Power Bank IC with 1A Linear Charger and 1.2A Boost Converter

General Description

The HX8400 is a highly integrated Power Bank IC with a Linear Li-Ion Charger up to 1A charge current and 1.2A output current Asynchronous Boost Converter. With few external components, the HX8400 could enable Charger and Booster simultaneously and is well suited for portable power bank applications. In shutdown mode, reverse battery current I_{BAT} will be reduced to below 6uA.

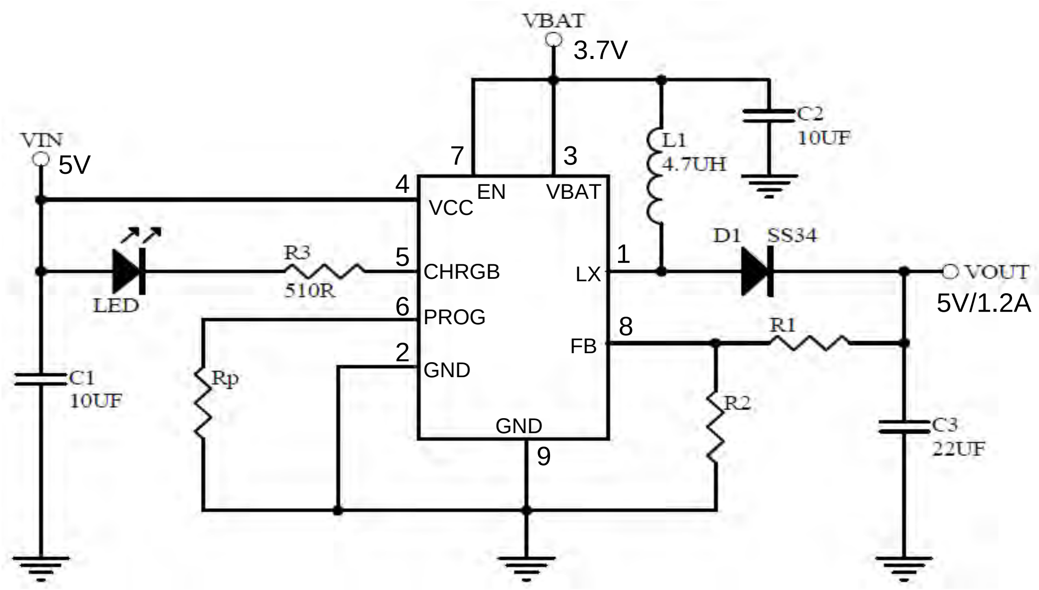
Features

- Up to 1A Programmable Battery Charging Current
- Up to 28V Output Voltage is adjustable
- Automatic Recharge
- Very Low Shutdown-Mode I_{BAT} Current
- Up to 90% Boost Conversion Efficiency
- Thermal Protection

Applications

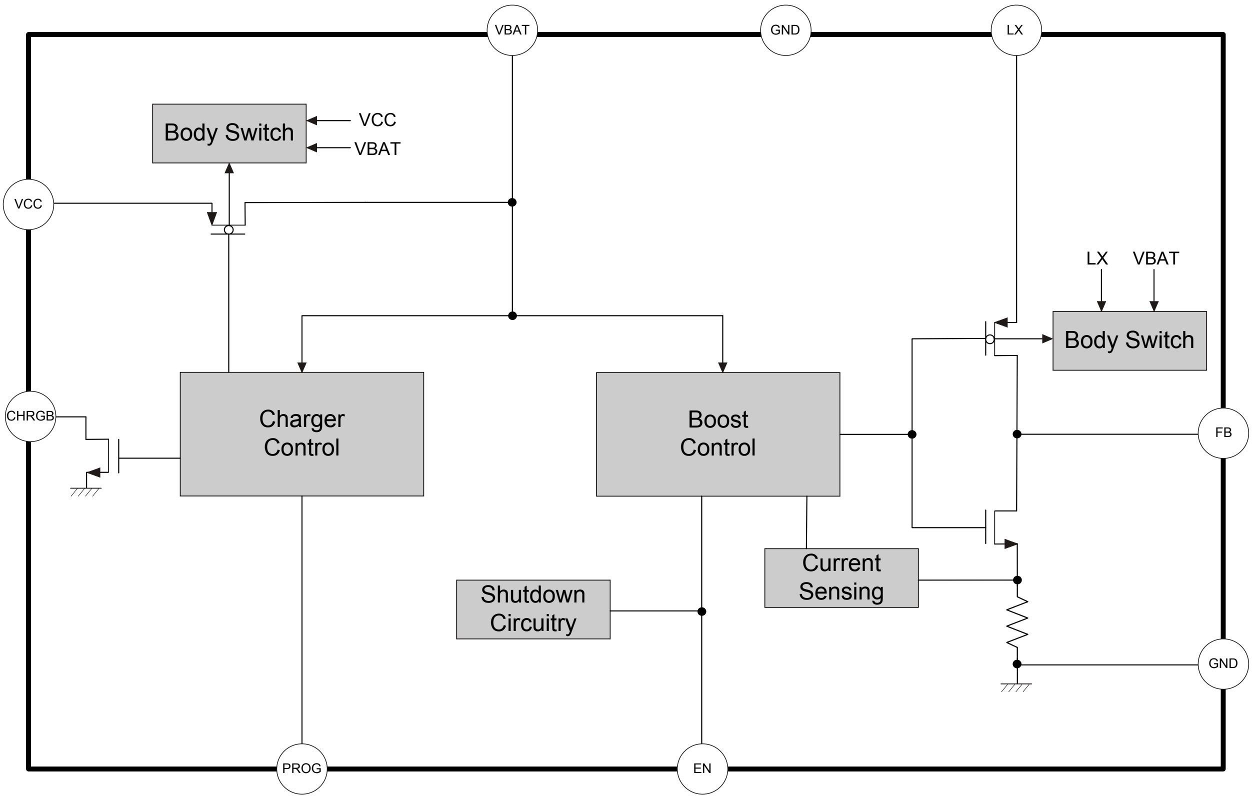
- Portable Power Bank Applications

Typical Application Circuit



VOUT=(R1/R2+1)X0.6

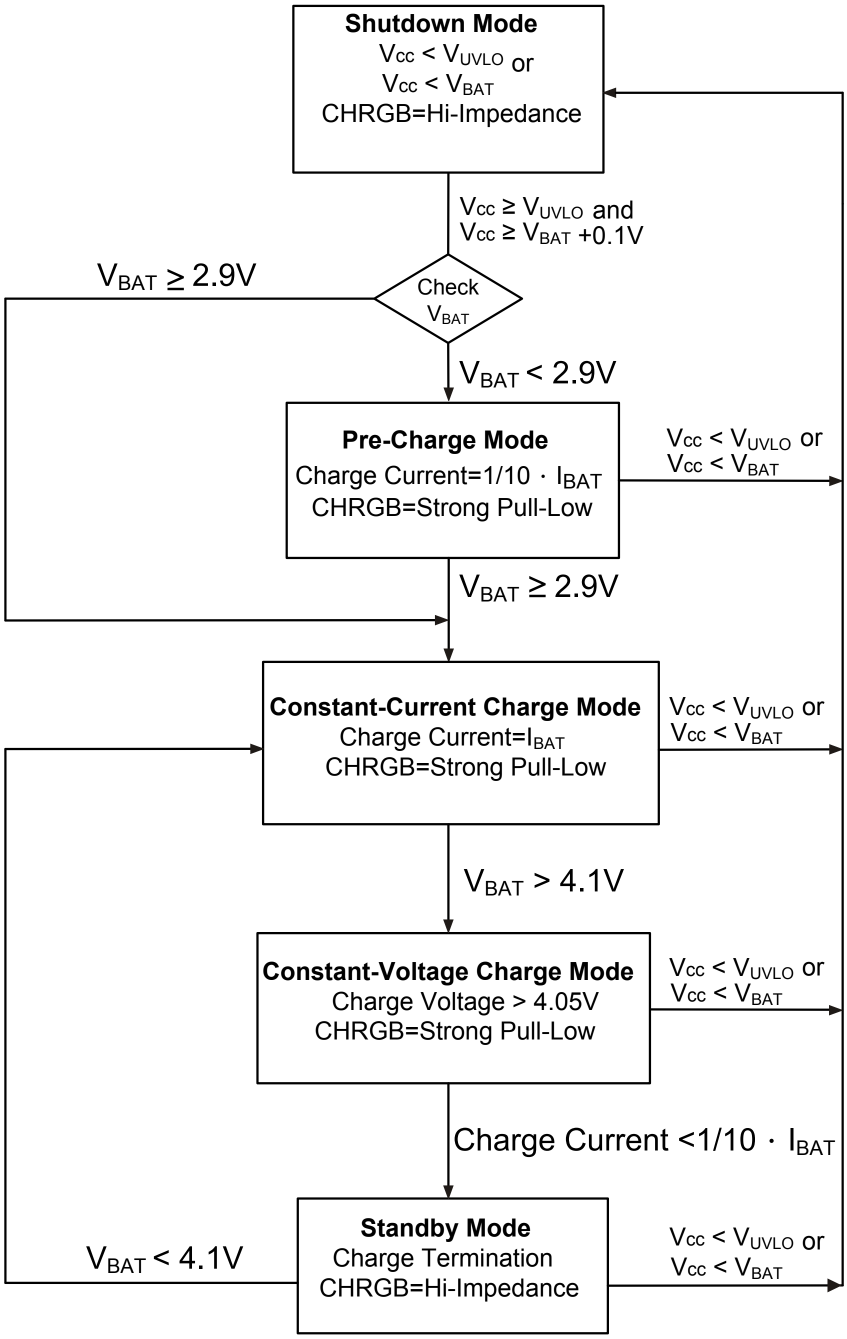
Function Block Diagram



Battery Charging Status Indicators

Charge Status	CHRGB (Red Light)
In Charging	ON
Charge Termination	OFF

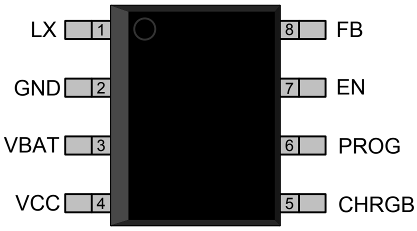
Battery Charging State Diagram



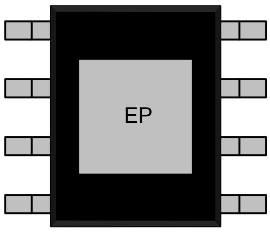
Pin Descriptions

SOP-8L (EP)

Top View



Bottom View



Name	No.	I / O	Description
LX	1	I	Switch Output. Connect this pin to the inductor.
GND	2	P	Ground.
VBAT	3	I	Battery Voltage
VCC	4	P	Supply Voltage
CHRGB	5	I	Charging Indicator
PROG	6	O	CC Charge Current Setting & monitor
EN	7	I	Boost Enable Control
FB	8	P	Feedback Input. The voltage at this pin is regulated to 0.6V. Connect to the resistor divider between output and ground to set output voltage
EP	9	P	IC Ground , Exposed PAD-Must connect to Ground

Ordering Information

MODEL	PRINT LABEL	DATE CODE	PACKAGING	PIN COUNT
HX8400	EDAA XXXX	XXXX	SOP-PP	8

Ordering Information

Part Number	Operating Temperature	Package	MOQ	Description
HX8400	-40℃ ~ +85℃	SOP-8L(EP)	3000	Tape & Reel

Absolute Maximum Ratings

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage	V_{IN}		-0.3		6	V
EN Voltage	V_{EN}		-0.3		V_{BAT}+0.3	V
LX Voltage	V_{LX}		0		26	V
All Other Pins			-0.3		6	V
BAT Pin Current	I_{BAT}				1.2	A
Junction Temperature	T_J				+150	℃
Storage Temperature	T_S		-65		+150	℃
Thermal Resistance	θ_{JA}	SOP-8L(EP)			60	℃ / W
	θ_{JC}				10	℃ / W
Operating Temperature			-40		+85	℃
Lead Temperature (Soldering, 10 Sec)					+260	℃

Recommended Operating Conditions

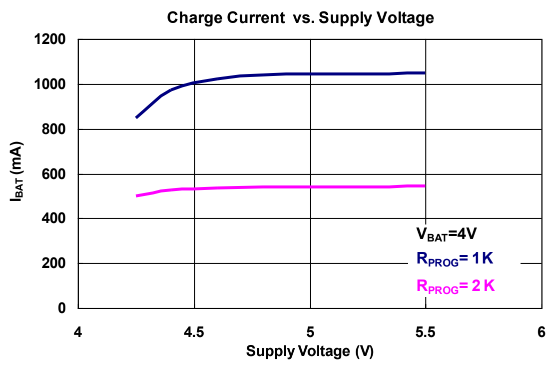
Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage	V_{IN}		4.5		5.5	V
Booster Operation Supply Voltage	V_{BAT}		2.8		4.4	V
Operating Temperature		Ambient Temperature	-40		85	℃

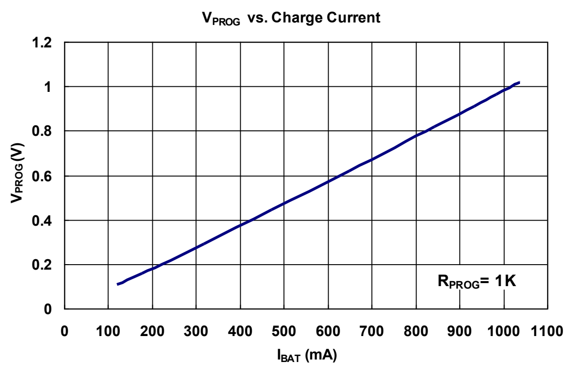
DC Electrical Characteristics (V_{IN}=5V, T_A= 25℃, unless otherwise noted)

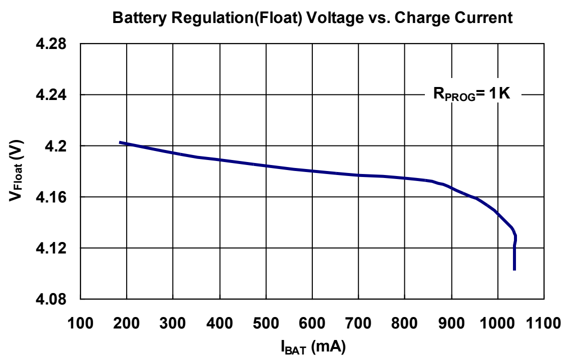
Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
V_{IN} Standby Current	$I_{VIN,STB}$	Charge Termination		600		μA
V_{IN} Shutdown Supply Current	$I_{VIN,SHDN}$	$V_{IN}< V_{BAT}$, $V_{IN}< V_{ADP,UV}$ $V_{BAT}< V_{BAT,UV}$		50		μA
BAT Pin Current	I_{BAT}	R_{PROG}=2.3K	450	500	550	mA
		R_{PROG} =1.1K	900	1000	1100	mA
		Standby-Mode, V_{BAT}=4.2V	0	-6	-15	μA
		Shutdown-Mode		±6	±10	μA
BAT CV Output (Float) Voltage	V_{FLOAT}	0°C<T_A<85°C	4.158	4.2	4.242	V
V_{IN} Charge Under Voltage Lockout Threshold	$V_{IN,UV}$	V_{IN} Rising	3.5	3.7	3.9	V
V_{IN} Charge Under Voltage Lockout Threshold Hysteresis	$V_{IN.UVHYS}$			500		mV
V_{IN}-V_{BAT} Charge Lockout Threshold	V_{ASD}	V_{IN} Rising		120		mV
		V_{IN} Falling		10		mV
C/10 Charge Termination Current Threshold	I_{TERM}	R_{PROG}=1.1K		100		mA
CHRGB Pin Output Low Voltage	V_{LED}	I_{LED}=5mA		0.35	0.6	V
Battery Recharge Threshold Voltage	V_{RECHRG}	V_{FLOAT}-V_{RECHRG}		120		mV
Recharge Comparator Filter Time	T_{RECHRG}	V_{BAT} High to Low		0.8		mS
C/10 Charge Termination Comparator Filter Time	T_{TERM}	I_{BAT} Falling below I_{TERM}		0.8		mS
Booster Operation Supply Range	V_{BAT}		2.8		4.4	V
Booster Under Voltage Lockout	$V_{BAT-UVLO}$			2.2		V
Under Voltage Lockout Hysteresis				0.1		V
Booster Operation Frequency	F_{OSC}		0.8	1.0	1.2	MHz
Regulated Feedback Voltage	V_{FB}	-40°C < T_a <85°C	0.588	0.6	0.612	V
Rds(ON) of N-channel FET		I_{SW} =-100mA		80	150	mΩ
LX Leakage Current		V_{EN} = 0V, V_{LX} = 0V or 5V V_{BAT} = 4.2V			1	μA
Thermal Shutdown	T_{LIM}			150		℃
EN Enable Voltage	$V_{EN,H}$		1.3			V
EN Shutdown Voltage	$V_{EN,L}$				0.4	V

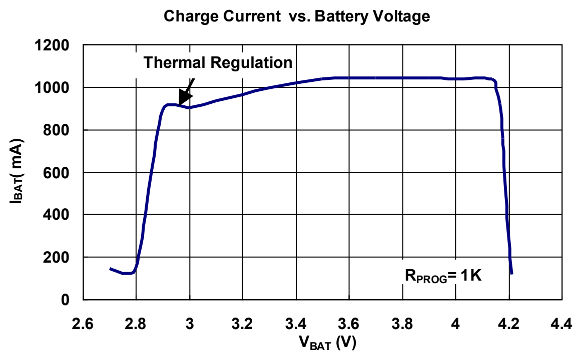
Typical Operating Characteristics

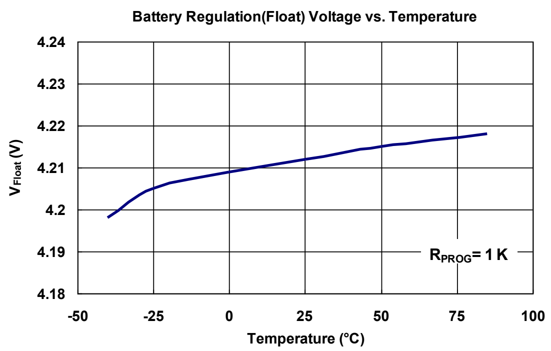
(Charger : V_{CC}=5V, T_A= 25℃, unless otherwise noted)

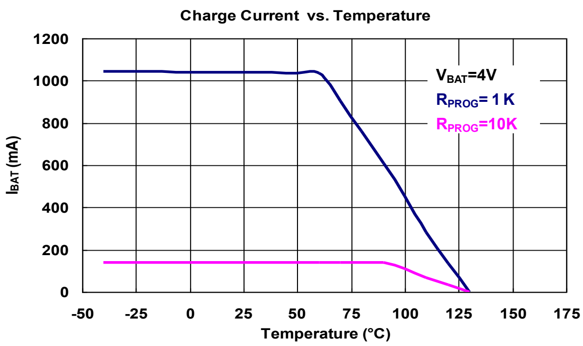




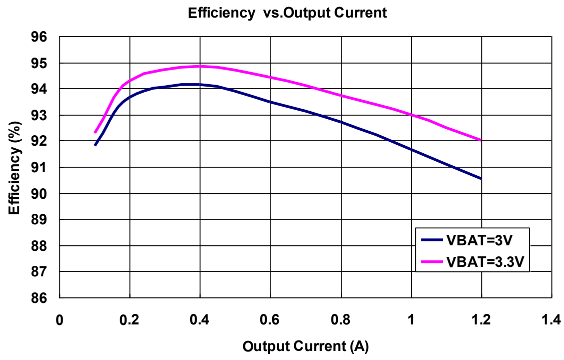


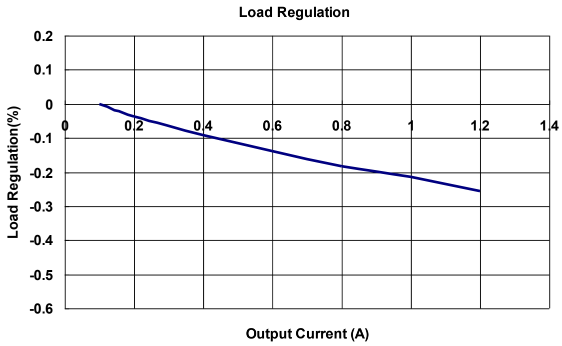


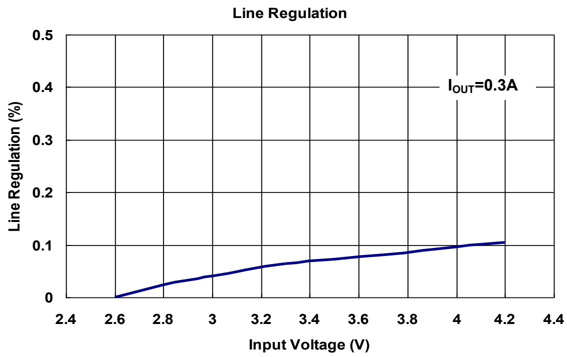


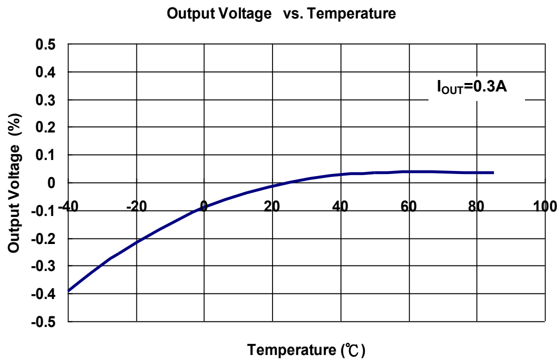


(Boost : V_{BAT}=3.3V, Vout=5V，T_A= 25℃, unless otherwise noted)



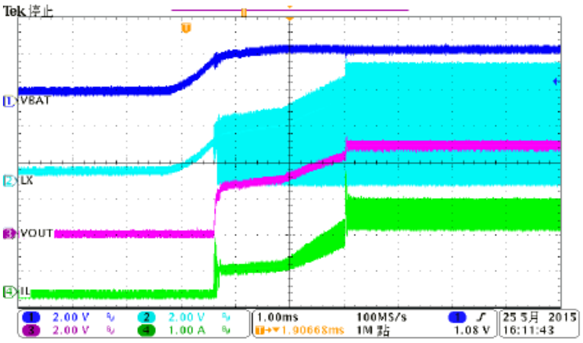






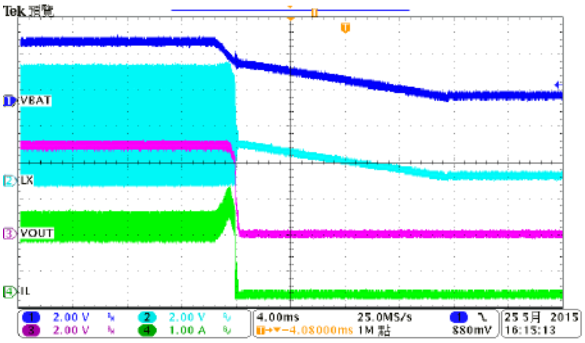
Power ON Test

(V_{BAT}=3.3V，Vout=5V，Iout=1.2A)



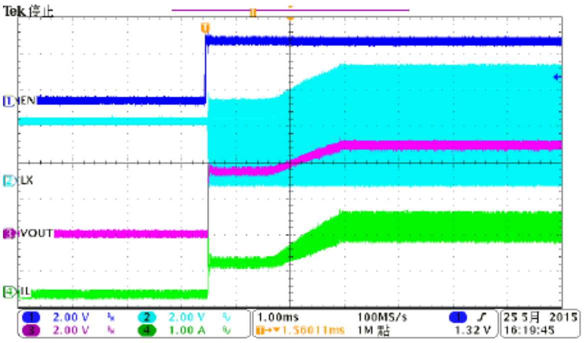
Power OFF Test

(V_{BAT}=3.3V，Vout=5V，Iout=1.2A)



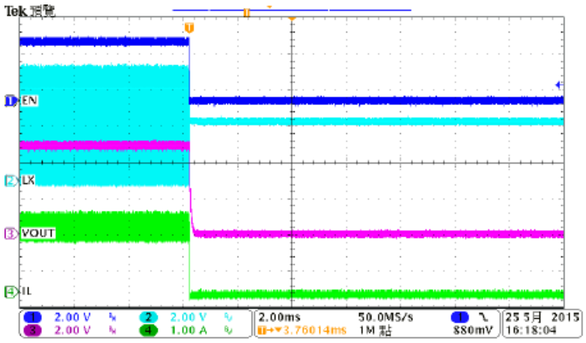
EN ON Test

(V_{BAT}=3.3V，Vout=5V，Iout=1.2A)



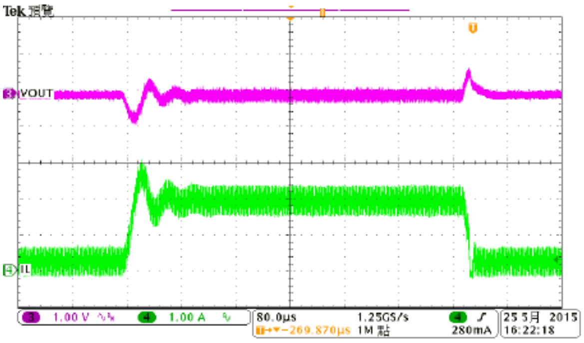
EN OFF Test

(V_{BAT}=3.3V，Vout=5V，Iout=1.2A)



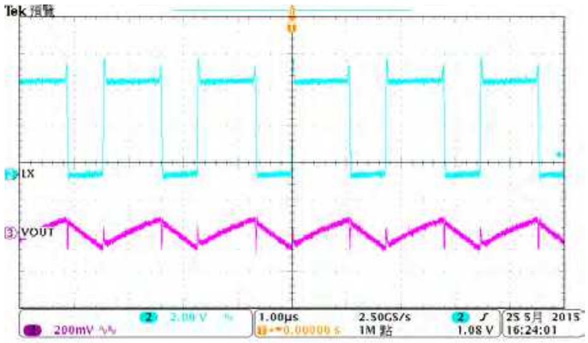
Transient Response

(V_{BAT}=3.3V，Vout=5V，Iout=0.2A~1.2A)



Full Load Output Ripple

(V_{BAT}=3.3V，Vout=5V，Iout=1.2A)



Function Description

For Battery Charging

Operation

The HX8400 is with a linear battery charger designed primarily for charging single cell lithium-ion battery. The charger uses a constant-current/constant-voltage charging algorithm with programmable current. Charging current can be programmed up to 1A by an external single resistor. The HX8400 includes an internal P-channel power MOSFET and thermal regulation circuitry. No blocking diode or external sense resistor are required. Thus, the basic charger circuit requires only two external components. Furthermore, The HX8400 is capable of operating from a USB power source.

Normal Charge Cycle

A charge cycle begins when the voltage at the V_{IN} pin rises above the UVLO threshold. If the BAT pin voltage is smaller than 2.9V, the charger enter trickle charge mode. In this mode, the HX8400 supplies approximately 1/10 the programmed charging current to bring the battery voltage up to a safe level for full current charging. When the BAT pin voltage rises above 2.9V, the charger enters constant-current mode, where the full programmed charge current is supplied to the battery. When the BAT pin approaches the final float voltage (4.2V), the HX8400 enters the constant-voltage mode and the charge current begins to decrease. When the charge current drops to 1/10 of the programmed value, the charge cycle ended.

Programming Charge Current

The charge current is programmed by a single resistor connected from the PROG pin to ground. The battery charging current is 1150 times the current flowing out of the PROG pin. The required resistor value can be calculated from the charge current with following equation:

$$R_{PROG} = \frac{1150}{I_{CHG(MAX)}}$$

The instantaneous charging current may differ from above equation in trickle or constant voltage modes. The instantaneous charging current provided to the battery can be determined by monitoring the PROG pin voltage at any time with the following equation:

$$I_{CHG} = \frac{V_{PROG}}{R_{PROG}} \times 1150$$

Charge Termination

A charge cycle is terminated when the charge current falls to 1/10 the programmed value after the final float voltage is reached. The charge current is shut off and the HX8400 enters standby mode, where the input supply current drops to 55uA. The HX8400 draws very few current from the battery in standby mode. This feature reduces the charge and discharge cycles on the battery, further prolong the battery life.

Thermal Protection when charging

An internal thermal feedback loop reduces the fixed charge current if the die temperature rises above a preset value of approximately 100℃. This feature protects the HX8400 from excessive temperature and allows the user to push the limits of the power handing capability of a given circuit board without risk of damaging the HX8400 . The charge current can be set according to typical ambient temperature with the assurance that the charge will automatically reduce the current in worst case condition.

V_{IN} under Voltage Lockout (UVLO)

An internal under voltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until V_{IN} rises above the under voltage lockout threshold. The UVLO circuit has a built-in hysteresis of 500mV. Furthermore, to protect against reverse current in the power MOSFET, the UVLO circuit force the HX8400 to enter shutdown mode if V_{IN} falls to within 10mV of the battery voltage. If the UVLO comparator is tripped, the charger will not come out of shutdown mode until V_{IN} rises 100mV above the battery voltage.

Automatic Recharge

Once the charge cycle is terminated, the HX8400 continuously monitors the voltage on the BAT pin using a comparator with a 0.8ms filter time ($T_{RECHARGE}$). A charge cycle restarts when the battery voltage falls below 4.05V (which corresponds to approximately 80% to 90% battery capacity).This ensures that the battery is kept at or near a fully charged condition and eliminated the need for periodic charge cycle initiations. CHRGB output enters a strong pull-down state during recharge cycles.

For Booster

NORMAL OPERATION

HX8400 monolithic 1.0MHz boost converter housed in a 6-lead SOT-23 package. The device features fixed frequency, current mode PWM control for excellent line and load regulation. The low $R_{ds(on)}$ NMOS switch enables the device to maintain high efficiency over a wide range of load current. Operation of the feedback loop which sets the peak inductor current to keep the output in regulation can be best understood by referring to the Block Diagram in Figure . At the start of each clock cycle a latch in the PWM logic is set and the NMOS switch is turned on. The sum of a voltage proportional to the switch current and a slope compensating voltage ramp is fed to the positive input to the PWM comparator. When this voltage exceeds either a voltage proportional to the 4A current limit or the PWM control voltage, the latch in the PWM logic is reset and NMOS switch is turned off. The PWM control voltage at the output of the error amplifier is the amplified and compensated difference between the feed- back voltage on the FB pin and the internal reference voltage of 0.6V. If the control voltage increases, more current is delivered to the output. When the control voltage exceeds the I_{LIMIT} reference voltage.

INDUCTOR SELECTION

The HX8400 Can utilize small surface mount inductors due to its 1.0MHz switching frequency. A 4.7μH or 22 μH inductor will be the best choice for most HX8400 applications.

The inductor should have low DCR (DC resistance) to reduce the I2R power losses, and must be able to handle the peak inductor current without saturating.

Several inductor manufacturers are listed in Table 1 Selected inductor by actual application:

Manufacturer	***Part Number***	***Inductance(uH)***	***DRC max (Ohms)***	***Dimensions L*W*H(mm3)***
Murata	LQH5BPN	4.7	0.03	5*5*2
	LQH32PN	4.7	0.06	3.2*2.5*1.7
Sumida	CDRH3D16	4.7	0.03	4*4*1.8
		4.7	0.07	

Table 1. Recommend Surface Mount Inductors

OUTPUT CAPACITOR SELECTION

A low ESR output capacitor is required in order to maintain low output voltage ripple. In the case of ceramic output capacitors, capacitor ESR is very small and does not contribute to the ripple, so a lower capacitance value is acceptable when ceramic capacitors are used. A 22uF ceramic output capacitor is suitable for most applications.

OUTPUT VOLTAGE PROGRAMMING

In the adjustable version, the output voltage is set by a resistive divider according to the following equation:

$$R_1 = R_2 \times \left(\frac{V_{OUT}}{0.6} - 1 \right)$$

Typically choose R2=20K and determine R1 from the following equation:
Connect a small capacitor across R2 feed forward capacitance at the FB pin for better performance.

Application Information

Power Dissipation

The conditions that cause the HX8400 to reduce charge current through thermal feedback can be approximated by considering the power dissipated in the IC. For high charge current, the HX8400 power dissipation is approximately:

$$P_D = (V_{IN} - V_{BAT}) \cdot I_{BAT}$$

Where P_D is the power dissipated, V_{CC} is the input supply voltage, V_{BAT} is the battery voltage and I_{BAT} is the charge current. It is not necessary to check any worst-case power dissipation scenarios because the HX8400 will automatically reduce the charge current to maintain the die temperature under 140℃ approximately. The approximate ambient temperature at which the thermal feedback begins to protect the IC is:

$$T_A = 140℃ - P_D\theta_{JA}$$
$$= 140℃ - (V_{IN} - V_{BAT}) \cdot I_{BAT} \cdot \theta_{JA}$$

For example: Consider an HX8400 operating from a 5V wall adapter providing 0.5A to a 4.0V Li-Ion battery. The ambient temperature above which the HX8400 will begin to reduce the 0.5A charge current is approximately:

$$T_A = 140°C - (5V - 4.0V) \bullet (0.5A) \bullet 60°C/W$$
$$= 140°C - 0.5W \bullet 60°C/W = 140°C - 30℃$$
$$= 110℃$$

The HX8400 can be used above 110°C, but the charge current will be reduced to smaller than 500mA. The approximate current at a given ambient temperature can be calculated:

$$I_{BAT} = \frac{140°C - T_A}{(V_{IN} - V_{BAT}) \cdot \theta_{JA}}$$

Using the previous example with an ambient temperature of 90°C, the charge current will be reduced to approximately:

$$I_{BAT} = \frac{140°C - 90°C}{(5V - 3.6V) \cdot 60°C/W} = 595mA$$

Furthermore, the voltage at the PROG pin will change proportionally with the charge current as discussed in the Programming Charge Current section. It is important to remember that HX8400 applications do not need to be designed for worst-case thermal conditions since the IC will automatically reduce power dissipation when the junction temperature reaches approximately 140°C.

Board Layout Considerations

Because of the small size of the SOP-8L(EP), it is very important to apply a good thermal conduction PC board layout to maximize the available charge current. The thermal path for the heat generated by the IC is from the die through the package leads(especially the ground lead) to the PC board copper. The PC board copper is the heat sink. The copper pads footprint should be as large as possible and expand out to large copper areas to spread and dissipate the heat to the surrounding ambient. Feed-through vias to inner or backside copper layers are also useful in improving the overall thermal performance of the charger. Other heat source on the board, not related to the charger, must also be consider when designing a PC board layout because they will affect overall temperature rise and the maximum charge current.

V_{IN} Bypass Capacitor

Many types of capacitors can be used for input bypassing, however, caution must be exercised when using multilayer ceramic capacitors. Because of the self-resonant and high Q characteristics of some types of ceramic capacitors, high voltage transients can be generated under some start-up conditions, such as connecting the charger input to a live power source. Adding a 0.4Ω resistor in series with an X5R ceramic capacitors (as shown in Figure 1) will minimize start-up voltage transients.

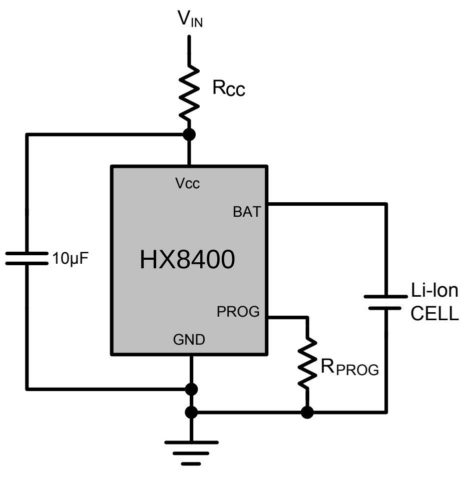
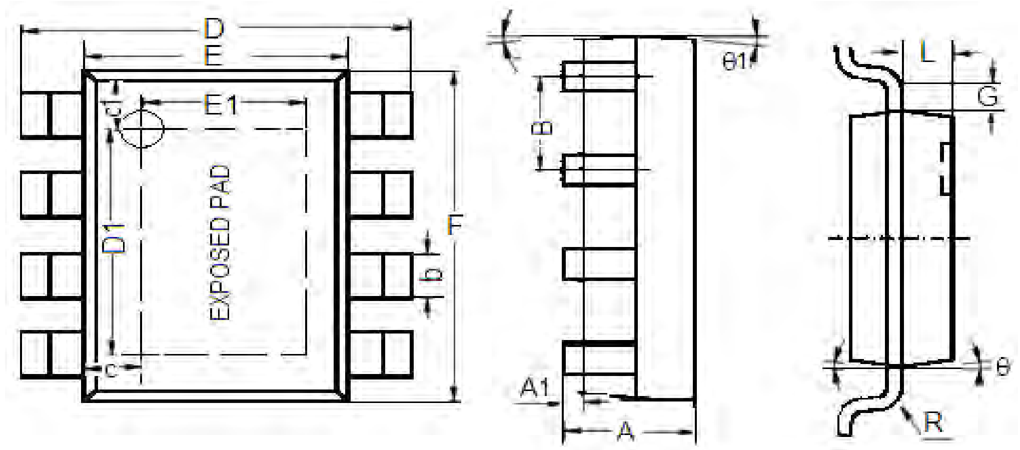


FIGURE 1

Package Outline

SOP-8L (EP)



Character	Dimension (mm)		Dimension (Inches)	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.1	0.3	0.004	0.012
B	1.27(Typ.)		0.05(Typ.)	
b	0.330	0.510	0.013	0.020
c	0.9(Typ.)		0.035(Typ.)	
c1	1.0(Typ.)		0.039(Typ.)	
D	5.8	6.2	0.228	0.244
D1	3.202	3.402	0.126	0.134
E	3.800	4.000	0.150	0.157
E1	2.313	2.513	0.091	0.099
F	4.7	5.1	0.185	0.201
L	0.675	0.725	0.027	0.029
G	0.32(Typ.)		0.013(Typ.)	
R	0.15(Typ.)		0.006(Typ.)	
θ1	7°		7°	
θ	8°		8°	