Application Note: SY6924

High Efficiency, 2.5A, Multi-Cell Li-Ion Battery Charger

General Description

SY6924 is a 4-14V input, 2.5A multi-cell Li-Ion battery step-down charger. The charge current up to 2.5A can be programmed by using the external resistor for different portable applications. It also has a programmable charge timeout and adaptive input power limit for safety battery charge operation. It consists of 16V rating reverse blocking FET and power switching FETs with extremely low ON resistance to achieve high charge efficiency and simple peripheral circuit design.

SY6924 along with small QFN3×3 footprint provides small PCB area application.

Ordering Information

SY6924 □(□□)□
- Temperature Code
- Package Code
- Optional Spec Code

Ordering Number	Package type	Note
SY6924QDC	QFN3×3-16	

Features

- Integrated Synchronous Buck and Reverse Blocking FET with 16V Rating
- Adaptive Input Power Limit for 4-14V Wide Input Voltage
- Maximum 2.5A Programmable Charge Current
- 4.2V and 4.35V Constant Voltage Selectable
- +/-0.5% Cell Voltage Accuracy
- Support Single-cell or Two-cell Battery Pack
- External Shutdown Function
- Input Voltage UVLO and OVP
- Thermal Fold-back Protection
- Over Temperature Protection
- Battery Short Protection
- Programmable Charge Timeout
- Charge Status Indication
- Low Profile QFN3×3 Package for Portable Applications

Applications

- Power Bank
- Cellular Telephones, PDA, MP3 Players, MP4 Players
- PSP Game Players, NDS Game Players
- Notebook

Typical Applications

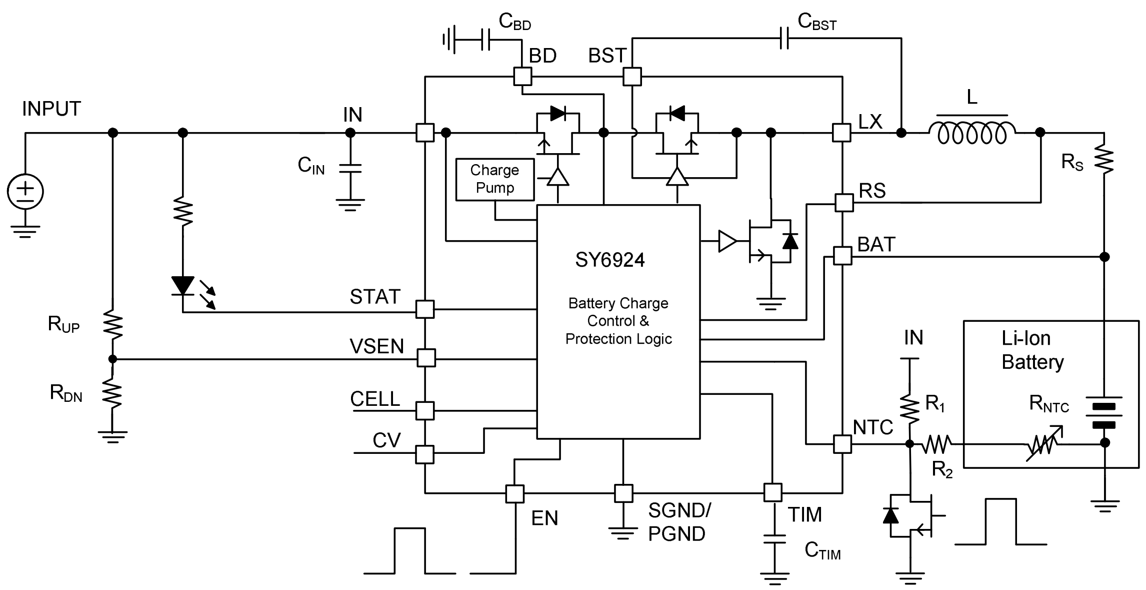
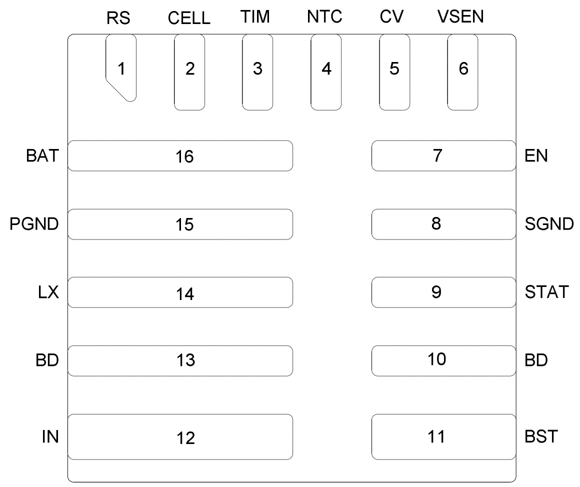


Figure1. Schematic Diagram

Pinout (top view)



(QFN3×3-16)

Top Mark: **Ynxyz**, **(**Device code: Yn, ***x=year code, y=week code, z= lot number code***)

Pin Name	Pin Number	Description
RS	1	Charge current sense resistor positive pin. The sensed voltage drop between RS and BAT is used for charge current regulation and charge termination detection.
CELL	2	Battery voltage selection pin. Floating for two cells battery and grounding for single cell battery. CELL pin can't be pulled high to any bias voltage higher than 3.3V.
TIM	3	Charge time-out programming pin. Connect this pin with a capacitor to ground to program the time-out protection threshold. Internal current source charge the capacitor for TC mode and fast charge (CC&CV) mode's charge time limit. TC charge time limit is about 1/9 of fast charge time.
NTC	4	Battery thermal sense pin. The voltage on the NTC pin is sensed for battery thermal protection. UTP threshold is typical 75% of V_{IN} and OTP threshold is typical 45% of V_{IN}. NTC pin also can be used for the adaptive input power limit reference refresh. The adaptive input power limit threshold will be refreshed when NTC is pulled low for more than 100ms. SY6924 sets the charge current to the trickle value; the IC will refresh the adaptive input power limit threshold according the input voltage. For higher than 6V input, the IC will clamp the input voltage at V_{IN}-0.6V by regulating the duty cycle of Buck converter. For lower than 6V input, the clamped input voltage is set by VSEN pin.
CV	5	Battery CV voltage selection pin.
VSEN	6	Input voltage sense pin for adaptive input power limit. If the voltage drops to internal 1.19V reference voltage, the V_{IN} will be clamped to setting value and input current will be limited.
EN	7	Enable control pin. High logic for enable on and low logic for enable off.
SGND	8	Signal ground pin.

STAT	9	Charge status indication pin. Open drain pin. Pull high to IN thru a LED to indicate the charge in process. When the charge is done, LED is off.
BD	10, 13	Connect to the drain of internal blocking FET. Bypass at least a 10μF ceramic cap to GND.
BST	11	Boot-strap pin. Supply main FET's gate driver. Decouple this pin to LX with a 0.1μF ceramic cap.
IN	12	DC power input pin. Connect a MLCC from this pin to ground to decouple high harmonic noise. This pin has OVP and UVLO function to make the charger operate within safe input voltage area.
LX	14	Switch node pin. Connect to external inductor.
PGND	15	Power ground pin.
BAT	16	Battery voltage sense pin.

Absolute Maximum Ratings (Note 1)

IN, BAT, LX, NTC, STAT, BD, EN, CV, VSEN -- 18V
TIM, CELL-- 4V
BST-LX Voltage --- 4V
RS -- BAT-0.3~BAT+0.3V
LX Pin Current Continuous --- 5A
Power Dissipation, P_D @ T_A = 25°C, QFN3×3--- 2.1W
Package Thermal Resistance (Note 2)
θ_{JA} -- 48 °C/W
θ_{JC} -- 4 °C/W
Junction Temperature Range -- -40°C to 125°C
Lead Temperature (Soldering, 10 sec.) --- 260°C
Storage Temperature Range --- -65°C to 150°C

Recommended Operating Conditions (Note 3)

IN -- 4V to 14V
BAT, LX, NTC, STAT, BD, EN, CV, VSEN---0V to16V
TIM, CELL-- 0V to 3.3V
BST-LX Voltage --- 0V to 3.3V
RS --- BAT-0.25~BAT+0.25V
LX Pin Current Continuous -- 4.5A
Junction Temperature Range --- -40°C to 100°C
Ambient Temperature Range --- -40°C to 85°C

Electrical Characteristics

T_A=25°C, V_{IN}=5V, GND=0V, C_{IN}=10μF, L=2.2μH, R_S=10mΩ, C_{TIM}=330nF, unless otherwise specified.

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Bias Supply (V_{IN})						
Supply Voltage Operation Range	V_{IN}		4		14	V
Input Voltage Lockout Threshold	V_{UVLO}	V_{IN} rising and measured from IN to ground			4	V
Input Voltage Lockout Hysteresis	ΔV_{UVLO}	Measured from IN to ground		0.2		V
Input Over Voltage Protection	V_{IN_OVP}	V_{IN} rising and measured from IN to ground	13.5			V
Input Over Voltage Protection Hysteresis	ΔV_{OVP}	Measured from IN to ground		0.5		V
Quiescent Current						
Battery Discharge Current	I_{BAT}	V_{IN} absent or EN=Low		5	10	μA
Input Quiescent Current	I_{IN}	Disable charge		0.8	1.1	mA
Oscillator and PWM						
Switching Frequency	f_{SW}			500		kHz
Power MOSFET						
$R_{DS(ON)}$ of Main N-FET	R_{NFET_M}			30		mΩ
$R_{DS(ON)}$ of Rectified N-FET	R_{NFET_R}			55		mΩ
$R_{DS(ON)}$ of Blocking N-FET	R_{NFET_B}			45		mΩ
Voltage Regulation						
Battery Charge Voltage	V_{BAT_REG}	1-cell battery, V_{CV}<0.4V	4.179	4.2	4.221	V
		1-cell battery, V_{CV}>1.5V	4.328	4.35	4.371	
		2-cell battery, V_{CV}<0.4V	8.358	8.4	8.442	
		2-cell battery, V_{CV}>1.5V	8.656	8.7	8.744	
Recharge Threshold Refer to V_{BAT_REG}	ΔV_{RCH}	1-cell battery	50	100	150	mV
		2-cell battery	100	200	300	
Trickle Charge Rising Edge Threshold	V_{TRK}	1-cell battery	2.7	2.8	2.9	V
		2-cell battery	5.4	5.6	5.8	
Adaptive Input Current REF Modify						
NTC Voltage Threshold for Adaptive Input Current Reference Refresh	V_{NTC}	NTC falling edge	0.4			V
NTC Low Time to Enable the Adaptive Input Current Refresh	t_{DET}	Low pulse width		100		ms
Charge Current						
Charge Current Accuracy for Constant Current Mode	I_{CC}	I_{CC}=25mV/R_S	-10%		10%	
Charge Current Accuracy for Trickle Current Mode	I_{TC}	I_{TC}=2.5mV/R_S	-50%		50%	
Termination Current	I_{TERM}	I_{TERM}=2.5mV/R_S	-50%		50%	
Output Voltage OVP						
Output Voltage OVP Threshold	V_{O_OVP}		105%	110%	115%	V_{BAT_REG}
Adaptive Input Power Limit Reference						
Reference for Adaptive Input Power Limit	V_{SEN}		1.16	1.19	1.22	V
The Adaptive Input Power Limit Reference is V_{IN}-ΔV_{AICL}	ΔV_{AICL}	NTC pull low than 100ms and V_{IN} is higher than 6V		600		mV

Timer						
Trickle Current Charge Timeout	t_{TC}		0.36	0.5	0.64	hour
Constant Current Charge Timeout	t_{CC}		3.5	4.5	5.5	hour
Charge Mode Change Delay Time	t_{MC}			30		ms
Termination Delay Time	t_{TERM}			30		ms
Recharge Time Delay	t_{RCHG}			30		ms
Short Circuit Protection						
Output Short Protection Threshold, Falling Edge	V_{SHORT}		1.7	2.00	2.3	V
Auto Shut Down						
Auto Shutdown Voltage Threshold	V_{ASD}	V_{IN} fall, measured from IN to BAT	40	110	180	mV
Auto Shutdown Voltage Threshold Hysteresis	ΔV_{ASD}	V_{IN} rise, measured from IN to BAT		65		
Logical Control						
High Level Logic for Enable Control	V_{ENH}		1.5			V
Low Level Logic for Enable Control	V_{ENL}				0.4	V
High Level Logic for CV	V_{CVH}		1.5			V
Low Level Logic for CV	V_{CVL}				0.4	V
Battery Thermal Protection NTC						
Under Temperature Protection	V_{NTC_UTP}		74%	75%	76%	V_{IN}
Under Temperature Protection Hysteresis	$V_{NTC\_UTP\_HYS}$	Falling edge		5%		
Over Temperature Protection	V_{NTC_OTP}		44%	45%	46%	
Over Temperature Protection Hysteresis	$V_{NTC\_OTP\_HYS}$	Rising edge		1.5%		
Thermal Fold-back and Thermal Shutdown						
Thermal Fold-back Threshold	T_{Fold}			120		ºC
Thermal Fold-back Hysteresis Falling Edge	$T_{FoldHYS}$			20		ºC
Thermal Fold-back Ratio	I_{Fold}			0.25		I_{CC}
Thermal Shutdown Temperature	T_{SD}	Rising threshold		160		ºC
Thermal Shutdown Temperature Hysteresis	T_{SDHYS}			30		ºC

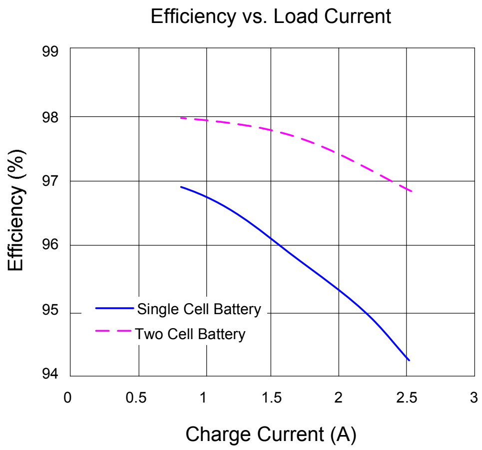
Note 1: Stresses beyond the "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

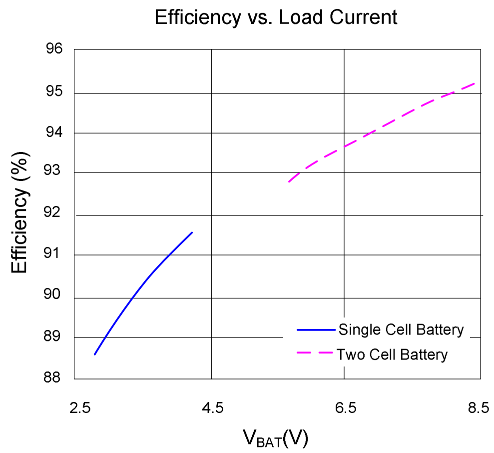
Note 2: θ_{JA} is measured in the natural convection at T_A = 25°C on a low effective four-layer thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

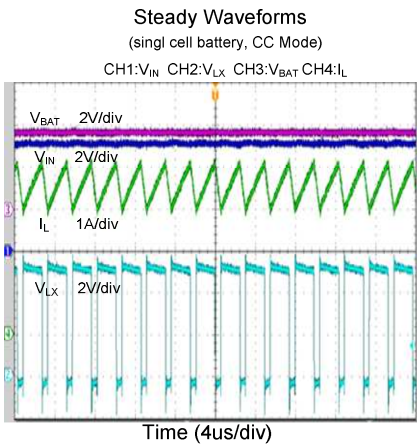
Note 3: The device is not guaranteed to function outside its operating conditions.

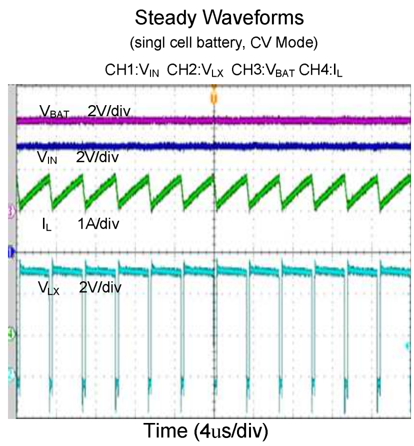
Typical Performance Characteristics

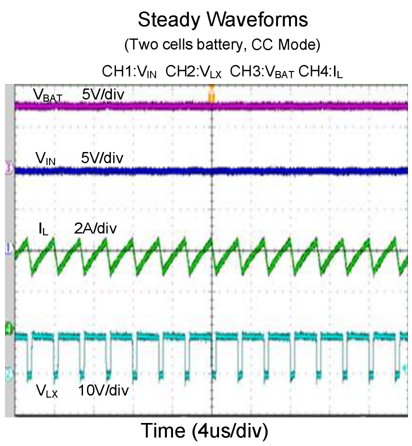
(T_A=25°C, V_{IN}=5V, V_{BAT}=3.6V for single-cell battery application. V_{IN}=9V, V_{BAT}=7.6V for two-cell battery application. R_s=10mΩ, C_{TIM}=330nf, unless otherwise specified.)

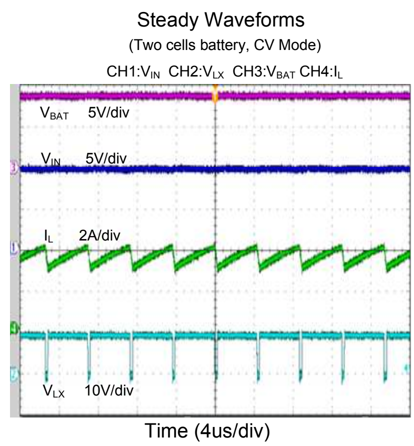








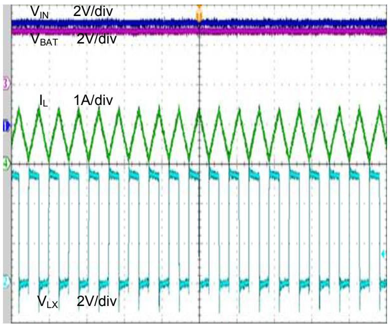




Steady Waveforms

(TC Mode)

CH1:V_{IN} CH2:V_{LX} CH3:V_{BAT} CH4:I_L

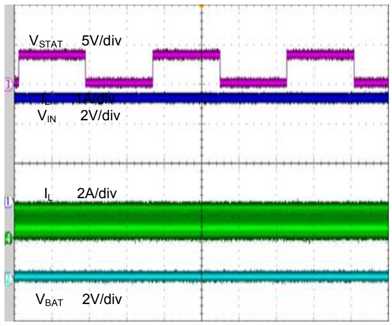


Time (4us/div)

Steady Waveforms

(Short Mode)

CH1:V_{IN} CH2:V_{BAT} CH3:V_{STAT} CH4:I_L

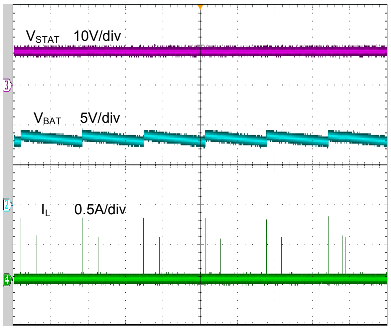


Time (200ms/div)

Steady Waveform When No Battery

(NTC=50% V_{IN}, No battery)

CH2: V_{BAT} CH3: V_{STAT} CH4: I_L

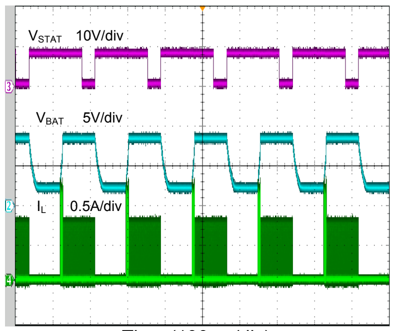


Time (100ms/div)

Steady Waveform

(NTC=50% V_{IN},100mA load to BAT,V_{BAT}=3V)

CH2: V_{BAT} CH3: V_{STAT} CH4: I_L

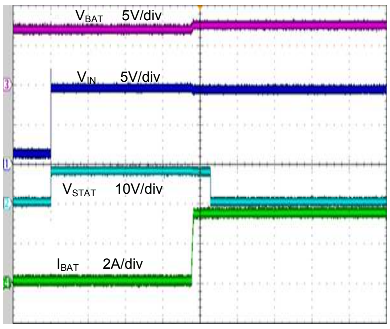


Time (100ms/div)

Power On

(Two Cell Battery)

CH1: V_{IN} CH2: V_{STAT} CH3: V_{BAT} CH4:I_{BAT}

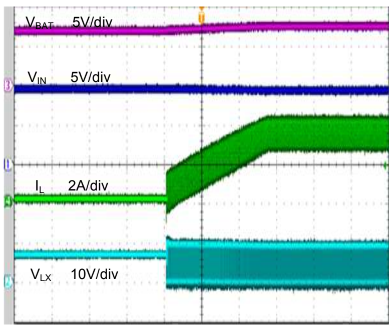


Time (200ms/div)

Soft Start

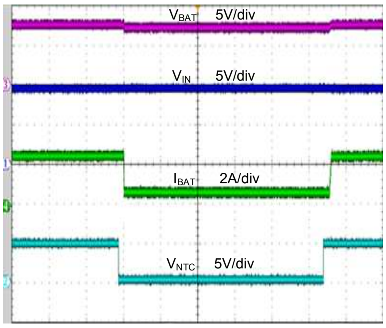
(Two Cell Battery)

CH1: V_{IN} CH2: V_{LX} CH3: V_{BAT} CH4: I_L



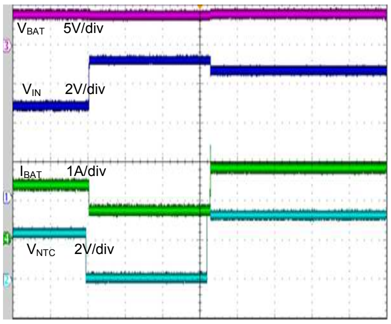
Time (4ms/div)

Low Pulse On NTC Pin
(V_{IN}=9V V_{BAT}=7.6V)
CH1: V_{IN} CH2: V_{NTC} CH3: V_{BAT} CH4:I_{BAT}



Time (200ms/div)

Adaptive Input Power Limit Reference Refresh
(Input Adapter changes to 7V/1A V_{BAT}=3.6V)
CH1: V_{IN} CH2:V_{NTC} CH3: V_{BAT} CH4:I_{BAT}



Time (400ms/div)

General Function Description

SY6924 is a 4V-14V input, 2.5A step-down multi-cell Li-Ion battery charger, which integrates reverse blocking FET, 500 kHz synchronous buck and full protection functions. The charge current up to 2.5A can be programmed by using the external resistor for different portable applications. It also has a programmable charge timeout and adaptive input power limit for safety battery charge operation. It consists of 16V rating FETs with extremely low ON resistance to achieve high charge efficiency and simple peripheral circuit design.

Charging Status Indication Description

STAT is an open drain pin and a pull up resistor is needed for charging status indication. Connect a LED from IN to STAT pin, LED ON means Charge-in-Process, LED OFF means Charge Done, LED Flashing with 1.3Hz means Fault Mode.

1. Charge-In-Process – Pull and keep STAT pin to Low;
2. Charge Done – Pull and keep STAT pin to High;
3. Fault Mode – Output high and low voltage alternatively with 1.3Hz frequency. The faults include input OVP, BAT OVP, BAT short, BAT UTP, BAT OTP, time-out and thermal shutdown.

Switching Mode Buck Charger Basic Operation Description

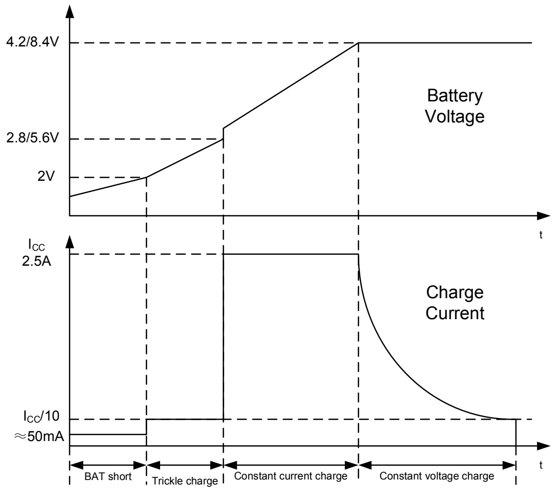
Switching Mode Control Strategy

SY6924 utilizes quasi-fixed frequency control to simplify the internal close-loop compensation design. The quasi-fixed frequency settled at 500 kHz is easy for the size minimization of peripheral circuit design. During the light load operation, the OFF time of the main switch is going to be stretched to achieve frequency fold back.

Operation Principle

SY6924 works as a synchronous Buck mode battery charger when the adapter is present. It utilizes 500 kHz switching frequency to minimize the PCB design.

The charger will operate in battery short mode, trickle charge mode, constant current charge mode and constant voltage charge mode according to the battery voltage. The charge current in every mode is showed in following charge curve. In constant voltage mode, if charge current is lower than termination current, the charger will stop charging until battery voltage drops to recharge voltage.



Basic Adaptive Input Power Limit Principle

SY6924 can limit the input power adaptively and adjust this threshold according the input voltage. It will automatically decrease charge current when IN voltage drops to adaptive input power limit reference V_{REF}.

For typical 5V adapter, V_{REF} is set by VSEN pin, that is calculated as：

$$V_{REF}=1.19\times\frac{R_{UP}+R_{DN}}{R_{DN}}$$

If IN voltage is higher than 6V, V_{REF} is calculated as:

$$V_{REF}=V_{IN}-\Delta V_{AICL}$$

Where, ΔV_{AICL} is 0.6V typically.

V_{IN} is the input voltage when adapter insert. V_{REF} can be modified after a more than 100ms low pulse on NTC pin if the adapter is always present.

When NTC is pulled low, the charge current is set to the trickle value; battery thermal protection and adaptive input power limit function are disabled.

Full Charger Protections Description

In charge mode, SY6924 has full protection to protect the IC and the battery.

Input Over Voltage Protection – SY6924 has IN over voltage protection. It will turn off switching charger when input OVP occurs. IC will auto recover normal operation when fault removes.

BAT Over Voltage Protection – SY6924 will stop charging when BAT OVP occurs. The IC will auto recover normal operation when fault removes.

Timeout Protection – The charger can detect a bad battery. It will stop charge and latch off when the charger works over safety time which is set by C_{TIM}. Only recycling the input can release this fault.

Battery Thermal Protection – When NTC voltage is lower than OTP threshold and higher than 0.4V or higher than UTP threshold, the converter will stop switching. IC will auto recovery when fault removes.

Thermal Shutdown Protection – The IC will stop operation when the junction temperature is higher than 160°C. It will auto recover normal when fault removes.

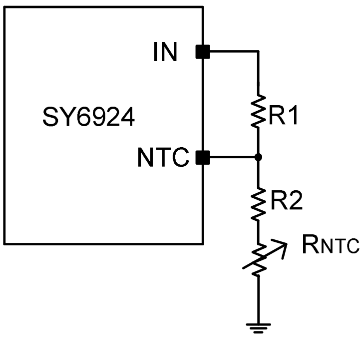
Applications Information

Because of the high integration of SY6924, the application circuit based on this regulator IC is rather simple. Only input capacitor C_{BD}, output capacitor C_{OUT}, inductor L, NTC resistors R1, R2, charging current sense resistor Rs and timer capacitor C_{TIM} need to be selected for the targeted applications specifications.

NTC Resistor:

SY6924 monitors battery temperature by measuring the input voltage and NTC voltage. The controller triggers the UTP or OTP when the ratio K ($K=V_{NTC}/V_{IN}$) reaches the threshold of UTP (K_{UT}) or OTP (K_{OT}). The temperature sensing network is showed as below.

Choose R1 and R2 to program the proper UTP and OTP points.



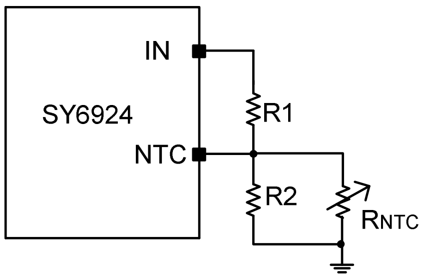
The calculation steps are:

1. Define K_{UT}, K_{UT} =74~76%
2. Define K_{OT}, K_{OT} =44~46%
3. Assume the resistance of the battery NTC thermistor is R_{UT} at UTP threshold and R_{OT} at OTP threshold.
4. Calculate R2,
$$R2=\frac{K_{OT}(1-K_{UT})R_{UT}-K_{UT}(1-K_{OT})R_{OT}}{K_{UT}-K_{OT}}$$
5. Calculate R1
$$R1=(1/K_{OT}-1)(R2+R_{OT})$$

If choose the typical values K_{UT} =75% and K_{OT}=45%, then

$$R2=0.375R_{UT}-1.375R_{OT}$$
$$R1=1.222(R2+R_{OT})$$

SY6924 accepts flexible NTC divider circuits. For below method, R1 and R2 can be calculated by below equations.



$$R2=\frac{R_{OT}\times R_{UT}\times(K_{UT}-K_{OT})}{K_{OT}\times K_{UT}\times(R_{OT}-R_{UT})+R_{UT}\times K_{OT}-R_{OT}\times K_{UT}}$$
$$R1=\frac{R2\times R_{UT}\times(1-K_{UT})}{K_{UT}\times(R2+R_{UT})}$$

If choose the typical values K_{UT} =75% and K_{OT}=45%, then

$$R2=\frac{0.3R_{UT}\times R_{OT}}{0.1125\times R_{UT}-0.4125\times R_{OT}}$$
$$R1=\frac{R2\times R_{UT}}{3(R_{UT}+R2)}$$

Charging Current Sense Resistor Rs

The charging current sense resistor R_S is calculated as below:

$$R_S=\frac{25mV}{I_{CC}},\qquad \text{Unit: m}\Omega$$

Where the I_{CC} is the battery constant charging current, unit: A.

Timer Capacitor C_{TIM}

The charger also provides a programmable charging timer. The charging time is programmed by the capacitor connected between the TIM pin and GND. The capacitance is given by the formula:

$C_{TIM}=2\times10^{-11}\ \mathrm{S}\times T_{CC}$, Unit: F

T_{CC} is the permitted fast charging time, unit: s.

Input Capacitor C_{BD}

The ripple current through input capacitor is greater than

$$I_{C_{BD}\_MIN} = I_{CC}\sqrt{D(1-D)}$$

To minimize the potential noise problem, place a typical X7R or a better grade ceramic capacitor really close to the BD and GND pins. Care should be taken to minimize the loop area formed by C_{BD}, and BD/GND pins.

Output Capacitor C_{OUT}

The output capacitor is selected to handle the output ripple noise requirements. Both steady state ripple and transient requirements must be taken into consideration when selecting this capacitor. For the best performance, it is recommended to use X7R or better grade ceramic capacitor with 10μF capacitance.

Output Inductor L

There are several considerations in choosing this inductor.

1) Choose the inductance to provide the desired ripple current. It is suggested to choose the ripple current to be about 40% of the average charge current. The inductance is calculated as:

$$L=\frac{V_{OUT}\times(1-V_{OUT}/V_{IN,MAX})}{F_{SW}\times I_{OUT,MAX}\times 40\%}$$

Where F_{SW} is the switching frequency and $I_{OUT,MAX}$ is the maximum load current.

SY6924 is quite tolerant of different ripple current amplitude. Consequently, the final choice of inductance can be slightly off the calculation value without significantly impacting the performance.

2) The saturation current rating of the inductor must be selected to be greater than the peak inductor current under full load conditions.

$$I_{SAT,MIN}>I_{OUT,MAX}+\frac{V_{OUT}\times(1-V_{OUT}/V_{IN,\ MAX})}{2\times F_{SW}\times L}$$

3) The DCR of the inductor and the core loss at the switching frequency must be low enough to achieve the desired efficiency requirement. It is desirable to choose an inductor with DCR<20mΩ to achieve a good overall efficiency.

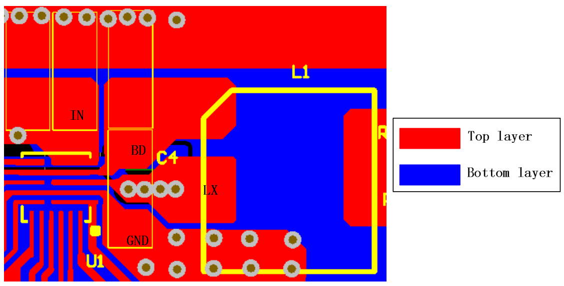
SY6924 is a high integrated charger and the internal compensation circuits also limit the inductor choice. Out of the range from 0.68μH to 3.3μH is not suggested. The 2.2μH inductor can almost cover the normal applications.

Layout Design

The layout design of SY6924 regulator is relatively simple. For the best efficiency and minimum noise problems, we should place the following components close to the IC: C_{BD}, L.

1) It is desirable to maximize the PCB copper area connecting to GND pin to achieve the best thermal and noise performance. If the board space allowed, a ground plane is highly desirable.

2) C_{BD} must be close to pins BD and GND. The loop area formed by C_{BD} and GND must be minimized. Following picture is the recommended layout design of C_{BD}.



3) The PCB copper area associated with LX pin must be minimized to avoid the potential noise problem.

4) The capacitor C_{TIM} and the trace connecting to the TIM pin must not be adjacent to the LX net on the PCB layout to avoid the noise problem.

5) The current sense resistor should be adjacent to the junction of the inductor and output capacitor. The routes from the sense leads on the sense resistor to the IC pins should be close to each other to minimize loop area. Please don't route the sense leads through a high current path. Following picture is the recommended layout design.

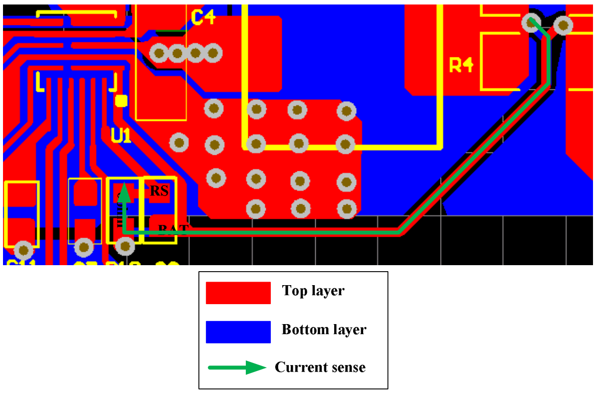
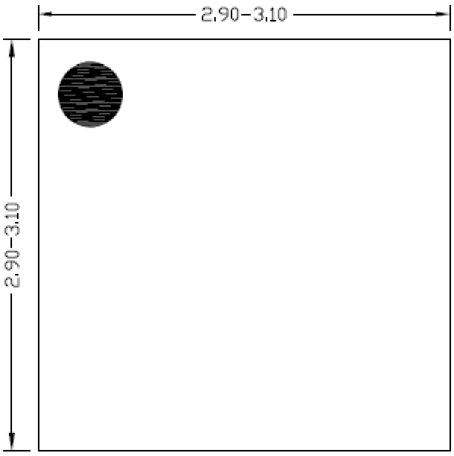
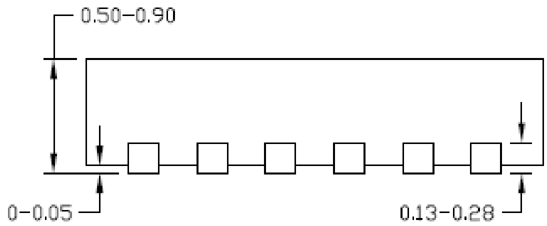


Figure2. PCB Layout Suggestion

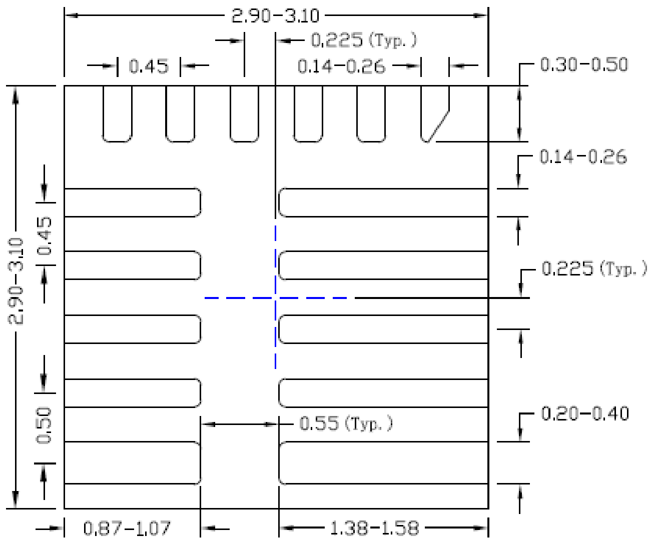
QFN3×3-16 Package Outline Drawing



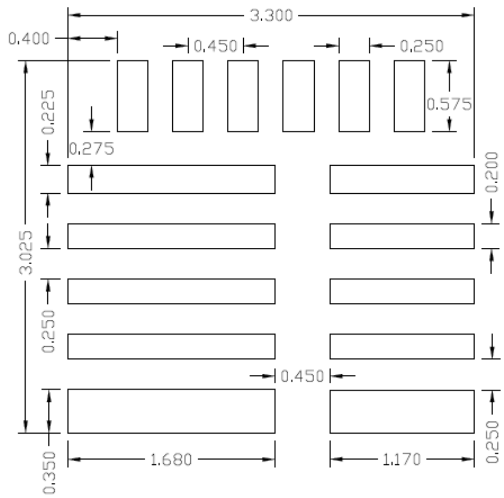
Top View



Side View



Bottom View



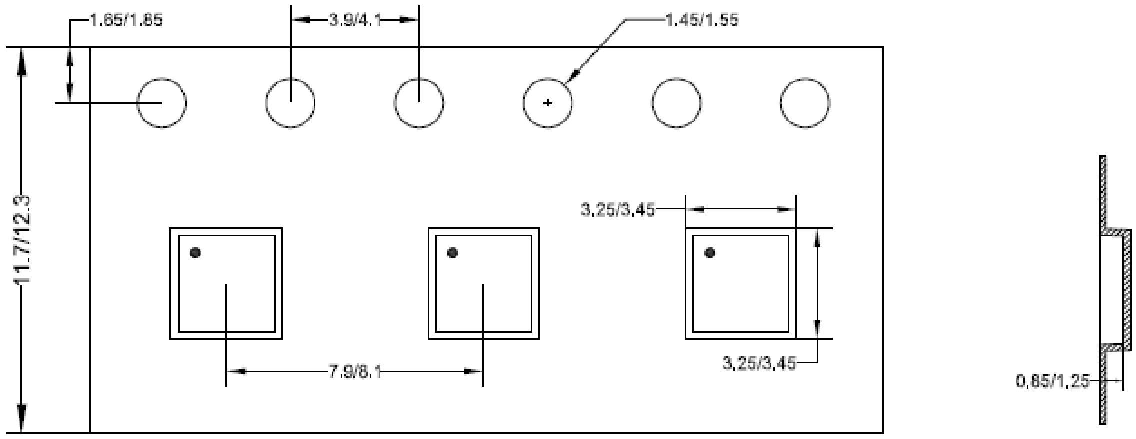
Recommended PCB Layout (Reference Only)

Notes: All dimension in millimeter and exclude mold flash & metal burr.

Taping & Reel Specification

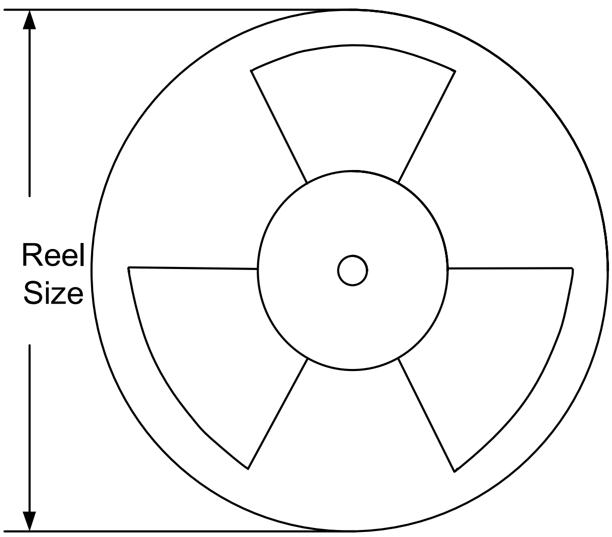
1. Taping orientation

QFN3x3



Feeding direction →

2. Carrier Tape & Reel specification for packages



Package type	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer length(mm)	Leader length (mm)	Qty per reel
QFN3x3	12	8	13"	400	400	5000

3. Others: NA

IMPORTANT NOTICE

1. **Right to make changes.** Silergy and its subsidiaries (hereafter Silergy) reserve the right to change any information published in this document, including but not limited to circuitry, specification and/or product design, manufacturing or descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products are sold subject to Silergy's standard terms and conditions of sale.

2. **Applications.** Application examples that are described herein for any of these products are for illustrative purposes only. Silergy makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification. Buyers are responsible for the design and operation of their applications and products using Silergy products. Silergy or its subsidiaries assume no liability for any application assistance or designs of customer products. It is customer's sole responsibility to determine whether the Silergy product is suitable and fit for the customer's applications and products planned. To minimize the risks associated with customer's products and applications, customer should provide adequate design and operating safeguards. Customer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Silergy assumes no liability related to any default, damage, costs or problem in the customer's applications or products, or the application or use by customer's third-party buyers. Customer will fully indemnify Silergy, its subsidiaries, and their representatives against any damages arising out of the use of any Silergy components in safety-critical applications. It is also buyers' sole responsibility to warrant and guarantee that any intellectual property rights of a third party are not infringed upon when integrating Silergy products into any application. Silergy assumes no responsibility for any said applications or for any use of any circuitry other than circuitry entirely embodied in a Silergy product.

3. **Limited warranty and liability.** Information furnished by Silergy in this document is believed to be accurate and reliable. However, Silergy makes no representation or warranty, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. In no event shall Silergy be liable for any indirect, incidental, punitive, special or consequential damages, including but not limited to lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges, whether or not such damages are based on tort or negligence, warranty, breach of contract or any other legal theory. Notwithstanding any damages that customer might incur for any reason whatsoever, Silergy' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Standard Terms and Conditions of Sale of Silergy.

4. **Suitability for use.** Customer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of Silergy components in its applications, notwithstanding any applications-related information or support that may be provided by Silergy. Silergy products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an Silergy product can reasonably be expected to result in personal injury, death or severe property or environmental damage. Silergy assumes no liability for inclusion and/or use of Silergy products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

5. **Terms and conditions of commercial sale**. Silergy products are sold subject to the standard terms and conditions of commercial sale, as published at http://www.silergy.com/stdterms, unless otherwise agreed in a valid written individual agreement specifically agreed to in writing by an authorized officer of Silergy. In case an individual agreement is concluded only the terms and conditions of the respective agreement shall apply. Silergy hereby expressly objects to and denies the application of any customer's general terms and conditions with regard to the purchase of Silergy products by the customer.

6. **No offer to sell or license**. Nothing in this document may be interpreted or construed as an offer to sell products that is open for acceptance or the grant, conveyance or implication of any license under any copyrights, patents or other industrial or intellectual property rights. Silergy makes no representation or warranty that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right. Information published by Silergy regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from Silergy under the patents or other intellectual property of Silergy.

For more information, please visit: www.silergy.com