Application Note: SQ20953

High Efficiency Fast Response, 3A, 30V Input Synchronous Step Down Regulator

General Description

The SQ20953 develops a high efficiency synchronous step-down DC/DC converter, which is capable of delivering 3A load current. The SQ20953 operates over a wide input voltage range from 4.5V to 30V and integrates main switch and synchronous switch with very low $R_{DS(ON)}$ to minimize the conduction loss.

The SQ20953 adopts peak current control scheme. The switching frequency is adjustable from 500kHz to 2.5MHz using an external resistor. The device also features ultra low quiescent operating to achieve high efficiency under light load. The internal soft-start limits inrush current during power on.

The SQ20953 is available in TSOT23-8 package.

Ordering Information

Ordering Number	Package type	Note
SQ20953AIC	TSOT23-8	--

Features

- Low $R_{DS(ON)}$ for Internal Switches (Top/Bottom): 110/70 mΩ
- 4.5-30V Input Voltage Range
- Internal Compensation
- Internal 1ms Soft-start Limits the Inrush Current
- Adjustable Switching Frequency Range: 500kHz to 2.5MHz
- 3A Output Current Capability
- 1.5% 0.6V Reference
- Low Quiescent Current
- Cycle-by-cycle Peak Current Limit
- Short Circuit Protection
- Thermal Shutdown and Auto Recovery
- RoHS Compliant and Halogen Free
- Compact Package: TSOT23-8

Applications

- LCD-TV
- SetTop Box
- Notebook
- Storage
- High Power AP Router
- Networking

Typical Applications

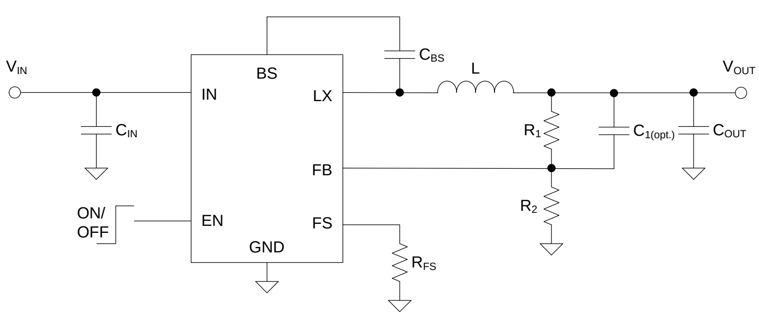


Figure 1. Schematic Diagram

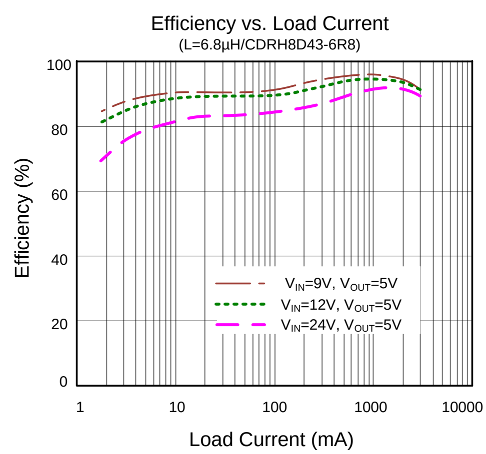
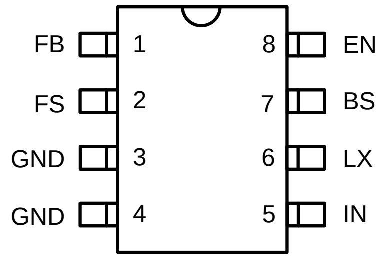


Figure 2. Efficiency vs. Load Current

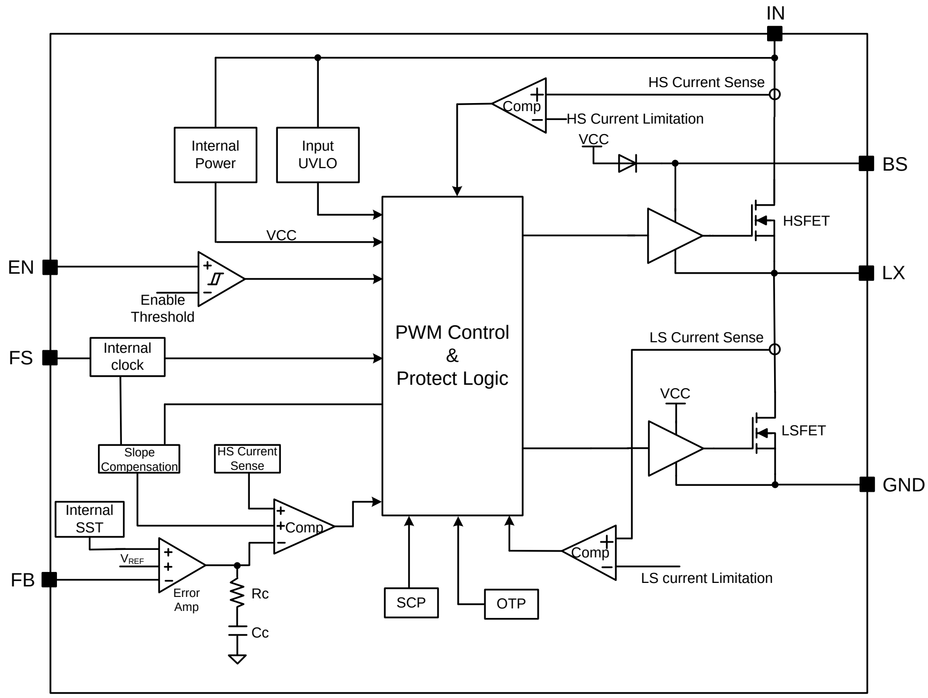
Pinout (top view)



Top Mark: **C5*xyz* (**Device code: C5, ***x=year code, y=week code, z= lot number code*)**

Pin Name	Pin Number	Pin Description
FB	1	Output feedback pin. Connect this pin to the center point of the output resistor divider (as shown in Figure 1) to program the output voltage: $V_{OUT}=0.6\times(1+R_1/R_2)$
FS	2	Frequency programming pin. Connect a resistor to ground to program a switching frequency between 500kHz to 2.5MHz. The switching frequency equals to: $f_{SW}=106800/(R_{FS}+7)$ kHz, where R_{FS} is in kΩ.
GND	3,4	Ground pin.
IN	5	Input pin. Decouple this pin to the GND pin with at least a 4.7μF ceramic capacitor.
LX	6	Inductor pin. Connect this pin to the switching node of inductor.
BS	7	Boot-strap pin. Supply high side gate driver. Connect a 0.1μF to the LX pin.
EN	8	Enable control. Pull high to turn on. Do not leave it floating.

Block Diagram



Absolute Maximum Ratings (Note 1)

IN to GND --- -0.3V to 33V
LX, FB, EN, FS to GND --- -0.3V to 33V
BS-LX --- -0.3V to 4V
Dynamic LX voltage in 20ns duration --- IN+3V to GND-6V
Power Dissipation, PD @ T_A = 25°C TSOT23-8 --- 2W
Package Thermal Resistance (Note 2)
θ_{JA} --- 60.2°C/W
θ_{JC} --- 11.2°C/W
Junction Temperature Range --- -40°C to 150°C
Ambient Temperature Range --- -40°C to 105°C
Lead Temperature (Soldering, 10 sec.) --- 260°C
Storage Temperature Range --- -65°C to 150°C

Recommended Operating Conditions (Note 3)

Supply Input Voltage --- 4.5V to 30V
Junction Temperature Range --- -40°C to 125°C
Ambient Temperature Range --- -40°C to 85°C

Electrical Characteristics

(V_{IN} = 12V, T_J= -40°C to +125°C. Typical values are at T_J=25°C, unless otherwise specified. The values are guaranteed by test, design or statistical correlation.)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Voltage Range	V_{IN}		4.5		30	V
Quiescent Current	I_Q	I_{OUT}=0, V_{FB}=V_{REF}×105%		10	27	µA
Shutdown Current	I_{SHDN}	EN=0		1.6	4	µA
Feedback Reference Voltage	V_{REF}	T_J=25°C	0.591	0.6	0.609	V
		T_J= -40~125°C	0.581	0.6	0.619	
FB Input Current	I_{FB}	V_{FB}=V_{CC}	-50		50	nA
Top FET RON	$R_{DS(ON)1}$			110	190	mΩ
Bottom FET RON	$R_{DS(ON)2}$			70	110	mΩ
Top FET Current Limit	$I_{LIM,TOP}$		3.8		6.8	A
EN Input Voltage Low	V_{ENL}				0.5	V
EN Input Voltage High	V_{ENH}		1.5			V
Input UVLO Threshold	V_{UVLO}		3.8	4.15	4.5	V
UVLO Hysteresis	V_{HYS}			0.4		V
Oscillator Frequency Program Range	f_{OSC}	R_{FS}=35.7k~206.6k	0.5		2.5	MHz
Oscillator Frequency Accuracy		R_{FS}=206.6k	400	500	630	kHz
Soft-start Time	t_{SS}		0.4	1	2.4	ms
Min ON Time				80		ns
Min OFF Time		R_{FS}=206.6k		120		ns
Thermal Shutdown Temperature	T_{SD}			150		°C
Thermal Shutdown Hysteresis	$T_{SD,HYS}$			15		°C

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.

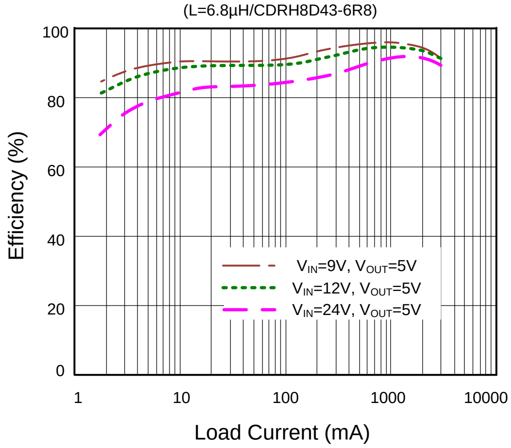
Note 2: θ_{JA} is measured in the natural convection at T_A = 25°C on a two-layer Silergy evaluation board.

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

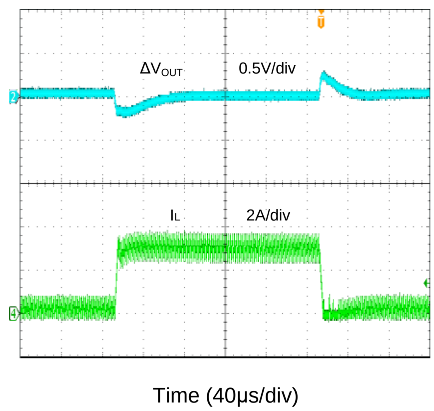
Typical Performance Characteristics

(F_{SW}=500kHz, T_A = 25°C)

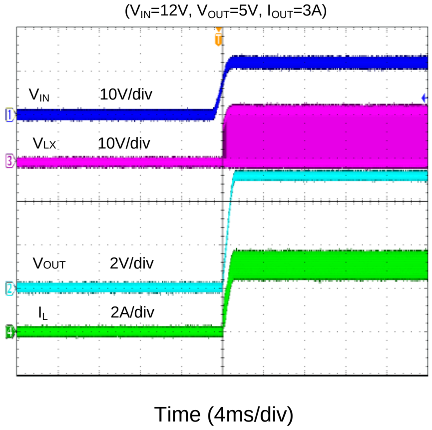
Efficiency vs. Load Current
(L=6.8µH/CDRH8D43-6R8)



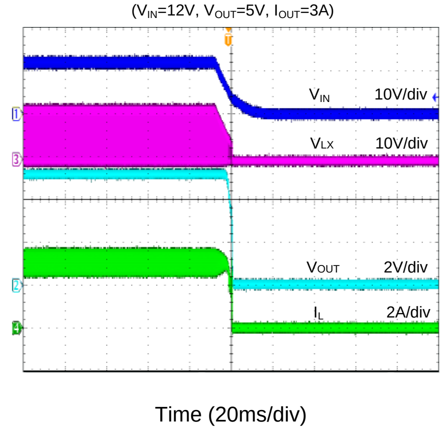
Load Transient
(V_{IN}=12V, V_{OUT}=5V, I_{OUT}=0.3A ~ 3A)



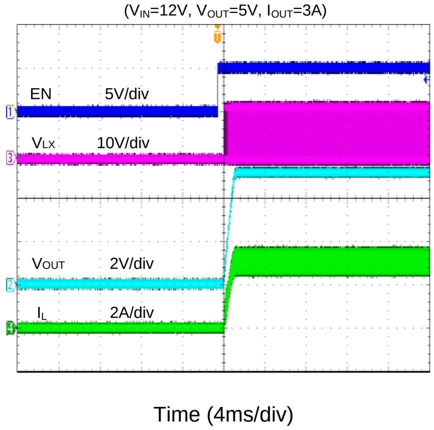
Startup from V_{IN}
(V_{IN}=12V, V_{OUT}=5V, I_{OUT}=3A)



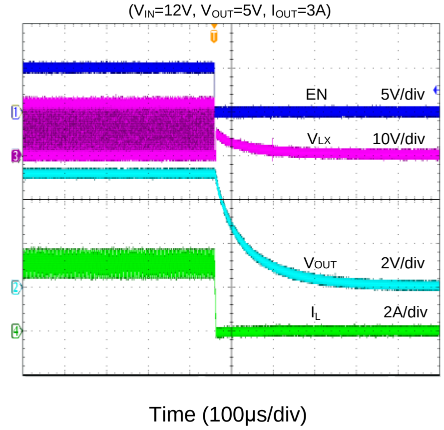
Shutdown from V_{IN}
(V_{IN}=12V, V_{OUT}=5V, I_{OUT}=3A)



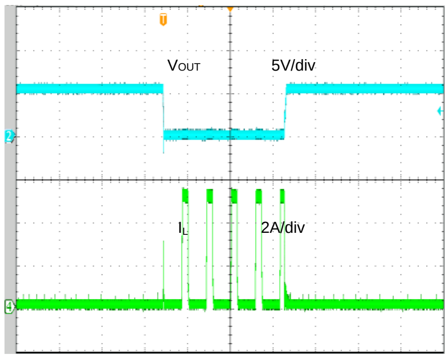
Startup from Enable
(V_{IN}=12V, V_{OUT}=5V, I_{OUT}=3A)



Shutdown from Enable
(V_{IN}=12V, V_{OUT}=5V, I_{OUT}=3A)

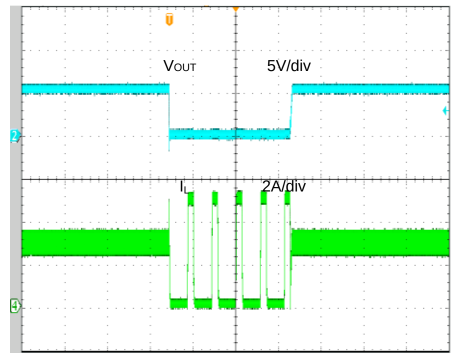


Short Circuit Protection
(V_{IN}=12V, V_{OUT}=5V, 0A to Short)



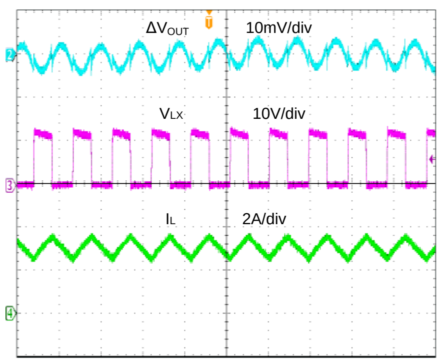
Time (10ms/div)

Short Circuit Protection
(V_{IN}=12V, V_{OUT}=5V, 3A to Short)



Time (10ms/div)

Output Ripple
(V_{IN}=12V, V_{OUT}=5V, I_{OUT}= 3A)



Time (2μs/div)

Operation

The SQ20953 develops a high efficiency synchronous step-down DC/DC converter, which is capable of delivering 3A load current. The SQ20953 operates over a wide input voltage range from 4.5V to 30V and integrates main switch and synchronous switch with very low $R_{DS(ON)}$ to minimize the conduction loss.

The SQ20953 adopts peak current control scheme. The switching frequency is adjustable from 500kHz to 2.5MHz using an external resistor. The device also features ultra low quiescent operating to achieve high efficiency under light load. The internal soft-start limits inrush current during power on.

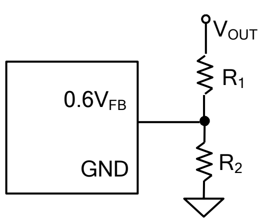
Applications Information

Because of the high integration in the IC, the application circuit based on this regulator IC is rather simple. Only input capacitor C_{IN}, output capacitor C_{OUT}, output inductor L and feedback resistors (R_1 and R_2) need to be selected for the targeted applications specifications.

Feedback Resistor Dividers R_1 and R_2

Choose R_1 and R_2 to program the proper output voltage. To minimize the power consumption under light loads, it is desirable to choose large resistance values for both R_1 and R_2. A value of between 10kΩ and 1MΩ is highly recommended for both resistors. If V_{OUT} is 3.3V, R_1=100k is chosen, then using following equation, R_2 can be calculated to be 22.1k:

$$R_2 = \frac{0.6V}{V_{OUT} - 0.6V} R_1 .$$



Input Capacitor C_{IN}

The ripple current through input capacitor is calculated as:

$$I_{CIN\_RMS} = I_{OUT} \times \sqrt{D(1-D)} .$$

To minimize the potential noise problem, place a typical X5R 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. In this case, a 4.7µF low ESR ceramic capacitor is recommended.

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 X5R or better grade ceramic capacitor greater than 22µF 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 maximum output 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 fsw is the switching frequency and $I_{OUT,MAX}$ is the maximum load current.

The SQ20953 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.

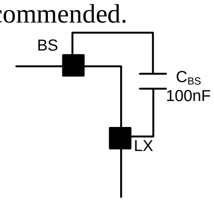
2) The saturation current rating of the inductor must be selected to be greater than the peak inductor current under full load conditions.

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

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<50mΩ to achieve a good overall efficiency.

External Bootstrap Capacitor

This capacitor provides the gate driver voltage for internal high side MOSEFET. A 100nF low ESR ceramic capacitor connected between the BS pin and the LX pin is recommended.



Switching Frequency Setting

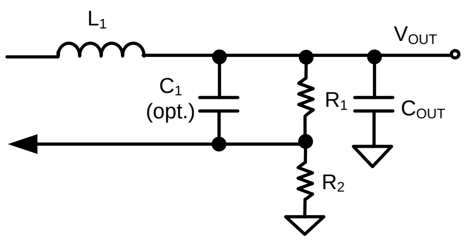
Connect a resistor from the FS pin to GND to adjust the switching frequency. The switching frequency is adjustable from 500kHz to 2.5MHz. The switching frequency can be calculated by below equation:

$$fsw(kHz)=\frac{106800}{R_{FS}+7}$$

Where R_{FS} is in kΩ.

Load Transient Considerations

The SQ20953 integrates the compensation components to achieve good stability and fast transient responses. In some applications, adding a ceramic capacitor in parallel with R_1 may further speed up the load transient response and it is recommended for applications with large load transient step requirements.



Short-circuit Protection

The SQ20953 integrates hic-cup mode short circuit protection function. If the device V_{OUT} drops below 33% of the set-point, the short-circuit protection mode will be initiated. The device will shut down for approximately 4.5ms, and then restart with a complete soft-start cycle that is approximately 1.5ms. If the short circuit condition remains another 'hiccup' cycle of shutdown and restart will continue indefinitely.

Over-temperature Protection (OTP)

The SQ20953 includes over-temperature protection (OTP) circuitry to prevent overheating due to excessive power dissipation. This will shut down switching operation when the junction temperature exceeds 150°C. Once the junction temperature cools down by approximately 15°C the IC will resume normal operation with a complete soft-start cycle. For continuous operation, provide adequate cooling so that the junction temperature does not exceed the OTP threshold.

Layout Design

The layout design of the SQ20953 regulator is relatively simple. For the best efficiency and minimum noise problem, the following components should be placed 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 components R_1 and R_2, and the trace connected to the FB pin must NOT be adjacent to the LX net on the PCB layout to avoid the noise problem.

5) If the system chip interfacing with the EN pin has a high impedance state at shutdown mode and the IN pin is connected directly to a power source such as a Li-Ion battery, it is desirable to add a pull down 1Mohm resistor between the EN and GND pins to prevent the noise from falsely turning on the regulator at shutdown mode.

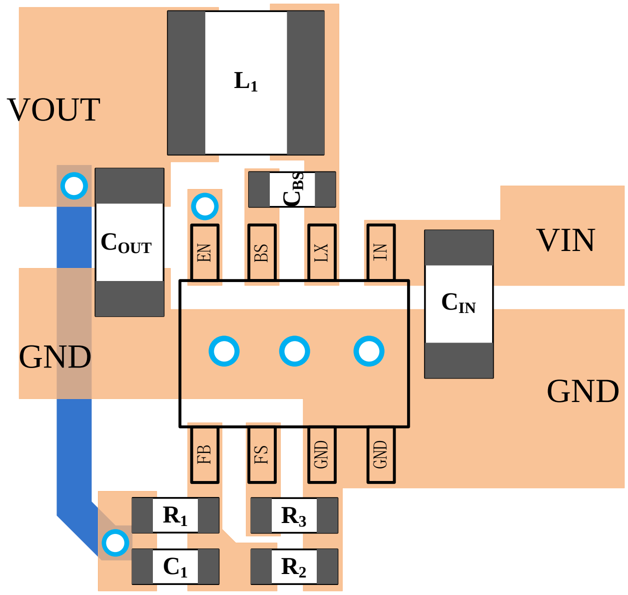
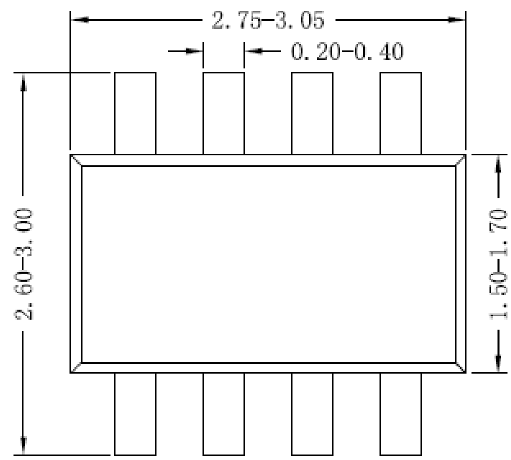
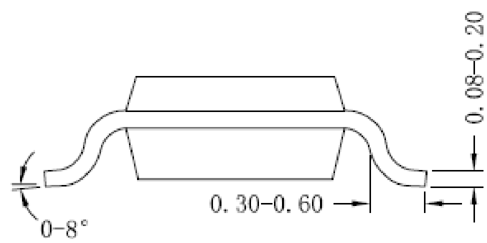


Figure3. PCB Layout Suggestion

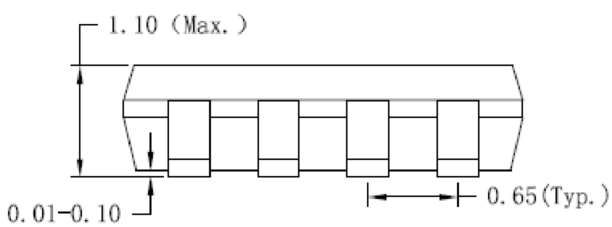
TSOT23-8 Package Outline Drawing



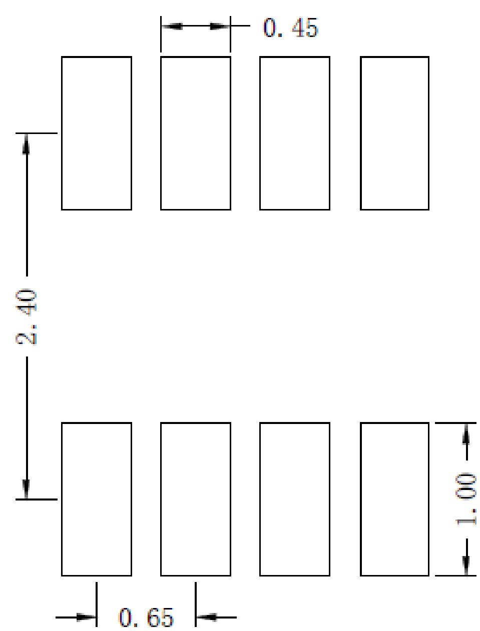
Top view



Side view A



Side view B



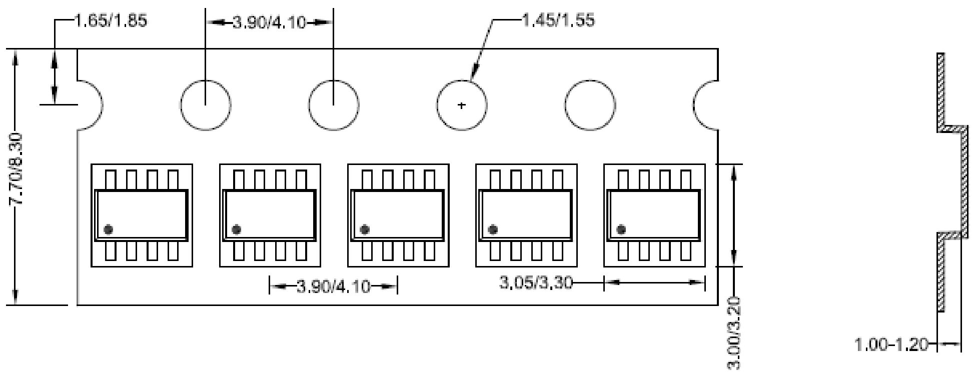
Recommended PCB layout
(Reference only)

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

Taping & Reel Specification

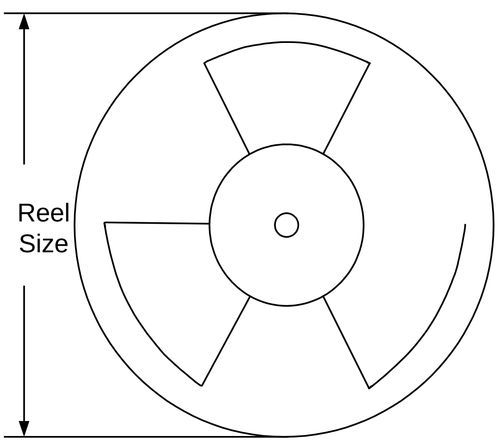
1. Taping orientation

TSOT23-8



Feeding direction →

2. Carrier Tape & Reel specification for packages



Package types	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer * length(mm)	Leader * length (mm)	Qty per reel (pcs)
TSOT23-8	8	4	7	400	160	3000

3. Others: NA

Revision History

The revision history provided is for informational purpose only and is believed to be accurate, however, not warranted. Please make sure that you have the latest revision.

Date	**Revision**	**Change**
Sep.16, 2020	Revision 0.9	Initial Release

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