ABSOLUTE MAXIMUM RATINGS

LX, Vo, V_{BATT} , LBON, FB to GND pin .... -0.3 to 6.0V
SHDN, LBI .... -0.3V to V_{BATT} +1.0V
Vo, GND, LX Current 2A
Reverse V_{BATT} Current 220mA
Forward V_{BATT} Current 500mA
Storage Temperature .... -65 °C to 150°C

Operating Temperature .... -40°C to +85°C
ESD Rating .... 1.5kV HBM

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.

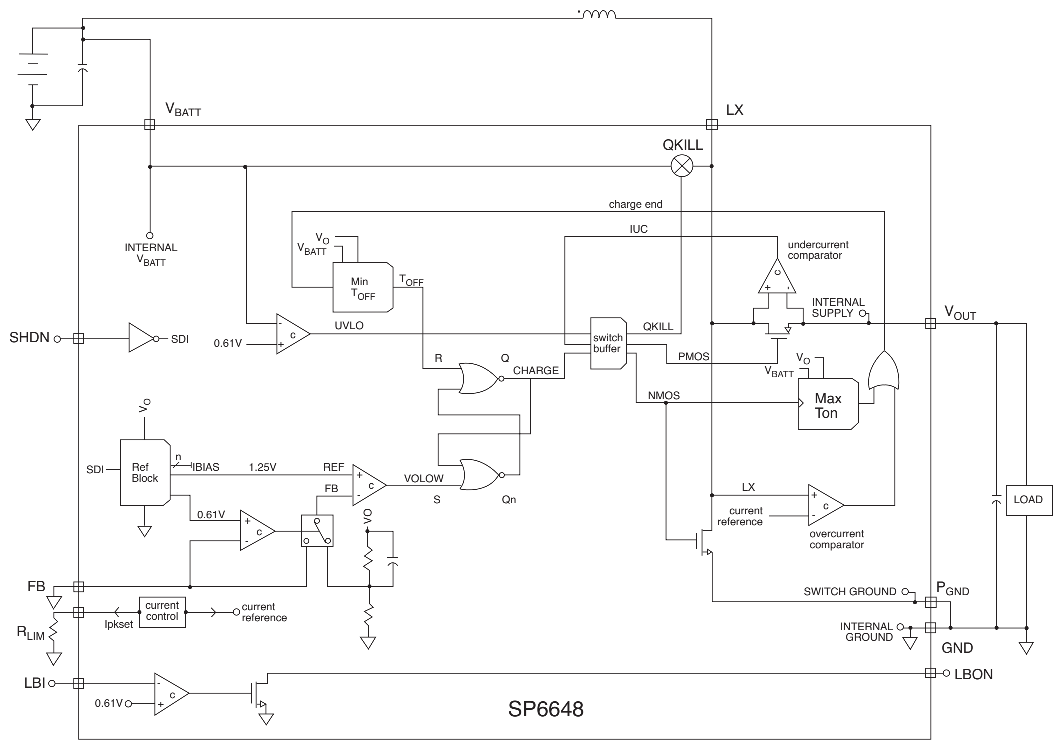
ELECTRICAL SPECIFICATIONS

V_{BATT} =V_{SHDN} = 2.6V, V_{FB}=0.0V, I_{LOAD} = 0mA, T_{AMB} = -40°C to +85°C, V_{OUT} = +3.3V, typical values at 27°C unless otherwise noted. The ♦ denotes the specifications which apply over full operating temperature range -40°C to +85°C, unless otherwise specified.

PARAMETER	MIN	TYP	MAX	UNITS	♦	CONDITIONS
Input Voltage Operating Range, V_{BATT}	0.7		4.5	V	♦	After Startup
Output Voltage Range, V_{OUT}	2.5		5.5	V	♦	
Start-up Input Voltage, V_{BATT}		0.85	1.1	V	♦	R_{LOAD} = 3kΩ
Under Voltage Lock-out/UVLO	0.5	0.61	0.7	V	♦	
Output Voltage, V_O	3.12	3.30	3.48	V	♦	Internal Feedback Divider
Quiescent Current into V_O, I_{QO}		12	25	µA	♦	V_{OUT} = 3.3V, V_{FB} = 1.5V, Toggle SHDN
Quiescent Current into V_{BATT}, I_{QB}		250	750	nA	♦	V_{OUT} = 3.3V, V_{FB} = 1.5V
Shutdown Current into V_O, I_{SDO}		1	500	nA	♦	V_{SHDN} = 0.0V
Shutdown Current into V_{BATT}, I_{SDB}		250	750	nA	♦	V_{SHDN} = 0.0V, V_{BATT} = 2.6V
Efficiency		84 92		% %		V_{BATT} = 1.3V, I_{OUT} = 100mA, R_{LIM} =2kΩ V_{BATT} = 2.6V, I_{OUT} = 200mA, R_{LIM} =2kΩ
Inductor Current Limit, I_{PK} = 1600/R_{LIM}	650 1300	800 1600	1000 2000	mA mA	♦ ♦	R_{LIM} = 2kΩ R_{LIM} = 1kΩ
Output Current		100 200		mA mA		V_{BATT} = 1.3V, R_{LIM} = 4kΩ V_{BATT} = 2.6V, R_{LIM} = 4kΩ
		150 400		mA mA		V_{BATT} = 1.3V, R_{LIM} =2kΩ V_{BATT} = 2.6V, R_{LIM} =2kΩ
Minimum Off-Time Constant K_{OFF}	0.5	1.0	1.5	V*µs	♦	$K_{OFF} \leq T_{OFF}$ (V_{OUT}- V_{BATT})
Maximum On-Time Constant K_{ON}	2.5	4.0	5.5	V*µs	♦	$K_{ON} \geq T_{ON}$ (V_{BATT})
Enable Valid to Output Stable		300	500	µs		I_{LOAD} = 1mA
NMOS Switch Resistance		0.30	0.6	Ω	♦	I_{NMOS} = 100mA
PMOS Switch Resistance		0.30	0.6	Ω	♦	I_{PMOS} = 100mA
FB Set Voltage, V_{FB}	1.19	1.25	1.31	V	♦	External feedback
FB Input Current		1	100	nA	♦	V_{FB} =1.3V
LBI Falling Trip Voltage	0.56	0.61	0.66	V	♦	
LBI Hysteresis		25		mV		
Low Output Voltage for LBON, V_{OL}			0.4	V	♦	V_{BATT} = 1.3V, I_{SINK} = 1mA
Leakage current for LBON			1	µA	♦	V_{BATT} = 1.3V, V_{LBON} = 3.3V
SHDN Input Voltage, Note 1 V_{IL} V_{IH} V_{IL} V_{IH}	 1.0 2.0		 0.25 0.5 	V	 ♦ ♦ ♦ ♦	 V_{BATT} = 1.3V V_{BATT} = 1.3V V_{BATT} = 2.6V V_{BATT} = 2.6V
SHDN Input Current		1	100	nA	♦	
LX Pin Leakage			3	µA		

Note 1: SHDN must transition faster than 1V/100mS for proper operation.

PIN NUMBER	PIN NAME	DESCRIPTION
1	V_{BATT}	Battery Voltage. The startup circuitry is powered by this pin. Battery Voltage is used to calculate switch off time: $t_{OFF} = K_{OFF}/ (V_{OUT} - V_{BATT})$. When the battery voltage drops below 0.61V the SP6648 goes into an undervoltage lockout mode (UVLO), where the part is shut down.
2	LBI	Low Battery Input. LBI below 0.61V causes the SP6648 pin to pull LBON pin down to ground. Use a resistor divider to program the low voltage threshold for a specific battery configuration.
3	LBON	Low Battery Output Not. Open drain NMOS output that sinks current to ground when LBI is below 0.61V.
4	R_{LIM}	Current Limit Resistor. By connecting a resistor R_{LIM} from this pin to ground the inductor peak current is set by I_{PEAK}=1600/R_{LIM}. The range for R_{LIM} is 9kΩ (for 180mA) to 1.KΩ (for 1.6A).
5	SHDN	Shutdown Not. Tie this pin high to $V_{BATT,}$ for normal operation. Pull this pin to ground to disable all circuitry inside the chip. In shutdown the output voltage will float down to a diode drop below the battery voltage.
6	FB	Feedback. Connect this pin to GND for fixed +3.3V operation. Connect this pin to a resistor voltage divider between V_{OUT} and GND for adjustable output operation.
7	GND	Ground. Connect to ground plane.
8	PGND	Power Ground. The inductor charging current flows out of this pin.
9	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 the PGND pin.
10	V_{OUT}	Output Voltage. The inductor current flows out of this pin during switch off-time. It is also used as the internal regulator voltage supply. Connect this pin to the positive terminal of the output capacitor.



THEORY OF OPERATION

Detailed Description

The SP6648 is a step-up DC-DC converter that can start up with input voltages as low as 0.85V (typically) and operates with an input voltage down to 0.61V. Ultra low quiescent current of 12μA provides excellent efficiency, up to 94%. In addition to the main switch, a 0.3Ω internal MOSFET the SP6648 has an internal synchronous rectifier, increasing efficiency and reducing the space requirements of an external diode. An internal inductive-damping switch significantly reduces inductive ringing for low-noise, high efficiency operation. If the supply voltage drops below 0.61V the SP6648 goes into under voltage lock-out mode, thus opening both internal switches. An externally programmable low battery detector with open drain output provides the ability to flag a battery-low condition. The inductor peak current is externally programmable to allow for a range of inductor values.

Control Scheme

A minimum off-time, current limited pulse frequency modulation (PFM) control scheme combines the high output power and efficiency of a pulse width modulation (PWM) device with the ultra low quiescent current of the traditional PFM. At low to moderate output loads, the PFM control provides higher efficiency than traditional PWM converters are capable of delivering. At these loads, the switching frequency is determined by a minimum off-time ($t_{OFF,\ MIN}$) and a maximum on-time ($t_{ON,\ MAX}$) where:

$$t_{OFF} \geq K_{OFF} / (V_{OUT} - V_{BATT}) \text{ and}$$
$$t_{ON} \leq K_{ON} / V_{BATT} \text{ with}$$
$$K_{OFF} = 1.0V\mu s \text{ and}$$
$$K_{ON} = 4.0V\mu s.$$

At light loads (as shown in plot A in *Figure 1*) the charge cycle will last the maximum value for t_{ON}: For a 1V battery this would be as follows:

$t_{ON} = K_{ON} / V_{BATT} = 4.0V\mu s / 1V = 4.0\mu s$

The current built up in the coil during the charge cycle gets fully discharged in the discontinuous conduction mode (DCM). When the current in the coil has reached zero, the synchronous rectifier switch is opened and the voltage across the coil (from V_{BATT} to LX) is shorted internally to eliminate inductive ringing.

With increasing load (as shown in plot B in *Figure 1*) this inductor damping time becomes shorter, because the output will quickly drop below its regulation point due to heavier load. If the load current increases further, the SP6648 enters continuous conduction mode (CCM) where there is always current flowing in the inductor. The charge time remains at maximum t_{ON} as long as the inductor peak current limit is not reached as shown in plot C in *Figure 1*. The inductor peak current limit can be programmed by tying a resistor R_{LIM} from the R_{LIM} pin to ground where:

$$\mathbf{I_{PEAK} = 1600 / R_{LIM}}$$

When the peak current limit is reached the charge time is short-cycled.

In plot D of *Figure 1*, the switch current reaches the peak current limit during the charge period

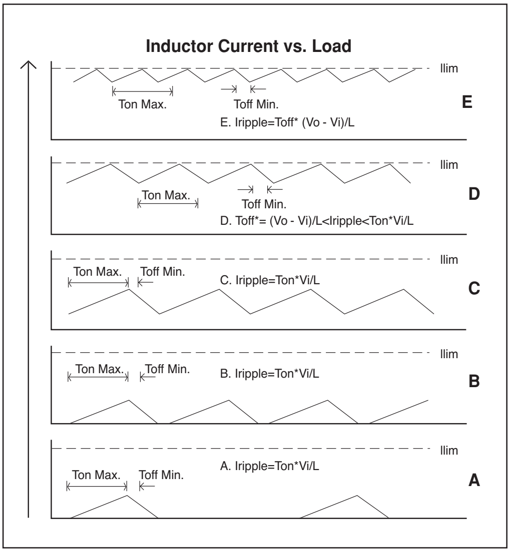
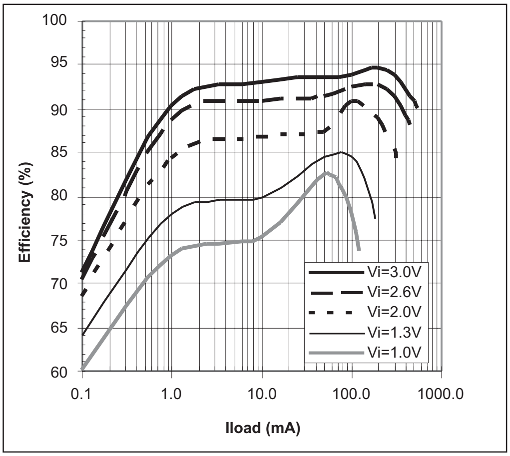


Figure 1. Inductor Current vs. Load

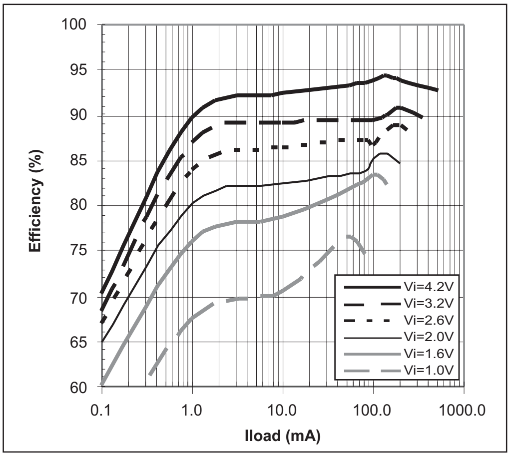
which ends the charge cycle and starts the discharge cycle. However, full load is not yet achieved because at the end of the minimum discharge time the output was still within regulation.

Maximum load is reached when this discharge time has shrunk to the minimum allowed value T_{OFF} as shown in Plot E of *Figure 1*.

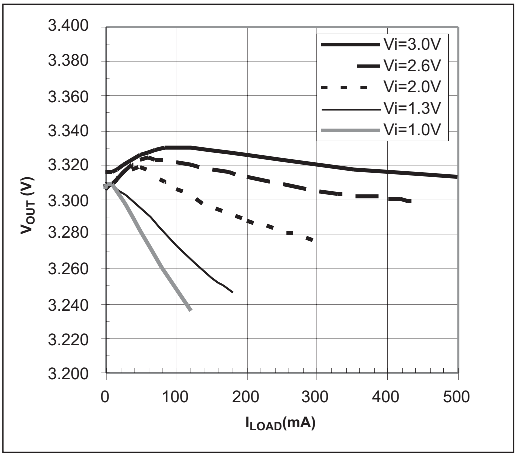
Refer to the Typical Application Circuit on page 1, T_{AMB}=+25°C.



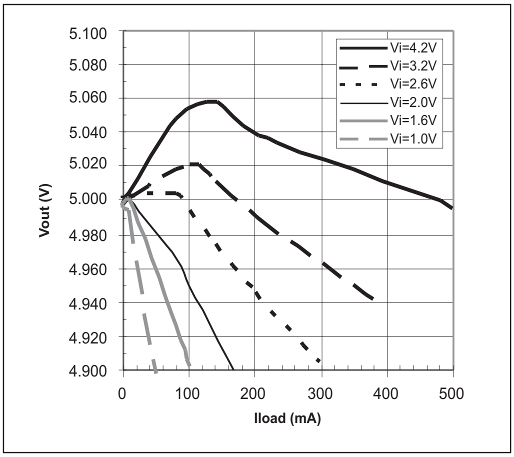
Efficiency vs. Load Current, V_{OUT}=3.3V



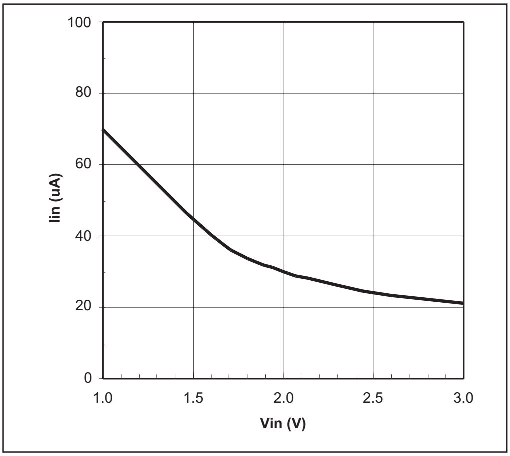
Efficiency vs. Current Load, V_{OUT}=5.0V



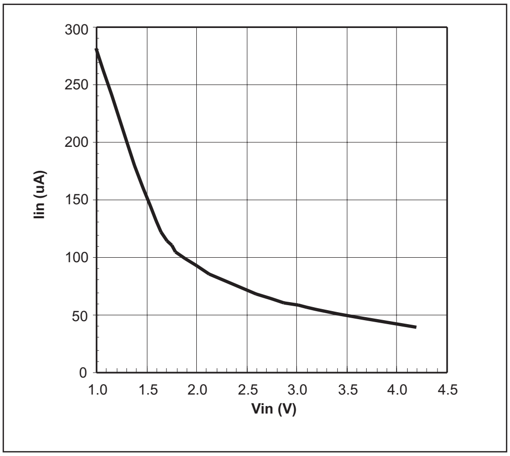
Line/Load Rejection vs. Load Current, V_{OUT} = 3.3V



Line/Load Rejection vs. Load Current, V_{OUT} = 5.0V

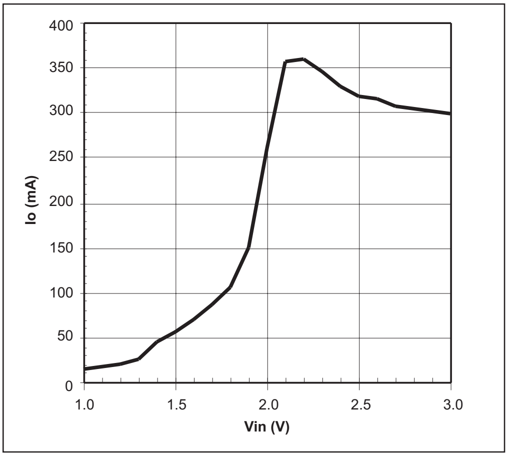


No Load Battery Current, V_{OUT}=3.3V

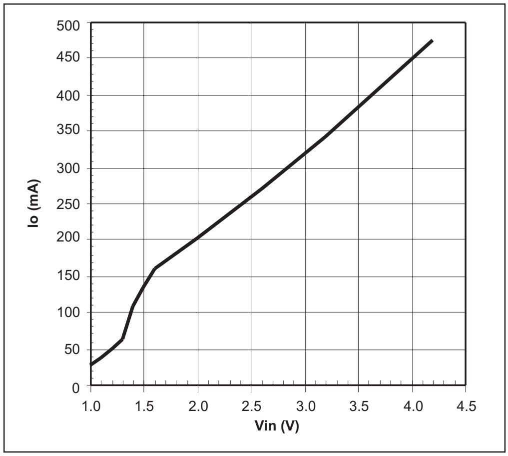


No Load Battery Current, V_{OUT}=5.0V

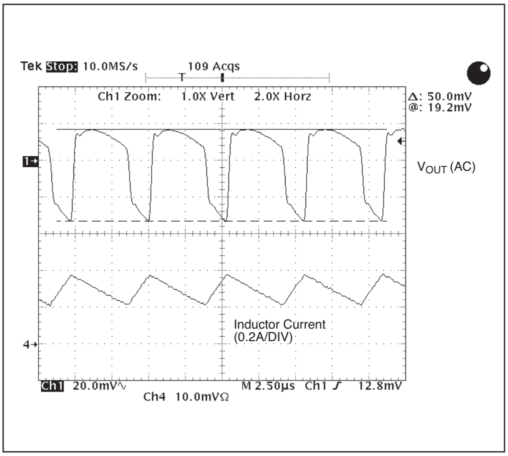
Refer to the Typical Application Circuit on page 1, T_{AMB}=+25°C.



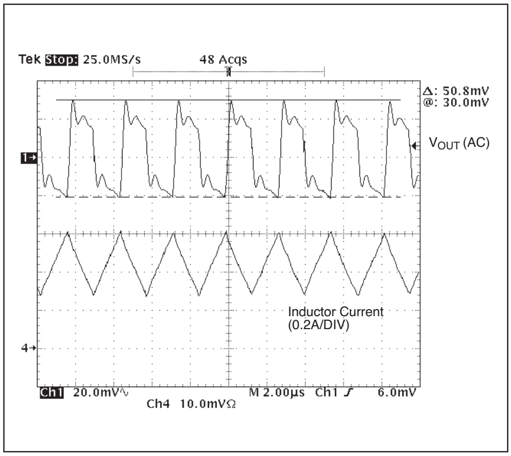
Maximum Resistive Load Current in Startup, V_{OUT}=3.3V



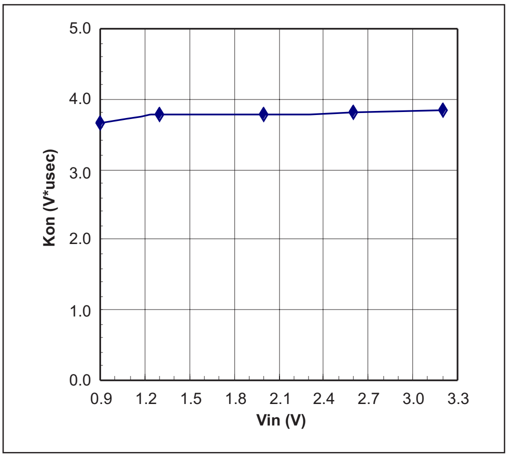
Maximum Resistive Load Current in Startup, V_{OUT}=5.0V



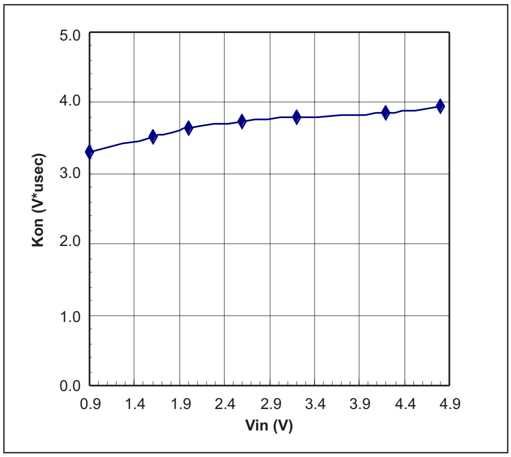
Output Ripple, V_{IN}=2.6V, I_{LOAD}=200mA, V_{OUT}=3.3V



Output Ripple, V_{IN}=2.6V, I_{LOAD}=200mA, V_{OUT}=5.0V

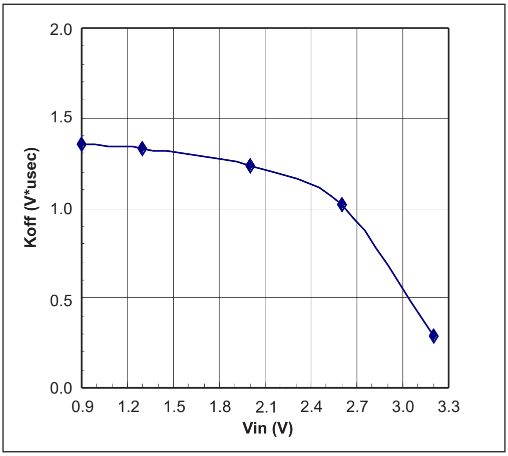


K_{ON} vs. V_{IN}, V_{OUT}=3.3V

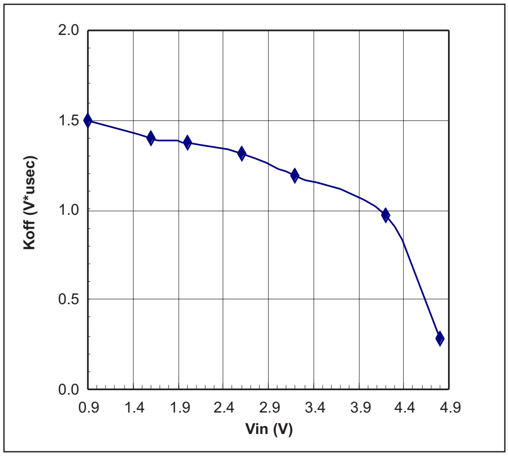


K_{ON} vs. V_{IN}, V_{OUT}=5.0V

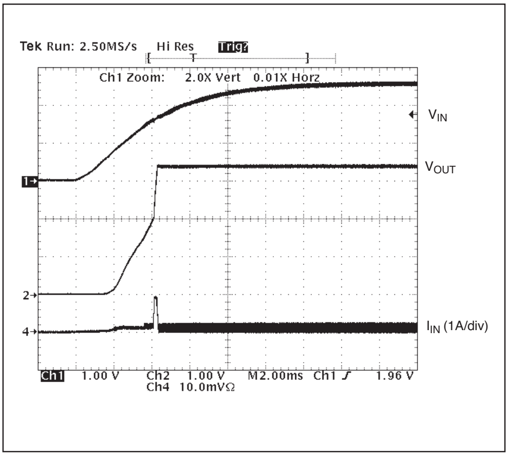
Refer to the Typical Application Circuit on page 1, T_{AMB}=+25°C.



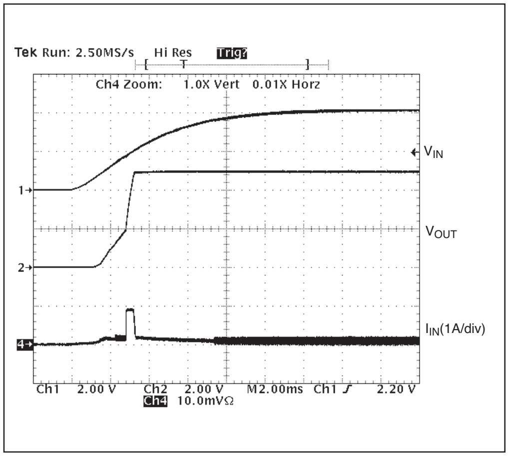
K_{OFF} vs. V_{IN}, V_{OUT}=3.3V



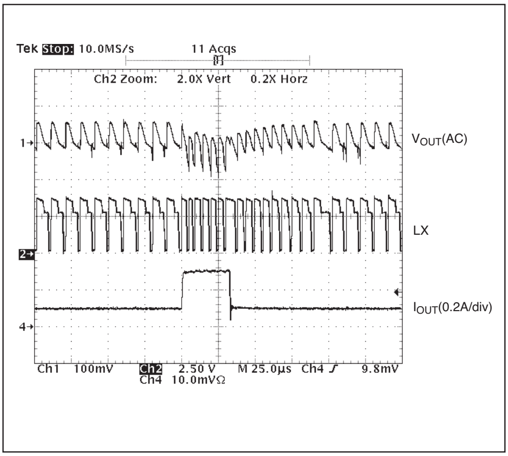
K_{OFF} vs. V_{IN}, V_{OUT}=5.0V



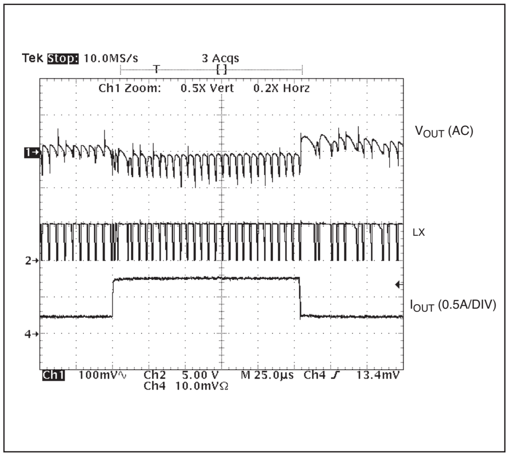
Startup, V_{IN}=2.6V, V_{OUT}=3.3V, R_{LOAD} = 100Ω



Startup, V_{IN}=4.2V, V_{OUT}=5.0V, R_{LOAD} = 100Ω



Load Step, 0.1A to 0.3A, V_{IN} = 2.6V, V_{OUT} = 3.3V



Load Step, 0.3A to 0.5A, V_{IN} = 4.2V, V_{OUT} = 5.0V

Circuit Layout

Printed circuit board layout is a critical part of a power supply design. Poor designs can result in excessive EMI on the feedback paths and on the ground planes with applications involving high switching frequencies and large peak currents. Excessive EMI can result in instability or regulation errors. All power components should be placed on the PC board as closely as possible with the traces kept short, direct, and wide (>50mils or 1.25mm). Extra copper on the PC board should be integrated into ground as a pseudo-ground plane. On a multilayer PC board, route the star ground using component-side copper fill, then connect it to the internal ground plane using vias. For the SP6648 devices, the inductor and input- and output-filter capacitors should be soldered with their ground pins as close together as possible in a star-ground configuration. The V_{OUT} pin must be bypassed directly to ground as close to the SP6648 devices as possible (within 0.2in or 5mm). The DC-DC converter and any digital circuitry should be placed on the opposite corner of the PC board as far away from sensitive RF and analog input stages. Noisy traces, such as from the LX pin, should be kept away from the voltage-feedback V_{OUT} node and separated from it using grounded copper to minimize EMI. See the SP6648EB Evaluation Board Manual for PC Board Layout design details.

Component Selection

Selection of capacitors for SP6648 power supply circuits can be made through the use of the Component Selection Table. Capacitor equivalent series resistance (ESR) in the range of 0.2Ω to 0.3Ω is a requirement for obtaining sufficient output voltage ripple for the SP6648 to properly regulate under load. For ESR values in this range, low ESR tantalum capacitors are recommended. For example, in the SP6648 application circuit a 47µF, 10V, low-ESR, surface-mount tantalum output filter capacitor typically provides 50mV output ripple when stepping up from 2.6V to 3.3V at 200mA. Ceramic capacitors have ESR too low to produce enough output ripple for the SP6648 to regulate the output. Designers should select input and output capacitors with a rating exceeding the inductor current ripple, which is typically set by the inductor value and the K_{ON} value as given in the following relationship:

$$I_{L(RIPPLE)} = K_{ON}/L$$

For the example of the 10µH inductor the inductor current ripple would be 330mA, while for the 22µH inductor the inductor current ripple value would be 150mA. Do not allow tantalum capacitors to exceed their ripple-current ratings. An input filter capacitor can reduce peak currents drawn from the battery and improve efficiency. For most applications, use the same 47µF tantalum capacitor as used for the input. Low-ESR aluminum electrolytic capacitors are acceptable, provided they meet the ESR requirement of 0.2Ω to 0.3Ω, and we list an appropriate 100µF aluminum electrolytic in the component selection table, but standard aluminum electrolytic capacitors are not recommended.

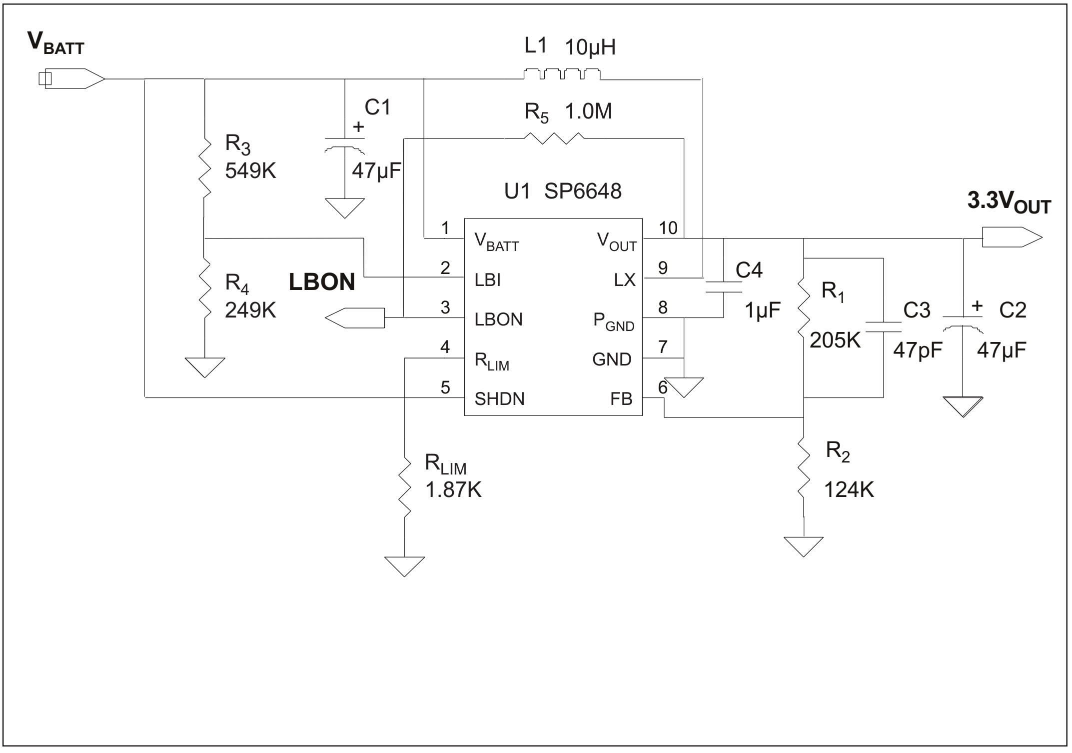
In selecting an inductor, the saturation current specified for the inductor needs to be greater than the SP6648 peak current to avoid saturating the inductor, which would result in a loss in efficiency and could damage the inductor. The SP6648 evaluation board uses a Sumida CDRH5D28 10µH inductor with an I_{SAT} value of 1.3A and a DCR of 0.065Ω, which easily handles the I_{PEAK} of 0.85A of the SP6648 and will deliver high efficiencies. Other inductors could be selected provided their I_{SAT} is greater than the I_{PEAK} of the SP6648.

INDUCTORS - SURFACE MOUNT						
		Inductor Specification				
Inductance (μH)	Manufacturer/Part No.	Series R Ω	I_{SAT} (A)	Size LxWxH (mm)	Intuctor Type	Manufacturer Website
10	**Sumida CDRH5D28-100**	**0.065**	**1.30**	**5.7x5.5x3.0**	**Shielded Ferrite Core**	www.sumida.com
10	TDK RLF5018T-100MR94	0.067	0.94	5.6x5.2x2.0	Shielded Ferrite Core	www.tdk.com
10	Sumida CD43-100	0.180	1.04	4.0x4.5x3.5	Unshielded Ferrite Core	www.sumida.com
22	Sumida CDRH5D28-220	0.122	0.90	5.7x5.5x3	Shileded Ferrite Core	www.sumida.com
22	TDK RLF5018T-220MR63	0.067	0.63	5.6x5.2x2.0	Shielded Ferrite Core	www.tdk.com
22	Sumida CD43-220	0.378	0.68	4.0x4.5x3.5	Unshielded Ferrite Core	www.sumida.com

CAPACITORS - SURFACE MOUNT & LEADED							
		Capacitor Specification					
Capacitance (μF)	Manufacturer Part No.	ESR Ω(max)	Ripple Current (A) @ 85°C	Size LxWxH (mm)	Voltage (V)	Capacitor Type	Manufacturer Website
47	**Kemet T494C476K010AS**	**0.300**	**1.06**	**6.0x3.2x2.5**	**10**	**SMT Tantalum**	www.kemet.com
47	Kemet T494V476K010AS	0.300	0.99	7.3x4.3x2.0	10	SMT Tantalum	www.kemet.com
100	Sanyo 25MV100AX	0.220	0.30	6.3DX11L	25	Radial Al Electrolytic	www.sanyovideo.com

Note: Components highlighted in **bold** are those used on the SP6648EB Evaluation Board.

Component Selection Table



SP6648EB Evaluation Board Schematic

V_{OUT} Programming

The SP6648 can be programmed as either a voltage source or a current source. To program the SP6648 as a voltage source, the SP6648 requires 2 feedback resistors R1 & R2, as shown in the SP6648EB evaluation board schematic, to control the output voltage. To set V_{OUT} in the voltage mode, use the equation:

$$R1 = [(V_{OUT}/1.25)-1] * R2$$

Using the R_{LIM} Function

The peak inductor current, I_{PEAK}, is programmed externally by the R_{LIM} resistor connected between the R_{LIM} pin and GND. The peak inductor current is defined by:

$$I_{PEAK} = 1600/R_{LIM}$$

The saturation current specified for the inductor needs to be greater than the peak current to avoid saturating the inductor, which would result in a loss in efficiency and could damage the inductor. The SP6648 evaluation board uses a R_{LIM} value of 1.87K for an I_{PEAK} = 850mA to allow the circuit to deliver up to 180mA for 1.3V input and 400mA for 2.6V input. Other values could be selected using the above relationships.

Using the LBON - Low Battery Output Function

The SP6648 will regulate the output until the input battery is completely discharged or until the under voltage lock-out (UVLO) occurs at V_{BATT} = 0.61V. To provide a low battery warning, the Low Battery Output function of the SP6648 can be used. LBON is programmed externally by the R_3 and R_4 resistor divider connected between V_{BATT}, the LBI input pin and GND. The LBON is an open drain output, which is active low and is pulled up by a 1MΩ resistor R_5 to V_{OUT}. When the LBI comparator falling threshold of 0.61V is reached, the LBON output goes low as determined by the relationship:

$$V_{LOWBATT} = 0.61 * [(R_3 + R_4)/R_4]$$

The SP6648 evaluation board R_3 & R_4 resistors have been set to trip for a falling battery threshold of about 2.0V. Using this relationship, other low battery threshold values can be set by the user.

UVLO the Under Voltage Lock-Out Function

Once started up, the SP6648 will regulate the output until the input battery is completely discharged or until the under voltage lock-out (UVLO) occurs at V_{BATT} = 0.61V. The UVLO function will completely open all switches until the battery again rises above the 0.61V threshold.

Maximum Startup Current

It should be noted that for low input voltages the SP6648 startup circuit cannot support large load currents at startup. In startup the SP6648 needs to boost the output from zero volts using the input voltage. Once the output is greater than 1.9V, the operating circuit takes over and the SP6648 can supply much more current. Curves of maximum load current in startup for the SP6648 are shown in the typical performance characteristics and can be compared with the page one curve for maximum load current in operation.

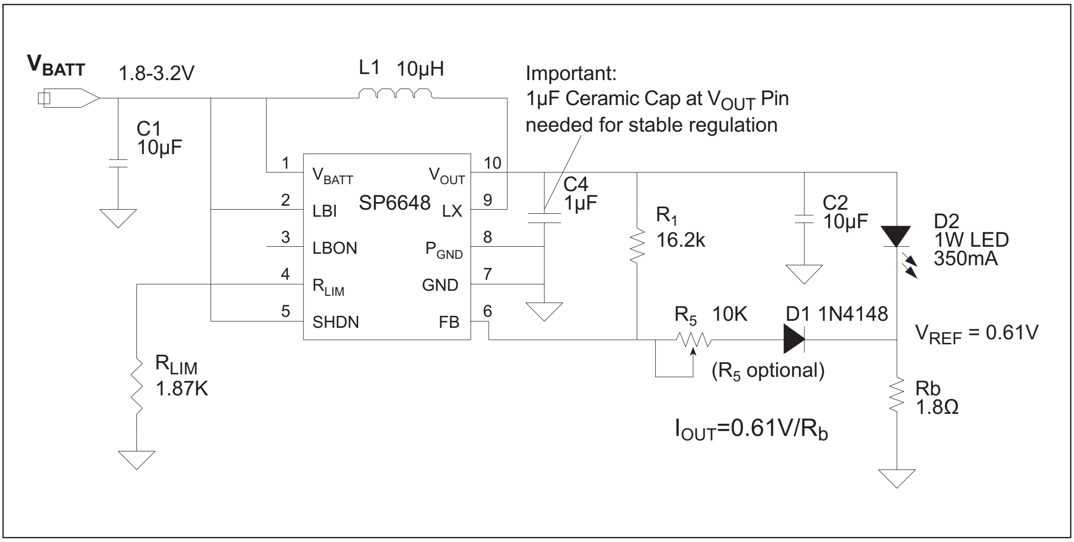
For 1-cell battery applications, it is recommended to apply any large load current after the SP6648 has started up, typically in a few milliseconds. This is typically not a problem in many applications where the load is a processor whose load current is low until the processor voltage comes up.

SP6648LEDEB Evaluation Board with LumiLED High Brightness White LED

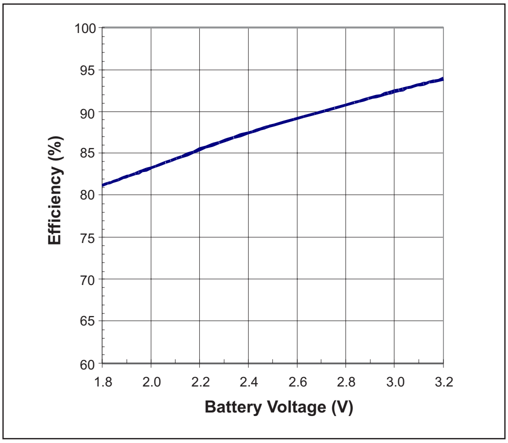
For the high brightness LumiLED white LED application, the SP6648 is generally programmed as a current source. The bias resistor R_b is used to set the operating current of the white LED in the equation:

$R_b = V_{REF}/I_F$

where V_{REF} is around 0.61V, I_F is the operating current of the LumiLED. To set the operating current to be about 350mA, R_b is selected as 1.8 Ω as shown in the following schematic. The efficiency of the SP6648 LumiLED circuit is improved by the use of a silicon diode D1 and resistor R_1 to set the voltage at the current sense resistor R_2 to 0.61V instead of the higher 1.25V at the FB pin. An efficiency curve follows showing the SP6648 efficiency driving 350mA output current into the high brightness LumiLED.

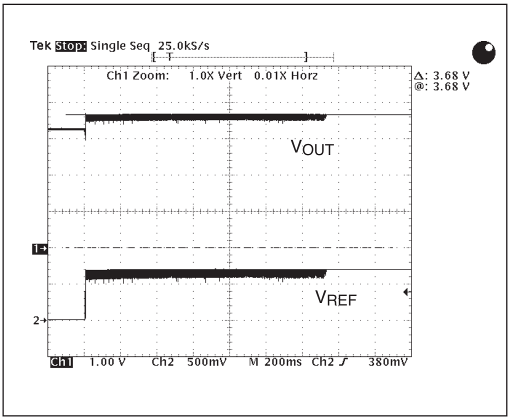


SP6648LEDEB Evaluation Board Schematic

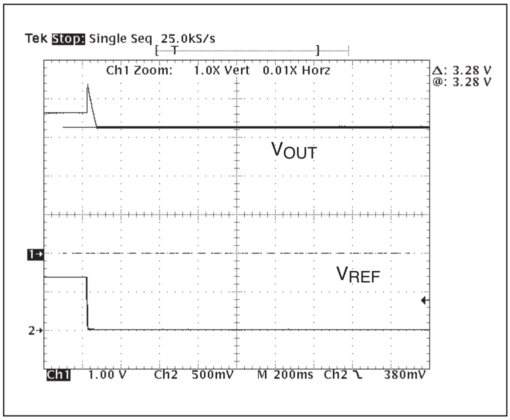


SP6648LEDEB Efficiency Curve

As shown in following scope photos, if the SP6648 is powered up before the LumiLED is plugged in, the circuit will bring the Feedback pin to 0.0V and the SP6648 has a feature to set the output voltage to be 3.3V. Once the LumiLED is plugged in, the Feedback pin will go up to 1.25V and begin to regulate. The output voltage will go from 3.3V to 3.68V (=V_F+0.61V), where V_F is the forward voltage of the LumiLED. When the LumiLED is open, the Feedback pin voltage will go to 0.0V and the output voltage will go to 3.3V which will protect the part.



Plug in the LumiLED

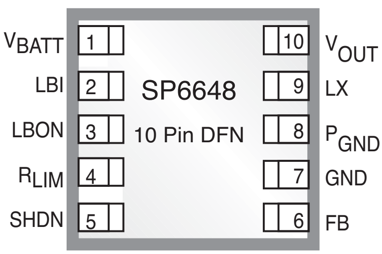


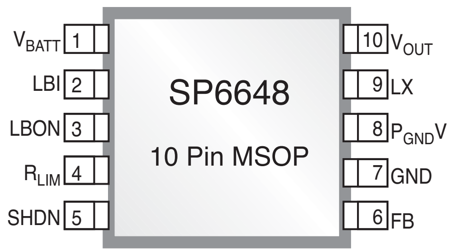
Unplug the LumiLED

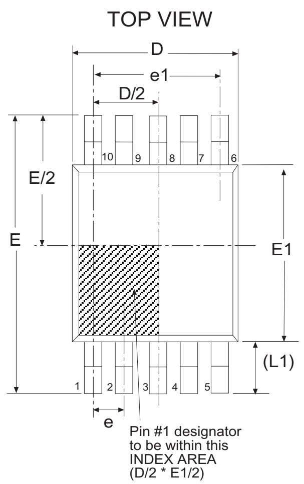
Brightness Control

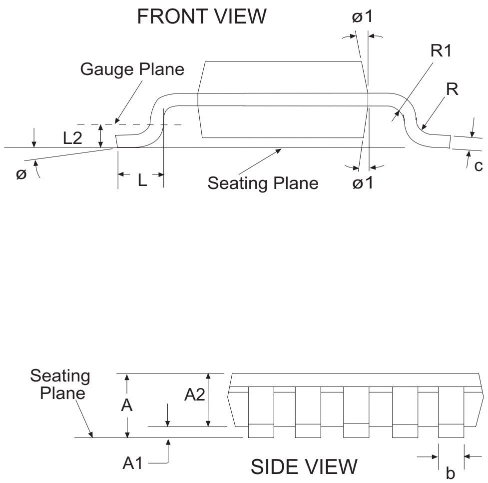
One approach to control LED brightness is to apply a PWM signal to the SHDN input of the SP6648. In this case, the output current will be equal to the product of 350mA and the average duty cycle at the SHDN pin. An optional 10KΩ potentiometer (R_5) may also be used for dimming the LED current by varying the potentiometer between low brightness and full brightness.

PINOUTS

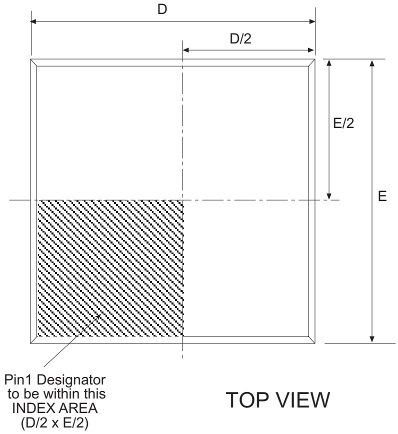




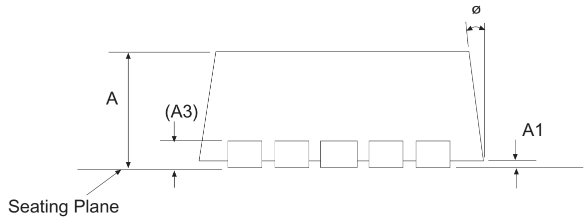




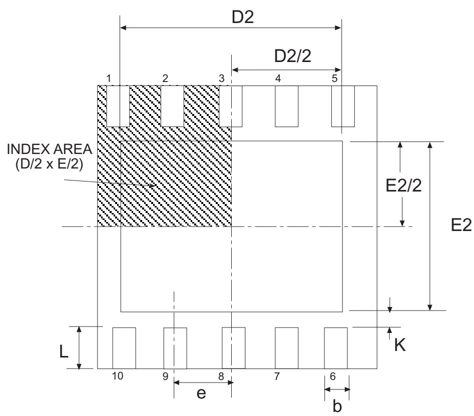
10 Pin MSOP JEDEC MO-187 Variation BA						
SYMBOL	Dimensions in Millimeters: Controlling Dimension			Dimensions in Inches Conversion Factor: 1 Inch = 25.40 mm		
	MIN	NOM	MAX	MIN	NOM	MAX
A1	0.00	-	0.15	0.000	-	0.006
c	0.08	-	0.23	0.004	-	0.009
R	0.07	-	-	0.003	-	-
R1	0.07	-	-	0.003	-	-
ø	0º	-	8º	0º	-	8º
ø1	5º	-	15º	5º	-	15º
A	-	-	1.10	-		0.043
A2	0.75	0.85	0.95	0.030	0.034	0.038
b	0.17	-	0.33	0.007	-	0.013
D	3.00 BSC			0.118 BSC		
E	4.90 BSC			0.193 BSC		
E1	3.00 BSC			0.118 BSC		
e	0.50 BSC			0.020 BSC		
e1	2.00 BSC			0.079 BSC		
L	0.40	0.60	0.80	0.016	0.024	0.032
L1	0.95 REF			0.037 REF		
L2	0.25 BSC			0.010 BSC		
SIPEX Pkg Signoff Date/Rev:				JL Aug09-05 RevA		



TOP VIEW



SIDE VIEW



BOTTOM VIEW

3x3 10 Pin DFN	JEDEC MO-229		VARIATION VEED-5			
SYMBOL	Dimensions in Millimeters: Controlling Dimension			Dimensions in Inches Conversion Factor: 1 Inch = 25.40 mm		
	MIN	NOM	MAX	MIN	NOM	MAX
A	0.80	0.90	1.00	0.032	0.036	0.039
A1	0.00	0.02	0.05	0.000	0.001	0.002
A3	0.20 REF			0.008 REF		
K	0.20	-	-	0.008	-	-
ø	0º	-	14º	0º	-	14º
b	0.18	0.25	0.30	0.008	0.010	0.012
D	3.00 BSC			0.119 BSC		
D2	2.20	-	2.70	0.087	-	0.106
E	3.00 BSC			0.119 BSC		
E2	1.40	-	1.75	0.056	-	0.069
e	0.50 BSC			0.020 BSC		
L	0.30	0.40	0.50	0.012	0.016	0.020
SIPEX Pkg Signoff Date/Rev:				JL Aug09-05 / RevA		

Part Number	Top Mark	Operating Temperature Range	Package Type
SP6648EU	SP6648EU	-40°C to +85°C	10 Pin MSOP
SP6648EU/TR	SP6648EU	-40°C to +85°C	10 Pin MSOP
SP6648ER	SP6648ERYWW	-40°C to +85°C	10 Pin DFN
SP6648ER/TR	SP6648ERYWW	-40°C to +85°C	10 Pin DFN

Available in lead free packaging. To order add "-L" suffix to part number.

Example: SP6648EU/TR = standard; SP6648EU-L/TR = lead free

/TR = Tape and Reel

Pack quantity is 2,500 for MSOP and 3,000 for DFN.

Sipex Corporation

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233 South Hillview Drive
Milpitas, CA 95035
TEL: (408) 934-7500
FAX: (408) 935-7600

For further assistance:

Email:	Sipexsupport@sipex.com
WWW Support page:	http://www.sipex.com/content.aspx?p=support
Sipex Application Notes:	http://www.sipex.com/applicationNotes.aspx
Product Change Notices:	http://www.sipex.com/content.aspx?p=pcn

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faX: (408) 935-7600

The following sections contain information which is mo changeable in nature and is therefore generated as appendices.

1) **Package Outline Drawings**
2) **Ordering Information**

If Available:

3) **Frequently Asked Questions**
4) **Evaluation Board Manuals**
5) **Reliability Reports**
6) **Product Characterization Reports**
7) **Application Notes for this product**
8) **Design Solutions for this product**

Power Management

- Boost Regulators
- Buck Regulators
- Charge Pumps
- LED Drivers
- Linear Regulators
- Power Blox™
- PWM Controllers
- References
- Supervisors
- USB Vbus Switches

Interface

- Multiprotocol
- RS232
- RS422
- RS485
- USB

Optical Storage

- Advanced Power Control
- Photo Detector IC

Ultra-low Quiescent Current, High Efficiency Boost Regulator

Features

- Ultra-low 12μA Quiescent Current
- 400mA Output Current at 2.6V Input: 3.3VOUT
- 94% Efficiency from 2 cell to 3.3VOUT
- Wide Input Voltage Range: 0.95V to 4.5V
- 3.3V Fixed or Adjustable Output
- Integrated Synchronous Rectifier: 0.3Ω
- 0.3Ω Switch
- Anti-Ringing Switch Technology
- Programmable Inductor Peak Current
- Logic Shutdown Control
- Under Voltage Lock-Out at 0.61V
- Programmable Low Battery Detect
- Single or Dual Cell Alkaline
- Small 10 pin DFN Package and Industry Standard 10 pin MSOP

Fixed 3.3V

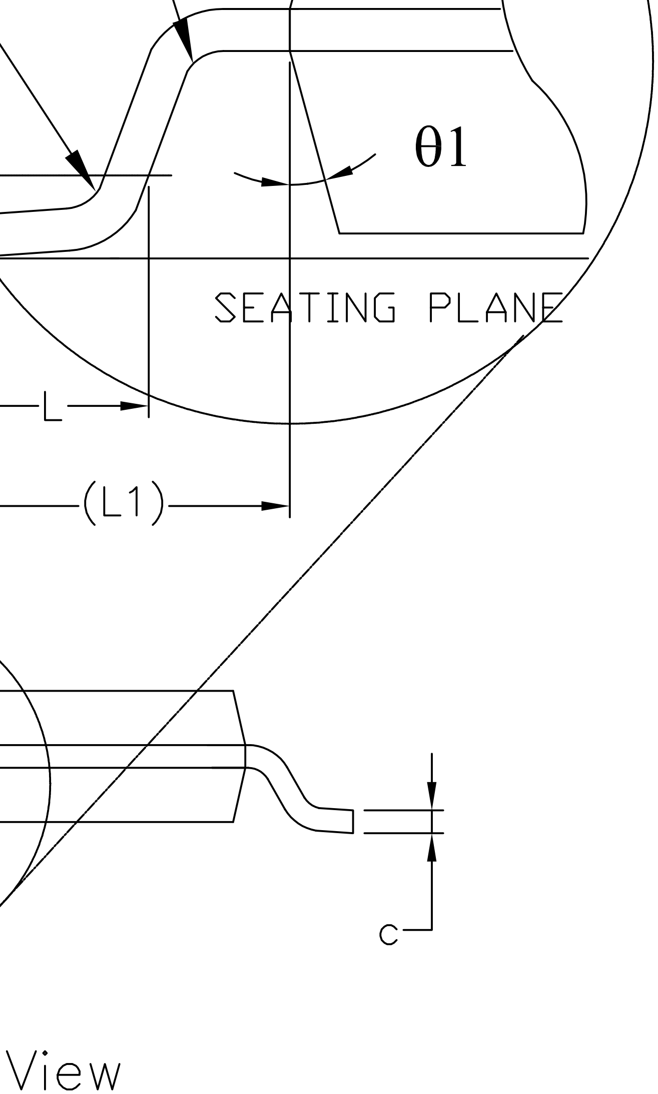
Ordering Part Number

Part Number	Package Code	RoHS	MIN. Temp. (°C)	MAX. Temp. (°C)	Status	Buy
SP**6648**ER-L	DFN10	▪	-40	85	Active	Buy Now
SP**6648**ER-L/TR	DFN10	▪	-40	85	Active	Buy Now
SP**6648**EU-L	MSOP10	▪	-40	85	Active	Buy Now
SP**6648**EU-L/TR	MSOP10	▪	-40	85	Active	Buy Now
BOOST REGULATOR SP**6648**						
SP**6648**EB	Board		0	70	Active	Buy Now
SP**6648**LEDEB	Board		0	70	Active	Buy Now
SP**6648**UEB	Board		0	70	Active	Buy Now
SP**6648**ER	DFN10		-40	85	EOL	Buy Now
SP**6648**ER/TR	DFN10		-40	85	EOL	Buy Now
SP**6648**EU	MSOP10		-40	85	EOL	Buy Now
SP**6648**EU/TR	MSOP10		-40	85	EOL	Buy Now

Part Status Legend

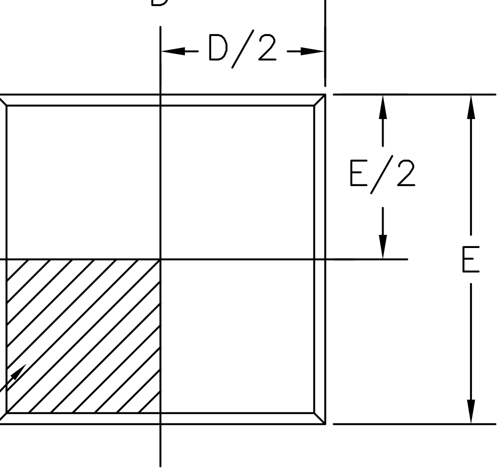
Active - the part is released for sale, standard product.

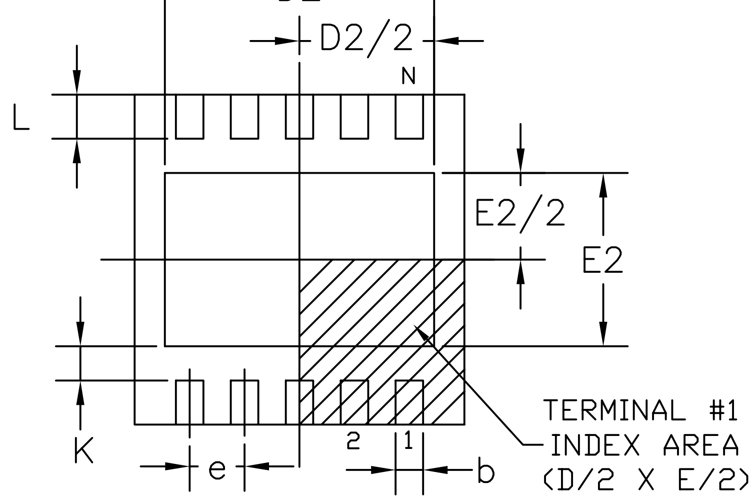
EOL (End of Life) - the part is no longer being manufactured, there may or may not be inventory still in stock.

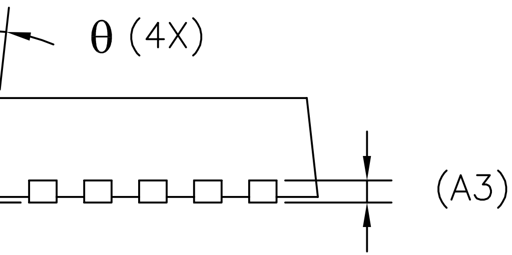


c	0.08	—	0.23	0.003	—	0.009
E	4.90 BSC			0.193 BSC		
E1	3.00 BSC			0.118 BSC		
e	0.50 BSC			0.020 BSC		
e1	2.00 BSC			0.079 BSC		
L	0.40	0.60	0.80	0.016	0.024	0.031
L1	0.95 REF			0.037 REF		
L2	0.25 BSC			0.010 BSC		
R	0.07	—	—	0.003	—	—
R1	0.07	—	—	0.003	—	—
θ	0°	—	8°	0°	—	8°
θ1	5°	—	15°	5°	—	15°
D	3.00 BSC			0.118 BSC		
N	10			10		

Solved by Sipex™	SIPEX CORPORATION
	10 PIN MSOP PACKAGE OUTLINE
Packaging Approval:	Drawing No: 10–PIN MSOP
By: JL · Date: 07/19/06	Revision: B · Sheet: 1 OF 1





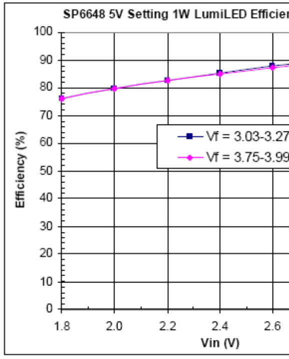


10LD 3x3 DFN JEDEC MO-229 Variation VEED-5						
SYMBOLS	DIMENSIONS IN MM (Control Unit)			DIMENSIONS IN INCH (Reference Unit)		
	MIN	NOM	MAX	MIN	NOM	MAX
A	0.80	0.90	1.00	0.032	0.036	0.039
A1	0.00	0.02	0.05	0.000	0.001	0.002
A3	0.20 REF			0.008 REF		
b	0.18	0.25	0.30	0.007	0.010	0.012
D	3.00 BSC			0.118 BSC		
D2	2.20	—	2.70	0.087	—	0.106
E	3.00 BSC			0.118 BSC		
E2	1.40	—	1.75	0.056	—	0.069
e	0.50 BSC			0.020 BSC		
L	0.30	0.40	0.50	0.012	0.016	0.020
K	0.20	—	—	0.008	—	—
θ	0°	—	14°	0°	—	14°
N	10			10		
ND	5			5		

Solved by Sipex	SIPEX CORPORATION
	10 PIN 3x3 DFN PACKAGE OUTLINE
Packaging Approval:	Drawing No: 10-PIN 3x3 DFN
By: JL Date: 07/10/06	Revision: B Sheet: 1 OF 1

FEATURES

- 1.8V → 3.2V Input range
- Regulated 350mA output current
- Highly integrated design, minimal components
- On chip synchronous power switches
- Small 3x3mm 10 Pin DFN package
- High efficiency: Greater than 90%
- Constant brightness over full battery range
- Uses 2 cell Alkaline, NiCAD or NiMH battery
- Also works for Lithium camera battery

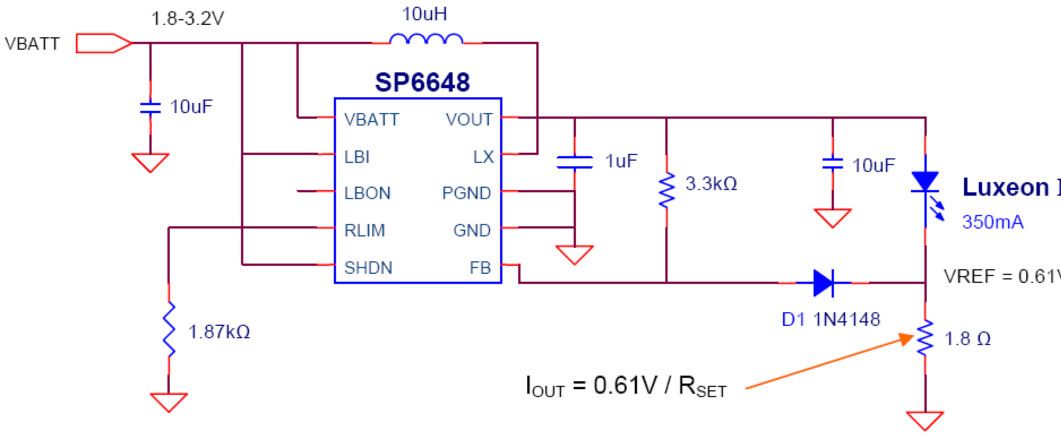


Efficiency over ful voltage rang

Introduction

The SP6648 integrated synchronous boost regulator is a compact circuit that provides a ultra-high efficiency drive current for an LED flashlight using a Luxeon™ I light source. The circuit shown below is configured to provide 350mA constant output current for a two cell alkaline battery application. All components are compact surface mount devices, yielding a tiny final solution.

Diode D1 has been added to reduce the effective feedback voltage from 1.25V down to 0.61V improve efficiency. The LED current can be programmed as high as 900mA depending on the resistor value. Operating quiescent current of the part is only 12uA, so only a negligible amour power is used by the part itself. The SP6648 is available in MSOP for easy pin access in proto type and testing, and also 3x3mm DFN for the smallest production circuit.



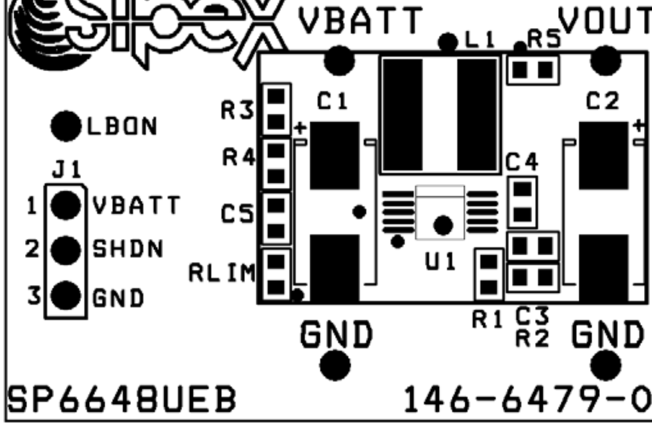
Application Schematic

For further assistance:

Email:	Sipexsupport@sipex.com
WWW Support page:	http://www.sipex.com/content.aspx?p=support
Live Technical Chat:	http://www.geolink-group.com/sipex/
Sipex Application Notes:	http://www.sipex.com/applicationNotes.aspx

Sipex Corporation
Headquarters and
Sales Office
233 South Hillview Drive
Milpitas, CA95035
tel: (408) 934-7500
faX: (408) 935-7600

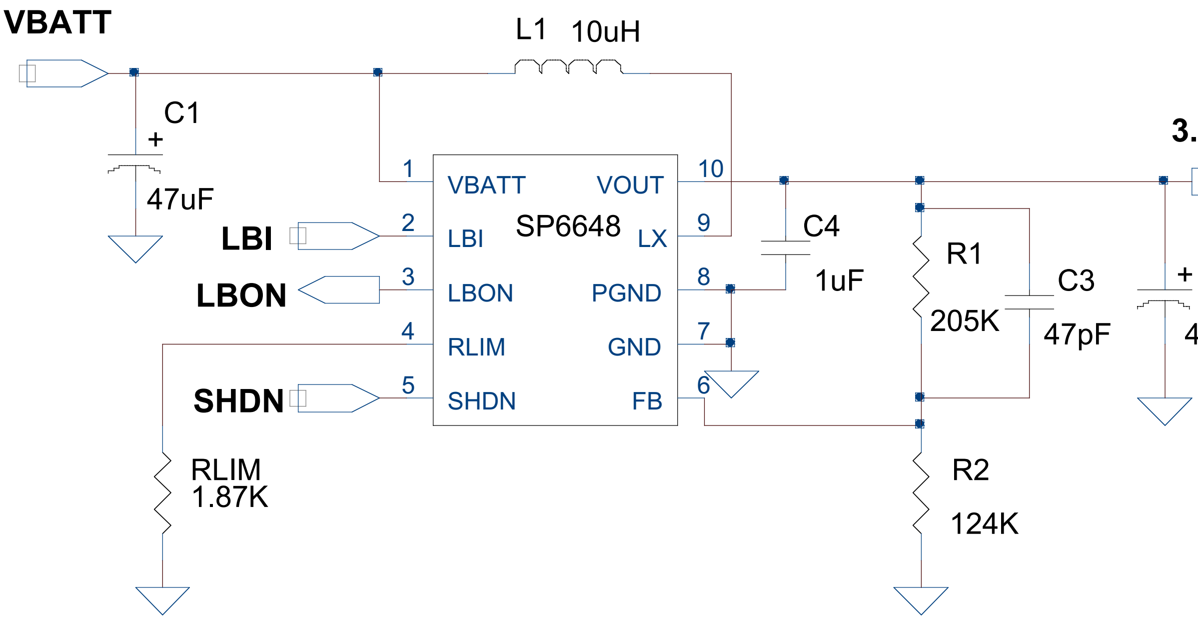
- Easy Evaluation for the SP6648 Single or Dual Cell Alkaline to 2V to 5V Output
- Provides 300mA output at 3.3V output for 2.0V Input
- High Efficiency: 94%
- µSOIC Package & SMT components for small, low profile Power Supply



DESCRIPTION

The **SP6648 Evaluation Board** is designed to help the user evaluate the performanc SP6648 for use as a single or dual cell input to +3.3V output DC-DC Converter. The o the SP6648 is preset to +3.3V or can be adjusted from +2V to +5.5V by manipulating t external resistors. The evaluation board is a completely assembled and tested surfac board which provides easy probe access points to all SP6648 Inputs and Outputs so t user can quickly connect and measure electrical characteristics and waveforms.

SP6648 EVALUATION BOARD SCHEMATIC



The SP6648 output will be Enabled if the J1 Jumper is in the top or pin 1 to 2 position. in the pin 2 to 3 position, the Shutdown pin is brought to GND, which puts the SP6648 quiescent Shutdown Mode.

3) Using the Rlim Function

The peak inductor current, $\mathbf{I_{PEAK}}$, is programmed externally by the RLIM resistor conne between the RLIM pin and GND. The peak inductor current is defined by:

$$\mathbf{I_{PEAK} = 1400/R_{LIM}}$$

The SP6648 datasheet specifications for RLIM give a range of 1750 to 4000 ohms. U IPEAK equation above gives an IPEAK range of

$\mathbf{I_{PEAK}}$ range = 350 to 800mA.

The saturation current specified for the inductor needs to be greater then the peak cur avoid saturating the inductor, which would result in a loss in efficiency and could dama inductor. The SP6648 evaluation board uses a Rlim value of 1.87K for an Ipeak = 750 allow the circuit to deliver up to 180mA for 1.3V input and 400mA for 2.6V input. Othe could be selected using the above relationships.

4) Using the LBON - Low Battery Output Function

The Low Battery Output function, LBON, is programmed externally by the R3 and R4 r divider connected between Vbatt, the LBI input pin and GND. The LBON is an open d output, which is active low and is pulled up by a 1M resistor R5 to Vout. When the LB comparator falling threshold of 0.625V is reached, the LBON output goes low as deter the relationship:

LBON falling = Vbatt*R4/(R3 +R4)

The SP6648 evaluation board R3 & R4 resistors have been set to trip for a falling batt threshold of about 2.0V. Using this relationship, other low battery threshold values ca by the user.

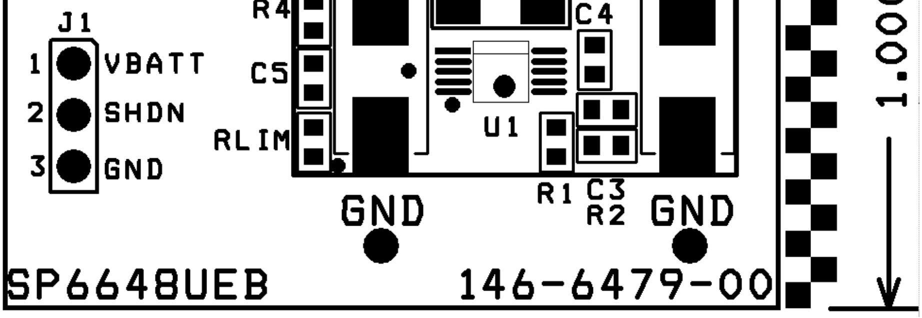


FIGURE 1: SP6648UEB COMPONENT PLACEMENT

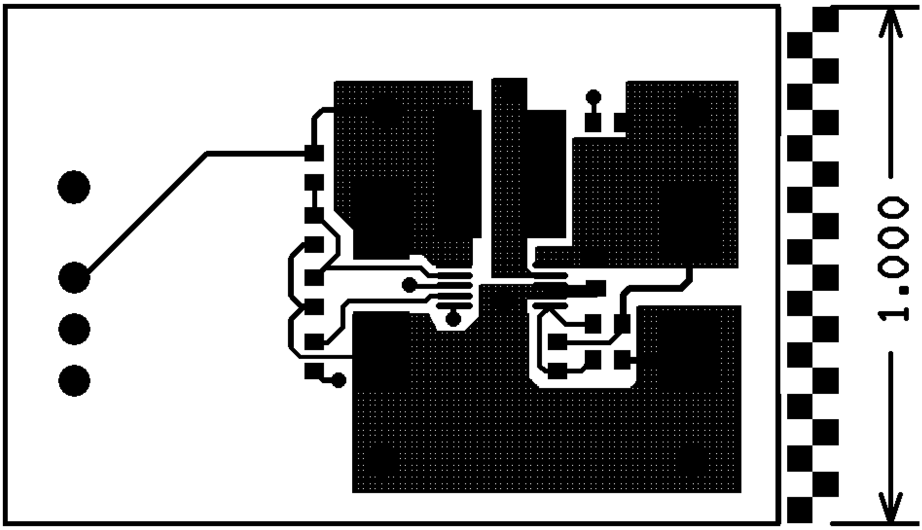


FIGURE 2: SP6648UEB PC LAYOUT TOP SIDE

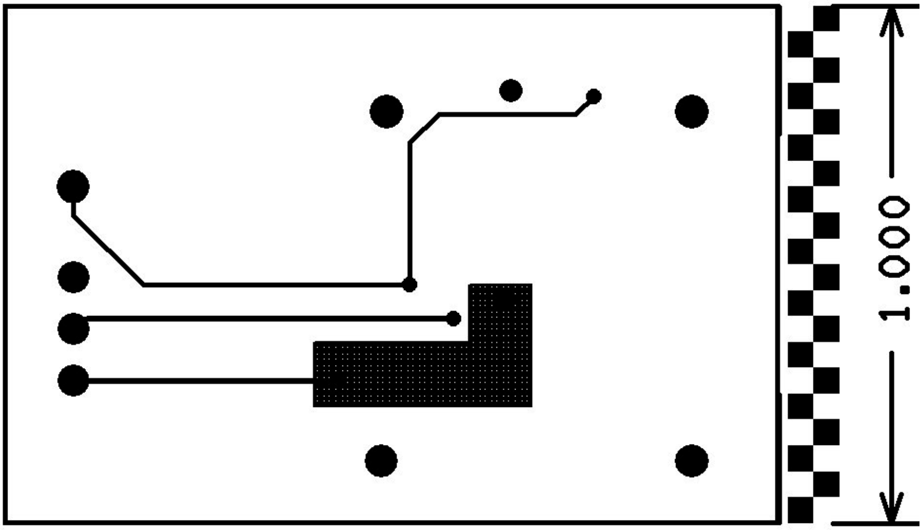


FIGURE 3: SP6648UEB PC LAYOUT BOTTOM SIDE

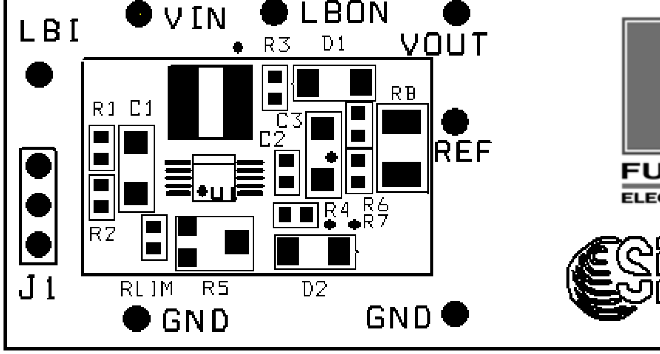
C4	1	TDK Corp	C1608X5R1A105M	0603	Ceramic 10V 1uF SM 0.02ohm ESR	TDK 84
L1	1	Sumida	CDRH5D28-100	6.7x6.5x3.0mm	10uH, 1.3A, 0.065ohm, SM Inductor	Sumida 8
L1	1	TDK Corp	RLF5018-100MR94	5.6x5.2x2.0mm	10uH, 0.94A, 0.067ohm, SM Inductor	TDK 84
R1	1	Panasonic	ERJ-3EKF2053	0603	205K ohm 1/8W 1% 0603 SM	Digi-Key 8
R2	1	Panasonic	ERJ-3EKF2493	0603	124K ohm 1/8W 1% 0603 SM	800-
R3	1	Panasonic	ERJ-3EKF5493	0603	549K ohm 1/8W 1% 0603 SM	800-
R4	1	Panasonic	ERJ-3EKF2493	0603	249K ohm 1/8W 1% 0603 SM	800-
R5	1	Panasonic	ERJ-3GEYJ105	0603	1M ohm 1/8W 5% 0603 SM	800-
RLIM	1	Panasonic	ERJ-3EKF1871	0603	1.87K ohm 1/8W 1% 0603 SM	800-
TP	5	Mill-Max	0300-115-01-4727100	.042 Dia	Test Point Female Pin	800-
J1	1	Sullins	PTC36SAAN	.23x.12	3-Pin Header	800-
	1	Sullins	STC02SYAN	.2x.1	Shunt	800-

ORDERING INFORMATION

Model	Temperature Range	Package Ty
SP6648UEB...................................	-40°C to +85°C...................	SP6648 Evaluation Boa
SP6648EU....................................	-40°C to +85°C......................................	10-pin µSOI

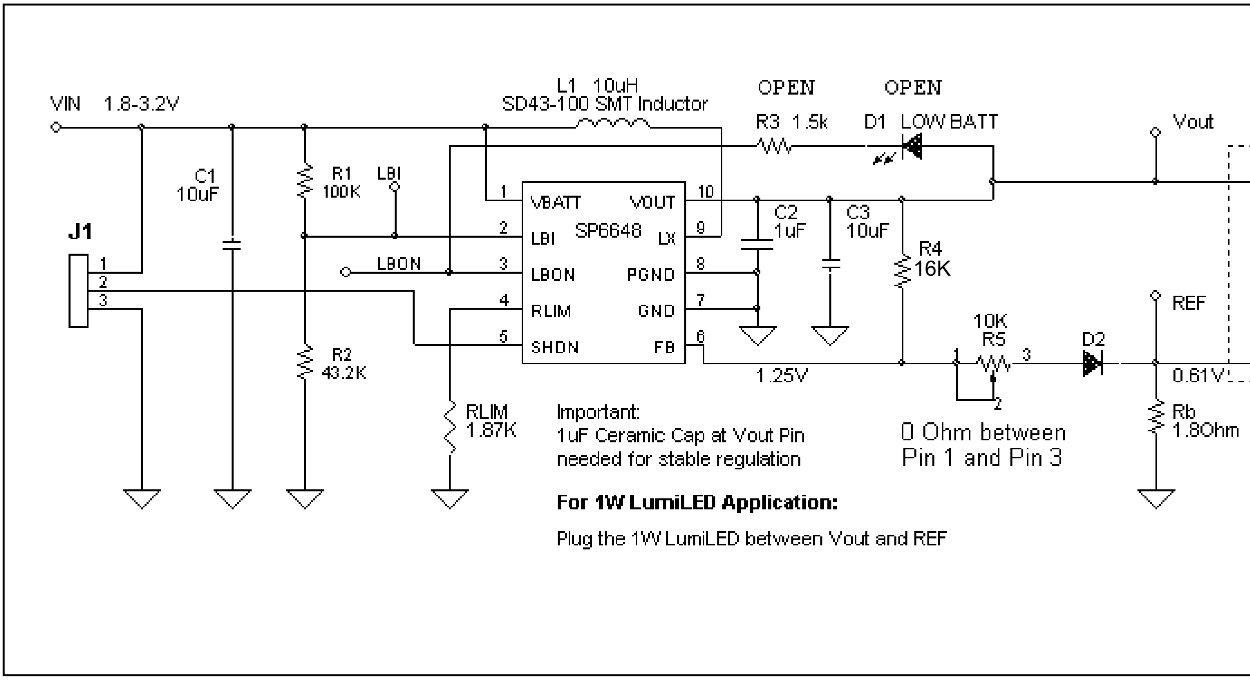
performance of driving 1W LumiLED.

- Plug & Light ON
- Self Protection
- Programmable Inductor Peak Current
- High Efficiency: up to 94%
- µSOIC Package & SMT components for small, low profile Power Supply



DESCRIPTION AND BOARD SCHEMATIC

The **SP6648LED Evaluation Board** is designed to help the user evaluate the perfo the SP6648 for use as a dual cell input to drive a 1W LumiLED. The evaluation completely assembled and tested surface mount board which provides easy pro points to all SP6648 inputs and outputs so that the user can quickly connect and electrical characteristics and waveforms.



is a low resistance from FB to GND. As shown in Figures 1 and 2, if the board is p
before the LumiLED is plugged in, the circuit will bring the Feedback pin to 0V and th
has a feature to set the output voltage to be 3.3V. Once the LumiLED is plugg
Feedback pin will go up to 1.25V and begin to regulate. The output voltage will go fr
3.68V (=V_F+0.61V) accordingly (as shown in Fig. 1), where V_F is the forward volt
LumiLED. When the LumiLED is open, the Feedback pin voltage will go to 0V and
voltage will go to 3.3V which will protect the part (as shown in Fig 2).

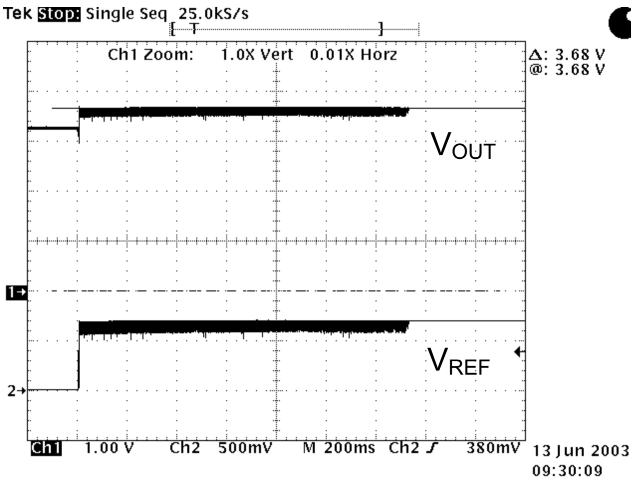


Fig 1. Plug in the LumiLED

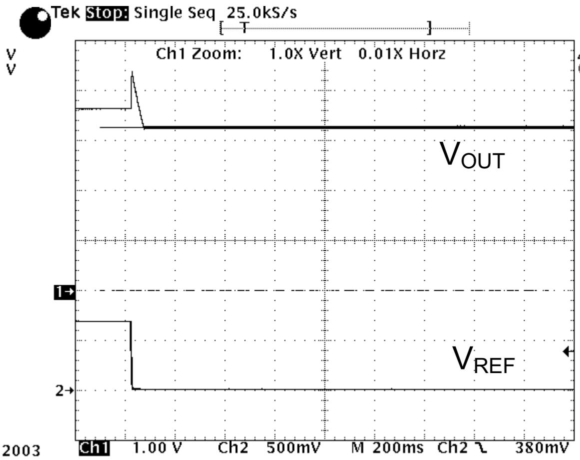


Fig. 2. Unplug the LumiLED

2) Using the J1 Jumper: Enabling the SP6648 Output and using the Shutdown M

The SP6648 output will be enabled if the J1 Jumper is in the top or pin 1 to 2 positior
the pin 2 to 3 position, the Shutdown pin is brought to GND, which puts the SP6648
quiescent Shutdown Mode.

3) Selecting the Bias Resistor

In the white LEDs application, the SP6648 is generally programmed as a current so
bias resistor is used to set the operating current of the white LED as equation

$$R_b = \frac{V_{REF}}{I_F}$$

where V_{REF} is around 0.61V, I_F is the operating current of the Lumiled. To set the
current to be about 350mA, R_b is selected as 1.8 Ohm as shown in the schematic.

4) Vout Programming

The SP6648 can be programmed as either a voltage source or a current source. To p
SP6648 as voltage source, the SP6648 requires 2 feedback resistors R_6 & R_7 to
output voltage. To set Vout in the voltage mode, use the equation:

$$R_6 = \left(\frac{V_{out}}{0.61} - 1\right) \bullet R_7$$

equation above gives an I_{PEAK} range of 350 to 750mA.
The saturation current specified for the inductor needs to be greater then the peak avoid saturating the inductor, which would result in a loss in efficiency and could da inductor. The SP6648 evaluation board uses a R_{lim} value of 1.87K for an I_{peak} = 750m the circuit to deliver up to 180mA for 1.3V input and 400mA for 2.6V input. Other va be selected using the above relationships.

6) Using the LBON - Low Battery Output Function

The SP6648 will regulate the output current until the input battery is completely disc provide an early low battery warning, the Low Battery Output function of the SP6648 regulator can be used. LBON is programmed externally by the R_1 and R_2 resis connected between VIN, the LBI input pin and GND. When the LBI comparator falling of 0.61V is reached, D1 switches on, indicating low battery condition. Low battery point can be calculated by the following formula:

$$V_{LOWBAT} = 0.61 \cdot \frac{R_1 + R_2}{R_2}$$

The SP6648 evaluation board R_1 & R_2 resistors have been set to trip for a falli threshold of about 2.0V. Using this relationship, other low battery threshold values by the user.

7) Brightness Control

One approach to control LED brightness is to apply a PWM signal to the SHDN in SP6648. In this case, the output current will be equal to the product of 350mA and th duty cycle at the SHDN pin. An additional 10K potentiometer (R_5) may also be used fo LED. LED current is varied by the potentiometer between almost zero and full 350mA.

POWER SUPPLY DATA

For the standard evaluation board, The efficiency curve is shown in the figure below.

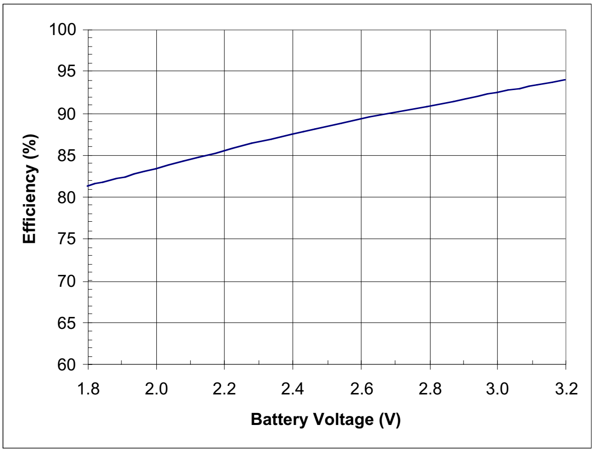


Fig.3 Efficiency curve of the SP6648LED evaluation board

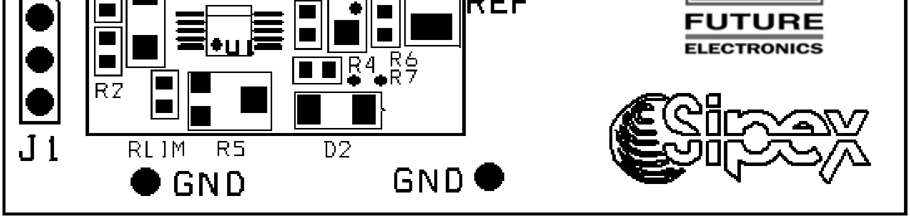


FIGURE 1: SP6648LEDEB COMPONENT PLACEMENT

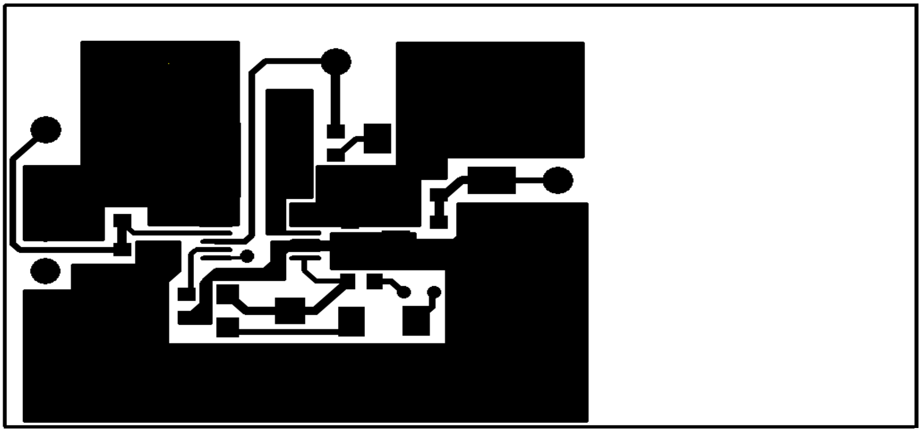


FIGURE 2: SP6648LEDEB PC LAYOUT TOP SIDE

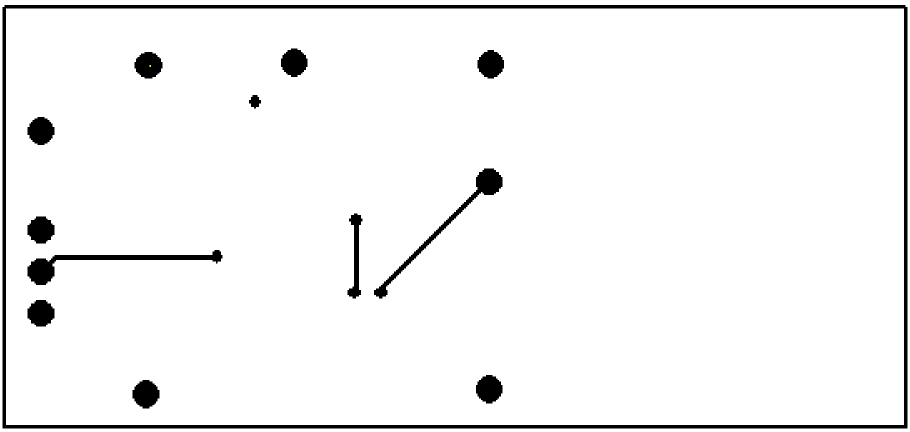


FIGURE 3: SP6648LEDEB PC LAYOUT BOTTOM SIDE

[illegible]	2	TDK Corp	TDKC3216X5R0J106K	1206	10uF/6.3V/X5R/10% Ceramic	Future 888-5
C2	1	TDK Corp	TDKC1608X5R0J105K	603	1uF/6.3V/X5R/10% Ceramic	Future 888-5
L1	1	Sumida	CD43-100	4x4.5x3.2mm	10uH, 1.04A, 0.18 Ohm, SM inductor	Future 888-5
R1	1	Rohm	MCR03EZPFX1003	603	100K 1/16W 1% 0603 SM	Future 888-5
R2	1	Rohm	MCR03EZPFX4322	603	43.2K 1/16W 1% 0603 SM	Future 888-5
R3	1	Rohm	MCR03EZPFX1501	603	Open	Future 888-5
R4	1	Rohm	MCR03EZPFX1622	603	16.2K 1/16W 1% 0603 SM	Future 888-5
R5	1	Rohm	MVR32HXBRN103	3x3.6x1.3mm	0 Ohm between pin 1 and pin 3	Future 888-5
R6	1	Rohm			Open	Future 888-5
R7	1	Rohm			Open	Future 888-5
Rlim	1	Rohm	MCR03EZPFX1871	603	1.87K 1/16W 1% 0603 SM	Future 888-5
Rb	1	Rohm	MCR25JZHJ1R8	1210	1.8 Ohm 1/4W 5% 1210 SM	Future 888-5
D1	1	Stanley	BR1101W-TR	3x1.5x1.5mm	Open	Future 888-5
D2	1	Diode Inc.	1N4148W-7	SOD-123	75V 150mA SM Diode	Future 888-5
TP	7	Mill-Max	0300-115-01-4701100	.042 Dia	Test Point Female Pin	Future 888-5
J1	1	Sullins	PTC36SAAN	.23x.12	2-Pin Header	Future 888-5

ORDERING INFORMATION

Model	Temperature Range	Package Ty
SP6648LEDEB	-40°C to +85°C	SP6648LED Evaluation
SP6648EU	-40°C to +85°C	10-pin µSC

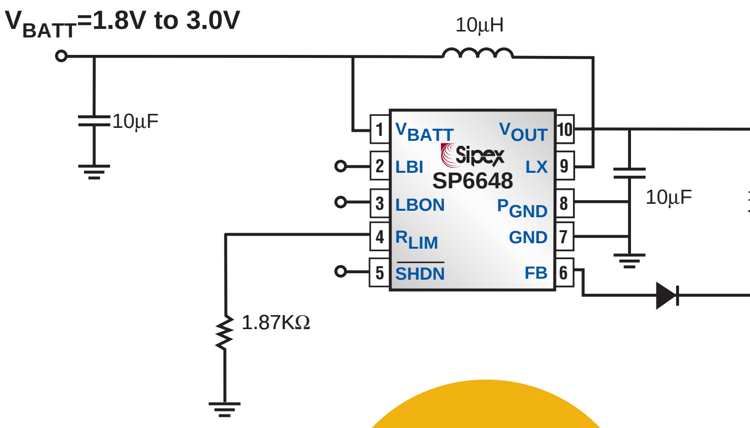
SP6648 Boost Regulator

The SP6648 is an ideal solution for today's low power systems through its ability to power either alkaline or Li-Ion based battery applications. The SP6648 consumes ultra-low quiescent current of only 12µA, while delivering up to 800mA output current. This unique combination of high output power and low quiescent current is accomplished by automatically switching from pulse width modulation (PWM) to pulse frequency modulation (PFM) under light load conditions. The SP6648 combines its low energy requirements with enabling features such as programmable peak current, low battery detect and power shutdown control. The high efficiency, wide input voltage range, and small package size make these parts well-suited for use in LED-based flashlight power supply circuits.

SP6648 Features

- Ultra-low quiescent current
- 800mA inductor current at 2.6V input: $3.3V_{OUT}$
- 94% efficiency from 2 cell to $3.3V_{OUT}$
- Wide input voltage range: 0.7V to 4.5V
- 3.3V fixed or adjustable output
- Integrated synchronous rectifier: 0.3Ω
- Anti-ringing switch technology
- Programmable inductor peak current
- Logic shutdown control
- Under-voltage lock-out at 0.61V
- Programmable low battery detect
- Single or dual cell alkaline
- Small package size: 10-pin DFN or 10-pin MSOP

Typical Application for the SP664



High Efficiency Synchronous Solution

Typical Applications for the SP664

- Flashlights
- Camera flash LED driver
- Wireless mouse
- Pagers
- Medical monitors
- Handheld portable devices

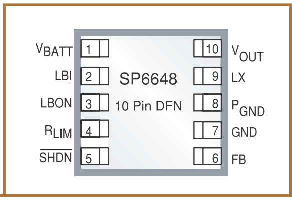
FUTURE ELECTRONICS

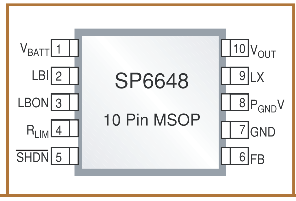
FUTURE•ACTIVE INDUSTRIAL ELECTRONICS

For a complete list of evaluation boards and application notes visit www.sipex.com or call: 1.888.441.0183

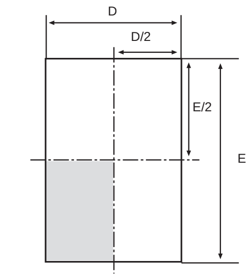
SP6648ER/TR	-40C to +85C	10 Pin DFN

Notes: 1. /TR = Tape and Reel 2. Available in lead free packaging. To order add "-L" suffix. Example: SP6648EU-L/TR

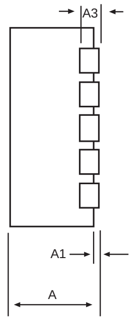




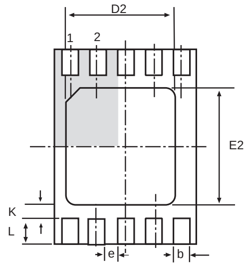
PACKAGE: 10 PIN DFN



Top View



Side View



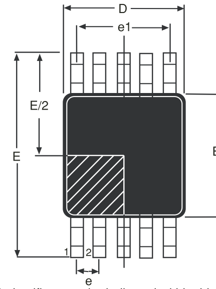
Bottom View

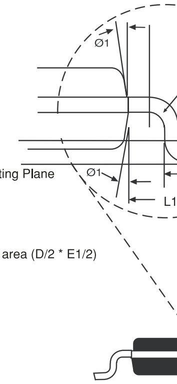
10 Pin DFN (JEDEC MO-229, VEED-5 VARIATION)	DIMENSIONS in (mm)		
SYMBOL	MIN	NOM	MAX
A	0.80	0.90	1.00
A1	0	0.02	0.05
A3	0.20 REF		
b	0.18	0.25	0.30
D	3.00 BSC		
D2	2.20	-	2.70
e	0.50 PITCH		
E	3.00 BSC		
E2	1.40	-	1.75
K	0.20	-	-
L	0.30	0.40	0.50

10 Pin DFN

(ALL DIMENSIONS IN MILLIMETERS)

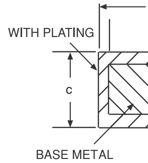
PACKAGE: 10 PIN MSOP

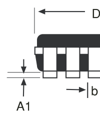




Pin #1 indentifier must be indicated within this shaded area (D/2 * E1/2)

Dimensions in (mm)	10-PIN MSOP JEDEC MO-187 (BA) Variation		
	MIN	NOM	MAX
A	-	-	1.1
A1	0	-	0.15
A2	0.75	0.85	0.95
b	0.17	-	0.27
c	0.08	-	0.23
D	3.00 BSC		
E	4.90 BSC		
E1	3.00 BSC		
e	0.50 BSC		
e1	2.00 BSC		
L	0.4	0.60	0.80
L1	-	0.95	-
L2	-	0.25	-
N	-	10	-
R	0.07	-	-
R1	0.07	-	-
Ø	0º		8º
Ø1	0º	-	15º





(ALL DIMENSIONS IN MILLIMETERS)