SY20741C

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

General Description

SY20741C is a 4-13V 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.

SY20741C along with small QFN3×3 footprint provides small PCB area application.

Ordering Information

SY20741 □(□□)□

- Temperature Code
- Package Code
- Optional Spec Code

Ordering Number	Package type	Note
SY20741CQDC	QFN3×3-16	

Features

- Integrated Synchronous Buck and Reverse Blocking FET with 16V Rating
- Adaptive Input Power Limit for 4-13V Wide Input Voltage
- Maximum 2.5A Programmable Charge Current
- 4.1V and 4.2V 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

Typical Applications

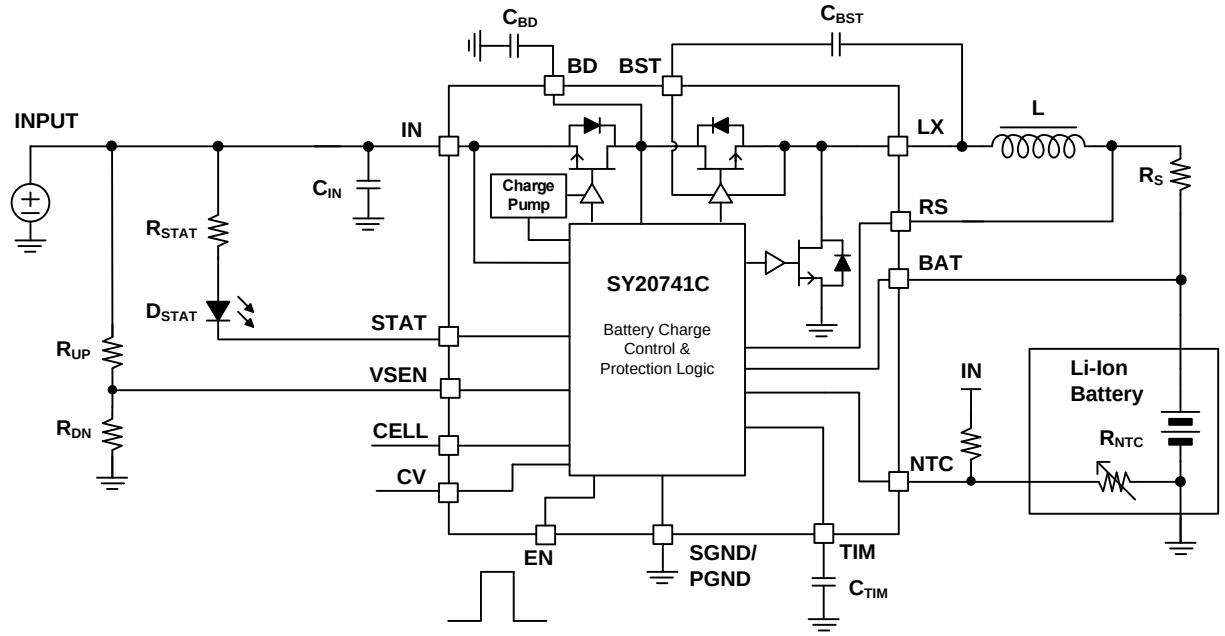
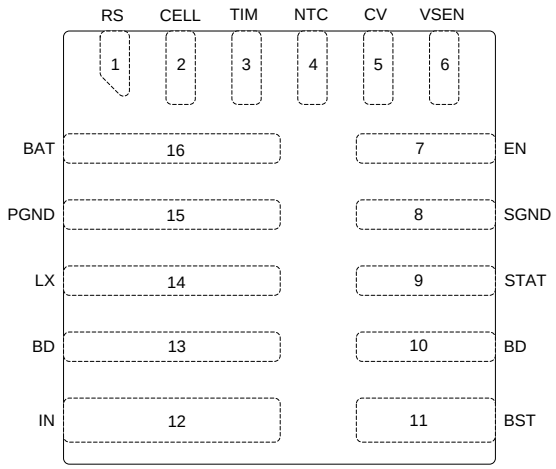


Figure1. Schematic Diagram

Pinout (top view)



(QFN3×3-16)

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

Pin Name	Pin No	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 charges 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 76% of V_{IN} and OTP threshold is typical 45% of V_{IN}.
CV	5	Battery CV voltage selection pin.
VSEN	6	Input voltage sense pin for adaptive input power limit. If the voltage drops to internal 1.2V 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, RS, BAT, LX, NTC, STAT, BD, EN, CV, VSEN ---------- -0.3V to 18V
TIM, CELL---------- -0.3V to 4V
BST-LX ---------- -0.3V to 4V
RS-BAT ---------- -0.3V to 0.3V
LX Pin Current Continuous ---------- 3.5A
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 13V
RS, BAT, LX, NTC, STAT, BD, EN, CV, VSEN----------0V to 16V
TIM, CELL---------- 0V to 3.3V
BST-LX ---------- 0V to 3.3V
RS-BAT ---------- -0.25V to 0.25V
LX Pin Current Continuous ---------- 2.5A
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		13	V
Input Voltage Lockout Threshold	V_{UVLO}	V_{IN} rising and measured from IN to ground			3.9	V
Input Voltage Lockout Hysteresis	ΔV_{UVLO}	Measured from IN to ground		150		mV
Input Over Voltage Protection	V_{IN_OVP}	V_{IN} rising and measured from IN to ground	13.1	14		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 and 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	4.079	4.1	4.121	V
		1-cell battery, V_{CV}>1.5V	4.179	4.2	4.221	
		2-cell battery, V_{CV}<0.4V	8.159	8.2	8.241	
		2-cell battery, V_{CV}>1.5V	8.358	8.4	8.442	
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	2.73	2.83	2.93	V
		2-cell battery	5.46	5.66	5.86	
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	1.2	1.24	V
Timer						
Trickle Current Charge Timeout	t_{TC}	C_{TIM}=330nF	0.34	0.5	0.67	hour
Constant Current Charge Timeout	t_{CC}		3.1	4.5	6.2	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	30	90	170	mV
Auto Shutdown Voltage Threshold Hysteresis	ΔV_{ASD}	V_{IN} rise, measured from IN to BAT		65		
Logic 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}		75%	76%	77%	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}	Rising edge		120		ºC
Thermal Fold-back Threshold Hysteresis	$T_{FoldHYS}$			20		ºC
Thermal Fold-back Ratio	I_{Fold}			0.25		I_{CC}
Thermal Shutdown Temperature	T_{SD}	Rising edge		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.

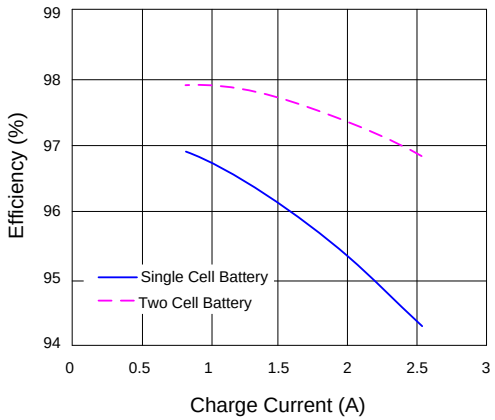
Note 2: θ_{JA} is measured in the natural convection at T_A = 25°C on a low effective four-layer thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

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

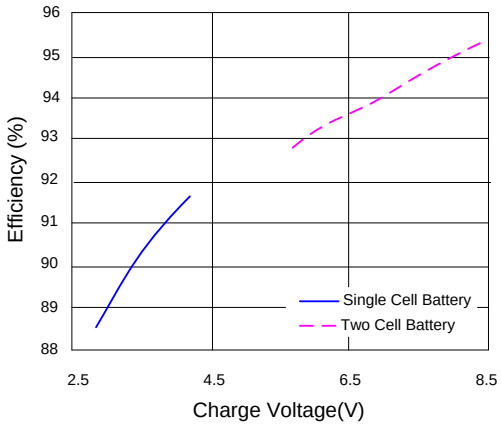
Typical Performance Characteristics

(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.)

Efficiency vs. Charge Current (CV Mode)



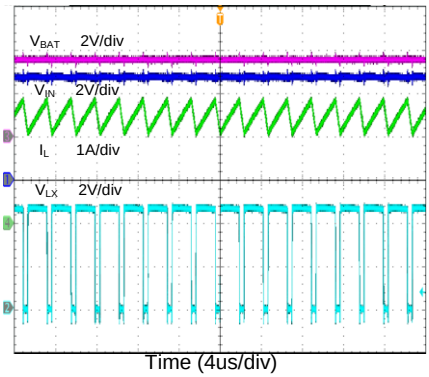
Efficiency vs. Charge Voltage (CC Mode)



Steady Waveforms

(singl cell battery, CC Mode)

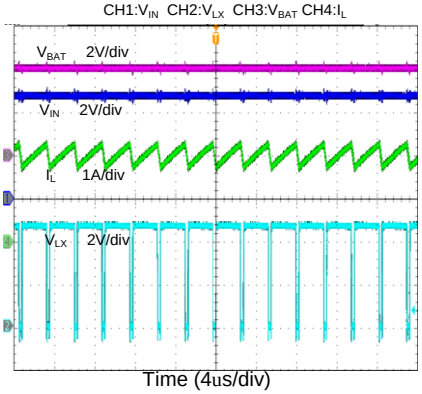
CH1:V_{IN} CH2:V_{LX} CH3:V_{BAT} CH4:I_L



Steady Waveforms

(singl cell battery, CV Mode)

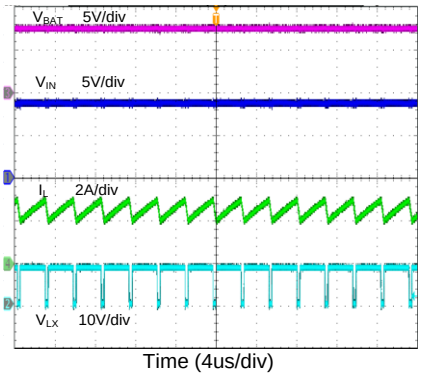
CH1:V_{IN} CH2:V_{LX} CH3:V_{BAT} CH4:I_L



Steady Waveforms

(Two cells battery, CC Mode)

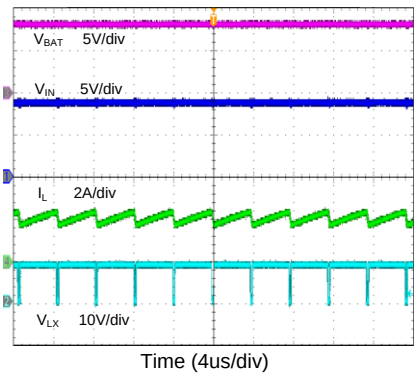
CH1:V_{IN} CH2:V_{LX} CH3:V_{BAT} CH4:I_L



Steady Waveforms

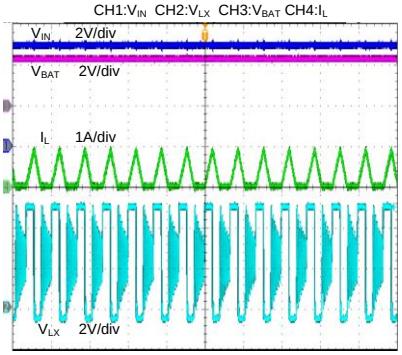
(Two cells battery, CV Mode)

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



Steady Waveforms

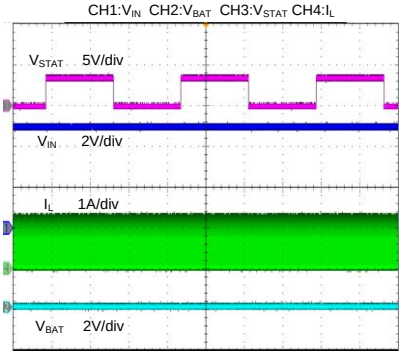
(TC Mode)



Time (4us/div)

Steady Waveforms

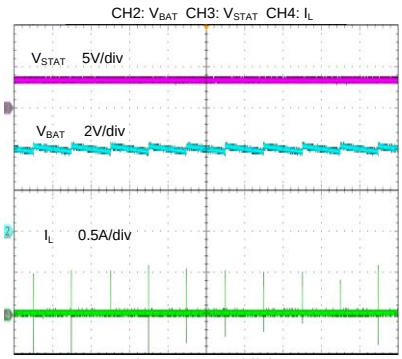
(Short Mode)



Time (200ms/div)

Steady Waveform When No Battery

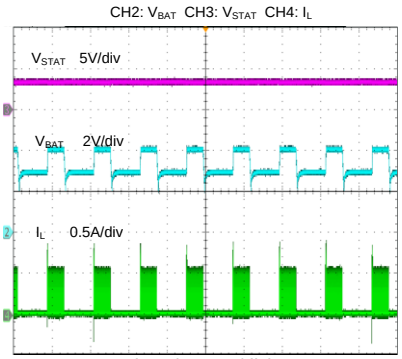
(NTC=50% V_{IN}, No battery)



Time (200ms/div)

Steady Waveform

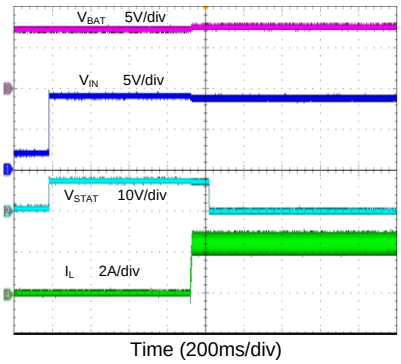
(NTC=50% V_{IN},100mA load to BAT,V_{BAT}=3V)



Time (100ms/div)

Power On

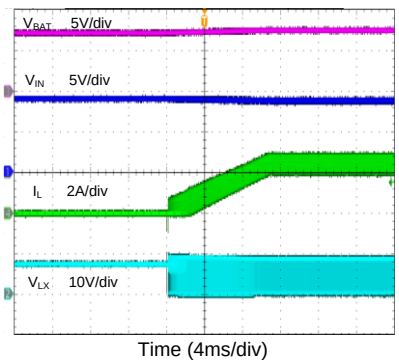
(Two Cell Battery)



Time (200ms/div)

Soft Start

(Two Cell Battery)



Time (4ms/div)

General Function Description

SY20741C is a 4V-13V 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

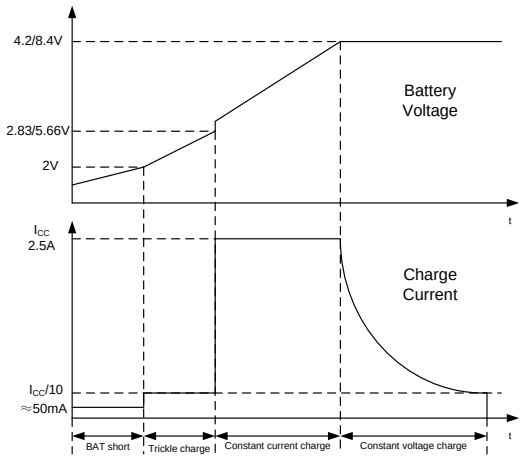
Switching Mode Control Strategy

SY20741C 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

SY20741C 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

SY20741C can limit the input power adaptively. It will automatically decrease charge current when IN voltage drops to adaptive input power limit reference V_{REF}.

V_{REF} is set by VSEN pin, that is calculated as:

$$V_{REF}=1.2\times\frac{R_{UP}+R_{DN}}{R_{DN}}$$

Full Charger Protections Description

In charge mode, SY20741C has full protection to protect the IC and the battery.

Input Over Voltage Protection – SY20741C 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 – SY20741C will stop charging when BAT OVP occurs. 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 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.

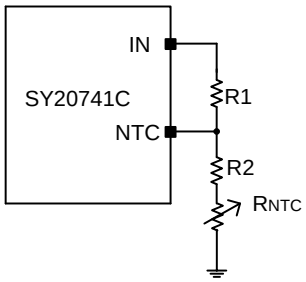
Applications Information

Because of the high integration of SY20741C, 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

SY20741C 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 R_1 and R_2 to program the proper UTP and OTP points.



The calculation steps are:

1. Define K_{UT}, K_{UT} =75~77%
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 R_2,

$$R_2= \frac{K_{OT}(1-K_{UT})R_{UT}-K_{UT}(1-K_{OT})R_{OT}}{K_{UT}-K_{OT}}$$

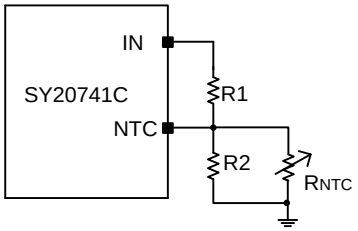
5. Calculate R_1

$$R_1=(1/K_{OT}-1)(R_2+R_{OT})$$

If choose the typical values K_{UT} =76% and K_{OT}=45%, then

$$R_2=0.348R_{UT}-1.348R_{OT}$$
$$R_1=1.222(R_2+R_{OT})$$

SY20741C accepts flexible NTC divider circuits. For below method, R_1 and R_2 can be calculated by below equations.



$$R_2= \frac{R_{OT}\times R_{UT}(K_{UT}-K_{OT})}{K_{OT}\times K_{UT}\times (R_{OT}-R_{UT})+R_{UT}\times K_{OT}-R_{OT}\times K_{UT}}$$

$$R_1= \frac{R_2\times R_{UT}\times (1-K_{UT})}{K_{UT}\times (R_2+R_{UT})}$$

If choose the typical values K_{UT} =76% and K_{OT}=45%, then

$$R_2= \frac{0.31R_{UT}\times R_{OT}}{0.108\times R_{UT}-0.418\times R_{OT}}$$

$$R_1= \frac{0.316R_2\times R_{UT}}{R_{UT}+R_2}$$

Charging Current Sense Resistor Rs

The charging current sense resistor R_S is calculated as below:

$$R_S = \frac{25mV}{I_{CC}},$$ Unit: mΩ

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:

$C_{TIM}=2\times10^{-11}\ S\times T_{CC}$, 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.

SY20741C 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.

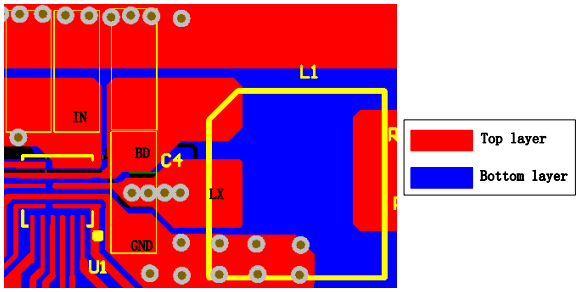
SY20741C is a high integrated charger and the internal compensation circuits also limit the inductor choice. Out of the range from 0.68μH to 3.3μH is not suggested. The 2.2μH inductor can almost cover the normal applications.

Layout Design

The layout design of SY20741C 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.

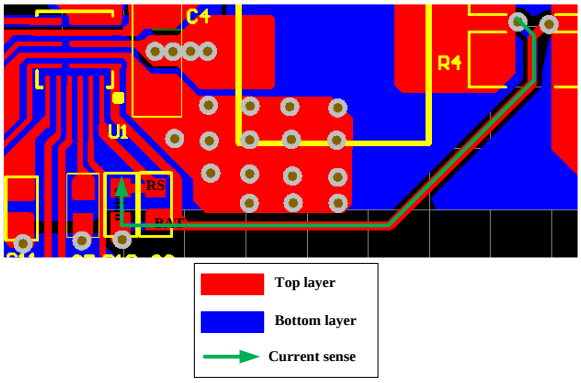
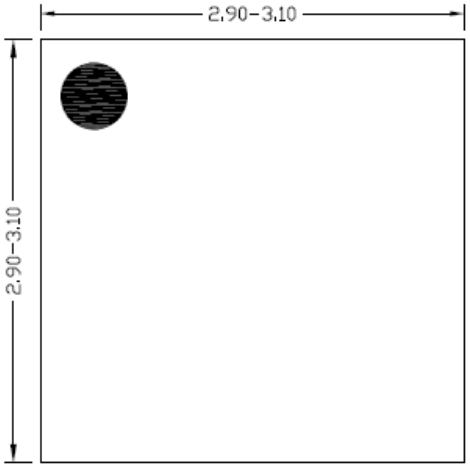
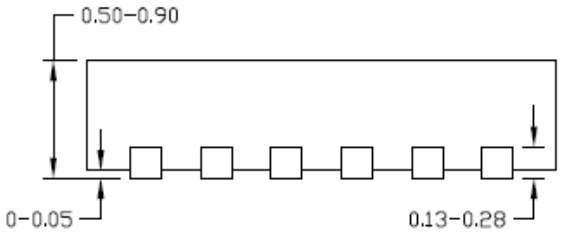


Figure2. PCB Layout Suggestion

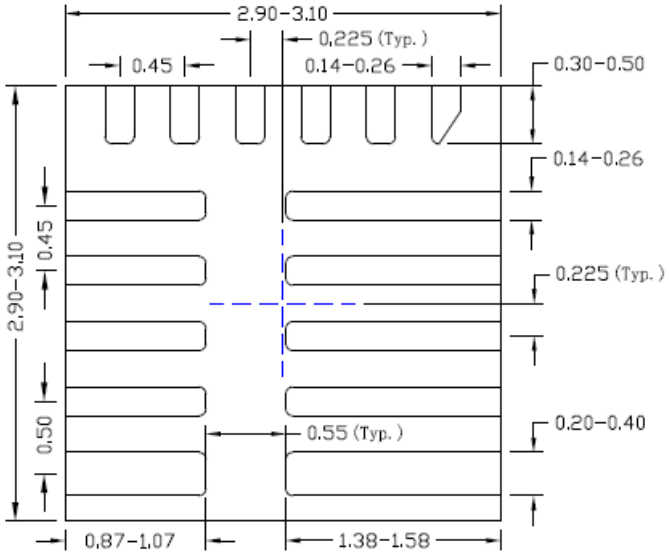
QFN3×3-16 Package Outline Drawing



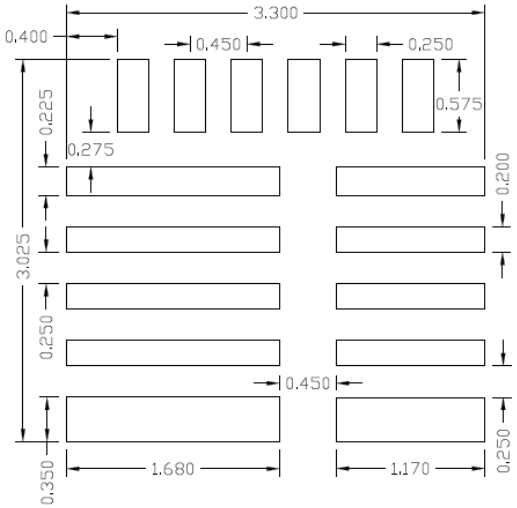
Top View



Side View



Bottom View



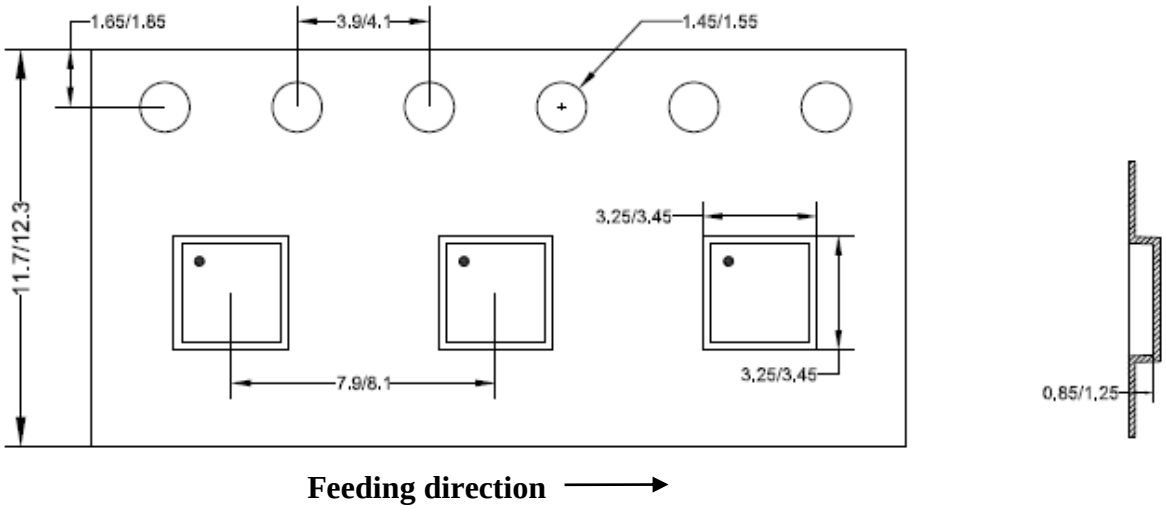
Recommended PCB Layout (Reference Only)

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

Taping & Reel Specification

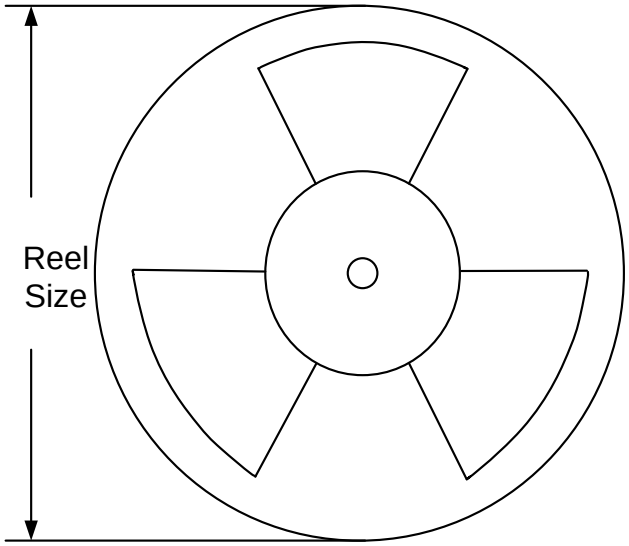
1. Taping orientation

QFN3×3



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
QFN3×3	12	8	13"	400	400	5000

3. Others: NA

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