# Application Note:AN_SY6912A

## 2A Multi-Cell High Efficiency Switching Charger

***Preliminary Specification***

## General Description

SY6912A is a 4.0-23V input, 2A multi-cell synchronous Buck Li-Ion battery charger, suitable for portable application. Select pin is convenient for multi-cell charging. 800 kHz synchronous buck regulator integrates of 23V rating FETs with ultra low on- resistance to achieve high efficiency and simple circuit design.

## Ordering Information

SY6912 □(□□)□

- Temperature Code
- Package Code
- Optional Spec Code

Temperature Range: -40°C to 85°C

| Ordering Number | Package type | Note |
|---|---|---|
| SY6912AFCC | SO8E | |

## Features

- Wide Input Voltage Range: 4.0V to 23V
- High Efficiency Int. Synchronous Buck Regulator with Fixed 800kHz Switching Frequency
- Selectable for Multi-cell Charging
- Trickle Current / Constant Current / Constant Voltage Charge Mode
- Programmable (2A Max) Constant Charge Current
- Programmable Charging Timer
- Input Voltage UVLO and Battery OVP
- Over Temperature Protection
- Output Short Circuit Protection
- Automatic Shutdown Prevents Reverse Energy Flow
- Charge Status Indication
- Normal Synchronous Buck Operation when Battery Removed
- Compact package SO8E

## Applications

- Cellular Telephones,
- PDA, MP3 Players, MP4 Players
- Digital Cameras
- Bluetooth Applications
- PSP Game Players, NDS Game Players
- Notebook

## Typical Applications

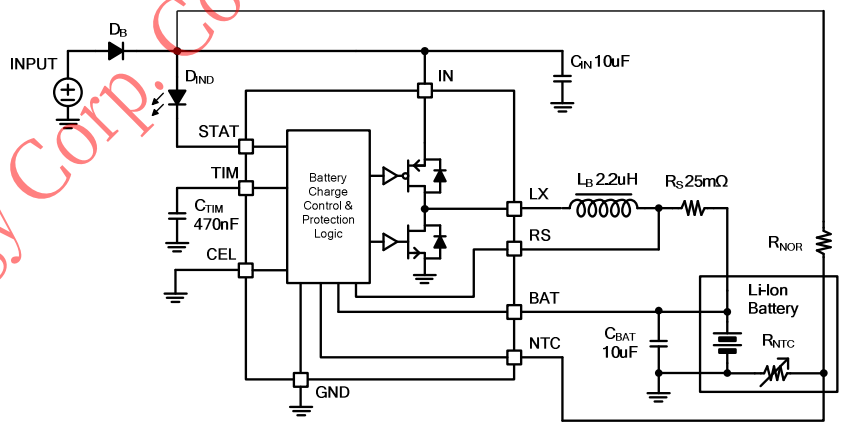
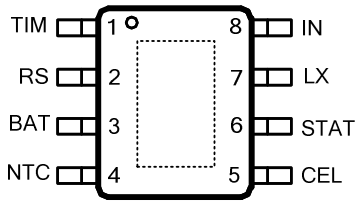



**Figure 1. SY6912A Schematic Diagram**

## Pinout (top view)




(SO8E)

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

| Name | Number | Description |
|---|---|---|
| RS | 2 | Charge current program pin. Connect a current sense resistor from RS pin to BAT pin. Average charge current is detected for both TC mode and CC mode. |
| BAT | 3 | Battery positive pin. |
| NTC | 4 | Thermal protection pin. UTP threshold is about 75%$V_{IN}$ and OTP threshold is about 30%$V_{IN}$. Pull up to VIN can disable charge logic and make the IC operate as normal buck regulator. Pull down to ground can shutdown the IC. |
| CEL | 5 | Pull down for single-cell, pull high for 2 cells, open for 3 cells. |
| STAT | 6 | Charge status indication pin. It is open drain output pin and can be used to turn on a LED to indicate the charge in process. When the charge is done, LED is off. |
| LX | 7 | Switch node pin. This pin connects the drains of the integrated main and synchronous power MOSFET switches. Connect to external inductor. |
| IN | 8 | Positive power supply input pin. $V_{IN}$ ranges from 4V to 23V for normal operation. It has UVLO function and must be 300mV greater than the battery voltage to enable normal operation. |
| TIM | 1 | Charge time limit pin. Connect this pin with a capacitor to ground. Internal current source charge the capacitor for TC mode and CC mode's charge time limit. TC charge time limit is about 1/9 of CC charge time. |
| GND | Exposed pad | Ground pin. |

## Absolute Maximum Ratings (Note 1)

CEL, NTC, STAT, ---------- -0.5-32V
IN, BAT, LX, ---------- -0.5- 25V
TIM, ---------- -0.5- 3.6V
RS, ---------- BAT-0.3~BAT+0.3
LX Pin current continuous ---------- 2A
Power Dissipation, $P_D$ @ $T_A$ = 25°C, SO8E---------- 3.3W
Package Thermal Resistance (Note 2)
$\theta_{JA}$ ---------- 30°C/W
$\theta_{JC}$ ---------- 20°C/W
Junction Temperature Range ---------- -40°C to 125°C
Lead Temperature (Soldering, 10 sec.) ---------- 260°C
Storage Temperature Range ---------- -65°C to 125°C

## Recommended Operating Conditions (Note 3)

CEL, NTC, STAT, ----------less than 32V
IN, BAT, LX, ----------less than 23V
TIM, ----------less than 3.6V
RS, ---------- in the range of BAT-0.3~BAT+0.3LX
Pin current continuous ---------- less than 2A
Junction Temperature Range ---------- ---------- -20°C to 100°C
Ambient Temperature Range ---------- -40°C to 85°C

## Electrical Characteristics

$T_A$=25°C, $V_{IN}$=15V, GND=0V, $C_{IN}$=10uF, $L_B$=2.2uH, $R_S$=25mΩ, $C_{TIM}$=470nF, unless otherwise specified.

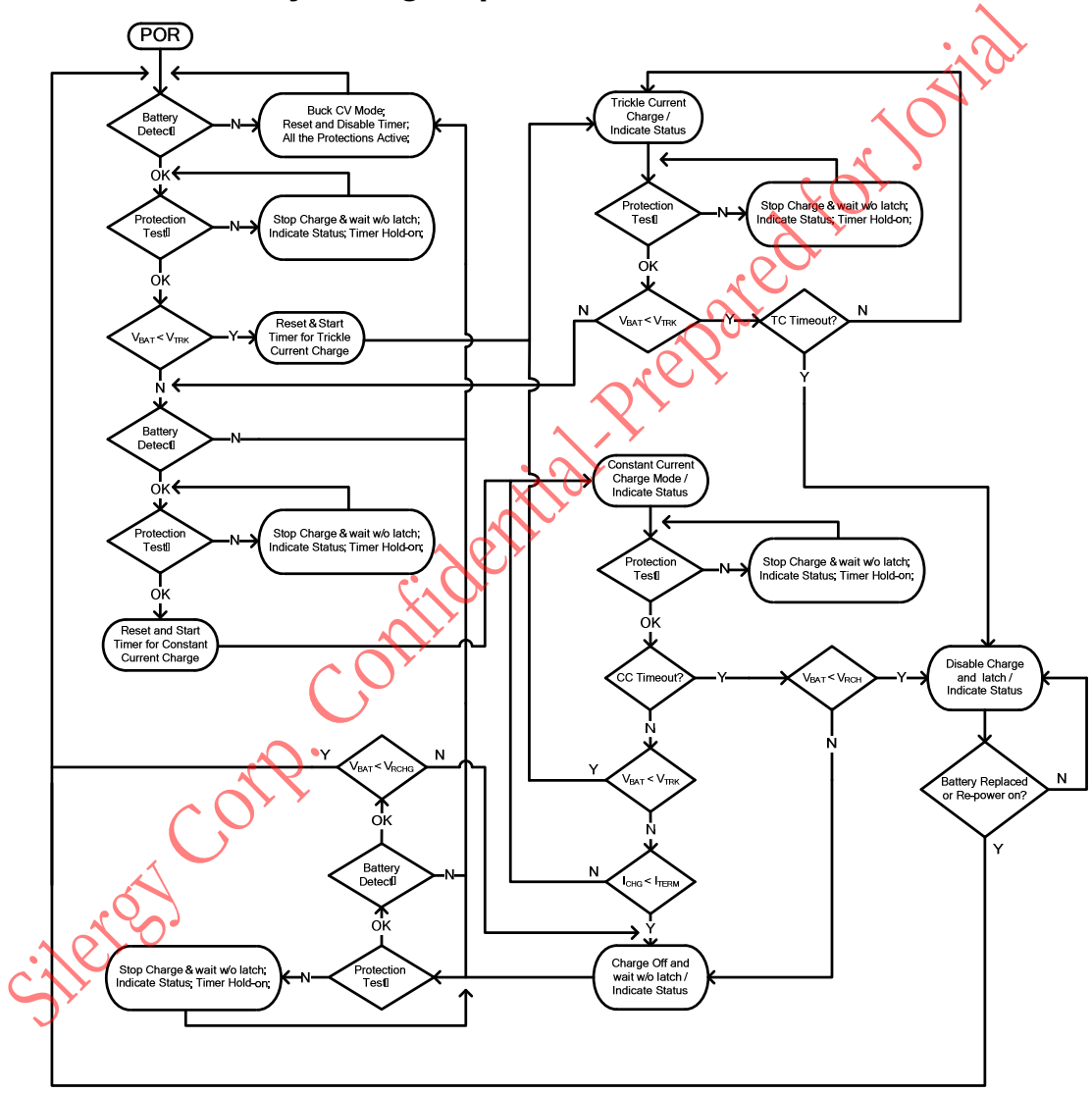
| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Bias Supply ($V_{IN}$)** | | | | | | |
| $V_{IN}$ | Supply voltage | | 4.0 | | 23 | V |
| $V_{UVLO}$ | $V_{IN}$ under voltage lockout threshold | $V_{IN}$ rising and measured from $V_{IN}$ to GND | | | 3.9 | V |
| $\Delta V_{UVLO}$ | $V_{IN}$ under voltage lockout hysteresis | Measured from $V_{IN}$ to GND | | 190 | | mV |
| $V_{OVP}$ | Input overvoltage protection | $V_{IN}$ rising and measured from $V_{IN}$ to GND | | | 24 | V |
| $\Delta V_{OVP}$ | Input overvoltage protection hysteresis | Measured from $V_{IN}$ to GND | | 750 | | mV |
| **Quiescent Current** | | | | | | |
| $I_{BAT}$ | Battery discharge current | NTC pull down to GND | | | 25 | uA |
| $I_{IN}$ | Input quiescent current | Disable Charge | | | 2.0 | mA |
| **Oscillator and PWM** | | | | | | |
| $f_{OSC}$ | Oscillator frequency | | 640 | 800 | 960 | kHz |
| D | PFET duty cycle | | | | 100 | % |
| **Power MOSFET** | | | | | | |
| $R_{NFET}$ | $R_{DS(ON)}$ of N-FET | | | 150 | | mΩ |
| $R_{PFET}$ | $R_{DS(ON)}$ of P-FET | | | 160 | | mΩ |
| **Voltage Regulation** | | | | | | |
| $V_{CV}$ | Single-cell CV charge mode | 0°C <=$T_A$<=70°C | 4.16 | 4.20 | 4.24 | V |
| | 2-cell CV charge mode | | 8.32 | 8.40 | 8.48 | |
| | 3-cell CV charge mode | | 12.48 | 12.60 | 12.72 | |
| $\Delta V_{RCH}$ | Single-cell Voltage threshold for Recharge | 0°C <=$T_A$<=70°C | 50 | 100 | 150 | mV |
| | 2-cell Voltage threshold for Recharge | | 100 | 200 | 300 | |
| | 3-cell Voltage threshold for Recharge | | 150 | 300 | 450 | |
| $V_{TRK}$ | Single-cell TC charge mode voltage threshold | 0°C <=$T_A$<=70°C | 2.2 | 2.5 | 2.8 | V |
| | 2-cell TC charge mode voltage threshold | | 4.4 | 5.0 | 5.6 | |
| | 3-cell TC charge mode voltage threshold | | 6.6 | 7.5 | 8.4 | |
| **Battery Connect Detection** | | | | | | |
| $V_{DET}$ | Detect voltage threshold | $V_{SHOT}$< $V_{BAT}$< $V_{RCH}$ | 80% | | 90% | $V_{IN}$ |
| $t_{DET}$ | Detect delay time | | | 30 | | ms |
| **Charge Current** | | | | | | |
| | Internal charge current accuracy for Constant Current Mode | $I_{CC}$=25mV/$R_S$ | -10% | | 10% | |
| | Internal charge current accuracy for Trickle Current Mode | $I_{TC}$=2.5mV/$R_S$ | -50% | | 50% | |
| **Output Voltage OVP** | | | | | | |
| $V_{OVP}$ | Output voltage OVP threshold | | 108% | 113% | 118% | $V_{CV}$ |
| **Output Short Protection** | | | | | | |
| $V_{SHOT}$ | Output short protection threshold | $V_{BAT}$ falling edge | 1.70 | 2.00 | 2.30 | V |
| $f_{FBK}$ | Frequency fold back | $V_{BAT}$<2V | | 12.5% | | $f_{OSC}$ |
| $I_{LM}$ | Power FET current limit | | | 4.0 | | A |
| **Timer** | | | | | | |
| $T_{TC}$ | Trickle current charge timeout | $C_{TIM}$=330nF | 0.23 | 0.5 | 0.67 | hour |
| $T_{CC}$ | Constant current charge timeout | | 3.0 | 4.5 | 6.0 | hour |
| $T_{MC}$ | Charge mode change delay time | | | 30 | | ms |
| $T_{TERM}$ | Termination delay time | | | 30 | | ms |
| $T_{RCHG}$ | Recharge time delay | | | 30 | | ms |
| **Battery Thermal Protection NTC** | | | | | | |
| UTP | Under temperature protection | | 70% | 75% | 80% | $V_{IN}$ |
| | Under temperature protection hysteresis | Falling edge | | 5% | | |
| OTP | Over temperature protection | | 28% | 30% | 32% | |
| | Over temperature protection hysteresis | Rising edge | | 2% | | |
| **Automatic Shutdown** | | | | | | |
| $\Delta V_{ASD}$ | ASD voltage threshold hysteresis | Measured from $V_{IN}$ to $V_{BAT}$ | 140 | 280 | 420 | mV |
| Thermal Shutdown Temperature | $T_{SD}$ | | | 160 | | ℃ |
| Thermal shutdown Hysterisys | $T_{HYS}$ | | | 20 | | ℃ |

**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**: $\theta_{JA}$ 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

## Basic Li-Ion Battery Charge Operation Flow Chart



# General Function Description

SY6912A is a 4.0-23 input, 2A multi-cell synchronous buck Li-Ion battery charger, suitable for portable application. Select pin is convenient for multi-cell charging. Integrated 800 kHz synchronous buck regulator consists of 23V rating FETs with extremely low on-resistance to achieve high charge efficiency and simple circuit design.

### Charging Status Indication Description

1. **Charge-In-Process** – Pulls and keeps STAT pin to Low;
2. **Charge Done** – Pulls and keeps STAT pin to High;
3. **Fault Mode** – Outputs high and low voltage alternatively with 0.5Hz frequency.

Connects a LED from VIN to STAT pin, **LED ON** indicates **Charge-in-Process**, **LED OFF** indicates **Charge Done**, **LED Flash** indicates **Fault Mode**.

## Buck Regulator Operation Description

If the Li-Ion battery is removed suddenly, the voltage on NTC pin increases higher than 90% Vin. Then, it operates as a normal peak current mode controlled synchronous buck converter and the output voltage on BAT pin is regulated at $V_{CV}$. In this operation mode, the constant output current loop is still active, however the charge timeout and the trickle current charge are disabled.

## Protection Description

**Thermal Protection-**Thermal shutdown is active for both battery and IC. IC resumes normal work when the temperature backs in normal range again.

**Short Circuit Protection-** When $V_{BAT}$ voltage is lower than the short circuit protection threshold, short circuit protection is active. In charger operation mode, the switching frequency is folded back to 12.5% of the default value and VC is folded back to 20% of the maximum value. The trickle charge timer is still active and would timeout the IC finally. In Buck operation mode, the switching frequency is folded back to 12.5% of the default value, and the VC initiates softstart periodically.

**Over Current Protection-**The internal current loop with different constant current capability is always active no matter in Buck mode or Battery Charging mode for the over current protection.

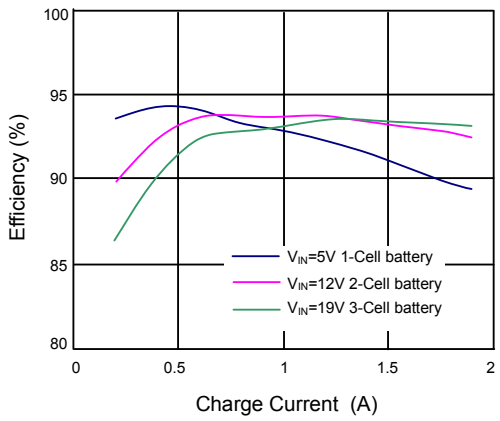
**Over Voltage Protection-**When $V_{BAT}$ voltage is higher than the over voltage protection threshold no matter with or without battery connecting, IC shuts down and recovers to normal work when $V_{BAT}$ backs to normal level. Input voltage has UVLO and OVP, which would make IC shutdown and recover to normal work when the $V_{IN}$ backs to normal range.

**Timeout Protection-**Programmable timeout protection is for both Trickle Current Charge Mode and Constant Current Charge Mode. Once timeout is active, IC stops the charge operation and latches off. Only power or battery re-plug in can get the latch logic reset and the IC restarted.

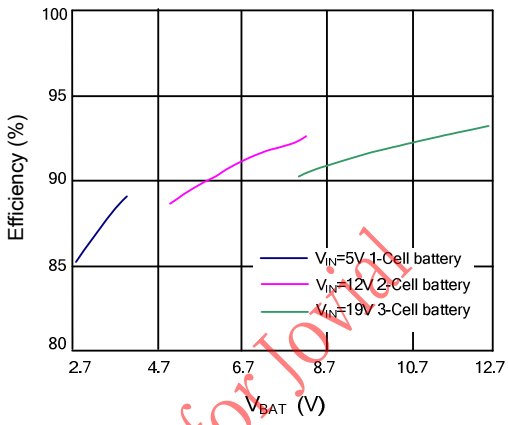
# Typical Performance Characteristics

$T_A$=25°C, $V_{IN}$=5V, $R_S$=20mΩ, 1cell battery, unless otherwise specified.

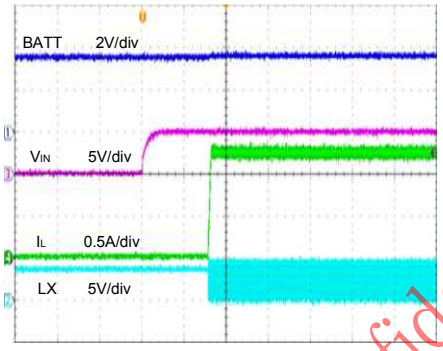
Efficiency vs. Charge Current (CV mode)




Efficiency vs. Charge Current (CC mode)

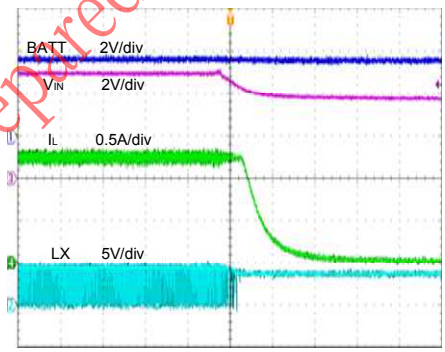



Power On



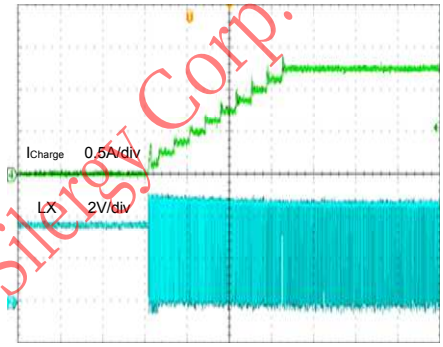

Time (20ms/div)

Power Off



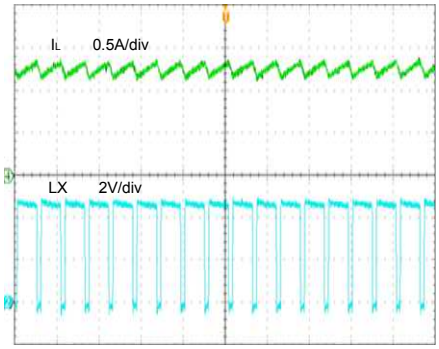

Time (200μs/div)

Charge Current Soft Start



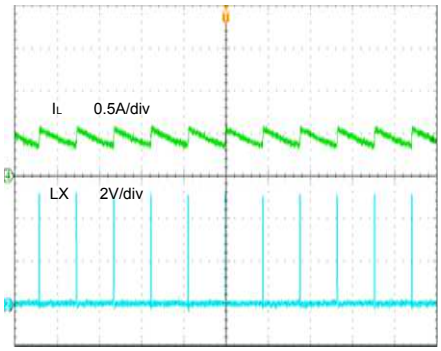

Time (400μs/div)

Constant Current Charge State



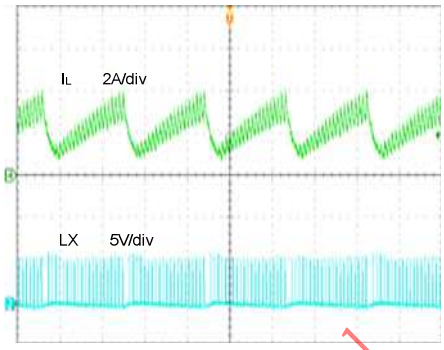

Time (2μs/div)

Battery Short




Time (10μs/div)

Buck Mode: Output Short



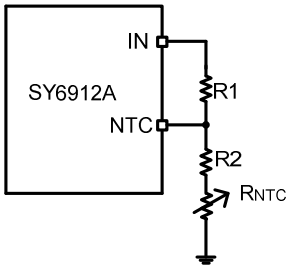

Time (100μs/div)

# Applications Information

Because of the high integration of SY6912A, the application circuit based on this regulator IC is rather simple. Only input capacitor $C_{IN}$, output capacitor $C_{OUT}$, inductor L, NTC resistors R1,R2 ,charge current sense resistor Rs and timer capacitor $C_{TIM}$ need to be selected for the targeted applications specifications.

**NTC resistor:**

SY6912A monitors battery temperature by measuring the input voltage and NTC voltage. The controller triggers the UTP or OTP when the rate K (K= $V_{NTC}$/VIN) 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 $K_{UT}$, $K_{UT}$ =70~80%
2. Define $K_{OT}$, $K_{OT}$ =28~32%
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 $K_{OT}$=30%, then

$$R2 = 0.17R_{UT} - 1.17R_{OT}$$

$$R1 = 2.3(R2 + R_{OT})$$

**Charge current sense resistor Rs**

The charge current sense resistor $R_S$ is calculated as below:

$$R_S = \frac{25}{I_{CHG}}, \quad \text{Unit: mohm}$$

While the $I_{CHG}$ is the battery constant charge current.

**Timer capacitor $C_{TIM}$**

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

$$C_{TIM} = 2*10^{-11}T_{CC} \quad \text{Unit: F}$$

$T_{CC}$ is the target constant charge time.

**Input capacitor $C_{IN}$:**

The ripple current through input capacitor is greater than

$$I_{CIN\_MIN} = I_{CHG}\sqrt{D(1-D)}$$

To minimize the potential noise problem, place a typical X7R or better grade ceramic capacitor really close to the IN and GND pins. Care should be taken to minimize the loop area formed by $C_{IN}$, and IN/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 10uF 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 input current. The inductance is calculated as:

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

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

The SY6912A regulator IC 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.

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

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<10mohm to achieve a good overall efficiency.

**Layout Design:**

The layout design of SY6912A regulator is relatively simple. For the best efficiency and minimum noise problems, we should place the following components close to the IC: $C_{IN}$, L, $R_1$ and $R_2$.

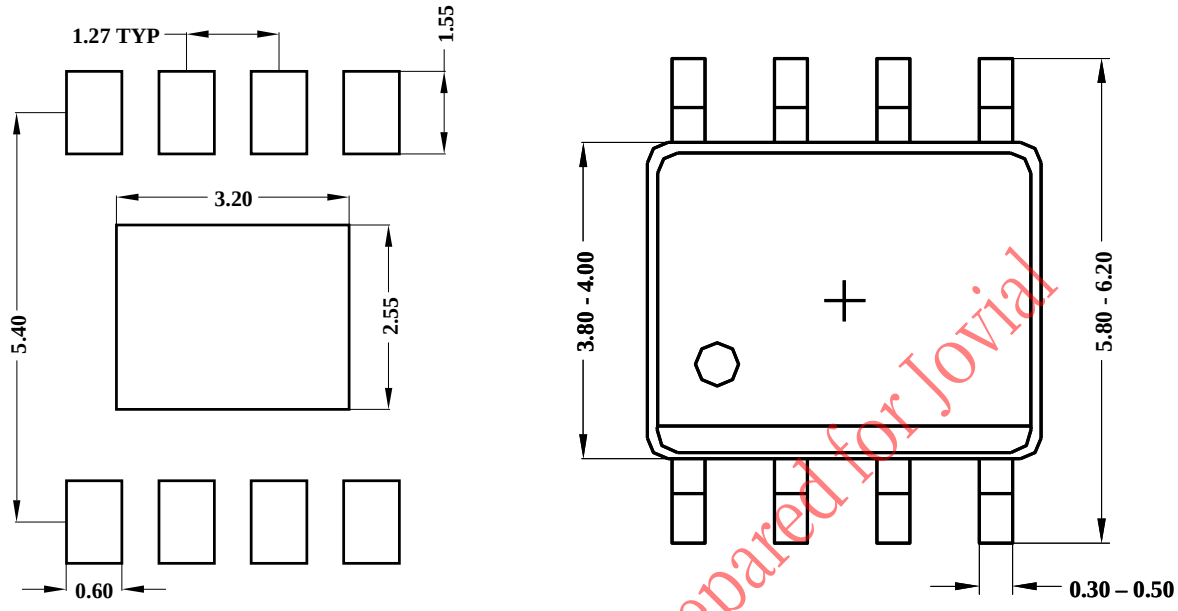
1) It is desirable to maximize the PCB copper area connecting to GND pin to achieve the best thermal and noise performance. If the board space allowed, a ground plane is highly desirable.

2) $C_{IN}$ must be close to Pins IN and GND. The loop area formed by $C_{IN}$ and GND must be minimized.

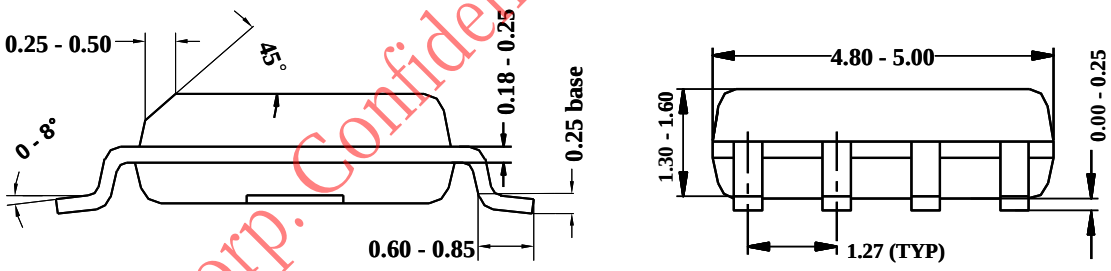
3) The PCB copper area associated with LX pin must be minimized to avoid the potential noise problem.

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. It should be better to ground $C_{TIM}$ to the output Capacitor's ground.

# SO8E Package outline & PCB layout design




**Recommended Pad Layout**

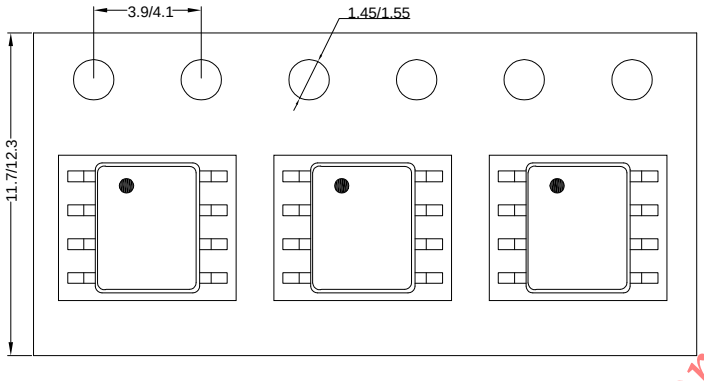



**Notes: All dimensions are in millimeters.**
**All dimensions don't include mold flash & metal burr.**

# Taping & Reel Specification

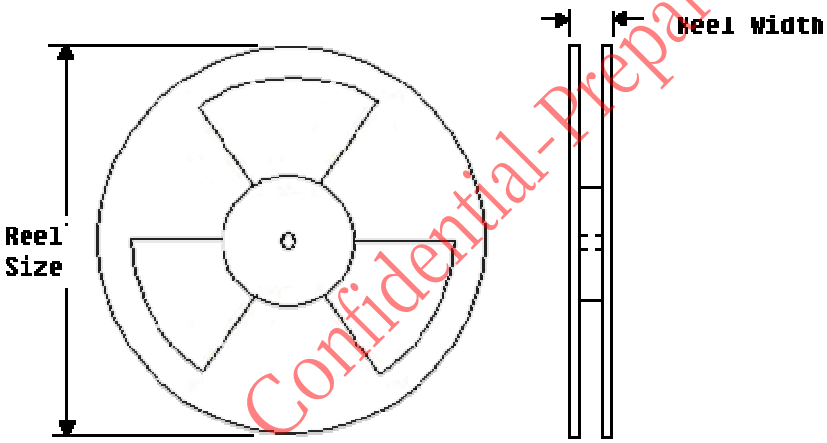
## 1. Taping orientation

**SO8E**




**Feeding direction** ⟶

## 2. Carrier Tape & Reel specification for packages




| Package types | Tape width (mm) | Pocket pitch(mm) | Reel size (Inch) | Reel width(mm) | Trailer length(mm) | Leader length (mm) | Qty per reel |
|---|---|---|---|---|---|---|---|
| SO8E | 12 | 8 | 13" | 12.4 | 400 | 400 | 2500 |

## 3. Others: NA