600mA, 650kHz Micropower Synchronous Boost Converter with Output Disconnect

FEATURES

- Up to 96% efficiency
- Low start-up voltage 0.8V
- Internal synchronous rectifier
- Up to 2MHz switching allows for tiny external components
- 0.5V to 4.4V input range
- 2.5V to 5.0V output range (Note 3)
- Feedback Voltage: 1.00V +/-2%
- Logic controlled shutdown (<1μA)
- Low 250μA operating supply current (measured at VOUT)
- Pulse skipping at light load for extended battery life
- Generates 3.3V at 100mA from single AA cell
- Stable with ceramic output capacitor
- Low profile 6-Leads SOT23-6 package

DESCRIPTION

converter delivering high efficiency in a SOT23-6 package. The device has an internal NMOS switch and PMOS synchronous rectifier and has the capacity of supplying 3.3V at 100mA from a single AA cell input.

High frequency switching (up to 2MHz) minimizes the board area by allowing the use of tiny, low profile inductors and ceramic capacitors.

The KB3436 provides automatic pulse skipping at light loads, thus reducing the supply current for extended battery life. At shutdown, the KB3436 fully discharges the output to ground and draws no supply current.

The KB3436 is available in small SOT23-6 package with both fixed and adjustable output voltage versions.

APPLICATIONS

- PDAs and organizers
- Digital cameras
- Wireless mice/ keyboards
- Portable medical equipment
- Cordless phones
- Wireless Headsets

TYPICAL APPLICATION

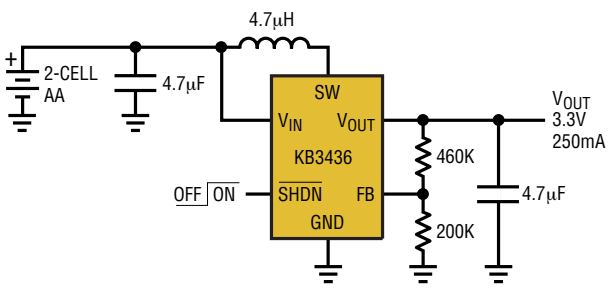
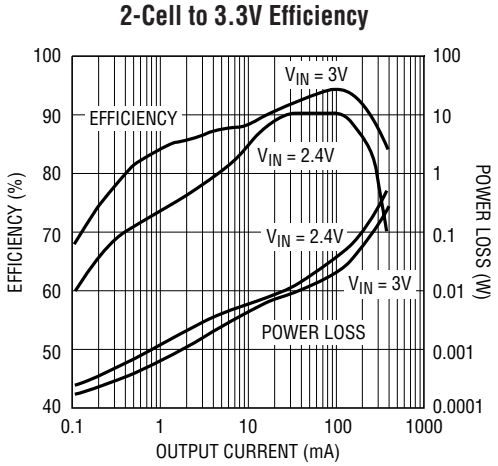


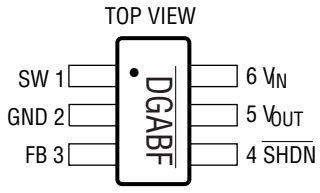
Figure 1. 2-Cell to 3.3V Synchronous Boost Converter



ABSOLUTE MAXIMUM RATINGS

V_{IN} Voltage ..... −0.3V to 4.4V
SW Voltage ..... −0.3V to 6V
SHDN, FB Voltage ..... −0.3V to 6V
V_{OUT} ..... −0.3V to 6V
Operating Temperature Range ..... −40°C to 85°C
Storage Temperature Range ..... −65°C to 150°
Lead Temperature (Soldering, 10 sec)..... 300°C

PACkAGE/ORDER INFORMATION



T_{JMAX} = 125°C, θ_{JC} = 102°C/W

ORDER PART NUMBER
KB3436
TOP MARKING
DGABF

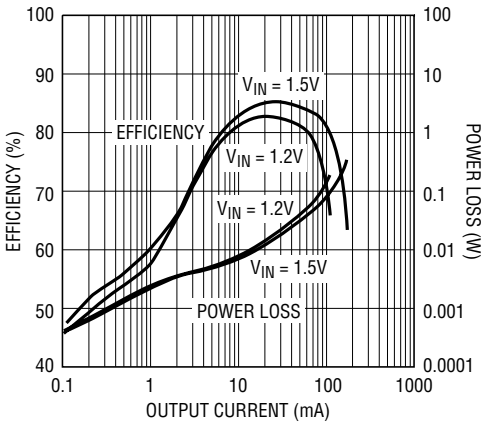
ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. V_{IN} = 1.2V, V_{OUT} = 3.3V, unless otherwise specified.

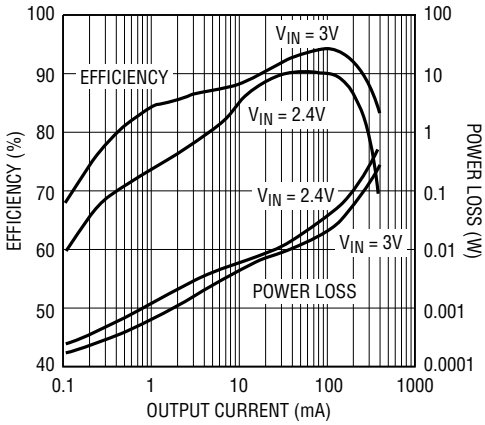
PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Minimum Start-Up Voltage	I_{LOAD} = 1mA, V_{OUT} = 0V			0.80		V
Minimum Operating Voltage	$\overline{SHDN}$ = V_{IN}			0.5	0.65	V
Output Voltage Adjust Range			2.5		5	V
Feedback Voltage +/-2%		●	0.980	1.000	1.020	V
Feedback Input Current	V_{FB} = 1.05V			1	50	nA
Quiescent Current (Burst Mode Operation)	V_{FB} = 1.2V			20	30	μA
Quiescent Current (Shutdown)	$V_{\overline{SHDN}}$ = 0V, Not Including Switch Leakage, V_{OUT} = 0V			0.01	1	μA
Quiescent Current (Active)	Measured on V_{OUT}, Nonswitching			350	500	μA
NMOS Switch Leakage	V_{SW} = 5V			0.1	5	μA
PMOS Switch Leakage	V_{SW} = 5V, V_{OUT} = 0V			0.1	5	μA
NMOS Switch On Resistance				0.35		Ω
PMOS Switch On Resistance				0.45		Ω
NMOS Current Limit			600	850		mA
Burst Mode Operation Current Threshold	L = 4.7μH			1.25		mA
Current Limit Delay to Output				40		ns
Max Duty Cycle	V_{FB} = 0.9V	●	80	90		%
Switching Frequency		●	500	650	800	kHz
$\overline{SHDN}$ Input High			1			V
$\overline{SHDN}$ Input Low					0.35	V
$\overline{SHDN}$ Input Current	$V_{\overline{SHDN}}$ = 5.5V			0.01	1	μA
Soft-Start Time	↓ $\overline{SHDN}$ to 90% of V_{OUT}			2.5		ms

TYPICAL PERFORMANCE CHARACTERISTICS (T_A = 25°C unless otherwise specified)

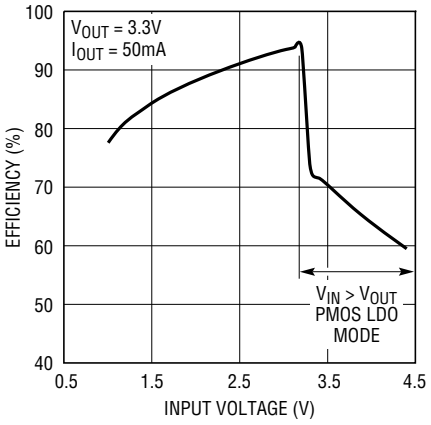
Single-Cell to 3.3V Efficiency



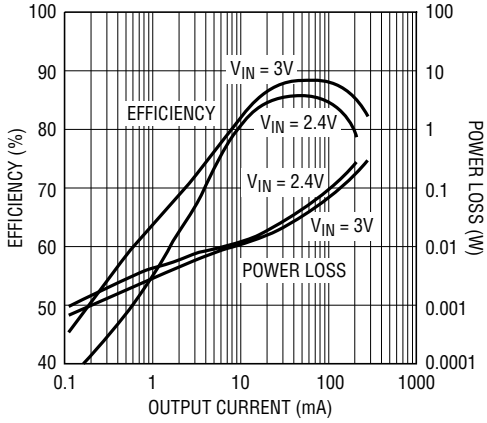
2-Cell to 3.3V Efficiency



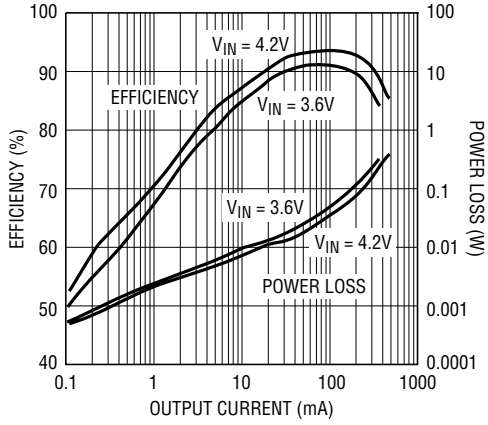
Efficiency vs Input Voltage



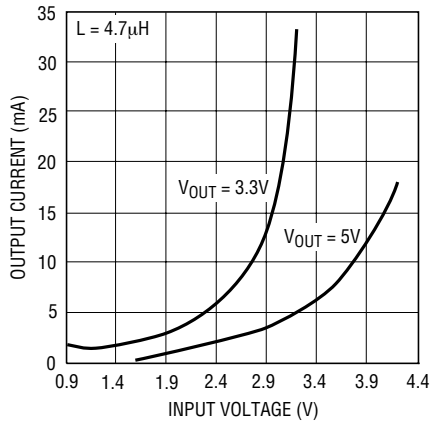
2-Cell to 5V Efficiency



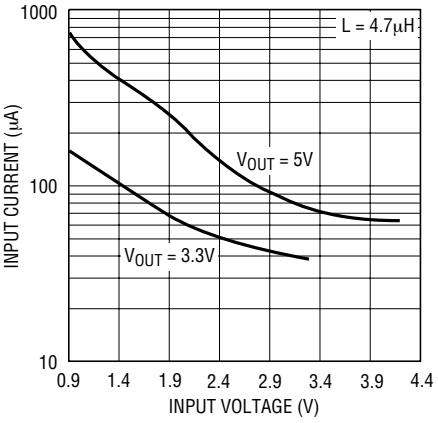
Li-Ion to 5V Efficiency



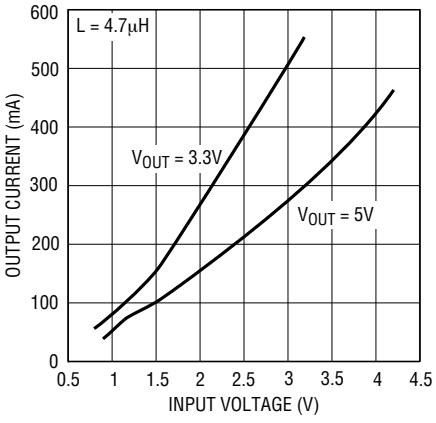
Burst Mode Output Current Threshold vs Input Voltage



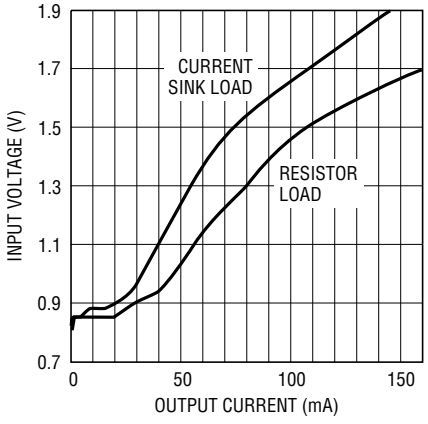
No Load Input Current vs Input Voltage



Maximum Load Current Capability at Output 4% Below Regulation Point

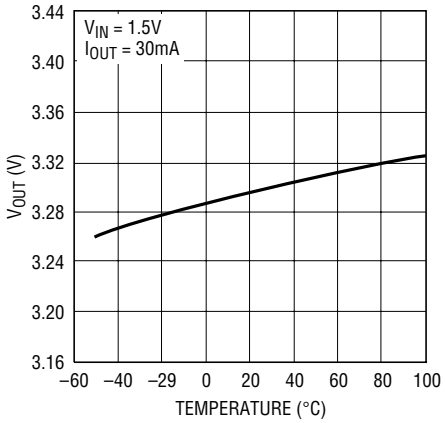


Minimum Start-Up Input Voltage vs Load Current

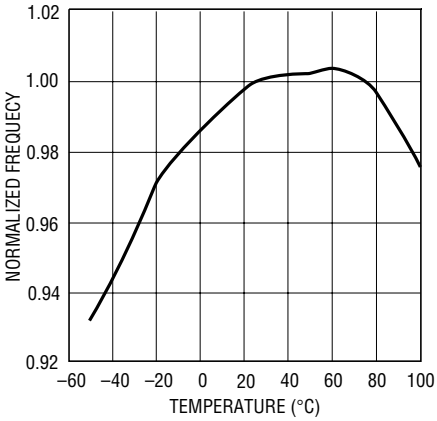


TYPICAL PERFORMANCE CHARACTERISTICS (T_A = 25°C unless otherwise specified)

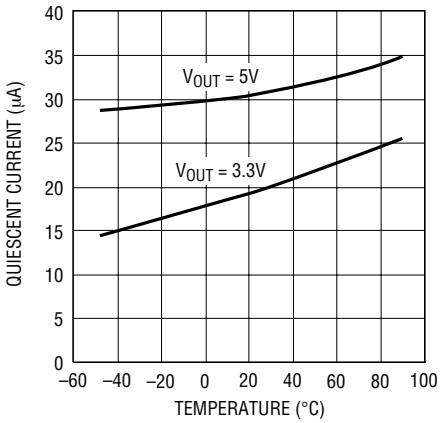
Output Voltage vs Temperature



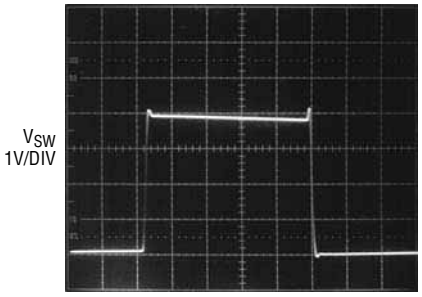
Normalized Oscillator Frequency vs Temperature



Burst Mode Quiescent Current vs Temperature

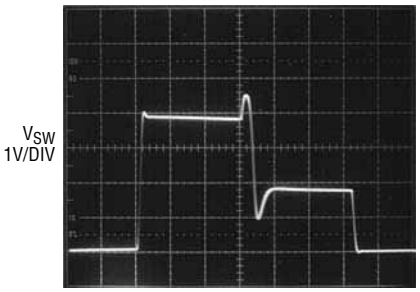


SW Pin Fixed Frequency Continuous Mode Operation



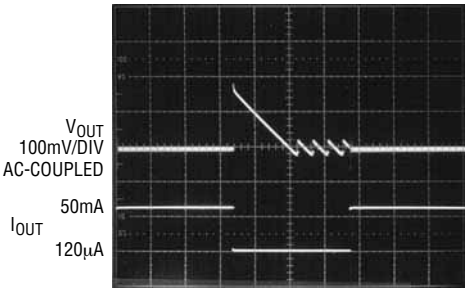
VIN = 1.5V 200ns/DIV
VOUT = 3.3V
IOUT = 50mA
L = 10µH
COUT = 10µF
CPL = 150pF

SW Pin Discontinuous Mode Antiringing Operation



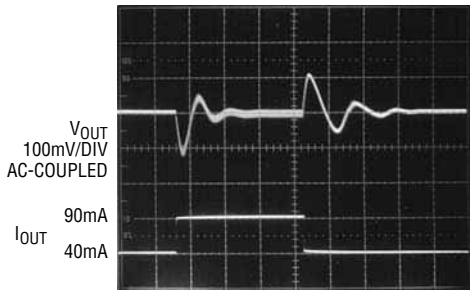
VIN = 1.5V 200ns/DIV
VOUT = 3.3V
IOUT = 20mA
L = 10µH
COUT = 10µF
CPL = 150pF

Fixed Frequency and Burst Mode Operation



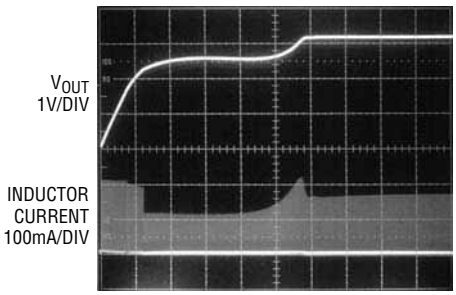
VIN = 1.5V 5ms/DIV
VOUT = 3.3V
IOUT = 120µA TO 50mA STEP
L = 10µH
COUT = 10µF
CPL = 150pF

Output Voltage Transient Response



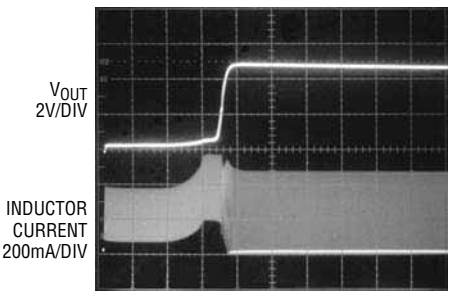
VIN = 1.5V 100µs/DIV
VOUT = 3.3V
IOUT = 40mA TO 90mA STEP
L = 10µH
COUT = 10µF
CPL = 150pF

Inrush Current Control and Soft-Start



VIN = 1.5V 500µs/DIV
VOUT = 3.3V
IOUT = 10mA
L = 4.7µH
COUT = 10µF
CPL = 100pF

Inrush Current Control and Soft-Start



VIN = 2.5V 2ms/DIV
VOUT = 5V
IOUT = 50mA
L = 4.7µH
COUT = 10µF
CPL = 100pF

PIN FUNCTIONS

SW (Pin 1): Switch Pin. Connect inductor between SW and V_{IN}. Keep these PCB trace lengths as short and wide as possible to reduce EMI and voltage overshoot. If the inductor current falls to zero, or $\overline{SHDN}$ is low, an internal 150Ω antiringing switch is connected from SW to V_{IN} to minimize EMI.

GND (Pin 2): Signal and Power Ground. Provide a short direct PCB path between GND and the (–) side of the output capacitor(s).

FB (Pin 3): Feedback Input to the g_m Error Amplifier. Connect resistor divider tap to this pin. The output voltage can be adjusted from 2.5V to 5V by:

$V_{OUT} = 1.00V \bullet [1 + (R1/R2)]$

$\overline{SHDN}$ (Pin 4): Logic Controlled Shutdown Input.

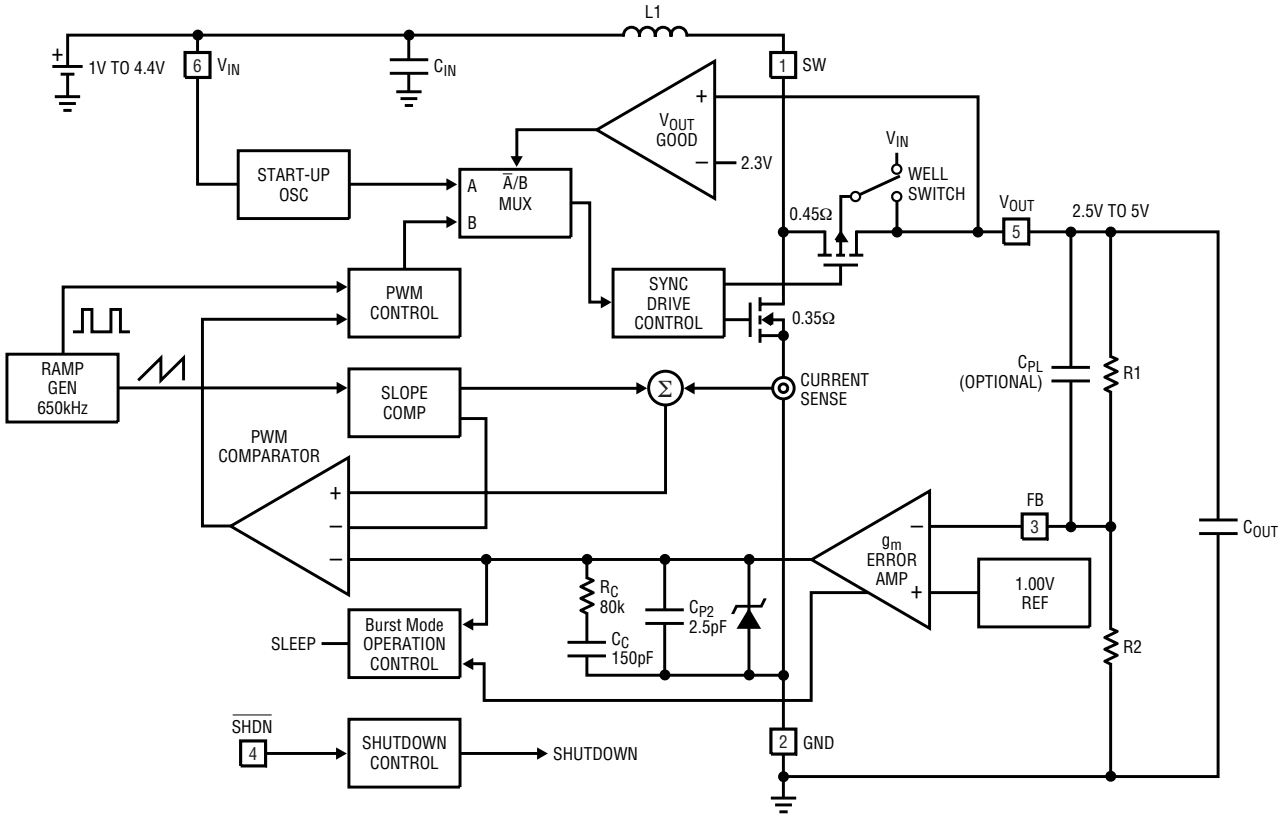
$\overline{SHDN}$ = High: Normal free running operation, 650kHz typical operating frequency.

$\overline{SHDN}$ = Low: Shutdown, quiescent current <1μA. Output capacitor can be completely discharged through the load or feedback resistors. A 150Ω resistor is internally connected between SW and V_{IN}.

V_{OUT} (Pin 5): Output Voltage Sense Input and Drain of the Internal Synchronous Rectifier MOSFET. Bias is derived from V_{OUT}. PCB trace length from V_{OUT} to the output filter capacitor(s) should be as short and wide as possible. V_{OUT} is completely disconnected from V_{IN} when $\overline{SHDN}$ is low due to the output disconnect feature.

V_{IN} (Pin 6): Battery Input Voltage. The device gets its start-up bias from V_{IN}. Once V_{OUT} exceeds V_{IN}, bias comes from V_{OUT}. Thus, once started, operation is completely independent from V_{IN}. Operation is only limited by the output power level and the battery's internal series resistance.

SIMPLIFIED BLOC DIAGRAM



OPERATION

The KB3436 are 650kHz, synchronous boost converters housed in a 6-lead SOT-23 package. Able to operate from an input voltage below 1V, the device features fixed frequency, current mode PWM control for exceptional line and load regulation. Low $R_{DS(ON)}$ internal MOSFET switches enable the device to maintain high efficiency over a wide range of load current. Detailed descriptions of the different operating modes follow. Operation can be best understood by referring to the Block Diagram.

LOW VOLTAGE START-UP

The KB3436 include an independent start-up oscillator designed to start up at input voltages of 0.8V typically. The frequency and duty cycle of the start-up oscillator are internally set to 150kHz and 67% respectively. In this mode, the IC operates completely open-loop and the current limit is also set internally to 600mA. Once the output voltage exceeds 2.3V, the start-up circuitry is disabled and normal close-loop PWM operation is initiated. In normal mode, the KB3436 power themselves from V_{OUT} instead of V_{IN}. This allows the battery voltage to drop to as low as 0.5V without affecting the circuit operation. The only limiting factor in the application becomes the ability of the battery to supply sufficient energy to the output. Soft-start and inrush current limiting are provided during start-up as well as normal mode operation.

Soft-Start

The KB3436 provide soft-start by charging an internal capacitor with a very weak current source. The voltage on this capacitor, in turn, slowly ramps the peak inductor current from zero to a maximum value of 850mA. The soft-start time is typically 2.5ms, the time it takes to charge the capacitor from zero to 1.20V. However, this time varies greatly with load current, output voltage and input voltage (see Typical Performance Characteristics, Inrush Current Control and Soft-Start). The soft-start capacitor is discharged completely in the event of a commanded shutdown or a thermal shutdown. It is discharged only partially in case of a short circuit at the output.

LOW NOISE FIXED FREQUENCY OPERATION

Oscillator

The frequency of operation is internally set to 650kHz.

Error Amp

The error amplifier is an internally compensated transconductance type (current output) with a transconductance (g_m) = 33 microsiemens. The internal 1.00V reference voltage is compared to the voltage at the FB pin to generate an error signal at the output of the error amplifier. A voltage divider from V_{OUT} to ground programs the output voltage via FB from 2.5V to 5V using the equation:

$$V_{OUT} = 1.00V \bullet [1 + (R1/R2)]$$

Current Sensing

Lossless current sensing converts the NMOS switch current signal to a voltage to be summed with the internal slope compensation. The summed signal is compared to the error amplifier output to provide a peak current control command for the PWM. Peak switch current is limited to approximately 600mA independent of input or output voltage. The switch current signal is blanked for 60ns to enhance noise rejection.

Zero Current Comparator

The zero current comparator monitors the inductor current to the output and shuts off the synchronous rectifier once this current reduces to approximately 27mA. This prevents the inductor current from reversing in polarity thereby improving efficiency at light loads.

Antiringing Control

The antiringing control circuitry prevents high frequency ringing of the SW pin as the inductor current goes to zero in discontinuous mode. The damping of the resonant circuit formed by L and C_{SW} (capacitance on SW pin) is achieved by placing a 150Ω resistor across the inductor.

Synchronous Rectifier

To prevent the inductor current from running away, the PMOS synchronous rectifier is only enabled when $V_{OUT} > (V_{IN} + 0.1V)$ and the FB pin is >0.8V.

OPERATION

Thermal Shutdown

An internal temperature monitor will start to reduce the peak current limit if the die temperature exceeds 125°C. If the die temperature continues to rise and reaches 160°C, the part will go into thermal shutdown, all switches will be turned off and the soft-start capacitor will be reset. The part will be enabled again when the die temperature drops by about 15°C.

Burst Mode OPERATION

Portable devices frequently spend extended time in low power or standby mode, only switching to high power consumption when specific functions are enabled. To improve battery life in these types of products, it is important to maintain a high power conversion efficiency over a wide output power range. The KB3436 provides automatic Burst Mode operation to increase efficiency of the power converter at light loads. Burst Mode operation is initiated if the output load current falls below an internally programmed threshold. This threshold has an inverse dependence on the duty cycle of the converter and also the value of the external inductor (See Typical Performance Characteristics, Output Current Burst Mode Threshold vs V_{IN}). Once Burst Mode operation is initiated, only the circuitry required to monitor the output is kept alive and the rest of the device is turned off. This is referred to as the sleep state in which the IC consumes only 20μA from the output capacitor. When the output voltage droops by about 1% from its nominal value, the part wakes up and commences normal PWM operation. The output capacitor recharges and causes the part to re-enter the sleep state if the output load remains less than the Burst Mode threshold. The frequency of this intermittent PWM or burst operation depends on the load current; that is, as the load current drops further below the burst threshold, the KB3436 turns on less frequently. When the load current increases above the burst threshold, the KB3436 seamlessly resumes continuous PWM operation. Thus, Burst Mode operation maximizes the efficiency at very light loads by minimizing switching and quiescent losses. However, the output ripple typically increases to about 2% peak-to-peak. Burst Mode ripple can be reduced, in some circumstances, by placing a small phase-lead capacitor (C_{PL}) between V_{OUT} and FB pins (refer to the Block Diagram). However, this may adversely affect the efficiency and the quiescent current requirement at light loads. Typical values of C_{PL} range from 15pF to 220pF.

OUTPUT DISCONNECT AND INRUSH LIMITING

The KB3436 are designed to allow true output disconnect by eliminating body diode conduction of the internal PMOS rectifier. This allows V_{OUT} to go to zero volts during shutdown, drawing zero current from the input source. It also allows for inrush current limiting at start-up, minimizing surge currents seen by the input supply. Note that to obtain the advantage of output disconnect, there must not be an external Schottky diode connected between the SWITCH pin and V_{OUT}.

Board layout is extremely critical to minimize voltage overshoot on the SWITCH pin due to stray inductance. Keep the output filter capacitor as close as possible to the V_{OUT} pin and use very low ESR/ESL ceramic capacitors tied to a good ground plane. For applications with V_{OUT} over 4.3V, a Schottky diode is required to limit the peak SWITCH voltage to less than 6V unless some form of external snubbing is employed. This diode must also be placed very close to the pins to minimize stray inductance. See the Applications Information.

SHORT CIRCUIT PROTECTION

Unlike most boost converters, the KB3436 allow their output to be short circuited due to the output disconnect feature. The devices incorporate internal features such as current limit foldback, thermal regulation and thermal shutdown for protection from an excessive overload or short circuit. In the event of a short circuit, the internal soft-start capacitor gets partially discharged. This, in turn, causes the maximum current limit to foldback to a smaller value. In addition to this, a thermal regulation circuit starts to dial back the current limit farther if the die temperature rises above 125°C. If the die temperature still reaches 160°C, the device shuts off entirely.

$V_{IN} > V_{OUT}$ OPERATION

The KB3436 will maintain voltage regulation even if the input voltage is above the output voltage. This

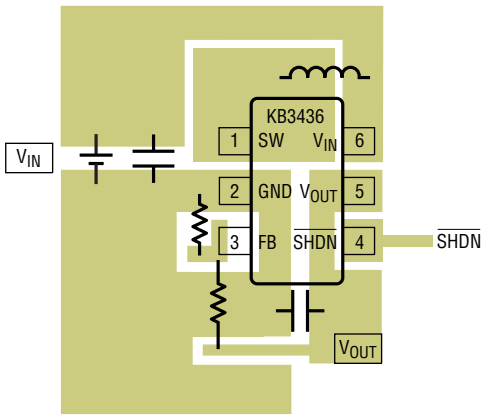
OPERATION

is achieved by terminating the switching of the synchronous PMOS and applying V_{IN} statically on its gate. This ensures that the slope of the inductor current will reverse during the time current is flowing to the output. Since the PMOS no longer acts as a low impedance switch in this mode, there will be more power dissipation within the IC. This will cause a sharp drop in the efficiency (see Typical Performance Characteristics, Efficiency vs V_{IN}). The maximum output current should be limited in order to maintain an acceptable junction temperature.

APPLICATIONS INFORMATION

PCB LAYOUT GUIDELINES

The high speed operation of the KB3436 demands careful attention to board layout. You will not get advertised performance with careless layout. Figure 2 shows the recommended component placement. A large ground pin copper area will help to lower the chip temperature. A multilayer board with a separate ground plane is ideal, but not absolutely necessary.



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

Figure 2. Recommended Component Placement for Single Layer Board

COMPONENT SELECTION

Inductor Selection

The KB3436 can utilize small surface mount and chip inductors due to its fast 650kHz switching frequency. Typically, a 4.7μH inductor is recommended for most applications. Larger values of inductance will allow greater output current capability by reducing the inductor ripple current. Increasing the inductance above 10μH will increase size while providing little improvement in output current capability.

The approximate output current capability of the KB3436 versus inductance value is given in the equation below and illustrated graphically in Figure 3.

$$I_{OUT(MAX)} = \eta \bullet \left(I_P - \frac{V_{IN} \bullet D}{f \bullet L \bullet 2}\right) \bullet (1 - D)$$

where:

η = estimated efficiency

I_P = peak current limit value (0.6A)

V_{IN} = input (battery) voltage

D = steady-state duty ratio = $(V_{OUT} - V_{IN})/V_{OUT}$

f = switching frequency (650kHz typical)

L = inductance value

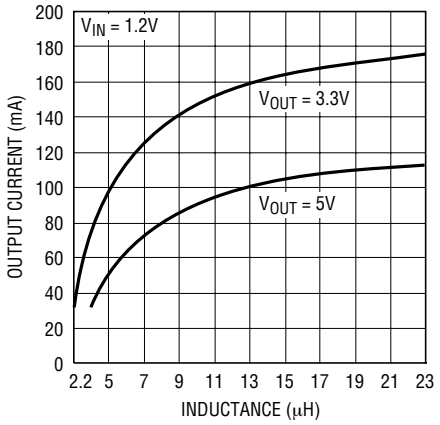


Figure 3. Maximum Output Current vs Inductance Based on 90% Efficiency

APPLICATIONS INFORMATION

The inductor current ripple is typically set for 20% to 40% of the maximum inductor current (I_P). High frequency ferrite core inductor materials reduce frequency dependent power losses compared to cheaper powdered iron types, improving efficiency. The inductor should have low ESR (series resistance of the windings) to reduce the I^2R power losses, and must be able to handle the peak inductor current without saturating. Molded chokes and some chip inductors usually do not have enough core to support the peak inductor currents of 850mA seen on the KB3436. To minimize radiated noise, use a toroid, pot core or shielded bobbin inductor. See Table 1 for some suggested components and suppliers.

Table 1. Recommended Inductors

PART	L (μH)	MAX DCR mΩ	HEIGHT (mm)	VENDOR
CDRH5D18-4R1	4.1	57	2.0	Sumida
CDRH5D18-100	10	124	2.0	www.sumida.com
CDRH3D16-4R7	4.7	105	1.8	
CDRH3D16-6R8		170	1.8	
CR43-4R7	4.7	109	3.5	
CR43-100	10	182	3.5	
CMD4D06-4R7MC	4.7	216	0.8	
CMD4D06-3R3MC	3.3	174	0.8	
DS1608-472	4.7	60	2.9	Coilcraft
DS1608-103	10	75	2.9	www.coilcraft.com
DO1608C-472	4.7	90	2.9	
D52LC-4R7M	4.7	84	2.0	Toko
D52LC-100M	10	137	2.0	www.tokoam.com
LQH32CN4R7M24	4.7	195	2.2	Murata www.murata.com

Output and Input Capacitor Selection

Low ESR (equivalent series resistance) capacitors should be used to minimize the output voltage ripple. Multilayer ceramic capacitors are an excellent choice as they have extremely low ESR and are available in small footprints. A 4.7μF to 15μF output capacitor is sufficient for most applications. Larger values up to 22μF may be used to obtain extremely low output voltage ripple and improve transient response. An additional phase lead capacitor may be required with output capacitors larger than 10μF to maintain acceptable phase margin. X5R and X7R dielectric materials are preferred for their ability to maintain capacitance over wide voltage and temperature ranges.

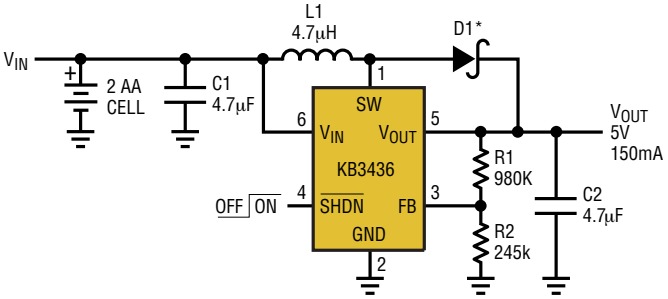
Low ESR input capacitors reduce input switching noise and reduce the peak current drawn from the battery. It follows that ceramic capacitors are also a good choice for input decoupling and should be located as close as possible to the device. A 10μF input capacitor is sufficient for virtually any application. Larger values may be used without limitations. Table 2 shows a list of several ceramic capacitor manufacturers. Consult the manufacturers directly for detailed information on their entire selection of ceramic capacitors.

Table 2. Capacitor Vendor Information

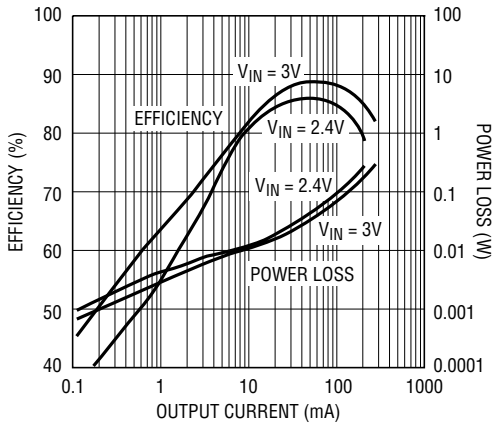
SUPPLIER	WEBSITE
AVX	www.avxcorp.com
Murata	www.murata.com
Taiyo Yuden	www.t-yuden.com

TYPICAL APPLICATION

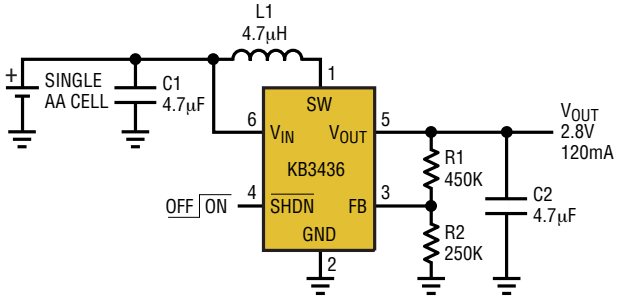
Application Circuit for V_{OUT} > 4.3V Where Inrush Current Limiting and Output Disconnect are Not Required



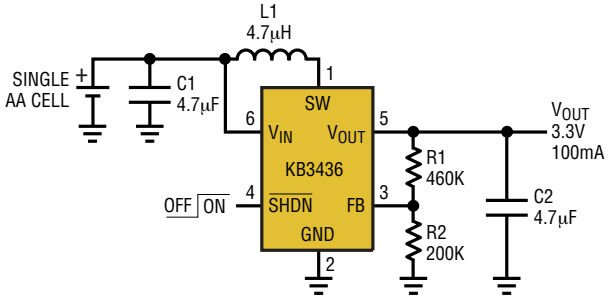
2-Cell to 5V Efficiency



Single AA Cell to 2.5V Synchronous Boost Converter

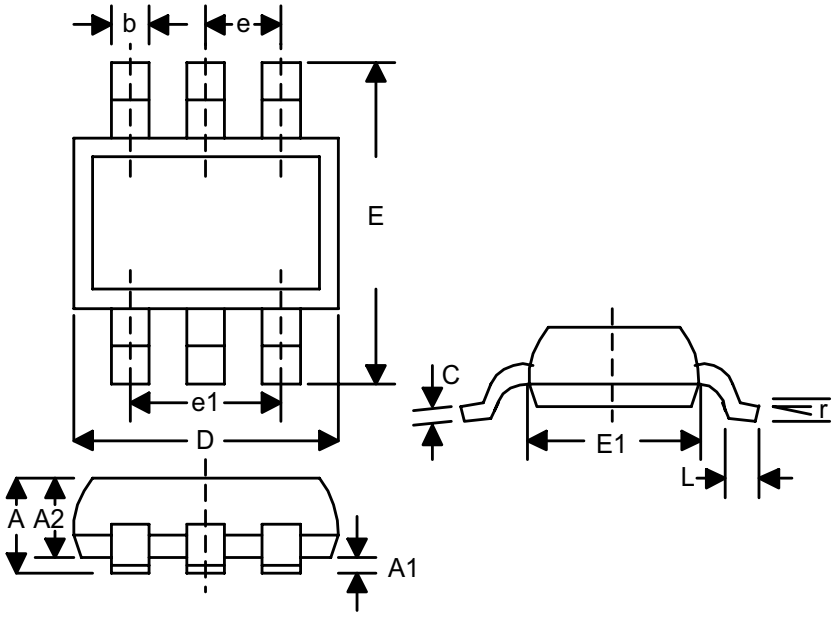


Single AA Cell to 3.3V Synchronous Boost Converter



PACAGE DESCRIPTION

Small Outline SOT23-6



SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.035	0.057	0.90	1.45	-
A1	0.000	0.006	0.00	0.15	-
A2	0.035	0.051	0.90	1.30	-
b	0.010	0.020	0.25	0.50	-
C	0.003	0.008	0.08	0.20	-
D	0.110	0.122	2.80	3.10	-
E	0.102	0.118	2.60	3.00	-
E1	0.059	0.069	1.50	1.75	-
L	0.014	0.022	0.35	0.55	
e	0.037ref		0.95ref		
e1	0.075ref		1.90ref		
r	0^0	10^0	0^0	10^0	-