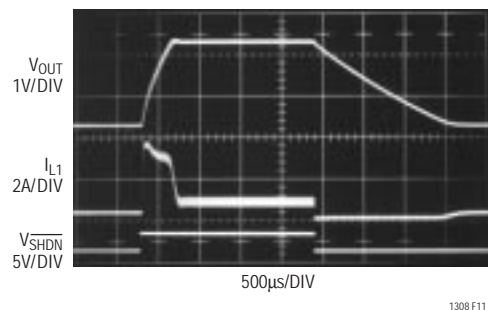


Figure 11. 5V Boost Converter of Figure 1. Start-Up from 3V Input into 5Ω Load

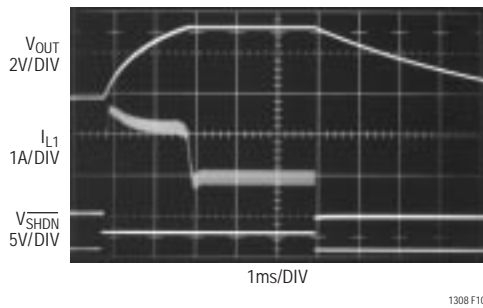


Figure 10. 5V Boost Converter of Figure 1. Start-Up from 1.5V Input into 20Ω Load

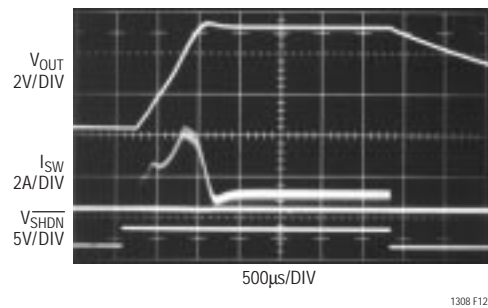


Figure 12. 5V SEPIC Start-Up from 9V Input into 10Ω Load

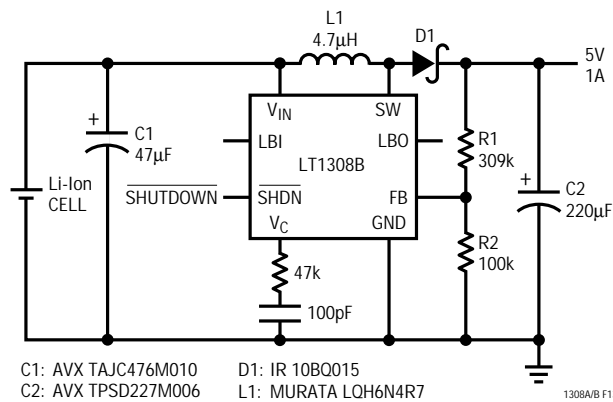


Figure 13. Li-Ion to 5V Boost Converter Delivers 1A

APPLICATIONS INFORMATION

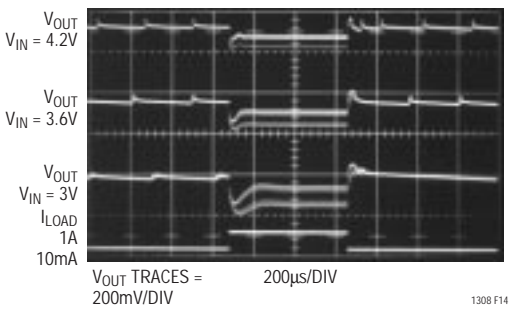


Figure 14. LT1308A Li-Ion to 5V Boost Converter Transient Response to 1A Load Step

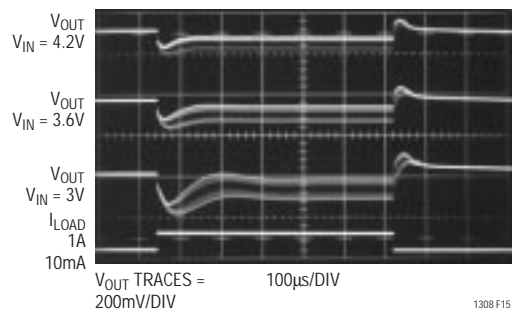
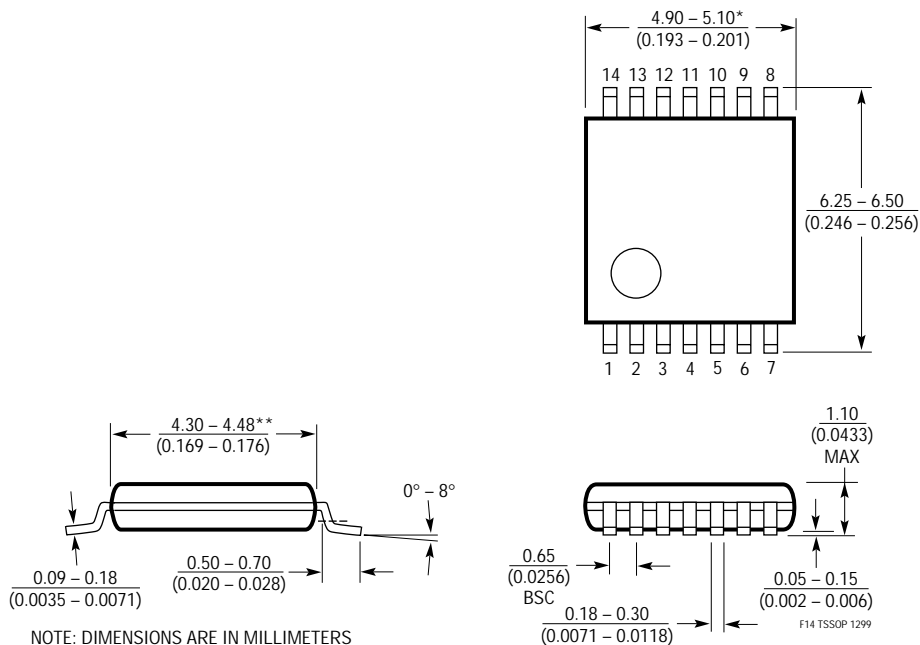


Figure 15. LT1308B Li-Ion to 5V Boost Converter Transient Response to 1A Load Step

PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

F Package
14-Lead Plastic TSSOP (4.4mm)
(LTC DWG # 05-08-1650)

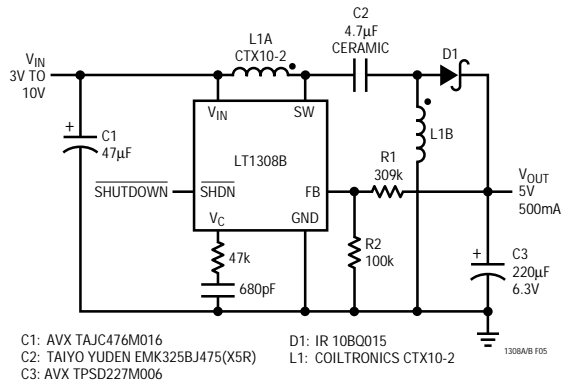


NOTE: DIMENSIONS ARE IN MILLIMETERS
*DIMENSIONS DO NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.152mm (0.006") PER SIDE
**DIMENSIONS DO NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.254mm (0.010") PER SIDE

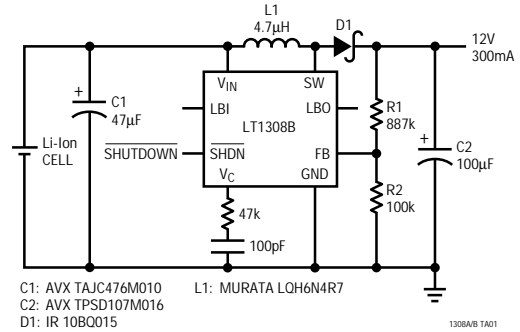
LT1308A/LT1308B

TYPICAL APPLICATION

SEPIC Converts 3V to 10V Input to a 5V/500mA Regulated Output



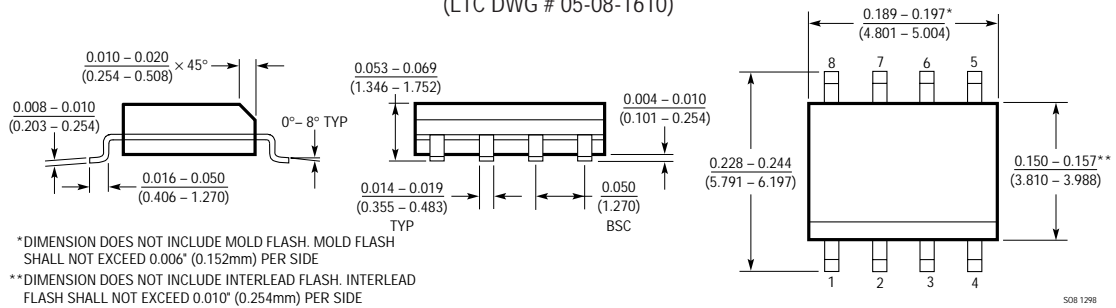
3.3V to 12V/300mA Step-Up DC/DC Converter



PACKAGE DESCRIPTION

Dimensions in inches (millimeters) unless otherwise noted.

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



RELATED PARTS

PART NUMBER	DESCRIPTION	COMMENTS
LT1302	High Output Current Micropower DC/DC Converter	5V/600mA from 2V, 2A Internal Switch, 200µA I _Q
LT1304	2-Cell Micropower DC/DC Converter	5V/200mA, Low-Battery Detector Active in Shutdown
LT1307/LT1307B	Single Cell, Micropower, 600kHz PWM DC/DC Converters	3.3V at 75mA from One Cell, MSOP Package
LT1316	Burst Mode Operation DC/DC with Programmable Current Limit	1.5V Minimum, Precise Control of Peak Current Limit
LT1317/LT1317B	Micropower, 600kHz PWM DC/DC Converters	100µA I _Q , Operate with V _{IN} as Low as 1.5V
LTC® 1474	Micropower Step-Down DC/DC Converter	94% Efficiency, 10µA I _Q , 9V to 5V at 250mA
LTC1516	2-Cell to 5V Regulated Charge Pump	12µA I _Q , No Inductors, 5V at 50mA from 3V Input
LTC1522	Micropower, 5V Charge Pump DC/DC Converter	Regulated 5V ±4% Output, 20mA from 3V Input
LT1610	Single-Cell Micropower DC/DC Converter	3V at 30mA from 1V, 1.7MHz Fixed Frequency
LT1611	Inverting 1.4MHz Switching Regulator in 5-Lead SOT-23	-5V at 150mA from 5V Input, Tiny SOT-23 package
LT1613	1.4MHz Switching Regulator in 5-Lead SOT-23	5V at 200mA from 4.4V Input, Tiny SOT-23 package
LT1615	Micropower Step-Up DC/DC in 5-Lead SOT-23	20µA I _Q , 36V, 350mA Switch
LTC1682	Doubler Charge Pump with Low Noise LDO	Adjustable or Fixed 3.3V, 5V Outputs, 60µV _{RMS} Output Noise
LT1949	600kHz, 1A Switch PWM DC/DC Converter	1.1A, 0.5Ω, 30V Internal Switch, V _{IN} as Low as 1.5V