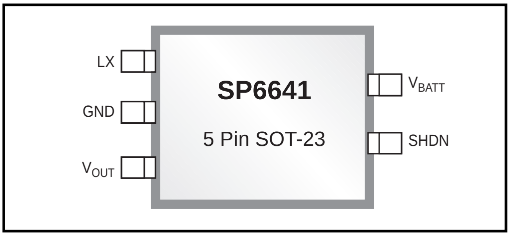
SP6641A/6641B

Ultra Low Quiescent Current, High Efficiency Boost DC-DC Regulator

- 10µA, Ultra Low Quiescent Current
- Wide Input Voltage Range: 0.9V to 4.5V
- 90mA I_{OUT} at 1.3V Input, 1AA (SP6641A)
- 500mA, I_{OUT} at 2.6V Input, 2AA (SP6641B)
- Fixed 3.3V or 5.0V Output Voltage
- 85% Efficiency
- 0.3Ω NFET R_{DS}on
- Only 4 External Components Required
- Startup Voltage Guaranteed at 0.9V
- 0.33A Inductor Current Limit (SP6641A)
- 1A Inductor Current Limit (SP6641B)
- Logic Shutdown Control



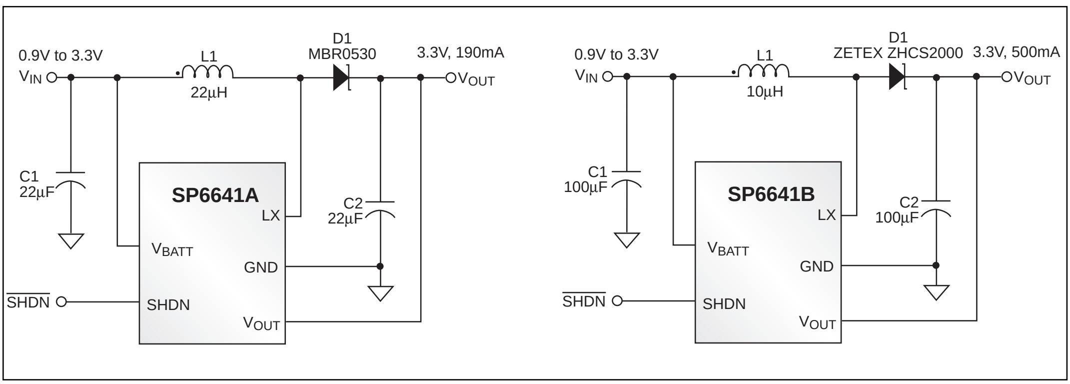
APPLICATIONS

- Medical Monitors
- PDA's
- DSC's
- MP3 Players
- Pagers
- Portable Handheld Devices

DESCRIPTION

The SP6641 is an ultra-low quiescent current, high efficiency, DC-DC boost converter designed for single and dual cell alkaline, or Li-ion battery applications found in medical monitors, PDA's, MP3 players, and other handheld portable devices. The SP6641 features a 10µA quiescent current, a 0.3Ω N-channel charging switch, 0.9V input startup, and a 0.33A or 1.0A inductor current limiting feature. It is offered in a 5 pin SOT-23 package and provides an extremely small power supply footprint optimized for portable applications. The SP6641 is preset to 3.3V and can be controlled by a 1nA active LOW shutdown pin.

TYPICAL APPLICATION DIAGRAMS



ABSOLUTE MAXIMUM RATINGS

These are stress ratings only and functional operation of the device at these ratings or any other above those indicated in the operation sections of the specifications below is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.

LX, V_{OUT}, SHDN, V_{BATT} to GND pin .... -0.3 to 6.0V
LX Current 1.5A
Reverse V_{BATT} Current 220mA
Storage Temperature .... -65°C to 150°C
Operating Temperature .... -40°C to +85°C
Lead Temperature (Soldering, 10 sec) .... 300 °C

ELECTRICAL SPECIFICATIONS

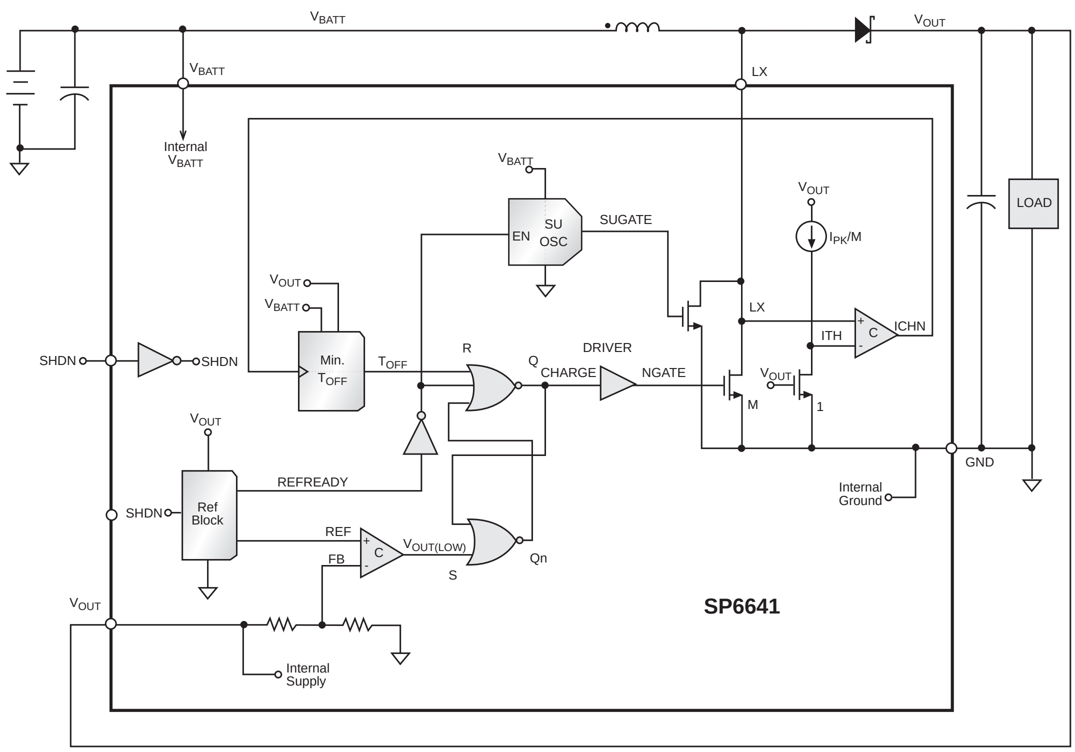
$V_{BATT} = V_{SHDN} = 1.3V$, $I_{LOAD} = 0mA$, $-40°C < T_A < +85°C$, $V_{OUT} = +3.3V$, typical values at 27°C unless otherwise noted.

PARAMETER	MIN	TYP	MAX	UNITS	CONDITIONS
Input Voltage Operating Range, V_{BATT}	0.5		4.5	V	after startup
Start-up Voltage, V_{BATT}		0.85	0.90 1.00	V V	R_{LOAD}=3kΩ, T_A =27°C R_{LOAD}=3kΩ,-40°C <T_A < +85°C
Output Voltage, V_{OUT}	3.16	3.30	3.44	V	3.3V V_{OUT} preset
Quiescent Current into V_{OUT}, $I_{Q(OUT)}$		10	15	mA	V_{OUT}=3.5V
Quiescent Current into V_{BATT}, I_{QB}		20	500	nA	V_{OUT}=3.5V
Shutdown Current into V_{OUT}, I_{SHDN}		1	500	nA	V_{SHDN} =0V
Shutdown Current into V_{BATT}, I_{SHDN}		5	100	nA	V_{SHDN} =0V
Efficiency (SP6641A)		79 85		% %	V_{BATT} =1.3V, I_{OUT} =60mA V_{BATT} =2.6V, I_{OUT} =120mA
Efficiency (SP6641B)		72 85		% %	V_{BATT} =1.3V, I_{OUT} =100mA V_{BATT} =2.6V, I_{OUT} =400mA
Inductor Current Limit (SP6641A)	280	330	380	mA	
Inductor Current Limit (SP6641B)	850	1000	1150	mA	
Output Current (SP6641A)		90 190		mA mA	V_{BATT} =1.3V V_{BATT} =2.6V
Output Current (SP6641B)		200 500		mA mA	V_{BATT} =1.3V V_{BATT} =2.6V
Minimum Off-Time Constant K_{OFF}		1.50		V*µs	$T_{OFF} \geq K_{OFF} / (V_{OUT} - V_{IN})$
NMOS Switch Resistance		0.3	0.75	Ω	Inmos=100mA
SHDN Input Voltage Vil Vih	 80		20 	% %	% of V_{BATT} % of V_{BATT}
SHDN Input Current		1	100	nA	

PIN DESCRIPTION

PIN NO.	PIN NAME	DESCRIPTION
1	LX	Inductor switching node. Connect one terminal of the inductor to the positive terminal of the battery. Connect the second terminal of the inductor to this pin. The inductor charging current flows into LX, through the internal charging N-channel FET, and out through the GND pin.
2	GND	Ground pin. The internal regulator bias currents and the inductor charging current flows out of this pin.
3	V_{OUT}	Output voltage sense pin, internal regulator voltage supply, and minimum off-time one shot input. Kelvin connect this pin to the positive terminal of the output capacitor.
4	SHDN	Shutdown. Tie this pin to V_{BATT} for normal operation. Tie this pin the ground to disable all circuitry inside the chip. In shutdown mode, the output voltage will float at a diode drop below the battery potential.
5	V_{BATT}	Battery voltage pin. The startup circuitry runs off of this pin. The regulating circuitry also uses this voltage to control the minimum off-time. $T_{OFF} \geq K_{OFF} / (V_{OUT} - V_{IN})$.

BLOCK DIAGRAM



OPERATION

General Overview

The SP6641 is a high efficiency, low quiescent current step-up DC-DC converter ideal for single and dual cell alkaline and single cell Li on battery applications such as medical monitors, PDA's, MP3 players, and other portable end products. The SP6641's 10µA quiescent current, low 0.3Ω NFET switch, and unique PFM control scheme combine to provide excellent efficiency over a wide output power range.

Other features include a logic level enable control pin, guaranteed 0.9V startup, a tiny SOT23 5 pin package, and precise inductor peak current control. SP6641A sources up to 90mA at 1.3V, typ. and SP6641B sources up to 500mA at 2.6V, typ. by supporting different peak inductor current levels. Only two capacitors, an inductor, and a diode are required to build a power supply.

Loop Regulation

The SP6641 combines a fixed inductor peak current limit, a feed-forward minimum off-time one-shot, and a precision loop comparator to regulate the output voltage. Under light-load conditions the loop operates as a standard PFM converter. The frequency of fixed amplitude inductor current triangles is modulated to regulate the load. Under heavy load conditions, the converter adjusts the number of successive continuous mode current pulses to regulate the load. Refer to the block diagram for the following explanation of operating modes in loop regulation.

The output voltage is internally divided down and fed to the negative terminal of the loop comparator. A +1.25V bandage reference voltage is applied to the positive terminal of the comparator. As the output voltage droops below the regulation threshold due to the load the loop comparator output (signal $V_{OUT(LOW)}$) transitions to a logic "1". This sets the SR latch and initiates inductor charging by pulling the signal NGATE high. Inductor charging continues until the current reaches the internally programmed limit, at which point, the off-time one-shot is triggered.

The off-time one-shot via signal T_{OFF} resets the SR latch regardless of the SET state ($V_{OUT(LOW)}$), opens the NMOS charge switch, and forces the inductor to discharge through the rectifying diode for a minimum time defined by the one-shot duration. The end of the off-time pulse releases the SR latch, and its output state is once again determined by the output of the loop comparator ($V_{OUT(LOW)}$). Under light load conditions, the output voltage will have been pulled above the regulation threshold during the minimum off-time, the signal $V_{OUT(LOW)}$ will be a logic "0", and the NMOS charging switch will remain open. The inductor current discharges until it reaches zero or the loop comparator triggers a new charge cycle.

Under a heavy load, the output voltage will remain below the regulation point at the end of the off-time pulse. In this condition, $V_{OUT(LOW)}$ has a logic value of 1 which immediately starts a new charge/discharge cycle defined by the peak inductor current and the minimum off-time. The inductor current will remain in a continuous conduction mode until the loop comparator indicates the output voltage is above the regulation threshold, and the inductor current will relax towards zero.

During continuous mode bursts, the inductor current frequency and ripple amplitude are controlled by the minimum off-time one-shot and the input and output voltage levels. The SP6641 sets the minimum off-time to:

$$T_{OFF} = \frac{K_{OFF}}{(V_{OUT} - V_{IN})}, \quad \text{where:}$$

K_{OFF} = Off-time Constant, typically 1.5µs*V

V_{OUT} = Output Voltage

V_{IN} = Input Voltage

Plugging the T_{OFF} expression into the boost mode equations yields the maximum output current in regulation:

$$I_{OUT(MAX)} \approx \eta \left(\frac{V_{IN}}{V_{OUT}}\right)\left(\frac{I_{PK} - K_{OFF}}{2L}\right)$$

where:

η = Efficiency, typically 0.80 to 0.90

I_{PK} = Programmed inductor peak current, typically 0.33A for the SP6641A, typically 1.0A for the SP6641B.

L = Inductor value

Loop Regulation: continued

The SP6641 feed forward off-time control delivers more load current than constant off-time control because the input battery voltage drops during its life cycle. The term ($I_{PK} - K_{OFF}/2L$) is the average current delivered to the output capacitor during the discharge phase. This is constant with respect to input and output voltage. With constant off-time control, the average discharge current term becomes

(I_{PK}-T_{OFF}*(V_{OUT}-V_{IN})/2L), which decreases as the input voltage drops.

Table 1 illustrates the average inductor current delivered to the load during discharge versus the input voltage. The SP6641 feed forward off-time control and the constant off-time control are compared. For purposes of illustration, the off times of each control scheme are normalized at a typical two cell alkaline input voltage of 2.6V. The values used in Table 1 are:

I_{PK} = 0.33A

L = 22µH

V_{OUT}= 3.3V

T_{OFF} (SP6641) = 1.5V*µs/(3.3-V_{IN})

T_{OFF} (constant) = 2.14µs

SP6641			Constant T_{OFF}	
V_{IN}	T_{OFF}	Avg Il	T_{OFF}	Avg Il
3.0	5.00µs	0.30A	2.14µs	0.32A
2.6	2.14µs	0.30A	2.14µs	0.30A
2.0	1.15µs	0.30A	2.14µs	0.27A
1.3	0.75µs	0.30A	2.14µs	0.23A
1.0	0.65µs	0.30A	2.14µs	0.22A

Table 1- Average I_L vs. Input Voltage

The following equation defines the burst mode frequency under heavy load conditions:

$$F_{BURST} = \left(\frac{V_{OUT} - V_{IN}}{K_{OFF}}\right)\left(\frac{V_{IN} - V_C}{V_{OUT} + V_D - V_C}\right)$$

where:

V_D = Forward schottky drop, (0.4V, typ)

V_C = Average charging switch drop, Rnmos*I_{PK}, typically 0.1V

Ignoring the conduction losses of V_D and V_C, the burst frequency equation simplifies to:

$$F_{BURST} = \frac{(V_{OUT} - V_{IN})V_{IN}}{K_{OFF}V_{OUT}}$$

Startup

The internal regulator circuitry is bootstrapped to the V_{OUT} pin. This requires a low voltage oscillator and charging switch powered from the V_{BATT} pin to pump up the output voltage until the reference is established. The reference provides a REFREADY signal that determines when output control is handed over to the regulator. REFREADY shuts down the startup circuit and enables the regulator when the reference is valid and V_{OUT} is above +1.9V. Once the regulator is given control it will continue to pump up the output at full power until regulation is reached.

For two cell alkaline input voltages and above, the output voltage will be pulled above +1.9V quickly through the rectifying diode before the reference has a chance to establish. In this scenario the startup circuit will coarsely regulate around +2.8V until the REFREADY signal asserts. This keeps the output from overshooting in startup with higher input voltages.

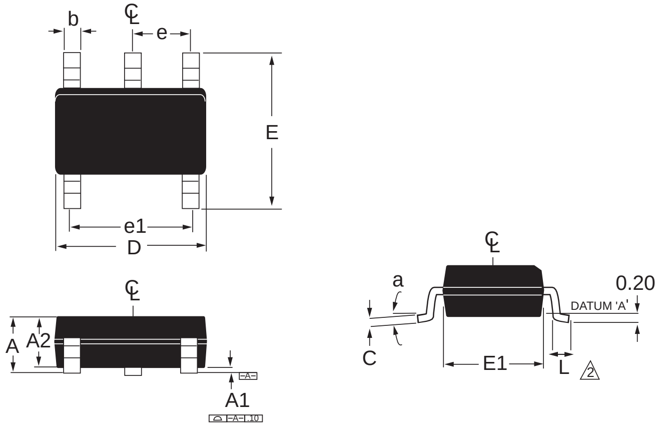
Startup is guaranteed at +0.9V at room temperature with a 3kΩ load. Heavier loads will require a higher input voltage.

Shutdown/Enable Control

Pin 4 of the device is a V_{BATT} referred control pin that shuts down the converter with the pin tied to ground, or enables the converter with the pin tied to V_{BATT}. When the converter is shutdown the power switch is opened and all circuit biasing is extinguished leaving only junction leakage currents on supply pins 3 and 5. The output voltage will droop to one diode drop below the battery voltage through the rectifying diode.

After pin 4 is brought high, the startup circuit is enabled and starts pumping up the output until REFREADY hands over control to the internal regulator.

PACKAGE: 5 Lead SOT23



SYMBOL	MIN	MAX
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
b	0.25	0.50
C	0.09	0.20
D	2.80	3.10
E	2.60	3.00
E1	1.50	1.75
L	0.35	0.55
e	0.95ref	
e1	1.90ref	
a	0°	10°

PRELIMINARY INFORMATION

ORDERING INFORMATION

Part Number	Temperature Range	Package Type
SP6641AEK-3.3	-40°C to 85°C	5-Pin SOT-23
SP6641AEK-3.3/TR	-40°C to 85°C	*(Tape & Reel)* 5-Pin SOT-23
SP6641BEK-3.3	-40°C to 85°C	5-Pin SOT-23
SP6641BEK-3.3/TR	-40°C to 85°C	*(Tape & Reel)* 5-Pin SOT-23

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