Application Note:AN_SY6902A

2A Single Cell High Efficiency Switching Charger

Preliminary Specification

General Description

SY6902A is a 4.0-23V input, 2A single-cell synchronous Buck Li-Ion battery charger, suitable for portable application. The 800 kHz synchronous buck regulator integrates 23V rating FETs with ultra low on-resistance to achieve high efficiency and simple circuit design.

Ordering Information

SY6902 □(□□)□

- Temperature Code
- Package Code
- Optional Spec Code

Temperature Range: -40°C to 85°C

Ordering Number	Package type	Note
SY6902AFAC	SO8	

Features

- Wide Input Voltage Range: 4.0V to 23V
- High Efficiency Int. Synchronous Buck Regulator with Fixed 800kHz Switching Frequency
- Trickle Current / Constant Current / Constant Voltage Charge Mode
- Programmable (2A Max) Constant Charge Current
- Charge Current with 10-step Soft-start
- Programmable Charging Timer
- Input Voltage UVLO and OVP
- 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 SO8

Applications

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

Typical Applications

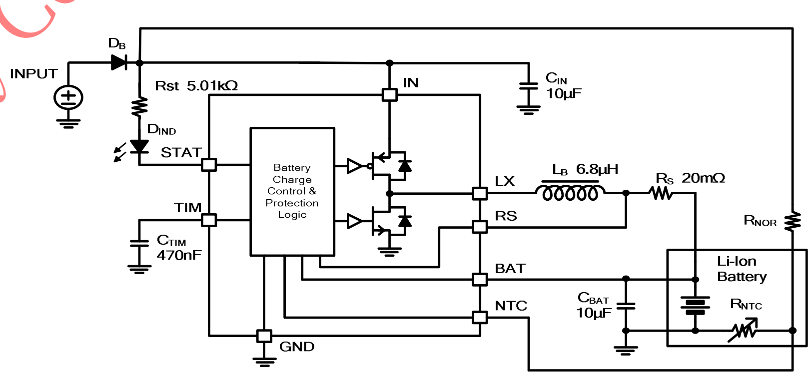
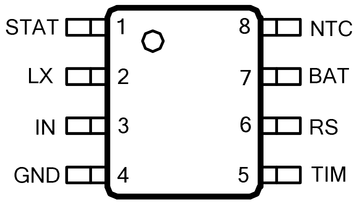


Figure 1. Schematic Diagram

Pinout (top view)



(SO8)

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

Name	Number	Description
RS	6	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	7	Battery positive pin.
NTC	8	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.
GND	4	Ground pin.
STAT	1	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	2	Switch node pin. This pin connects the drains of the integrated main and synchronous power MOSFET switches. Connect to external inductor.
IN	3	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	5	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.

Absolute Maximum Ratings (Note 1)

NTC, STAT, -- -0.5-32V
IN, BAT, LX, -- -0.5- 25V
TIM, -- -0.5- 3.6V
RS, --- BAT-0.3V to BAT+0.3V
LX Pin current continuous --- 2A
Power Dissipation, P_D @ T_A = 25°C, SO8------------------------------- 1.1W
Package Thermal Resistance (Note 2)

θJA -- 88°C/W

θJC -- 45°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

NTC, STAT, ---less than 32V
IN, BAT, LX, ---less than 25V
TIM, -- less than 3.6V
RS, --- in the range of BAT-0.3V to BAT+0.3V
LX 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.

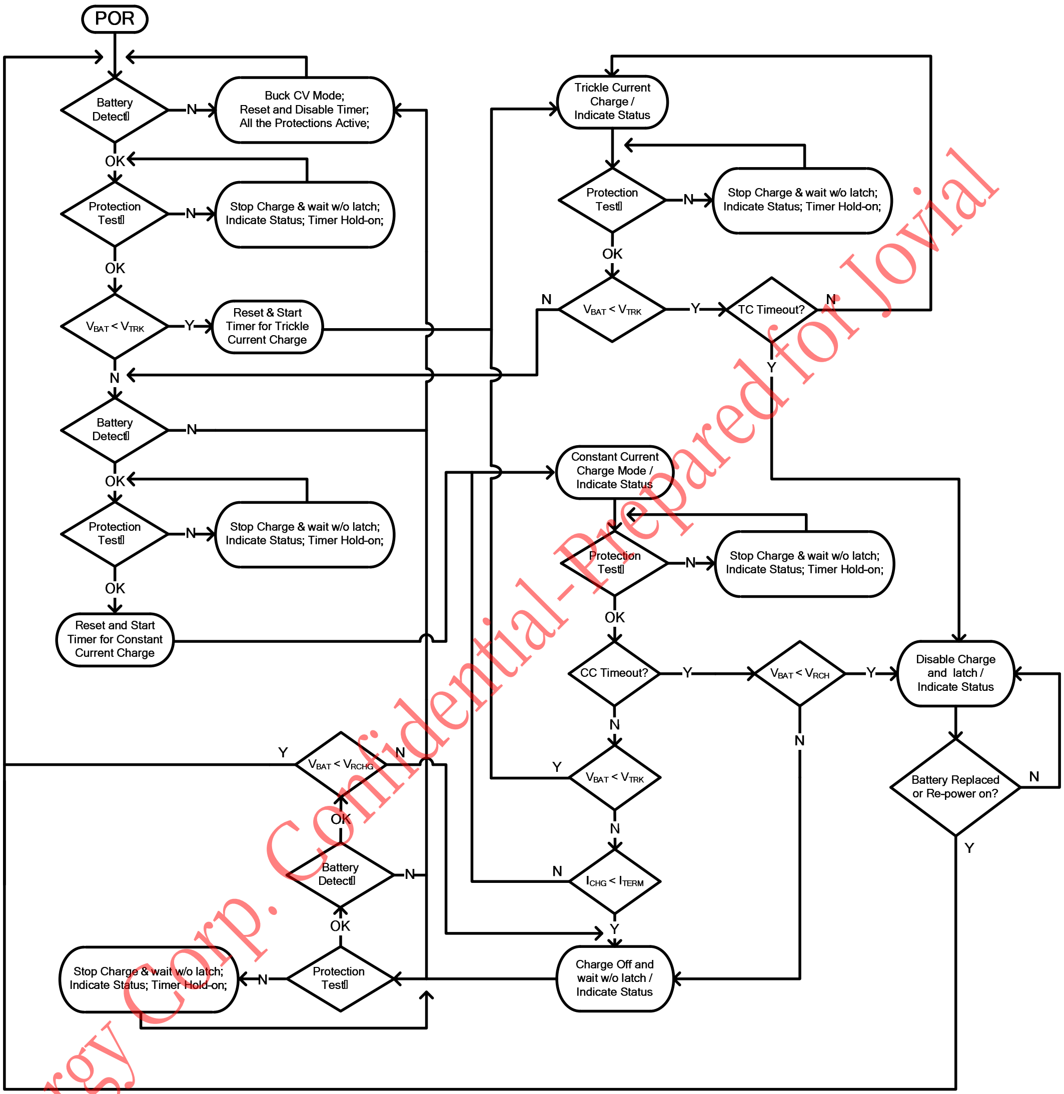
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Bias Supply (V_{IN})						
V_{IN}	Supply voltage		4.0		23	V
V_{UVLO}	V_{IN} under voltage lockout threshold	V_{IN} rising and measured from V_{IN} to GND			3.9	V
ΔV_{UVLO}	V_{IN} under voltage lockout hysteresis	Measured from V_{IN} to GND		190		mV
V_{OVP}	Input overvoltage protection	V_{IN} rising and measured from V_{IN} to GND			24	V
ΔV_{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
ΔV_{RCH}	Single-cell Voltage threshold for Recharge		50	100	150	mV
V_{TRK}	Single-cell TC charge mode voltage threshold		2.2	2.5	2.8	V
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						
ΔV_{ASD}	ASD voltage threshold hysteresis	Measured from V_{IN} to V_{BAT}	140	280	420	mV

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

Basic Li-Ion Battery Charge Operation Flow Chart



General Function Description

SY6902A is a 4.0-23V input, 2A single-cell synchronous Buck Li-Ion battery charger, suitable for portable application. The 800 kHz synchronous buck regulator integrates 23V rating FETs with ultra low on-resistance to achieve high 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 soft start 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.

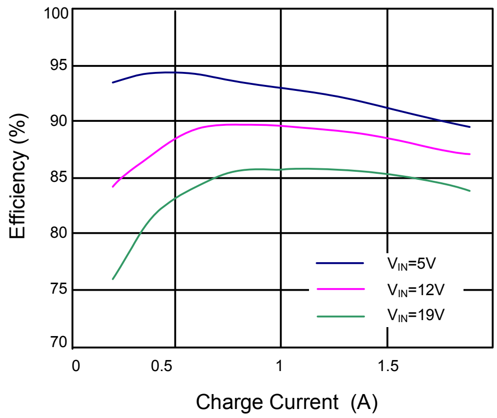
Over Voltage Protection-When V_{BAT} voltage is higher than the over voltage protection threshold no matter with or without battery connecting, IC shuts down and recovers to normal work when V_{BAT} backs to normal level. Input voltage has UVLO and OVP, which would make IC shutdown and recover to normal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

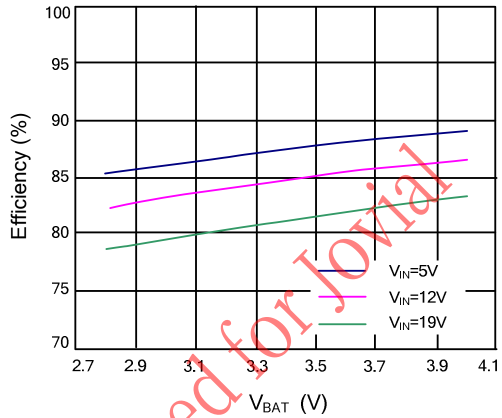
Typical Performance Characteristics

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

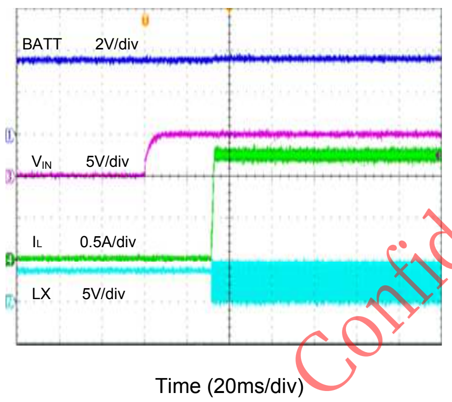
Efficiency vs. Charge Current (CV Mode)



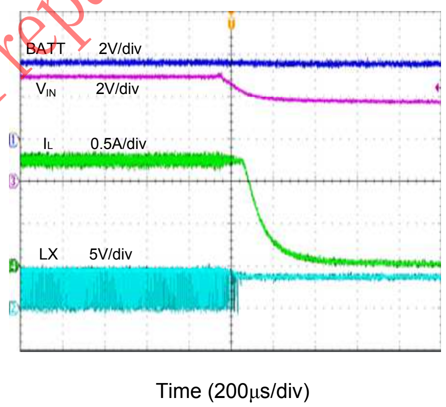
Efficiency vs. Charge Current (CC Mode)



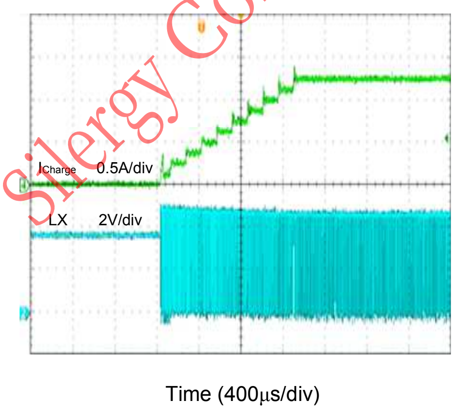
Power On



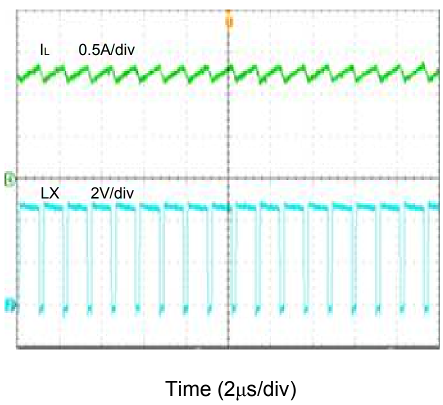
Power Off



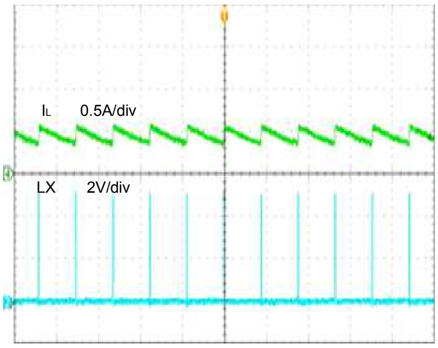
Charge Current Soft Start



Constant Current Charge State

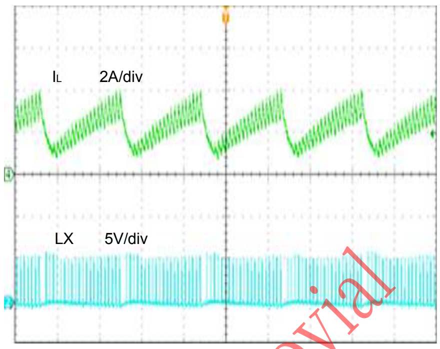


Battery Short



Time (10μs/div)

Buck Mode: Output Short



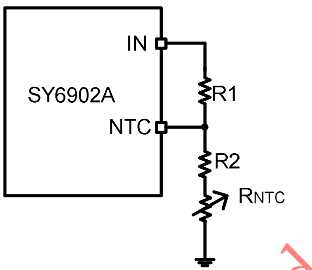
Time (100μs/div)

Applications Information

Because of the high integration of SY6902A, 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:

SY6902A 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:

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

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:

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

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 SY6902A 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 SY6902A 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.

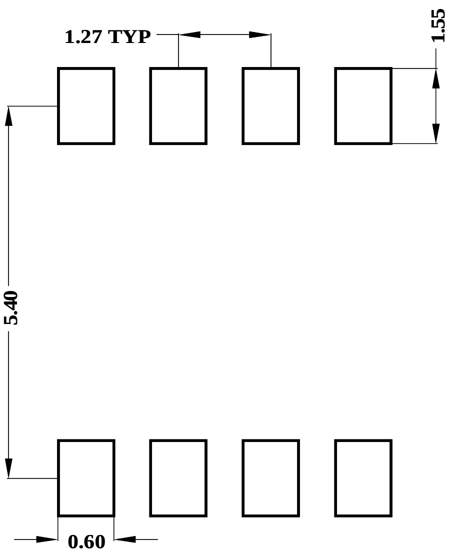
1) It is desirable to maximize the PCB copper area connecting to GND pin to achieve the best thermal and noise performance. If the board space allowed, a ground plane is highly desirable.

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

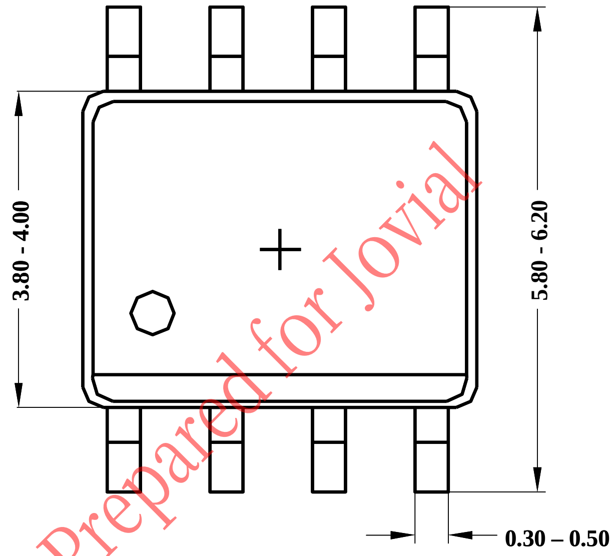
3) The PCB copper area associated with LX pin must be minimized to avoid the potential noise problem.

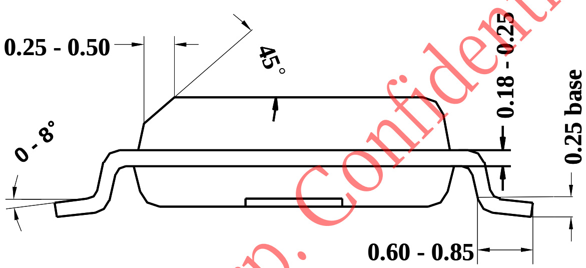
4) The capacitor C_{TIM} and the trace connecting to the TIM pin must NOT be adjacent to the LX net on the PCB layout to avoid the noise problem. It should be better to ground C_{TIM} to the output Capacitor's ground.

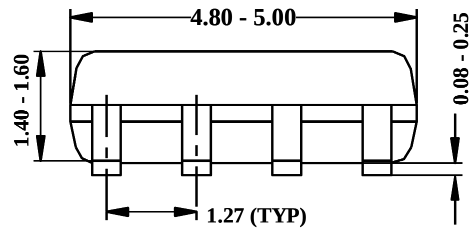
SO8 Package outline & PCB layout design



Recommended Pad Layout



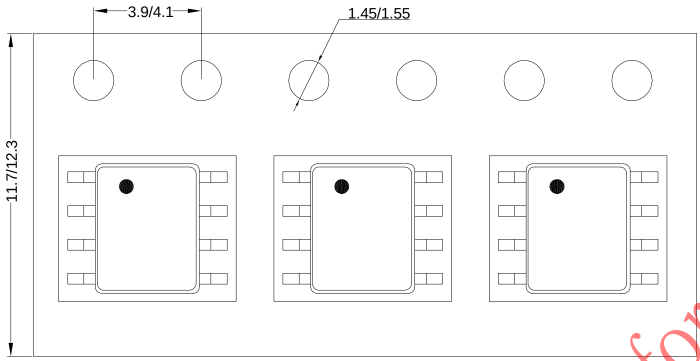




Notes: All dimensions are in millimeters.
All dimensions don't include mold flash & metal burr.

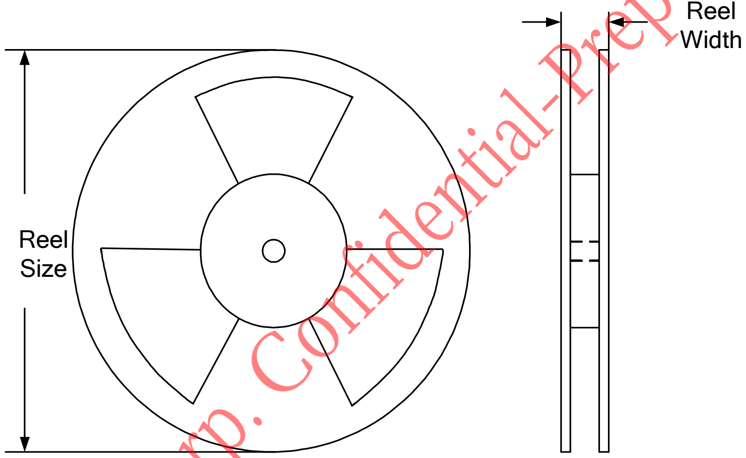
Taping & Reel Specification

1. Taping orientation for packages（SO8）



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
SOP8	12	8	13"	12.4	400	400	2500