HX7501C/HX7501S

One Chip Solution for Li-Ion Battery Powered Mobile Supply

Features

- High Accuracy Linear Li-Lon Battery Charger
- Programmable Charge Current up to 1A
- Fixed Output Voltage: 5V
- Input Voltage: up to 6V with Suitable MOSFET and Charging Current
- STAT1, STAT2, STAT3, STAT4 Pins: Charging Status Indicators or Indicate the Capacity of Battery when Step-up
- Flashlight Function with Sink Current up to 35mA
- Short-Circuit Protection
- Shutdown Step-up if No-Load
- Minimal External Components
- TSSOP-16L(HX7501C)/SOP-16(HX7501S) Package

Applications

- Portable Devices and PDAs
- MP3/MP4 Players
- Wireless Handhelds
- GPS Receivers, etc.

Description

The HX7501 is a complete, cost effective, high-efficient solution for Li-Ion Battery Powered Mobile Supply.

VBAT is a complete constant-current/constant voltage linear charger for one cell lithium-ion battery. The charge current of pre-charging and constant–current charging is adjustable and it can be programmed to 1A. An external sense resistor sets the charge current with high accuracy.

VOUT5 (5V) is a step-up DC/DC converter with internal power MOSFETs. It achieves 2A (with 2318 NMOSFET) continuous output current over a wide input supply range with excellent load and line regulation. In addition, the HX7501 can be used as a flashlight.

The HX7501C is available in a low profile TSSOP-16L package and The HX7501S is available in a low profile SOP-16 package.

Typical Application Circuit

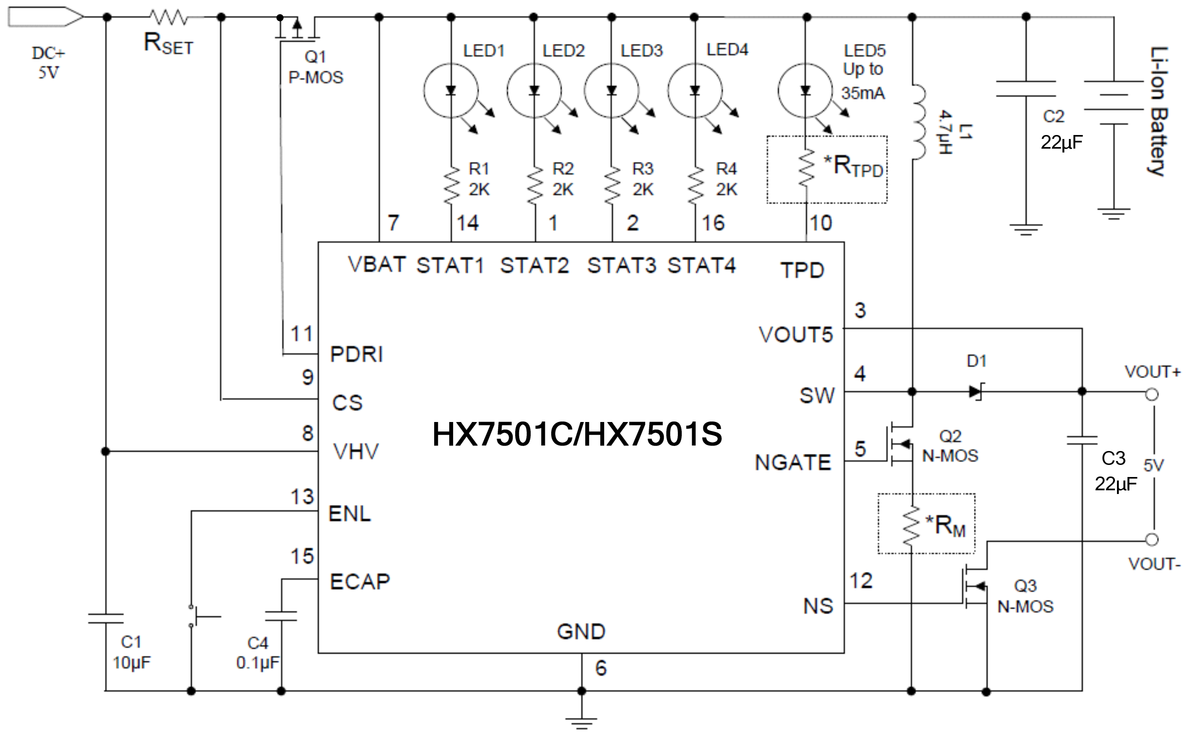


Figure 1: Typical Application Circuit

* The charge current $I_{BAT} = V_{CS}/R_{SET}$ (V_{CS} is usually 200mV). PMOS (Q1) is recommended to use TO252 package and the maximum current is up to 1A. The package with strong ability of heat dissipation will allow a larger charge current.
* ENL: On/Off control for VOUT5 (5V) and LED5 (short-presses for turn on or off).
* R_{TPD} is optional. The LED5 can be adjusted brightness by R_{TPD}. The current of LED5 is up to 35mA.
* NMOS (Q2, 2302), the maximum load is up to 1A, NMOS (Q2, HX2318), the maximum load is up to 2A.
* R_M is optional, R_M reference value: 0mΩ.
* Note: below table only for reference.

***Table 1: Switch Function and Description**

Mode	**Function**	**Press Switch (1s-2s)**	**Press Switch (≥2s)**
Charge	Step-up	/	/
	led1~ led4	Indicate the capacity of battery always	
	Flashlight	/	/
Discharging	Step-up	/	On/Off
	led1~ led4	/	Indicate the capacity of battery
	Flashlight	On/Off	/

* Measuring Conditions: TA=25℃, V_{BAT}=3.7V, C4=0.05µF.

***Table 2: Battery charge Indicator**

VBAT (V)			LED1	LED2	LED3	LED4
MIN	TYP	MAX				
		3.4	FLASH	OFF	OFF	OFF
	3.4		ON	FLASH	OFF	OFF
	3.65		ON	ON	FLASH	OFF
	3.84		ON	ON	ON	FLASH
	4.2		OFF	OFF	OFF	OFF

***Table 3: Battery discharge Indicator**

VBAT (V)			LED1	LED2	LED3	LED4
MIN	TYP	MAX				
3.7			ON	ON	ON	ON
	3.7		ON	ON	ON	OFF
	3.5		ON	ON	OFF	OFF
	3.3		ON	OFF	OFF	OFF
	3.0		OFF	OFF	OFF	OFF

***Table 4: C4 (ECAP) Capacitance & Start-up Time**

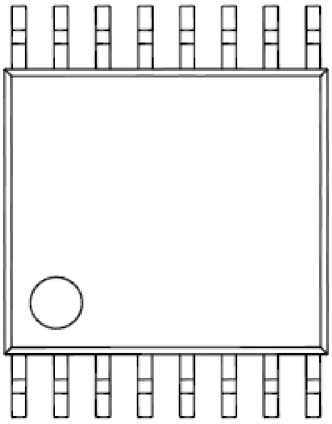
C4 (ECAP)	TPD	led1~led4
0.05μF	1s	2s
0.1μF	2s	4s

***Table 5: No-load automatic Shutdown Time**

VBAT	Shut-down Time	C4 (ECAP)
3.7V	35s	0.05μF

Pin Assignment and Description

TOP VIEW



TSSOP-16L/SOP-16

PIN	NAME	DESCRIPTION
1	STAT2	Charging Status Indicator 2
2	STAT3	Charging Status Indicator 3
3	VOUT5	Output Voltage (5V)
4	SW	Switching node for VOUT5
5	NGATE	Gate for NMOS
6	GND	Ground
7	VBAT	Charge Current Output
8	VHV	Input Voltage
9	CS	Charge Current Program
10	TPD	Flash ON/OFF Indicator (LED Current up to 35mA)
11	PDRI	Charge Current Monitor and Shutdown Pin
12	NS	NMOS Short-circuit Protection
13	ENL	On/Off Control Input (Low Enable)
14	STAT1	Charging Status Indicator 1
15	ECAP	Timing Control Comparator
16	STAT4	Charging Status Indicator 4

Absolute Maximum Ratings (Note 1)

- VIN Voltage .... -0.3V ～ 15V
- ENL, SW, PDRI Pin Voltages...-0.3V ～ 6.5V
- SW Pin Current...4A
- Operating Temperature Range (Note 2).. –40℃ ～ +85℃
- Operating Junction Temperature .... –40℃ ～+125℃
- Storage Temperature Range .... –65℃ ～ +125℃
- Lead Temperature (Soldering, 10 sec)... +265℃

Note 1: Stresses beyond those listed Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: The HX7501 is guaranteed to meet performance specifications from 0°C to 85°C. Specifications over the –40°C to 85°C operating temperature range are assured by design, characterization and correlation with statistical process controls.

Electrical Characteristics

VBAT: Operating Conditions: T_A=25℃, V_{IN}=5V, R_{SET} = 0.25Ω, unless otherwise specified.

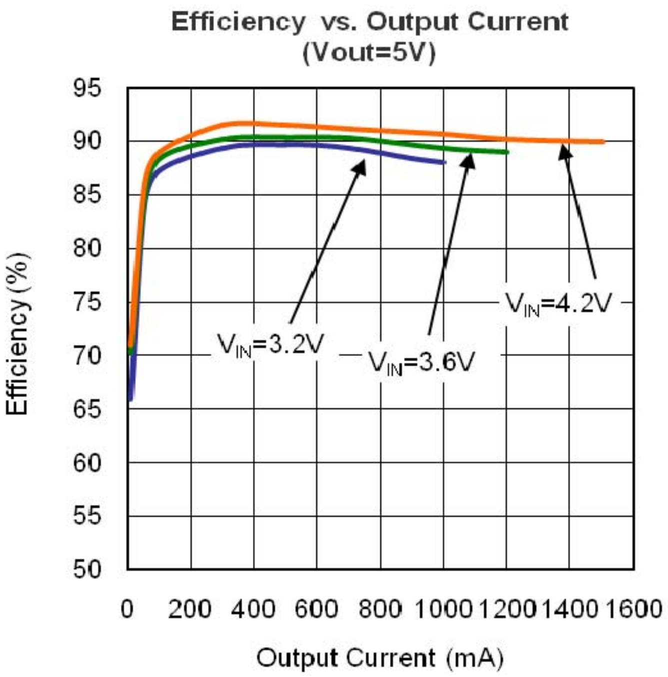
SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{IN}	Input Supply Voltage		4.5		6	V
I_{SLEEP}	Sleep Current	Sum of currents into VBAT pin, V_{IN}=0, V_{BAT}=3.6V		48		μA
Battery Voltage Regulation Constant-Current Charge						
V_{FLOAT}	Output(Float) Voltage		4.16	4.2	4.25	V
V_{CS}	Voltage Regulation Threshold	Voltage at pin CS , relative to VIN	175	200	225	mV
Trickle Charge						
V_{TRIKL}	Trickle Charge Threshold Voltage	$V_{BAT} < V_{TRIKL}$, R_{SET} =0.25Ω		3		V
I_{TRIKL}	Trickle Charge Current	V_{BAT} Rising, R_{SET} =0.25Ω		80		mA
V_{RECHRG} Comparator (Battery Recharge Threshold)						
ΔV_{RECHRG}	Recharge Battery Threshold Voltage	V_{FLOAT} - V_{RECHRG}		200		mV

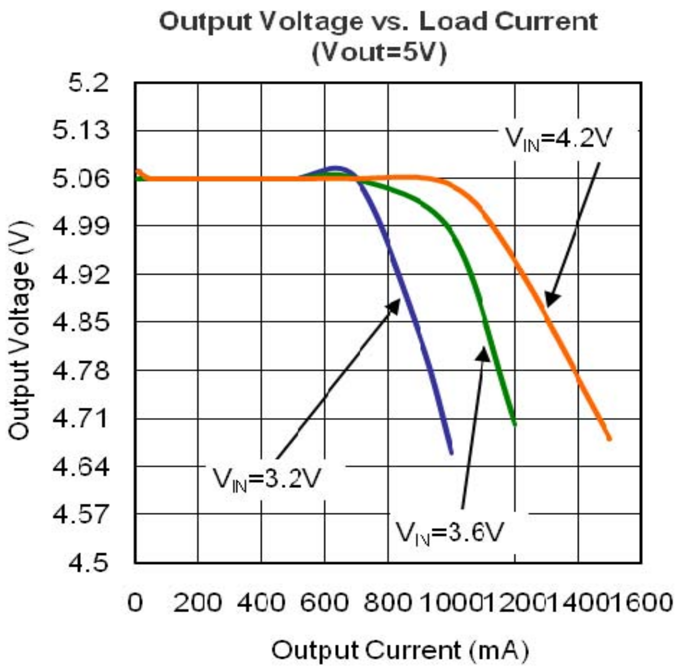
VOUT5: Operating Conditions: TA=25℃, unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OUT5}	Output Voltage Range		4.85	5	5.15	V
V_{UVLO}	Under Voltage Lockout Threshold			3		V
EFFI	Efficiency	V_{BAT}=3.6V, I_{OUT}=1A		90		%
ΔV_{LINE}	Output Voltage Line Regulation	V_{BAT}: 3.2V ～ 4.2V, I_{OUT}=10mA.		5		mV
ΔV_{LOAD}	Output Voltage Load Regulation	V_{BAT}=3.6V, I_{OUT}: 1mA ～ 1A		15		mV

Typical Performance Characteristics (Step-up DC-DC Converter)

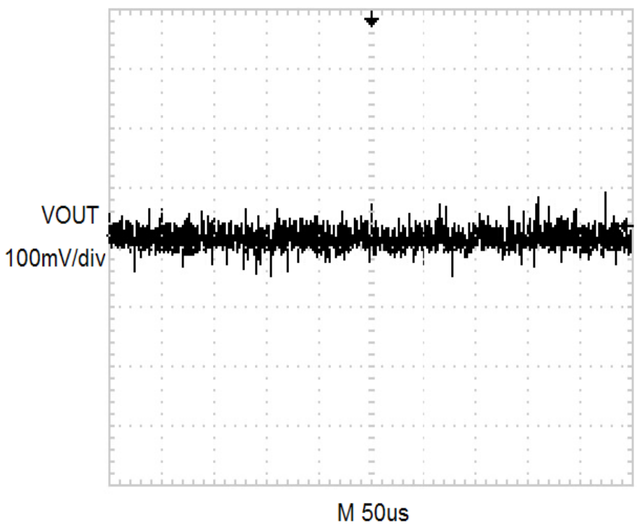
Operating Conditions: TA=25℃, C1=10μF, C2=C3=20μF, C4=0.1μF, Q1=2301, Q2=Q3=2302, L1=4.7μH, D1=SK52*2, R1=R2=R3=R4=R_{TPD}=2K, unless otherwise specified.





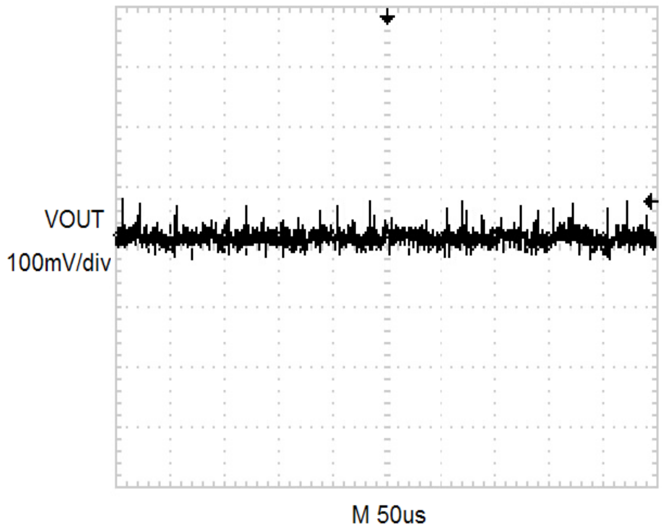
VOUT Ripple

(V_{IN}=3.6V, V_{OUT}=5V, I_{LOAD}=1A)

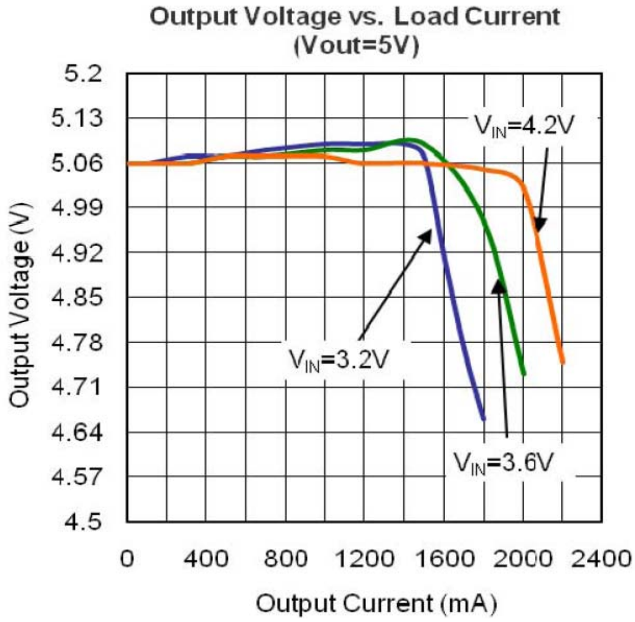


VOUT Ripple

(V_{IN}=4.2V, V_{OUT}=5V, I_{LOAD}=1A)

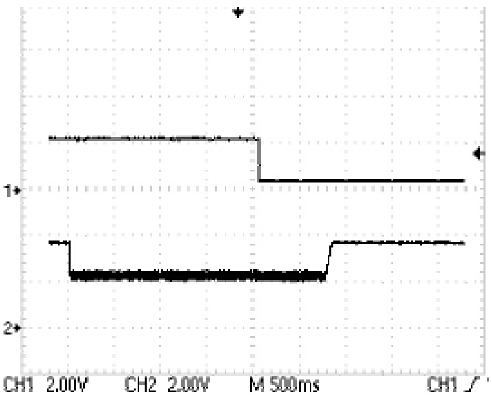


Operating Conditions: TA=25℃, C1 = 10μF, C2= 22μF, C3= 22μF+100μF (Electrolytic Capacitor), C4 = 0.1μF, Q1=2301, Q2=HX3400, Q3=2302, L1=4.7μH, D1=SK52*2, R1=R2=R3=R4=R_{TPD}=2K, unless otherwise specified.

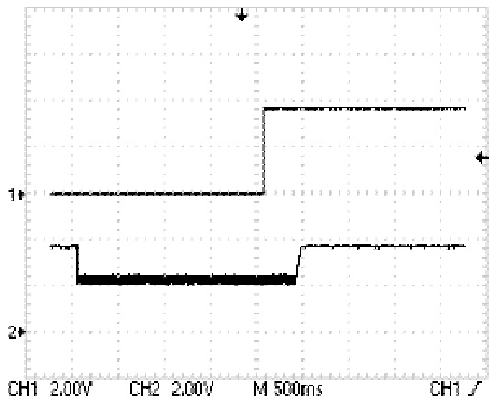


* Measuring Conditions: TA=25℃, V_{BAT}=3.7V, C4=0.05μF.

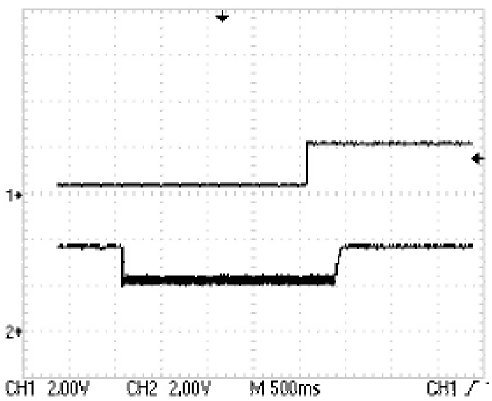
ECAP (C4) VS STAT1 (LED1) Open Time



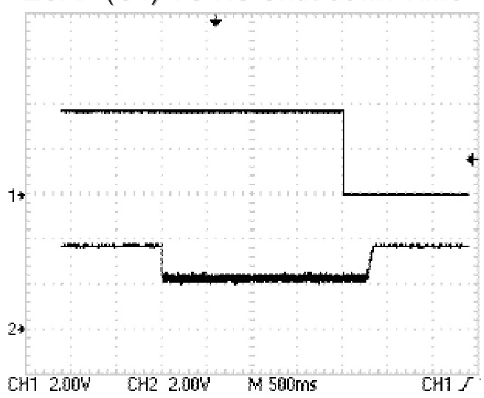
ECAP (C4) VS NS Open Time



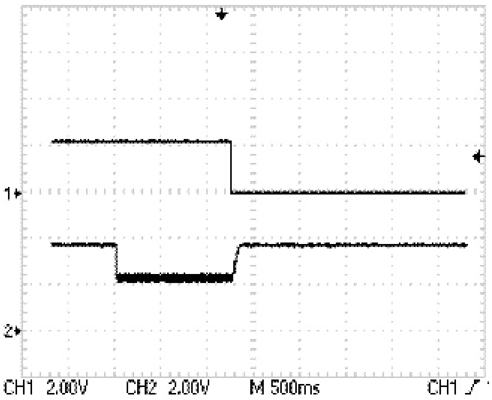
ECAP (C4) VS STAT1 (LED1) Shut-down Time



ECAP (C4) VS NS Shut-down Time



ECAP (C4) VS TPD (Flashlight) Open Time



Pin Functions

STAT2 (Pin 1): Charging Status Indicator 2.

STAT3 (Pin 2): Charging Status Indicator 3.

VOUT5 (Pin 3): Output Voltage. It is a fixed output voltage (5V) for the step-up DC/DC converter.

SW (Pin 4): Switch Node Connection to inductor.

NGATE (Pin 5): The gate for NMOS.

GND (Pin 6): Ground for the IC.

VBAT (Pin 7): Charge Current Output. It should be bypassed with at least a 22μF capacitor. It provides charge current to the battery and regulates the final float voltage to 4.2V.

VHV (Pin 8): Input Voltage. It should be bypassed with at least a 10μF capacitor.

CS (Pin 9): Charge Current Program, Charge Current Monitor and Shutdown Pin. The charge current is programmed by connecting a resistor, $R_{SET,}$ $I_{SET} = V_{CS}/R_{SET}$.

TPD (Pin 10): Flash ON/OFF Indicator (LED Current up to 35mA).

PDRI (Pin 11): Charge Current Monitor and Shutdown Pin. Connect to the grid of the PMOS.

NS (Pin 12): NMOS Short-circuit Protection.

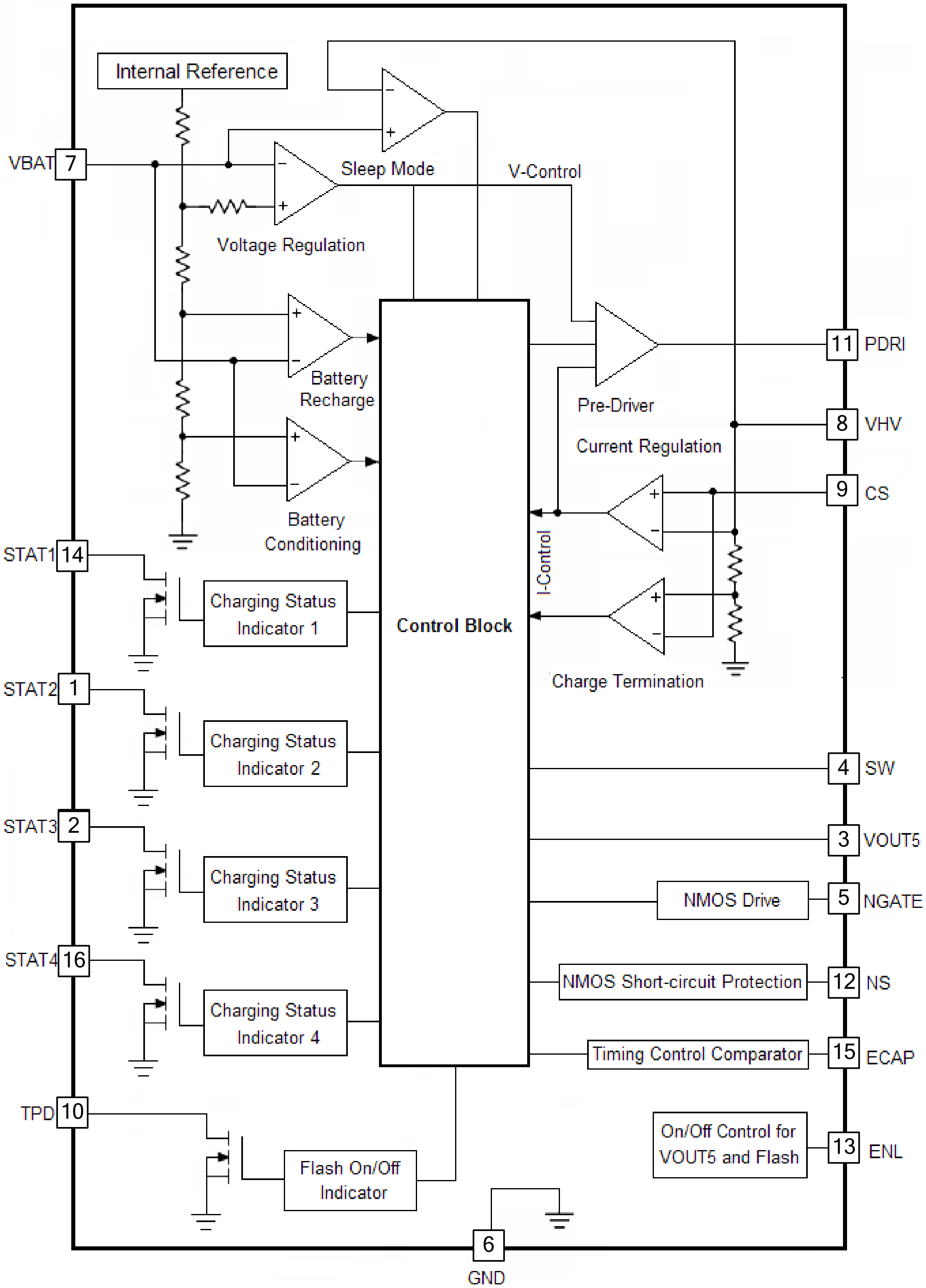
ENL (Pin 13): On/Off Control for VOUT5 (5V). EN=Low: Normal free running operation; EN=High: Shutdown.

STAT1 (Pin 14): Charging Status Indicator 1.

ECAP (Pin 15): Timing Control Comparator.

STAT4 (Pin 16): Charging Status Indicator 4.

Block Diagram



Application Information (Battery Charger)

Operation

The VBAT is a constant current, constant voltage Li-Ion battery charger. The charge current is set by an external sense resistor (R_{SET}) across the VHV and CS pins. The final battery float voltage is internally set to 4.2V. For batteries like lithium-ion that require accurate final float voltage, the internal reference, voltage amplifier and the resistor divider provide regulation with high accuracy.

A charge cycle begins when the input voltage rises above the UVLO level or greater than the battery voltage. At the beginning of the charge cycle, if the battery voltage is less than the trickle charge threshold, the charger goes into trickle charge mode. The trickle charge current is internally set to 10% of the full-scale current.

When the battery voltage exceeds the trickle charge threshold, the charger goes into the full-scale constant current charge mode. In constant current mode, the charge current is set by the external sense resistor R_{SET} and an internal 200mV reference: I_{BAT} = 200mV/ R_{SET}.

Undervoltage Lockout (UVLO)

An undervoltage lockout circuit monitors the input voltage and keeps the charger off until VIN rises above the UVLO threshold and at least 200mV above the battery voltage. To prevent oscillation around the threshold voltage, the UVLO circuit has 200mV per cell of built-in hysteresis. When specifying minimum input voltage requirements, the voltage dropped across the input blocking diode must be added to the minimum supply voltage specification.

Trickle Charge

At the beginning of a charge cycle, if the battery voltage is below the trickle charge threshold, the charger goes into trickle charge mode with the charge current reduced to 10% of the full-scale current.

Application Information (Step-up DC/DC Converter)

No-load Automatic Shutdown

The advantage of HX7501 is that this converter is disconnecting the output from the input of the power supply when there's no load connected with the output or the output current is below 17mA (so called true shutdown mode). In case of a connected battery it prevents it from being discharge during shutdown of the converter.

Inductor Selection

For most applications, the value of the inductor will fall in the range of 1μH to 4.7μH. Its value is chosen based on the desired ripple current. Larger value inductors reduce ripple current, which improves output ripple voltage. Lower value inductors result in higher ripple current and improved transient response time, but will reduce the available output current. Higher V_{IN} or V_{OUT} also increases the ripple current as shown in equation .A reasonable starting point for setting ripple current is $\triangle I_L$ = 0.72A (40% of 1.8A).

$$\Delta I_L = \frac{1}{(f)(L)} V_{OUT}\left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Choose an inductor with a DC current rating at least 1.5 times larger than the maximum load current to ensure that the inductor does not saturate during normal operation. Thus, a 2.16A rated inductor should be enough for most applications (1.8A + 0.36A). To maximize efficiency, choose an inductor with a low DC resistance.

Different core materials and shapes will change the size/current and price/current relationship of an inductor. Toroid or shielded pot cores in ferrite or perm alloy materials are small and do not radiate much energy, but generally cost more than powdered iron core inductors with similar electrical characteristics. The choice of which style inductor to use often depends more on the price versus size, performance and any radiated EMI requirements than on what VOUT5 requires to operate.

Output and Input Capacitor Selection

In continuous mode, the source current of the top MOSFET is a square wave of duty cycle V_{OUT}/V_{IN}. To prevent large voltage transient, a low ESR input capacitor sized for the maximum RMS current must be used. The maximum RMS capacitor current is given by:

$$C_{IN} \text{ required } I_{RMS} \cong I_{OMAX} \frac{\left[V_{OUT}(V_{IN} - V_{OUT})\right]^{1/2}}{V_{IN}}$$

This formula has a maximum value: $I_{RMS} = I_{OUT}/2$ at $V_{IN} = 2V_{OUT}$. This simple worst-case condition is commonly used for design because even significant deviations can't offer much relief. Note that the capacitor manufacturer's ripple current ratings are often based on lifetime of 2000 hours. This makes it advisable to further derate the capacitor, or choose a capacitor rated at a higher temperature than required. Always consult the manufacturer if there is any question.

The selection of C_{OUT} is driven by the required effective series resistance (ESR).Typically, once the ESR requirement for C_{OUT} has been met, the RMS current rating generally far exceeds the $I_{RIPPLE(P-P)}$ requirement. The output ripple ΔV_{OUT} is determined by:

$$\Delta V_{OUT} \cong \Delta I_L\left(ESR + \frac{1}{8fC_{OUT}}\right)$$

Where f = operating frequency, C_{OUT} = output capacitance and ΔI_L = ripple current in the inductor. For a fixed output voltage, the output ripple is highest at maximum input voltage since ΔI_L increases with input voltage.

Aluminum electrolytic and dry tantalum capacitors are both available in surface mount configurations. In the case of tantalum, it is critical that the capacitors are surge tested for use in switching power supplies. An excellent choice is the AVX TPS series of surface mount tantalum. These are specially constructed and tested for low ESR.

Efficiency Considerations

The efficiency of a switching regulator is equal to the output power divided by the input power times 100%. It is often useful to analyze individual losses to determine what is limiting the efficiency and which change would produce the most improvement. Efficiency can be expressed as: Efficiency = 100% - (L1+ L2+ L3+ ...) where L1, L2, etc. are the individual losses as a percentage of input power. Although all dissipative elements in the circuit produce losses, two main sources usually account for most of the losses: VIN quiescent current and I^2R losses. The VIN quiescent current loss dominates the efficiency loss at very low load currents whereas the I^2R loss dominates the efficiency loss at medium to high load currents. In a typical efficiency plot, the efficiency curve at very low load currents can be misleading since the actual power lost is of no consequence.

The VIN quiescent current is due to two components: the DC bias current as given in the electrical characteristics and the internal main switch and synchronous switch gate charge currents. The gate charge current results from switching the gate capacitance of the internal power MOSFET switches. Each time the gate is switched from high to low to high again, a packet of charge ΔQ moves from VIN to ground. The resulting $\Delta Q/\Delta t$ is the current out of VIN that is typically larger than the DC bias current. In continuous mode, $I_{GATECHG} = f\ (Q_T+Q_B)$ where Q_T and Q_B are the gate charges of the internal top and bottom switches. Both the DC bias and gate charge losses are proportional to VIN and thus their effects will be more pronounced at higher supply voltages.

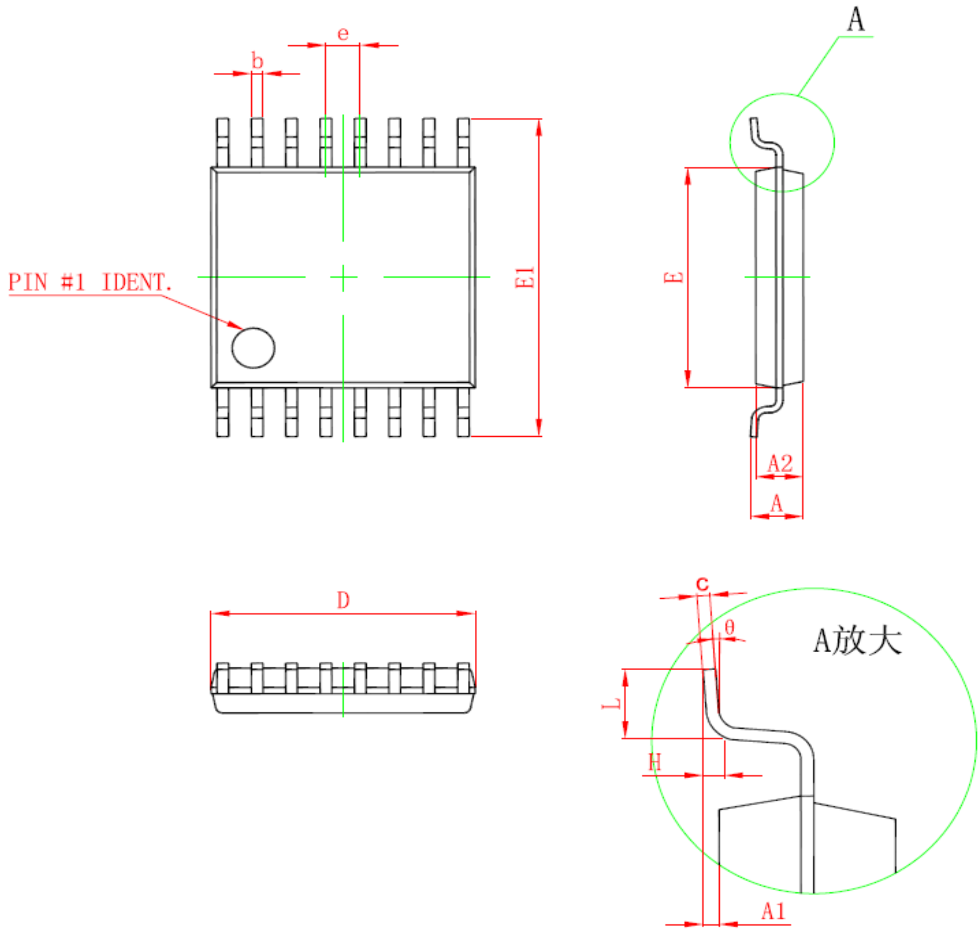
Board Layout Suggestions

Good PC board layout is important to achieve optimal performance from the HX7501. Poor design can cause excessive conducted and/or radiated noise. Conductors carrying discontinuous currents and any high-current path should be made as short and wide as possible. When laying out the printed circuit board, the following checklist should be used to ensure proper operation of the HX7501. Check the following in your layout.

1. The power traces, consisting of the GND trace, the SW trace and the VHV trace should be kept short, direct and wide.
2. Put the input capacitor as close as possible to the device pins (VHV and GND).
3. SW node is with high frequency voltage swing and should be kept small area. Keep analog components away from SW node to prevent stray capacitive noise pick-up.
4. Connect all analog grounds to a command node and then connect the command node to the power ground behind the output capacitor.

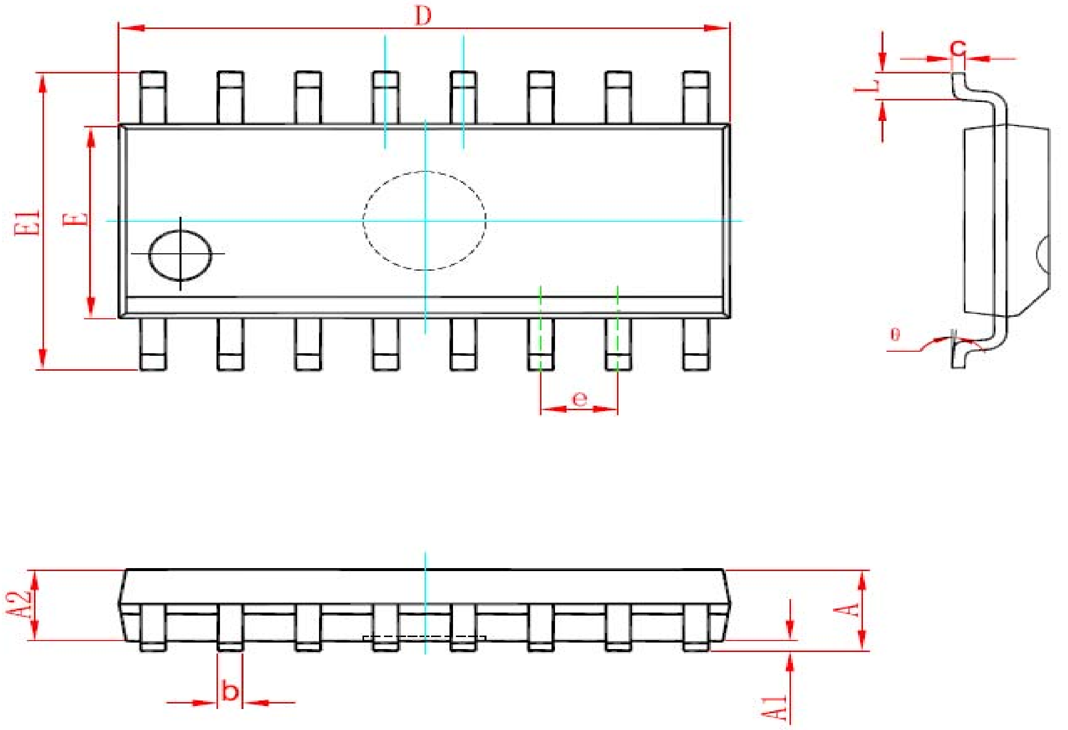
Packaging Information

TSSOP-16L Package Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
D	4.900	5.100	0.193	0.201
E	4.300	4.500	0.169	0.177
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
E1	6.250	6.550	0.246	0.258
A		1.100		0.043
A2	0.800	1.000	0.031	0.039
A1	0.020	0.150	0.001	0.006
e	0.65 (BSC)		0.026 (BSC)	
L	0.500	0.700	0.020	0.028
H	0.25 (TYP)		0.01 (TYP)	
θ	1°	7°	1°	7°

SOP-16 Package Outline Dimension



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	9.800	10.200	0.386	0.402
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

Subject changes without notice