

# AS1321

## 130mA Step-Up DC-DC Converter

### 1 General Description

The AS1321 is a high-efficiency step-up DC-DC converter designed to generate a fixed output voltage of +5.0V.

The AS1321 achieves an efficiency of up to 96%. The minimum input voltage is +1.5V, the output voltage is fixed at +5.0V, and output current is up to 130mA (@ 2V  $V_{BATT}$ ).

In order to save power the AS1321 features a shutdown mode, where it draws less than 1 $\mu$ A. In shutdown mode the battery is connected directly to the output enabling the supply of real-time-clocks.

The AS1321 provides a power-on reset output that goes high-impedance when the output reaches 90% of its regulation point.

The SHDNN trip threshold of the AS1321 can be used as an input voltage detector that disables the device when the battery voltage falls to a predetermined level.

An internal synchronous rectifier is included, which is parallel with the external Schottky diode.

The AS1321 is available in a 6-pin SOT23 package.

### 2 Key Features

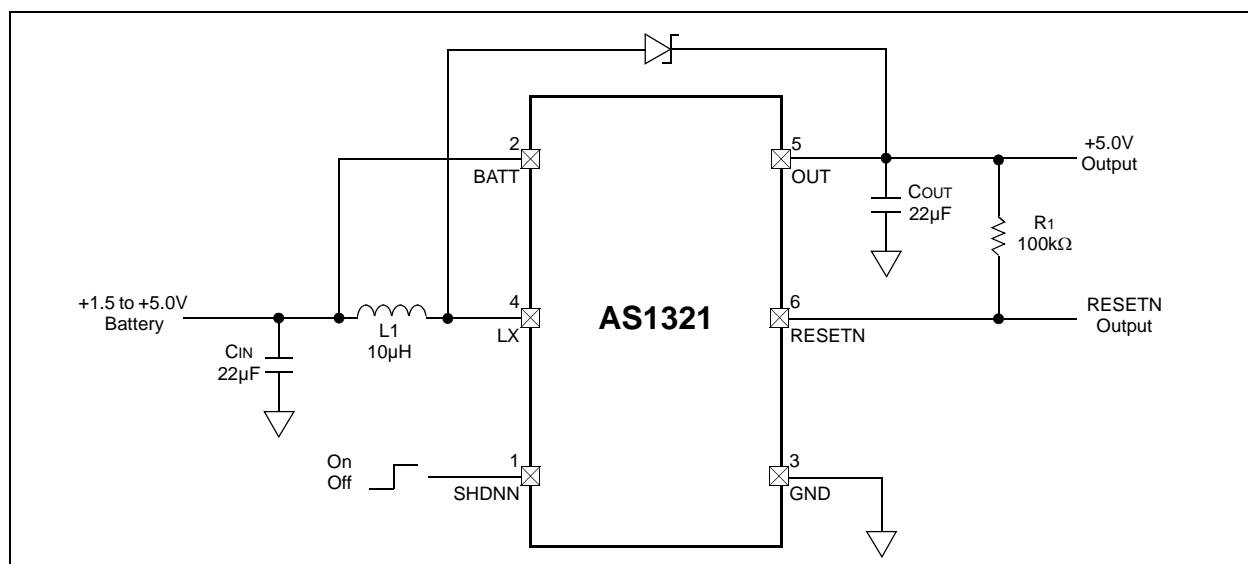
- Fixed Output Voltage: +5.0V
- Output Current: Up to 130mA (@ 2V  $V_{BATT}$ )
- Internal Synchronous Rectifier
- Shutdown Mode Supply Current: Less Than 1 $\mu$ A
- Efficiency: Up to 96%
- Minimum Input Voltage: +1.5V
- Accurate Shutdown Low-Battery Cutoff Threshold
- Battery Input Connected to Pin OUT in Shutdown Mode for Backup Power
- 6-pin SOT23 Package

### 3 Applications

The AS1321 is ideal for low-power applications where ultra-small size is critical as in medical diagnostic equipment, hand-held instruments, pagers, digital cameras, remote wireless transmitters, cordless phones, and PC cards.

The device is also perfect as a local +5.0V supply or as a battery backup.

Figure 1. Application Diagram



## 4 Absolute Maximum Ratings

Stresses beyond those listed in [Table 1](#) may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in [Section 5 Electrical Characteristics on page 3](#) is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 1. Absolute Maximum Ratings

Parameter	Min	Max	Units	Comments
All Pins to GND	-0.3	7	V	
LX Current		1	A	
Latch-Up	-100	100	mA	<i>JEDEC 78</i>
Package Power Dissipation ( $T_{AMB} = +70^{\circ}\text{C}$ )		500	mW	( $\Theta_{JA} = 9.1\text{mW}/^{\circ}\text{C}$ above $+70^{\circ}\text{C}$ )
Operating Temperature Range	-40	+85	$^{\circ}\text{C}$	
Electrostatic Discharge	-500	+500	V	<i>HBM MIL-Std. 883E 3015.7 methods</i>
Humidity (Non-Condensing)	5	85	%	
Storage Temperature Range	-55	125	$^{\circ}\text{C}$	
Junction Temperature		150	$^{\circ}\text{C}$	
Package Body Temperature		260	$^{\circ}\text{C}$	The reflow peak soldering temperature (body temperature) specified is in compliance with <i>IPC/JEDEC J-STD-020C "Moisture/ Reflow Sensitivity Classification for Non-Hermetic Solid State Surface Mount Devices"</i> .

## 5 Electrical Characteristics

$T_{AMB} = -40$  to  $+85^{\circ}\text{C}$ ,  $V_{BATT} = +2\text{V}$ ,  $V_{OUT} = +5.0$ ,  $V_{SHDNN} = +1.5\text{V}$  (unless otherwise specified). Typ values @  $T_{AMB} = +25^{\circ}\text{C}$ .

Table 2. Electrical Characteristics

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Battery Input Range	$V_{BATT}$		1.5		5.0	V
Startup Battery Input Voltage <sup>1</sup>	$V_{SU}$	$R_{LOAD} = 100\Omega$ , $T_{AMB} = +25^{\circ}\text{C}$		1.22	1.5	V
		$R_{LOAD} = 100\Omega$ , $T_{AMB} = -40$ to $+85^{\circ}\text{C}$		1.24		
Output Voltage <sup>2</sup>	$V_{OUT}$	$T_{AMB} = +25^{\circ}\text{C}$	4.950	5.000	5.050	V
		$T_{AMB} = -40$ to $+85^{\circ}\text{C}$	4.875		5.125	
N-Channel On-Resistance	$R_{NCH}$	$I_{LX} = 100\text{mA}$ , $T_{AMB} = +25^{\circ}\text{C}$		0.3	1.2	$\Omega$
		$I_{LX} = 100\text{mA}$ , $T_{AMB} = -40$ to $+85^{\circ}\text{C}$			1.5	
P-Channel On-Resistance	$R_{PCH}$	$I_{LX} = 100\text{mA}$ , $T_{AMB} = +25^{\circ}\text{C}$		0.4	1.3	$\Omega$
		$I_{LX} = 100\text{mA}$ , $T_{AMB} = -40$ to $+85^{\circ}\text{C}$			1.6	
N-Channel Switch Current Limit <sup>1</sup>	$I_{MAX}$	$T_{AMB} = +25^{\circ}\text{C}$	550	700	850	mA
		$T_{AMB} = -40$ to $+85^{\circ}\text{C}$	450		950	
Switch Maximum On-Time	$t_{ON}$	$T_{AMB} = +25^{\circ}\text{C}$	5	7	9	$\mu\text{s}$
		$T_{AMB} = -40$ to $+85^{\circ}\text{C}$	4		10	
Synchronous Rectifier Zero-Crossing Current		$T_{AMB} = +25^{\circ}\text{C}$	8	30	60	mA
		$T_{AMB} = -40$ to $+85^{\circ}\text{C}$	0		65	
Quiescent Current into OUT		$V_{OUT} = +5.5\text{V}$ , $T_{AMB} = +25^{\circ}\text{C}$		35	55	$\mu\text{A}$
		$V_{OUT} = +5.5\text{V}$ , $T_{AMB} = -40$ to $+85^{\circ}\text{C}$			60	
Shutdown Current into OUT		$V_{SHDNN} = 0\text{V}$ , $T_{AMB} = +25^{\circ}\text{C}$		0.01	1	$\mu\text{A}$
		$V_{SHDNN} = 0\text{V}$ , $T_{AMB} = -40$ to $+85^{\circ}\text{C}$			2	
Quiescent Current into BATT		$V_{OUT} = +5.5\text{V}$ , $T_{AMB} = +25^{\circ}\text{C}$		0.01	1	$\mu\text{A}$
		$V_{OUT} = +5.5\text{V}$ , $T_{AMB} = -40$ to $+85^{\circ}\text{C}$			2	
Shutdown Current into BATT		$V_{SHDNN} = 0\text{V}$ , $T_{AMB} = +25^{\circ}\text{C}$		0.01	1	$\mu\text{A}$
		$V_{SHDNN} = 0\text{V}$ , $T_{AMB} = -40$ to $+85^{\circ}\text{C}$			2	
SHDNN Logic Low <sup>1</sup>		$V_{BATT} = +1.5$ to $+5.0\text{V}$			0.3	V
SHDNN Threshold		Rising Edge, $T_{AMB} = +25^{\circ}\text{C}$	1.185	1.228	1.271	V
		Rising Edge, $T_{AMB} = -40$ to $+85^{\circ}\text{C}$	1.170		1.286	
SHDNN Threshold Hysteresis				0.02		V
RESETN Threshold		Falling Edge, $T_{AMB} = +25^{\circ}\text{C}$	4.288	4.500	4.712	V
		Falling Edge, $T_{AMB} = -40$ to $+85^{\circ}\text{C}$	4.242		4.758	
RESETN Voltage Low		$I_{RESETN} = 1\text{mA}$ , $V_{OUT} = +2.5\text{V}$ , $T_{AMB} = +25^{\circ}\text{C}$			0.15	V
		$I_{RESETN} = 1\text{mA}$ , $V_{OUT} = +2.5\text{V}$ , $T_{AMB} = -40$ to $+85^{\circ}\text{C}$			0.2	
RESETN Leakage Current		$V_{RESETN} = +5.5\text{V}$ , $T_{AMB} = +25^{\circ}\text{C}$		0.1	100	nA
		$V_{RESETN} = +5.5\text{V}$ , $T_{AMB} = +85^{\circ}\text{C}$		1		
LX Leakage Current		$T_{AMB} = +25^{\circ}\text{C}$		0.1	1000	nA
		$T_{AMB} = +85^{\circ}\text{C}$		10		
Maximum Load Current	$I_{LOAD}$	$V_{BATT} = +2\text{V}$		130		mA
Efficiency	$\eta$	$V_{BATT} = +3\text{V}$ , $I_{LOAD} = 100\text{mA}$		91		%

1. Guaranteed by design.

2. Voltage which triggers next loading cycle. Ripple and rms value depend on external components.

## 6 Typical Operating Characteristics

$V_{OUT} = 5.0V$ ,  $V_{BATT} = +2V$ ,  $T_{AMB} = +25^{\circ}C$ .

Figure 2.  $V_{OUT}$  vs.  $V_{BATT}$ ; On,  $39\Omega$

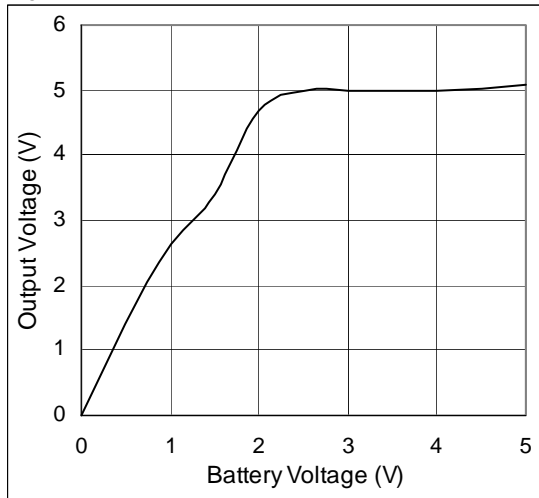


Figure 3.  $V_{OUT}$  vs.  $V_{BATT}$ ; On,  $470\Omega$

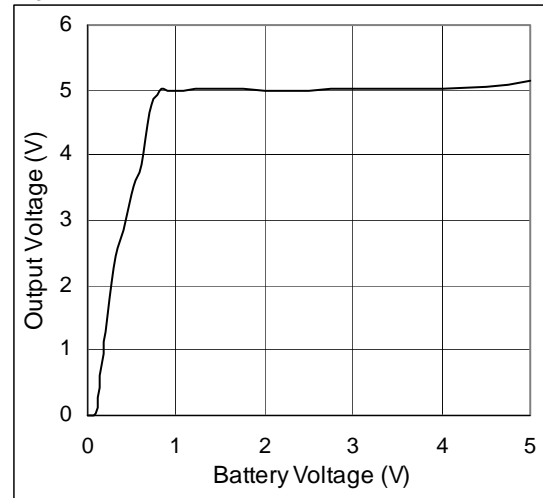


Figure 4.  $V_{OUT}$  vs.  $V_{BATT}$ ; Shutdown,  $130mA$  Load

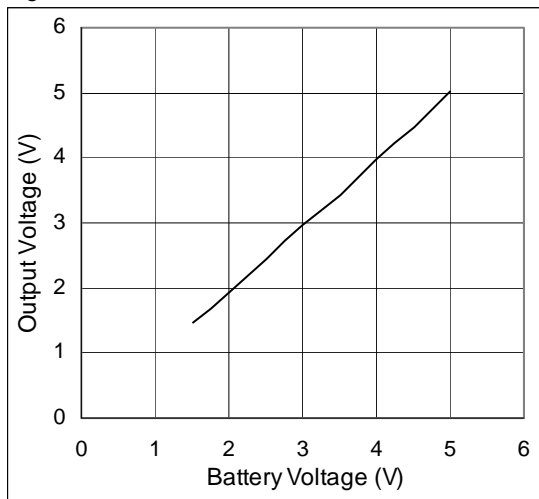


Figure 5.  $V_{OUT}$  vs.  $V_{BATT}$ ; Shutdown, No Load

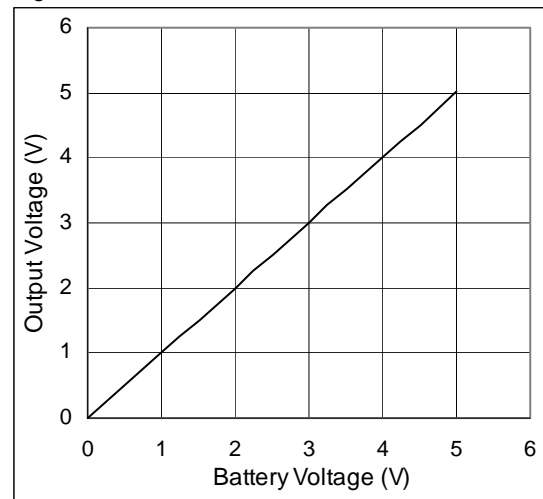


Figure 6. Maximum Output Current vs.  $V_{BATT}$

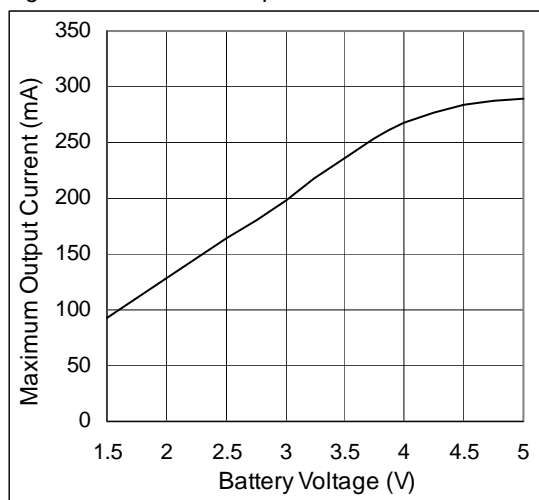


Figure 7. Startup Voltage vs. Load Resistance

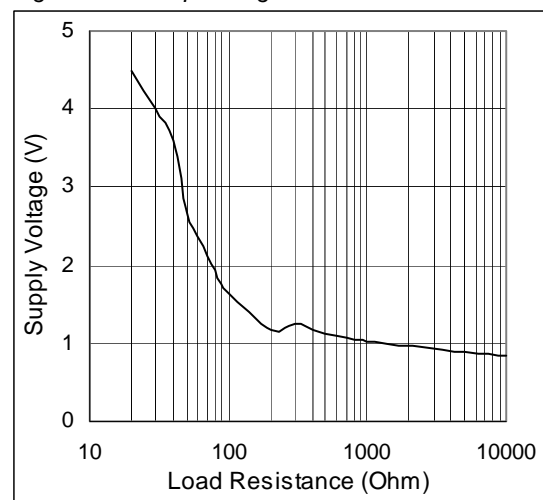


Figure 8. Line Transient

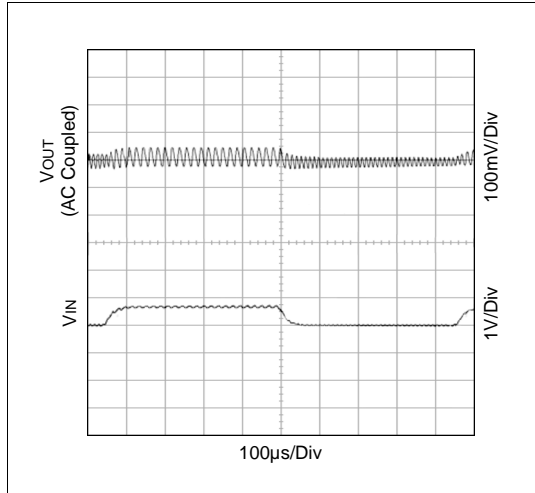


Figure 9. Load Transient

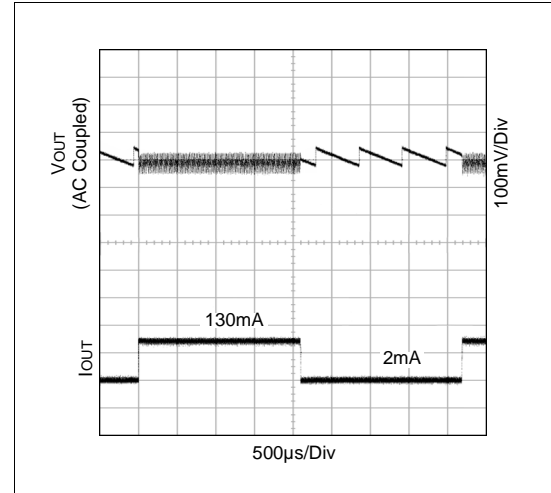


Figure 10. On/Off Response;  $R_{LOAD} = 100\Omega$

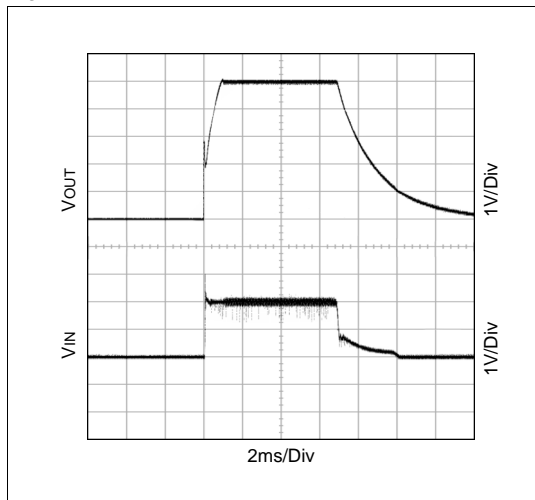


Figure 11. Shutdown Response;  $R_{LOAD} = 100\Omega$

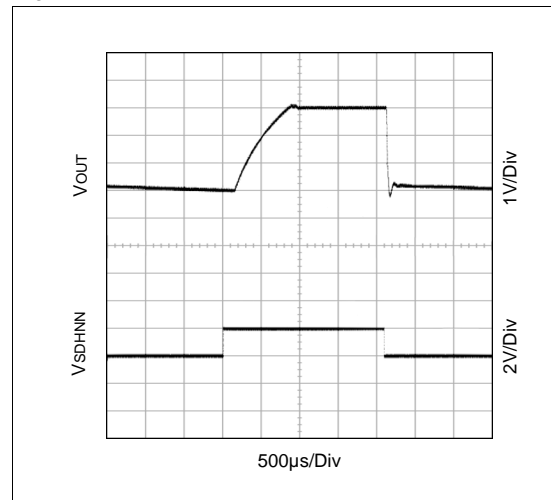


Figure 12. Waveforms;  $R_{LOAD} = 100\Omega$ ,  $V_{BATT} = 3V$

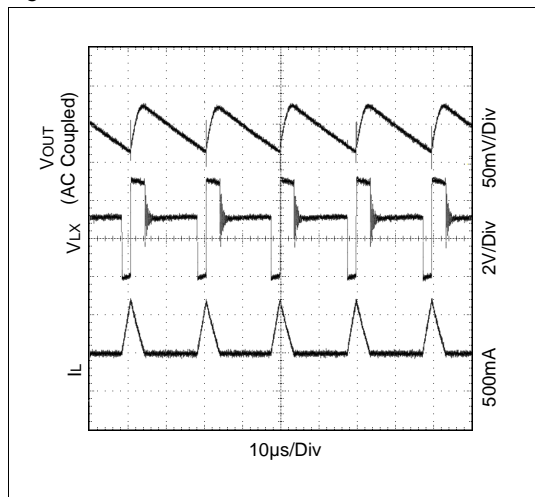
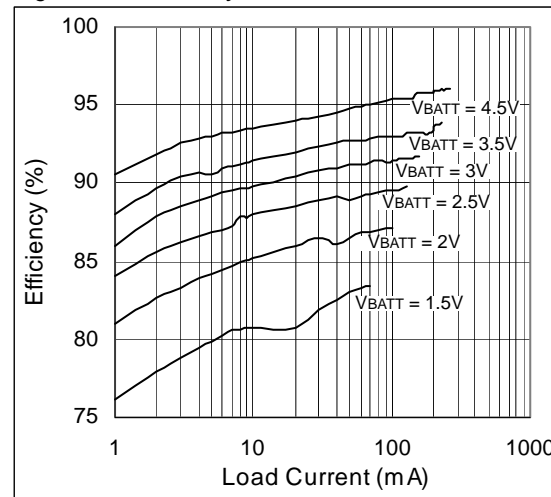


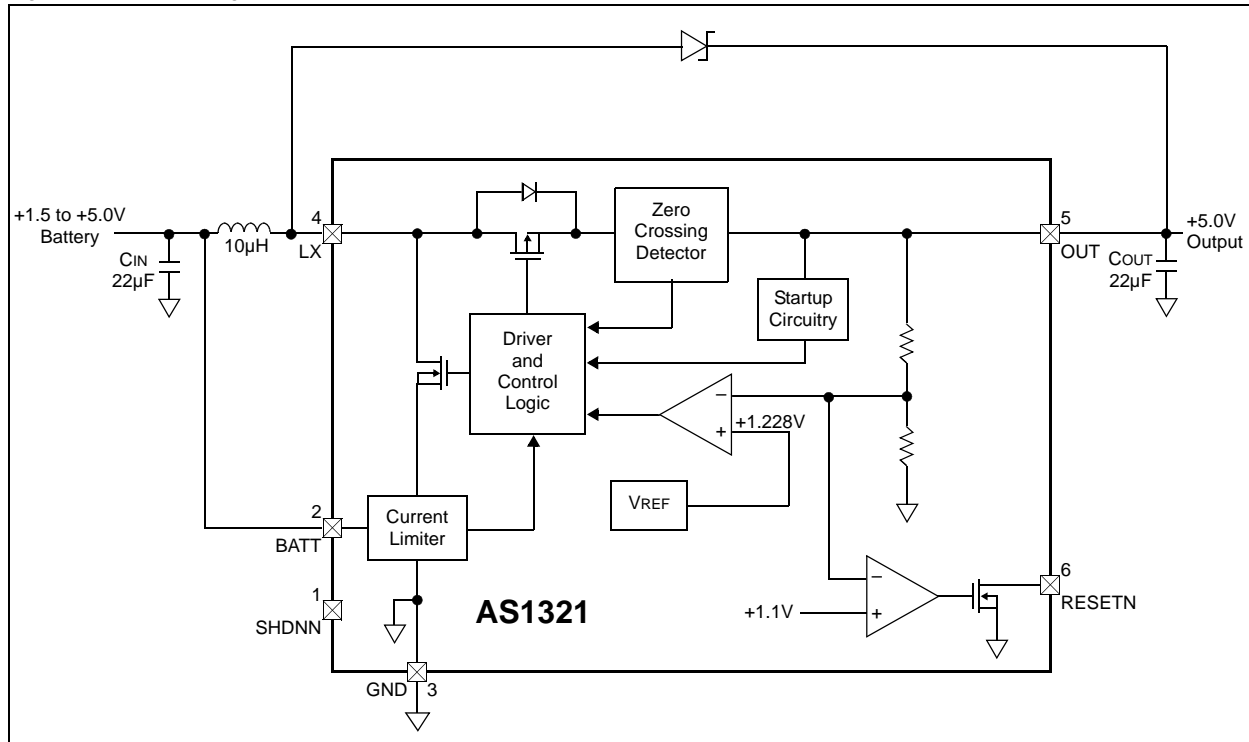
Figure 13. Efficiency vs. Load Current



## 7 Detailed Description

The AS1321 is a high-efficiency, compact step-up converter with 35µA quiescent supply current which ensures the highest efficiency over a wide load range. With a minimum of +1.5V input voltage, the device is well suited for applications with one- or two-cells, such as lithium ion (Li+), nickel-metal-hydride (NiMH), or alkaline.

Figure 14. Block Diagram



The input battery is connected to the device through an inductor and an internal P-FET when pin SHDNN is low. In this state, the step-up converter is off and the voltage drop across the P-FET body diode is eliminated, and the input battery can be used as a battery-backup or real-time-clock supply.

The built-in synchronous rectifier significantly improves efficiency.

### Control Circuitry

The AS1321 integrated current-limited key circuitry provides low quiescent current and extremely-high efficiency over a wide  $V_{OUT}$  range without the need for an oscillator. Inductor current is limited by the 7µs switch maximum on-time or by the 0.7A N-channel current limit. At each cycle, the inductor current must ramp down to zero after the on-time before the next cycle may start. When the error comparator senses that the output has fallen below the regulation threshold, another cycle begins.

### Shutdown

When pin SHDNN is low the AS1321 is switched off and no current is drawn from battery; when pin SHDNN is high the device is switched on. If SHDNN is driven from a logic-level output, the logic high-level (on) should be referenced to  $V_{OUT}$  to avoid intermittently switching the device on.

**Note:** If pin SHDNN is not used, it should be connected directly to pin OUT.

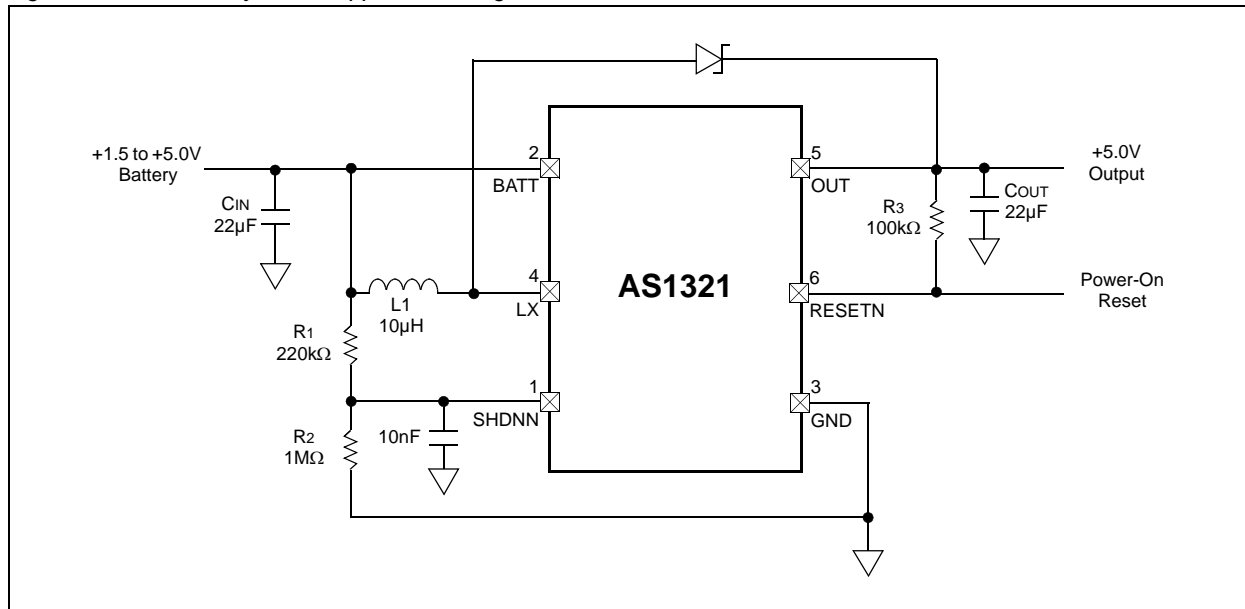
In shutdown the battery input is connected to the output through the inductor and the internal synchronous rectifier P-FET. This allows the input battery to provide backup power for devices such as an idle microcontroller, memory, or real-time-clock, without the usual diode forward drop. In this way a separate backup battery is not needed.

In cases where there is residual voltage during shutdown, some small amount of energy will be transferred from pin OUT to pin BATT immediately after shutdown, resulting in a momentary spike of the voltage at pin BATT. The ratio of  $C_{IN}$  and  $C_{OUT}$  partly determine the size and duration of this spike, as does the current-sink ability of the input device.

## Low-Battery Cutoff

The AS1321 SHDNN trip threshold (1.228V) can be used as an input voltage detector that disables the device when the battery input voltage falls to a pre-set level. An external resistor-divider network can be used to set the battery-detection voltage (see Figure 15).

Figure 15. Low-Battery Cutoff Application Diagram



For the resistor-divider network shown in Figure 15, calculate the value for R1 by:

$$R1 = R2 \times ((V_{OFF}/V_{SHDNN}) - 1) \quad (EQ 1)$$

### Where:

$V_{OFF}$  is the battery voltage at which the AS1321 shuts down.

$V_{SHDNN} = 1.228V$

The value of R2 should be between 100kΩ and 1MΩ to minimize battery drain.

**Note:** Input ripple can cause false shutdowns, therefore to minimize the effect of ripple, a low-value capacitor from SHDNN to GND should be used to filter out input noise. The value of the capacitor should be such that the R/C time constant is  $> 2ms$ .

## Power-On Reset

The AS1321 provides a power-on reset output (RESETN) that goes high-impedance when the output reaches 90% of its regulation point. RESETN goes low when the output is below 90% of the regulation point. A 100kΩ to 1MΩ pullup resistor between pin RESETN and pin OUT can provide a microprocessor logic control signal.

**Note:** Connect pin RESETN to GND when the power-on reset feature is not used.

## 8 Application Information

### Inductor Selection

The control circuitry of the AS1321 permits a wide range of inductor values to be selected – from 4.7 to 47µH; 10µH is ideal for most applications.

The intended application should dictate the value of L. The trade-off between required PCB surface area and desired output ripple are the determining factors: smaller values for L require less PCB space, larger values of L reduce output ripple. If the value of L is large enough to prevent I<sub>MAX</sub> from being reached before t<sub>ON</sub> expires, the AS1321 output power will be reduced.

For maximum output current calculate the value for L as:

$$(V_{BATT(MAX)} (1\mu s))/0.7A < L < (V_{BATT(MIN)}(7\mu s))/0.7A \quad (EQ 2)$$

$$I_{OUT(MAX)} = (0.7A/2)(V_{BATT(MIN)} - (0.7A/2)(R_{NCH} + R_{IND}))/V_{OUT} \quad (EQ 3)$$

#### Where:

R<sub>IND</sub> is the inductor series resistance.

R<sub>NCH</sub> is the R<sub>DS(ON)</sub> of the N-channel MOSFET (0.3Ω typ).

**Note:** Coils should be able to handle 500mARMS and have a I<sub>SAT</sub> ≥ 1A and should have a R<sub>IND</sub> ≤ 100mΩ.

### Capacitor Selection

#### C<sub>OUT</sub> Selection

Choose a C<sub>OUT</sub> value to achieve the desired output ripple percentage. A 22µF ceramic capacitor is a good initial value. The value for C<sub>OUT</sub> can be determined by:

$$C_{OUT} > (L + 2.5\mu H) \times V_{BATT(MAX)}^2 / (r\% \times 4) \quad (EQ 4)$$

#### Where:

r is the desired output ripple in %.

#### C<sub>IN</sub> Selection

C<sub>IN</sub> reduces the peak current drawn from the battery and can be the same value as C<sub>OUT</sub>. A larger value for C<sub>IN</sub> can be used to further reduce ripple and improve AS1321 efficiency.

### External Diode

An external Schottky diode must be connected, in parallel with the on-chip synchronous rectifier, from LX to OUT. Use diodes such as MBR0520L, EP05Q03L, or the generic 1N5817. The diode should be rated for 500mA, since it carries current during startup and after the synchronous rectifier turns off. The Schottky diode must be connected as close to the IC as possible. Ordinary rectifier diodes must not be used, since the slow recovery rate will compromise efficiency.

### PC Board Layout and Grounding

Well-designed printed circuit-board layout is important for minimizing ground bounce and noise.

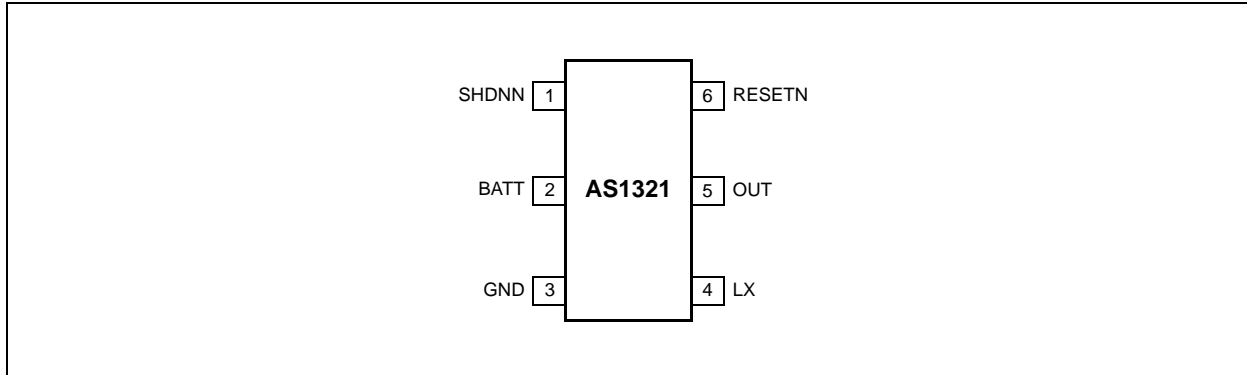
- Place pin GND lead and the ground leads of C<sub>IN</sub> and C<sub>OUT</sub> as close to the device as possible.
- Keep the lead to pin LX as short as possible.
- To maximize output power and efficiency and minimize output ripple voltage, use a ground plane and solder the GND pin directly to the ground plane.



## 9 Pinout and Packaging

### Pin Assignments

Figure 16. Pin Assignments (Top View)



### Pin Descriptions

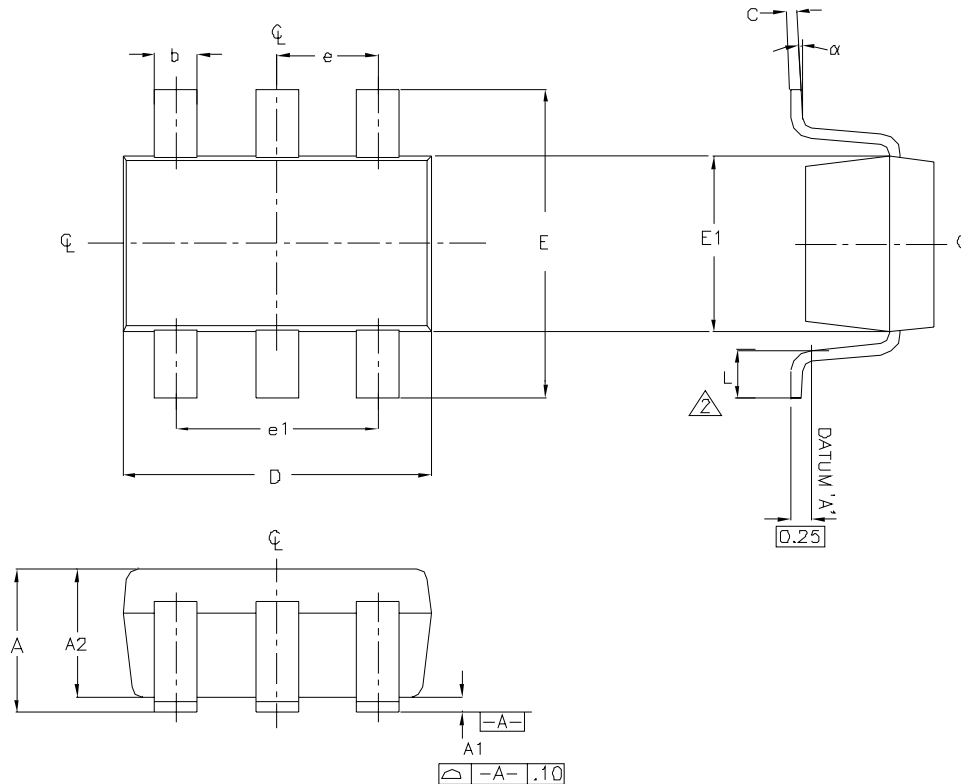
Table 3. Pin Descriptions

Name	Pin Number	Description
SHDNN	1	<b>Active-Low Logic Shutdown Input</b> 0 = The AS1321 is off and the current into BATT is $\leq 1\mu\text{A}$ (typ). 1 = The AS1321 is on.
BATT	2	<b>Battery Voltage Input</b>
GND	3	<b>Ground</b>
LX	4	<b>External Inductor Connection</b>
OUT	5	<b>Output Voltage</b>
RESETN	6	<b>Active-Low reset output</b>

## Package Drawings and Markings

The AS1321 is available in a 6-pin SOT23 package.

Figure 17. 6-pin SOT23 Package



### Notes:

1. All dimensions are in millimeters.
2. Foot length is measured at the intercept point between datum A and lead surface.
3. Package outline exclusive of mold flash and metal burr.
4. Pin 1 is the lower left pin when reading the top mark from left to right.
5. Pin 1 identifier dot is 0.3mm.φ min and is located above pin 1.
6. Meets JEDEC MO178.

Symbol	Min	Max
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
b	0.35	0.50
C	0.08	0.20
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.75
L	0.35	0.55
e	0.95 REF	
α	0°	10°

## 10 Ordering Information

The AS1321 is available as the standard products shown in [Table 4](#).

Table 4. Ordering Information

Part	Marking	Description	Delivery Form	Package
AS1321-T	ASKX	130mA Step-Up DC-DC Converter	Tape and Reel	6-pin SOT23

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