19-1802; Rev 0; 10/00

EVALUATION KIT AVAILABLE

MAXIM

High-Efficiency Step-Up Converters with Reverse Battery Protection in SOT23-6

General Description

The MAX1832–MAX1835 are high-efficiency step-up converters with complete reverse battery protection that protects the device and the load when the battery is reversed. They feature a built-in synchronous rectifier, which allows for over 90% efficiency and reduces size and cost by eliminating the need for an external Schottky diode.

These step-up converters operate from a +1.5V to +5.5V input voltage range and deliver up to 150mA of load current. The MAX1833/MAX1835 have a fixed +3.3V output, and the MAX1832/MAX1834 have adjustable outputs from +2V to +5.5V. In shutdown, the MAX1832/MAX1833 connect the battery input to the voltage output, allowing the input battery to be used as a backup or real-time clock supply when the converter is off (see *Selector Guide*).

The MAX1832–MAX1835 are available in a miniature 6-pin SOT23 package. The MAX1832EVKIT is available to shorten the design cycle.

Applications

Medical Diagnostic Equipment
Pagers
Hand-Held Instruments
Remote Wireless Transmitters
Digital Cameras
Cordless Phones
Battery Backup
PC Cards
Local 3.3V or 5V Supply

Features

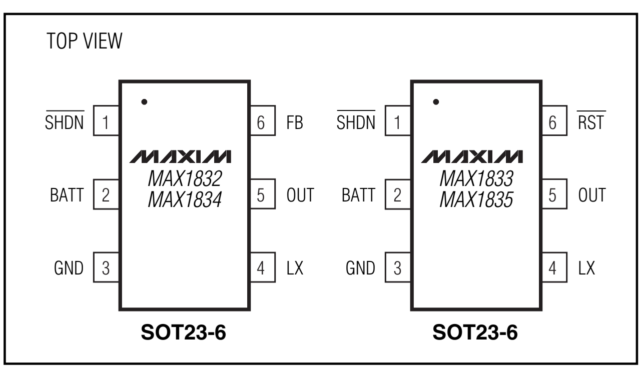
- **Reverse Battery Protection for DC-DC Converter and Load**
- **Up to 90% Efficiency**
- **No External Diode or FETs Needed**
- **Internal Synchronous Rectifier**
- **4µA Quiescent Current**
- **<1µA Shutdown Supply Current**
- **+1.5V to +5.5V Input Voltage Range**
- **Accurate $\overline{\text{SHDN}}$ Threshold for Low-Battery Cutoff**
- **BATT Connected to OUT in Shutdown for Backup Power (MAX1832/MAX1833)**
- **$\overline{\text{RST}}$ Output (MAX1833/MAX1835)**
- **Fixed +3.3V Output Voltage (MAX1833/MAX1835)**
- **Adjustable Output Voltage (MAX1832/MAX1834)**
- **Up to 150mA Output Current**
- **Tiny 6-Pin SOT23 Package**

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE	TOP MARK
MAX1832EUT-T	-40°C to +85°C	6 SOT23-6	AAOT
MAX1833EUT-T	-40°C to +85°C	6 SOT23-6	AAOU
MAX1834EUT-T	-40°C to +85°C	6 SOT23-6	AAOV
MAX1835EUT-T	-40°C to +85°C	6 SOT23-6	AAOW

Note: *Requires special solder temperature profile described in the Absolute Maximum Ratings.*

Pin Configurations



Selector Guide

PART	OUTPUT VOLTAGE	OUTPUT VOLTAGE IN SHUTDOWN
MAX1832EUT-T	Adjustable	V_{BATT}
MAX1833EUT-T	Fixed 3.3V	V_{BATT}
MAX1834EUT-T	Adjustable	V_{BATT} - 0.7V
MAX1835EUT-T	Fixed 3.3V	V_{BATT} - 0.7V

High-Efficiency Step-Up Converters with Reverse Battery Protection in SOT23-6

ABSOLUTE MAXIMUM RATINGS

BATT, LX to GND..-6V to +6V
LX to OUT...-6V to +1V
$\overline{SHDN}$ to GND...-6V to (V_{OUT} + 0.3V)
OUT, FB, $\overline{RST}$ TO GND ....-0.3V to +6V
LX Current...1A
Continuous Power Dissipation (T_A = +70°C)
SOT23-6 (derate 9.1mW/°C above +70°C) (Note 1)....727mW

Operating Temperature Range ....-40°C to +85°C
Junction Temperature...+150°C
Storage Temperature Range ....-65°C to +150°C
Lead Temperature (soldering, 10s) (Note 2) ....+300°C

Note 1: Thermal properties are specified with product mounted on PC board with one square-inch of copper area and still air.
Note 2: This device is constructed using a unique set of packaging techniques that impose a limit on the thermal profile the device can be exposed to during solder attach and rework. This limit permits only the use of the solder profiles recommended in the industry-standard specification, IPC/JEDEC J-STD-020A, paragraph 7.6, Table 3 for the IR/VPR and Convection reflow. Preheating is required. Hand or wave soldering is not allowed.

Stresses beyond those listed under “Absolute Maximum Ratings” 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 the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

($V_{\overline{SHDN}}$ = +1.5V, V_{OUT} = +3.3V, V_{BATT} = +2V, GND = 0, T_A = -40°C to +85°C. Typical values are at T_A = +25°C, unless otherwise noted.) (Note 3)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Output Range	V_{OUT}	MAX1832/MAX1834		2.0		5.5	V
Battery Input Range	V_{BATT}			1.5		5.5	V
Startup Battery Input Voltage	V_{SU}	R_{LOAD} = 2.6kΩ	T_A = +25°C		1.22	1.5	V
			T_A = -40°C to +85°C		1.24		
Output Voltage	V_{OUT}	MAX1833/ MAX1835	T_A = +25°C	3.225	3.290	3.355	V
			T_A = -40°C to +85°C	3.208		3.372	
FB Trip Voltage	V_{FB}	MAX1832/ MAX1834	T_A = +25°C	1.208	1.228	1.248	V
			T_A = -40°C to +85°C	1.204		1.252	
FB Input Bias Current	I_{FB}	MAX1832/ MAX1834, V_{FB} = +1.3V	T_A = +25°C		3.5	20	nA
			T_A = -40°C to +85°C		4.0		
N-Channel On-Resistance	R_{NCH}	V_{OUT} = +3.3V I_{LX} = 100mA	T_A = +25°C		0.4	1.2	Ω
			T_A = -40°C to +85°C			1.5	
P-Channel On-Resistance	R_{PCH}	V_{OUT} = +3.3V I_{LX} = 100mA	T_A = +25°C		0.5	1.3	Ω
			T_A = -40°C to +85°C			1.6	
P-Channel Catch-Diode Voltage		I_{LX} = 100mA, PCH off, V_{OUT} = +3.5V, V_{FB} = +1.3V			0.73		V
N-Channel Switch Current Limit	I_{MAX}	V_{OUT} = +3.3V	T_A = +25°C	435	525	615	mA
			T_A = -40°C to +85°C	400		650	
Switch Maximum On-Time	t_{ON}			3.5	5	6.5	µs
Synchronous Rectifier Zero-Crossing Current		V_{OUT} = +3.3V	T_A = +25°C	2	17	34	mA
			T_A = -40°C to +85°C	0		39	
Quiescent Current into OUT (Note 4)		V_{OUT} = +3.5V, V_{FB} = +1.3V	T_A = +25°C		2.5	7.0	µA
			T_A = -40°C to +85°C			8.0	
Shutdown Current into OUT		V_{OUT} = +3.5V, $V_{\overline{SHDN}}$ = V_{FB} = 0V			0.05	1	µA

ELECTRICAL CHARACTERISTICS (continued)

($V_{\overline{SHDN}}$ = +1.5V, V_{OUT} = +3.3V, V_{BATT} = +2V, GND = 0, T_A = -40°C to +85°C. Typical values are at T_A = +25°C, unless otherwise noted.) (Note 3)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Reverse Battery Current into OUT		V_{OUT} = 0, V_{BATT} = $V_{\overline{SHDN}}$ = V_{LX} = -3V			0	10	µA
Quiescent Current into BATT		V_{OUT} = +3.5V, V_{FB} = +1.3V	T_A = +25°C		1.8	5.0	µA
			T_A = -40°C to +85°C			6.0	
Shutdown Current into BATT		V_{OUT} = +3.5V, V_{BATT} = +2V, $V_{\overline{SHDN}}$ = 0			0.001	1	µA
Reverse Battery Current into BATT		V_{OUT} = 0, V_{BATT} = $V_{\overline{SHDN}}$ = V_{LX} = -3V			0.002	10	µA
$\overline{SHDN}$ Logic Low		V_{BATT} = +1.5V to +5.5V				0.3	V
$\overline{SHDN}$ Threshold		Rising edge	T_A = +25°C	1.185	1.228	1.271	V
			T_A = -40°C to +85°C	1.170		1.286	
$\overline{SHDN}$ Threshold Hysteresis					0.02		V
$\overline{SHDN}$ Input Bias Current		V_{OUT} = +5.5V, $V_{\overline{SHDN}}$ = +5.5V, T_A = +25°C			13	100	nA
$\overline{SHDN}$ Reverse Battery Current		V_{OUT} = 0, V_{BATT} = $V_{\overline{SHDN}}$ = V_{LX} = -3V			52	150	µA
$\overline{RST}$ Threshold		MAX1833/ MAX1835, falling edge	T_A = +25°C	2.830	2.980	3.110	V
			T_A = -40°C to +85°C	2.800		3.140	
$\overline{RST}$ Voltage Low		$I_{\overline{RST}}$ = 1mA, V_{OUT} = +2.5V				0.2	V
$\overline{RST}$ Leakage Current		$V_{\overline{RST}}$ = +5.5V	T_A = +25°C		0.1	100	nA
			T_A = -40°C to +85°C		1		
LX Leakage Current		V_{LX} = +5.5V	T_A = +25°C		1	100	nA
			T_A = -40°C to +85°C		100		
LX Reverse Battery Current		V_{OUT} = 0, V_{BATT} = $V_{\overline{SHDN}}$ = V_{LX} = -3V			0.001	10	µA
Maximum Load Current	I_{LOAD}	V_{BATT} = +2V, V_{OUT} = +3.3V			150		mA
Efficiency		V_{BATT} = +2V, V_{OUT} = +3.3V, I_{LOAD} = 40mA			90		%

Note 3: All units are 100% production tested at T_A=+25°C. Limits over the operating temperature range are guaranteed by design and not production tested.

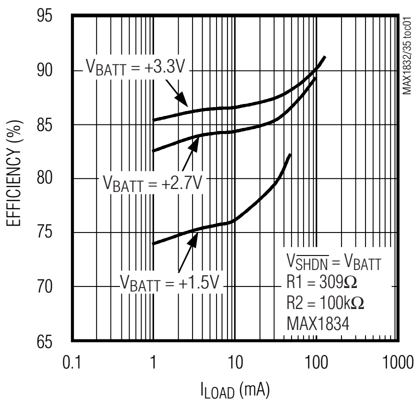
Note 4: Supply current into OUT. This current correlates directly to the actual battery-supply current, but is reduced in value according to the step-up ratio and efficiency.

High-Efficiency Step-Up Converters with Reverse Battery Protection in SOT23-6

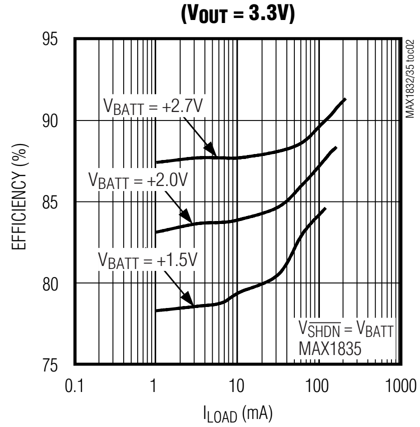
Typical Operating Characteristics

(V_{OUT} = +3.3V, V_{BATT} = +2V, unless otherwise noted.) (Figure 1)

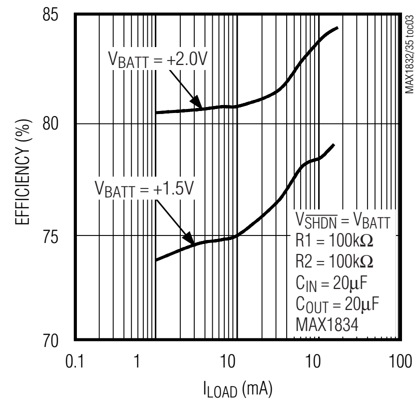
EFFICIENCY vs. LOAD CURRENT (V_{OUT} = 5.0V)



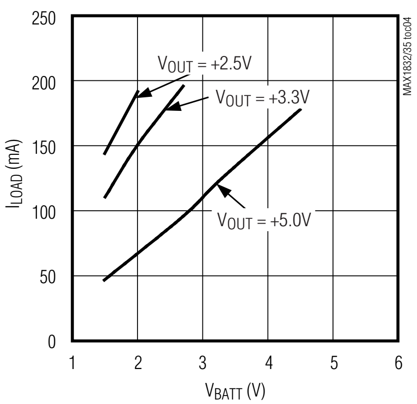
EFFICIENCY vs. LOAD CURRENT (V_{OUT} = 3.3V)



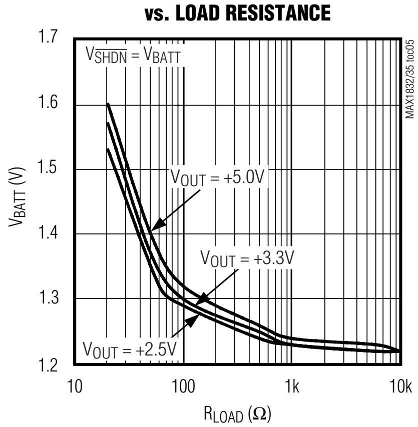
EFFICIENCY vs. LOAD CURRENT (V_{OUT} = 2.5V)



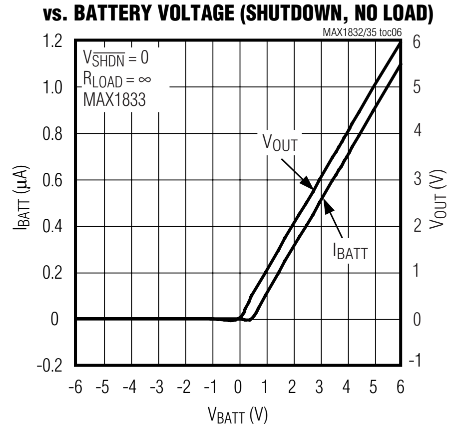
MAXIMUM OUTPUT CURRENT vs. BATTERY VOLTAGE



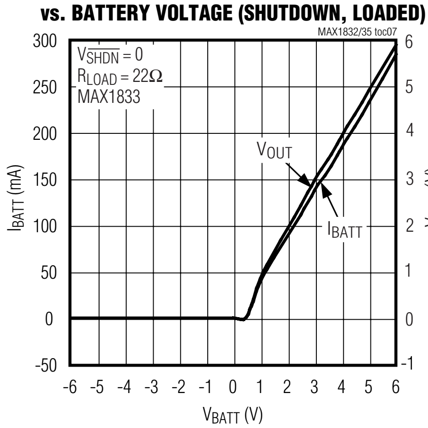
STARTUP BATTERY VOLTAGE vs. LOAD RESISTANCE



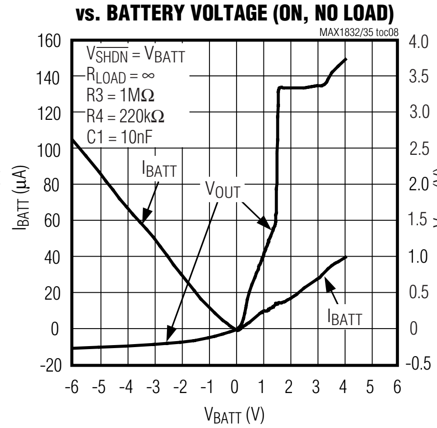
INPUT CURRENT AND OUTPUT VOLTAGE vs. BATTERY VOLTAGE (SHUTDOWN, NO LOAD)



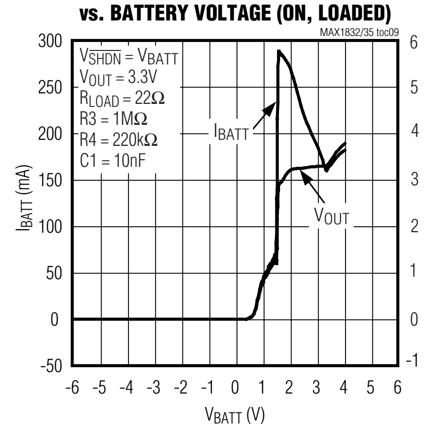
INPUT CURRENT AND OUTPUT VOLTAGE vs. BATTERY VOLTAGE (SHUTDOWN, LOADED)



INPUT CURRENT AND OUTPUT VOLTAGE vs. BATTERY VOLTAGE (ON, NO LOAD)



INPUT CURRENT AND OUTPUT VOLTAGE vs. BATTERY VOLTAGE (ON, LOADED)

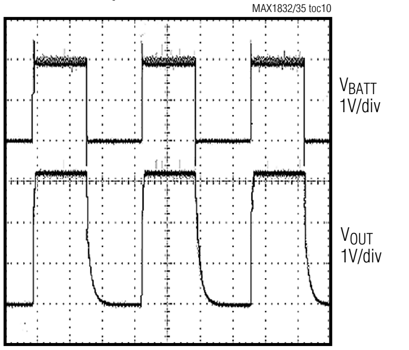


Typical Operating Characteristics (continued)

(V_{OUT} = +3.3V, V_{BATT}= +2V, unless otherwise noted.) (Figure 1)

ON/OFF RESPONSE

MAX1832/35 toc10

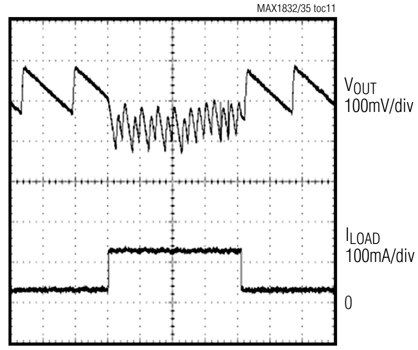


2ms/div

$V_{\overline{SHDN}}$ = V_{BATT} = 2.0V, R_{LOAD} = 22Ω,
V_{OUT} = 3.3V

LOAD TRANSIENT

MAX1832/35 toc11

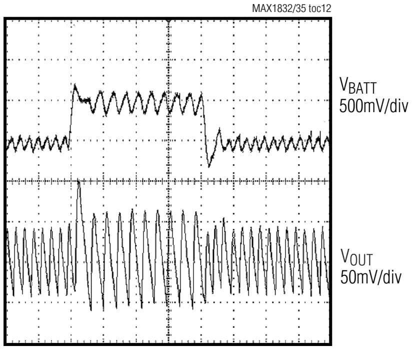


40µs/div

R_{LOAD} = 22Ω TO 200Ω,
V_{OUT} = +3.3V, V_{BATT} = +2.0V

LINE TRANSIENT

MAX1832/35 toc12

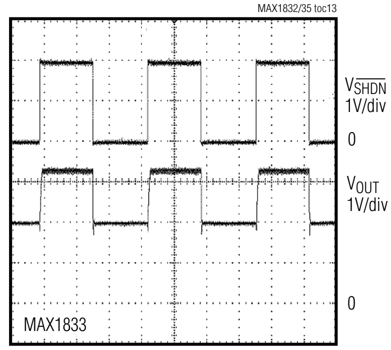


40µs/div

I_{OUT} = 100mA, V_{OUT} = +3.3V,
V_{BATT} = +2.0V TO +2.5V

SHUTDOWN RESPONSE

MAX1832/35 toc13

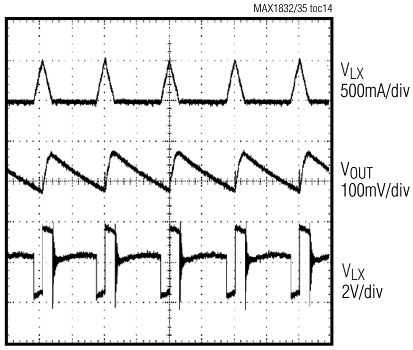


40µs/div

R_{LOAD} = 22Ω, V_{BATT} = 3.3V, V_{BATT} = 2.0V

SWITCHING WAVEFORMS

MAX1832/35 toc14



10µs/div

I_{OUT} = 40mA, V_{OUT} = +3.3V, V_{BATT} = +2.0V

High-Efficiency Step-Up Converters with Reverse Battery Protection in SOT23-6

Pin Description

PIN		NAME	FUNCTION
MAX1832 MAX1834	MAX1833 MAX1835		
1	1	$\overline{\text{SHDN}}$	Shutdown. A high logic level turns on the device. When $\overline{\text{SHDN}}$ is low the part is off, and the current into BATT is typically 0.1µA. For the MAX1832/MAX1833, the battery is connected to OUT through an internal PFET and the external inductor when $\overline{\text{SHDN}}$ is low. $\overline{\text{SHDN}}$ can be used for low-battery cutoff (1.228V threshold). *See Low-Battery Cutoff*. $\overline{\text{SHDN}}$ has reverse battery protection.
2	2	BATT	Battery Voltage Connection. BATT has reverse battery protection.
3	3	GND	Ground
4	4	LX	Inductor Connection. N-channel MOSFET switch drain and synchronous rectifier P-channel switch drain. LX has reverse battery protection.
5	5	OUT	Output Voltage. Bootstrapped supply for the device. Output sense point for MAX1833/MAX1835.
6	—	FB	MAX1832/MAX1834 Feedback Input. Set the output voltage through a resistor-divider network. See *Setting the Output Voltage*.
—	6	$\overline{\text{RST}}$	MAX1833/MAX1835 Power-On Reset Open-Drain Output. $\overline{\text{RST}}$ pulls low when the output is 10% below the regulation point. If not used, connect to GND.

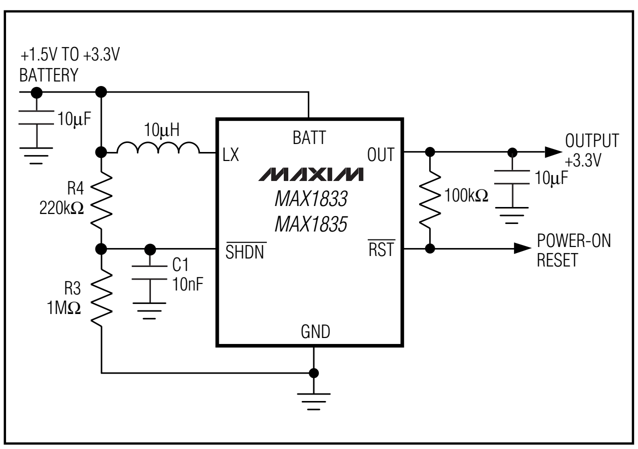


Figure 1a. MAX1833/MAX1835 Typical Operating Circuit

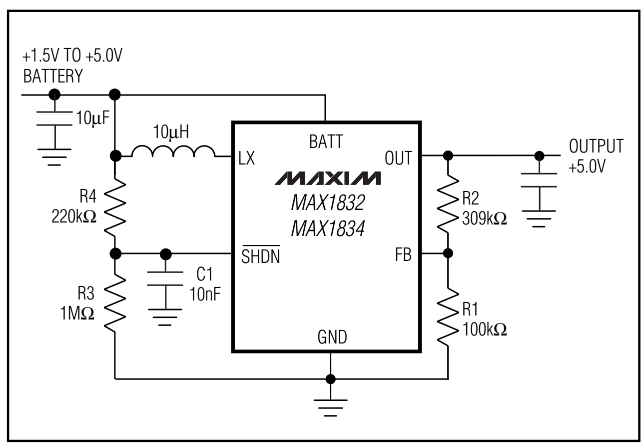


Figure 1b. MAX1832/MAX1834 Typical Operating Circuit

Detailed Description

The MAX1832–MAX1835 compact, high-efficiency step-up converters feature 4µA quiescent supply current to ensure the highest possible efficiency over a wide load range. With a minimum +1.5V input voltage, these devices are well suited for applications with two alkaline cells, two nickel-metal-hydride (NiMH) cells, or one lithium ion (Li+) cell. For the MAX1832 and MAX1833, the battery is connected to OUT through the inductor and an internal PFET when $\overline{SHDN}$ is low. This allows the input battery to be used as a backup or real-time clock supply when the converter is off by eliminating the voltage drop across the PFET body diode.

The MAX1832–MAX1835 are ideal for low-power applications where ultra-small size is critical. These devices feature built-in synchronous rectification that significantly improves efficiency and reduces size and cost by eliminating the need for an external Schottky diode. Furthermore, these devices are the industry's first boost regulators to offer complete reverse battery protection. This proprietary design protects the battery, IC, and the circuitry powered by the IC in the event the input batteries are connected backwards.

Control Scheme

A current-limited control scheme is a key feature of the MAX1832–MAX1835. This scheme provides ultra-low quiescent current and high efficiency over a wide output current range. There is no oscillator. The inductor current is limited by the 0.5A N-channel current limit or by the 5µs switch maximum on-time. Following each on-cycle, the inductor current must ramp to zero before another cycle may start. When the error comparator senses that the output has fallen below the regulation threshold, another cycle begins.

An internal synchronous rectifier eliminates the need for an external Schottky diode reducing cost and board space. While the inductor discharges, the P-channel MOSFET turns on and shunts the MOSFET body diode. As a result, the rectifier voltage drop is significantly reduced, improving efficiency without adding external components.

Reverse Battery Protection

The MAX1832–MAX1835 have a unique proprietary design that protects the battery, IC, and circuitry powered by the IC in the event that the input batteries are connected backwards. When the batteries are connected correctly, the reverse battery protection N-channel MOSFET is on and the device operates normally. When the batteries are connected backwards, the reverse battery protection N-channel MOSFET opens, protecting the device and load (Figures 2 and 3). Previously, this level of protection required additional circuitry and reduced efficiency due to added components in the battery current path.

Applications Information

Shutdown

When $\overline{SHDN}$ is low, the device is off and no current is drawn from the battery. When $\overline{SHDN}$ is high, the device is on. If $\overline{SHDN}$ is driven from a logic-level output, the logic high (on) level should be referenced to V_{OUT} to avoid intermittent turn on. If $\overline{SHDN}$ is not used at all, connect it to OUT. With $\overline{SHDN}$ connected to OUT, the MAX1834/MAX1835 startup voltage (1.65V) is slightly higher, due to the voltage across the PFET body diode. The $\overline{SHDN}$ pin has reverse battery protection.

In shutdown, the MAX1832/MAX1833 connect the battery input to the output through the inductor and the internal synchronous rectifier PFET. This allows the input battery (rather than a separate backup battery) to provide backup power for devices such as an idled microcontroller, SRAM, or real-time clock, without the usual diode forward drop. If the output has a residual voltage during shutdown, a small amount of energy will be transfered from the output back to the input immediately after shutdown. This energy transfer may cause a slight momemntary "bump" in the input voltage. The magnitude and duration of the input bump are related to the ratio of C_{IN} and C_{OUT} and the ability of the input to sink current. With battery input sources, the bump will be negligible, but with power-supply inputs (that typically cannot sink current), the bump may be 100s of mV.

In shutdown, the MAX1834/MAX1835 do not turn on the internal PFET and thus do not have an output-to-input current path in shutdown. This allows a separate backup battery, such as a Li+ cell, to be diode-connected at the output, without leakage current flowing to the input. The MAX1834/MAX1835 still have the typical input-to-output current path from the battery to the output, through the PFET body diode, in shutdown.

Low-Battery Cutoff

The $\overline{SHDN}$ trip threshold of the MAX1832–MAX1835 can be used as a voltage detector, with a resistor-divider, to power down the IC when the battery voltage falls to a set level (Figure 1). The $\overline{SHDN}$ trip threshold is 1.228V. To use a resistor-divider to set the shutdown voltage, select a value for R3 in the 100kΩ to 1MΩ

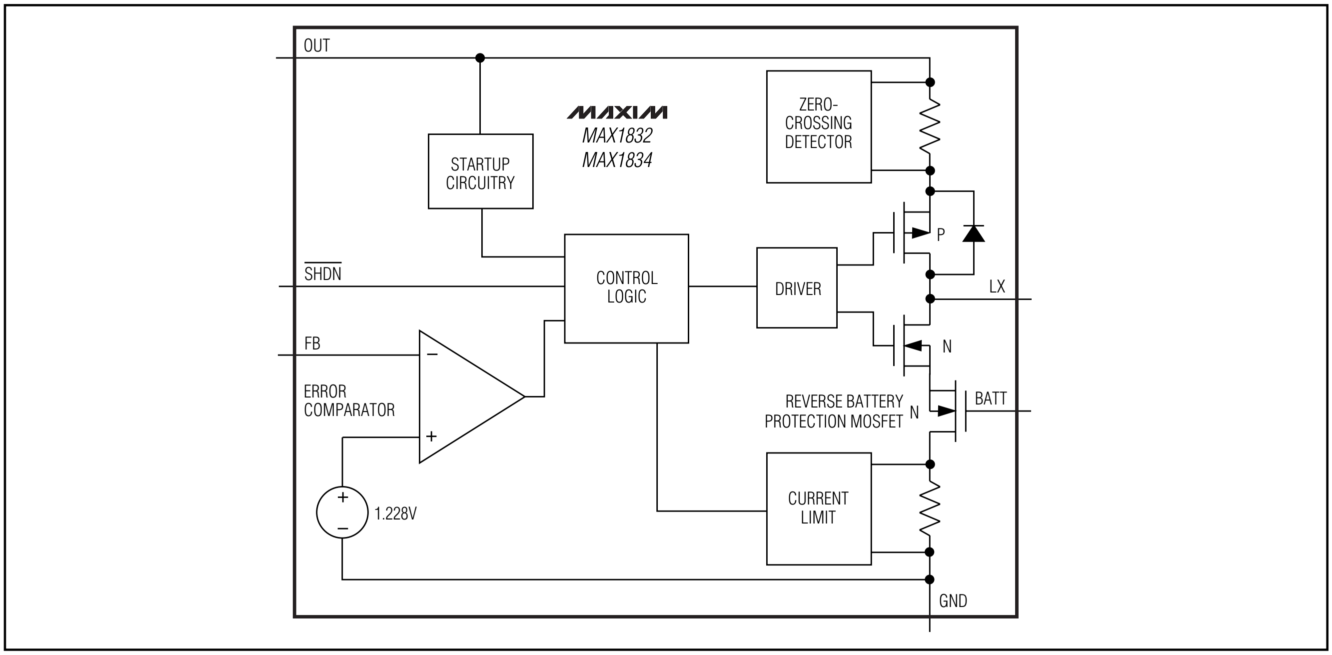


Figure 2. MAX1832/MAX1834 Simplified Functional Diagram

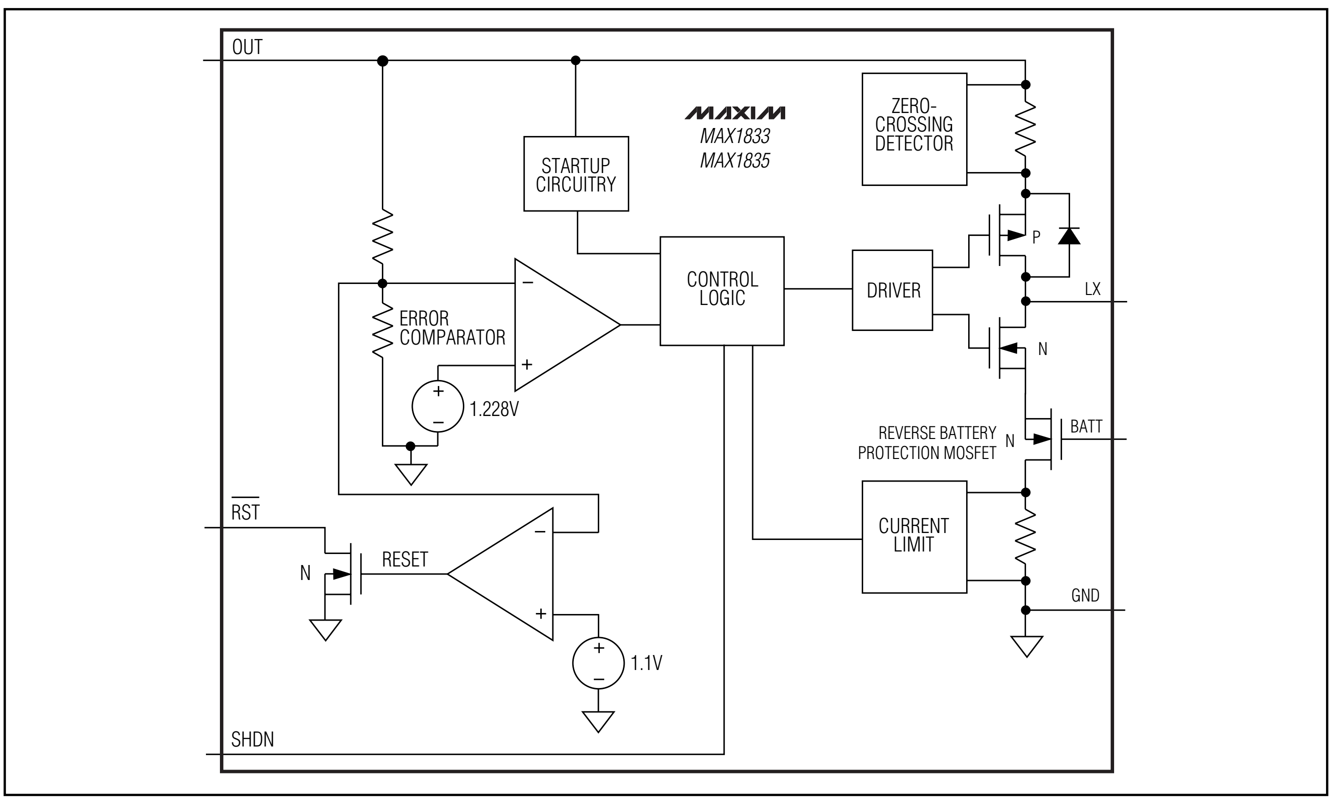


Figure 3. MAX1833/MAX1835 Simplified Functional Diagram

range to minimize battery drain. Calcuate R4 as follows:

$$R4 = R3 \times (V_{OFF} / V_{SHDN} - 1)$$

V_{OFF} is the battery voltage at which the part will shut down and V_{SHDN} = 1.228V. Note that input ripple can sometimes cause false shutdowns. To minimize the effect of ripple, connect a low-value capacitor (C1) from $\overline{SHDN}$ to GND to filter out input noise. Select a C1 value such that the R4 × C1 time constant is above 2ms.

Power-On Reset

The MAX1833/MAX1835 provide a power-on reset output ($\overline{RST}$). A 100kΩ to 1MΩ pullup resistor from $\overline{RST}$ to OUT provides a logic control signal. This open-drain output pulls low when the output is 10% below its regulation point. If not used, connect it to GND.

Setting the Output Voltage

The output voltage of the MAX1832/MAX1834 is adjustable from +2V to +5.5V, using external resistors R1 and R2 (Figure 1b). Since FB leakage is 20nA (max), select feedback resistor R1 to be 100kΩ to 1MΩ. Calculate R2 as follows:

$$R2 = R1\left(\frac{V_{OUT}}{V_{FB}} - 1\right)$$

where V_{FB} = 1.228V.

Inductor Selection

The control scheme of the MAX1832–MAX1835 permits flexibility in choosing an inductor. A 10µH inductor performs well for most applications, but values from 4.7µH to 100µH may also be used. Small inductance values typically offer smaller physical size. Large inductance values minimize output ripple but reduce output power. Output power is reduced when the inductance is large enough to prevent the maximum current limit (525mA) from being reached before the maximum on-time (5µs) expires.

For maximum output current, choose L such that:

$$\frac{V_{BATT(MAX)}(1\mu s)}{0.525A} < L < \frac{V_{BATT(MIN)}(5\mu s)}{0.525A}$$

$$I_{OUT(MAX)} = \frac{0.525A}{2} \times \frac{V_{BATT(MIN)} - \frac{0.525A}{2}(R_{NCH} + R_{IND})}{V_{OUT}}$$

where R_{IND} is the inductor series resistance, and R_{NCH} is the $R_{DS(ON)}$ of the N-channel MOSFET (0.4Ω typ).

Table 1. Suggested Inductors and Suppliers

MANUFACTURER	INDUCTOR	PHONE
Coilcraft	DS1608C-103 DO1606T-103	847-639-6400
Sumida	CDRH4D18-100 CR43-100	847-956-0666
Murata	LQH4N100K	814-237-1431

Table 2. Suggested Surface-Mount Capacitors and Manufacturers

VALUE (µF)	DESCRIPTION	MANU-FACTURER	PHONE
4.7 to 47	594/595 D-series tantalum	Sprague	603-224-1961
	TAJ, TPS-series tantalum	AVX	803-946-0690
4.7 to 10	X7R ceramic	TDK	847-390-4373
4.7 to 22	X7R ceramic	Taiyo Yuden	408-573-4150

Capacitor Selection

Choose an output capacitor to achieve the desired output ripple percentage.

$$C_{OUT} > \frac{0.5 \times L \times 0.525A^2}{r\% \times V_{OUT}^2}$$

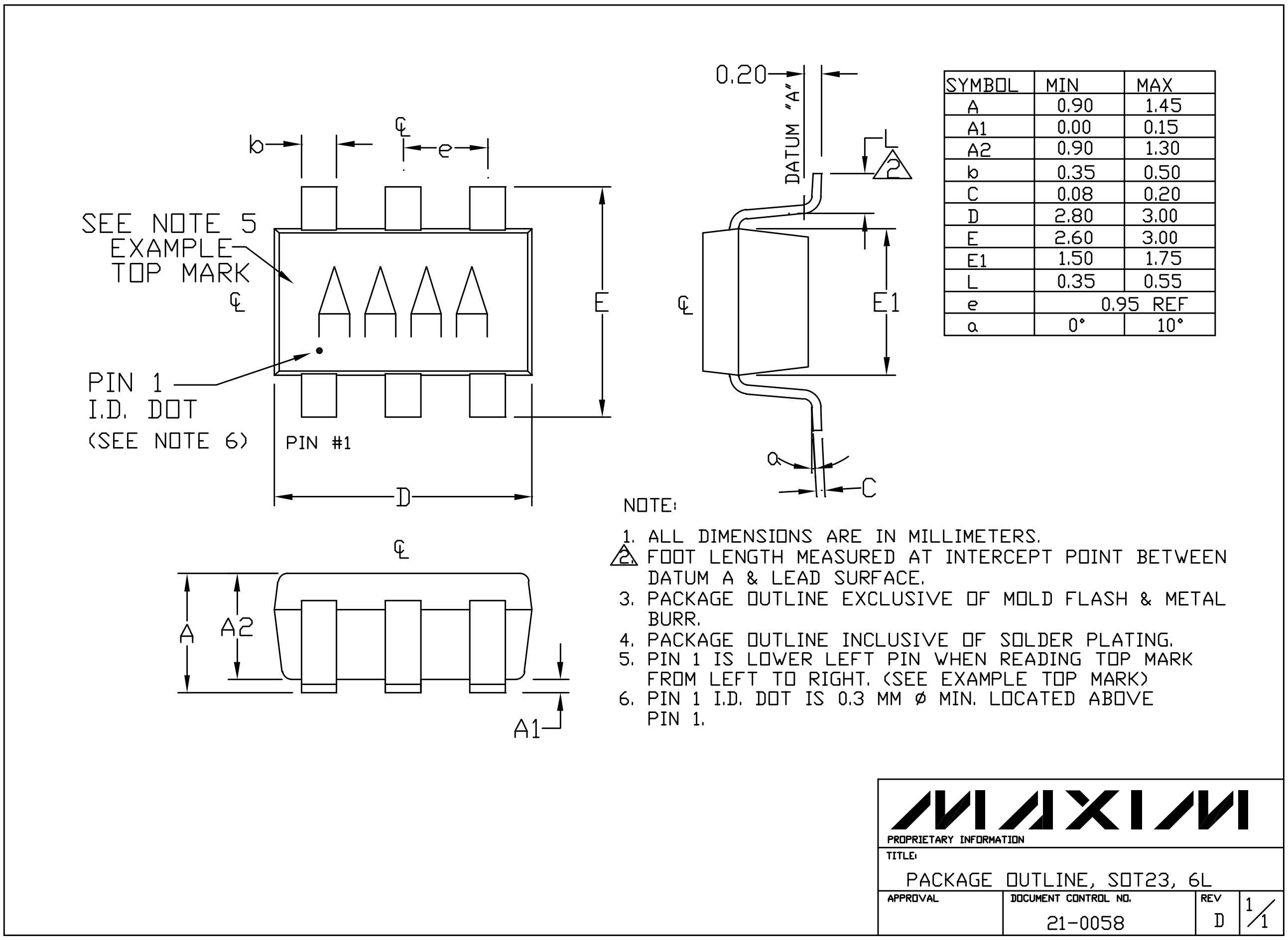
where r is the desired output ripple in %. A 10µF ceramic capacitor is a good starting value. The input capacitor reduces the peak current drawn from the battery and can be the same value as the input capacitor. A larger input capacitor can be used to further reduce ripple and improve efficiency.

PC Board Layout and Grounding

Careful printed circuit layout is important for minimizing ground bounce and noise. Keep the IC's GND pin and the ground leads of the input and output filter capacitors less than 0.2in (5mm) apart. In addition, keep all connections to the FB and LX pins as short as possible. In particular, when using external feedback resistors,

High-Efficiency Step-Up Converters with Reverse Battery Protection in SOT23-6

Package Information



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°