Application Note: SY8401

High Efficiency, 1.2MHz, 50V Input, 0.8A Asynchronous Step Down Regulator

Preliminary Specification

General Description

The SY8401 develops a high efficiency asynchronous step-down DC-DC converter which is capable of delivering 0.8A output current. The device adopts current mode adaptive constant off time control. The SY8401 operates over a wide input voltage range from 4.5V to 50V and integrates main switch with very low $R_{DS(ON)}$ to minimize the conduction loss.

Low output voltage ripple and small external inductor and capacitor sizes are achieved with 1.2MHz switching frequency.

Ordering Information

SY8401 □(□□)□
- Temperature Code
- Package Code
- Optional Spec Code

Ordering Number	Package type	Note
SY8401ABC	SOT23-6	--

Features

- Low $R_{DS(ON)}$ for internal N-channel power FET:700mΩ
- 4.5-50V input voltage range
- 0.8A output current capability
- 1.2MHz pseudo constant switching frequency
- Internal soft-start limits the inrush current
- Hic-cup mode output short circuit protection
- EN ON/OFF control with accurate threshold
- Cycle by cycle peak current limit
- 0.6V±1 % reference voltage
- SOT23-6 package

Applications

- Non-Isolated Telecommunication Buck Regulator
- Secondary High Voltage Post Regulator
- Automotive Systems

Typical Applications

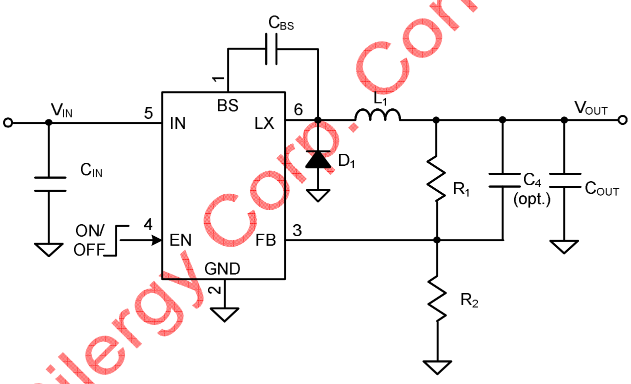


Figure 1. Schematic Diagram

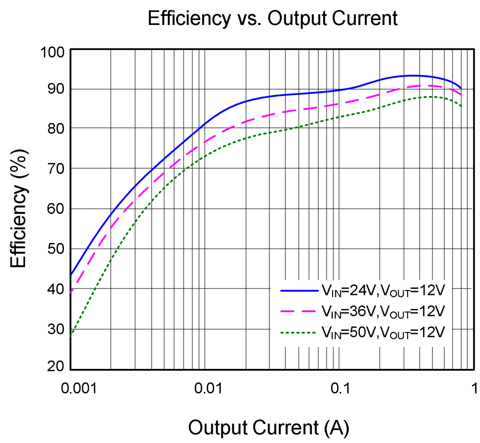
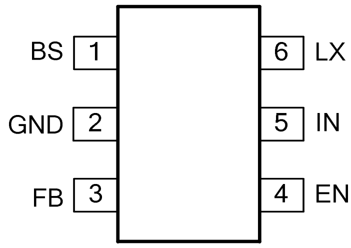


Figure 2. Efficiency

Pinout (top view)



(SOT23-6)

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

Pin Name	Pin Number	Pin Description
BS	1	Boot-Strap Pin. Supply high side gate driver. Decouple this pin to LX pin with 0.1uF ceramic cap.
GND	2	Ground pin
FB	3	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×(1+R1/R2).
EN	4	Enable control. Pull high to turn on. Do not leave it floating.
IN	5	Input pin. Decouple this pin to GND pin with at least 1uF ceramic cap.
LX	6	Inductor pin. Connect this pin to the switching node of inductor

Absolute Maximum Ratings (Note 1)

Supply Input Voltage ---------- 55 V
BS-LX ---------- 4V
All other pins ---------- V_{IN} + 0.3V
Power Dissipation, P_D @ T_A = 25°C SOT23-6, ---------- 1W
Package Thermal Resistance (Note 2)
θ_{JA} ---------- 100°C/W
θ_{JC} ---------- 25°C/W
Junction Temperature Range ---------- 150°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 50V
Junction Temperature Range ---------- -40°C to 125°C
Ambient Temperature Range ---------- -40°C to 85°C

Electrical Characteristics

(V_{IN} = 20V, V_{OUT} = 12V, L = 6.8uH, C_{OUT} = 10uF, T_A = 25°C, I_{OUT} =0.1A unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Voltage Range	V_{IN}		4.5		50	V
Quiescent Current	I_Q	LX not switching		150		µA
Shutdown Current	I_{SHDN}	EN=0		5	10	µA
Feedback Reference Voltage	V_{REF}		0.594	0.6	0.606	V
FB Input Current	I_{FB}	V_{FB}=V_{IN}	-50		50	nA
Power FET RON	$R_{DS(ON)1}$			700		mΩ
Power FET Peak Current Limit	$I_{LIM,TOP}$		1.05		1.65	A
EN Rising Threshold	V_{ENH}		1.14	1.2	1.26	V
EN Falling Threshold	V_{ENL}		0.94	1	1.06	V
Input UVLO Threshold	V_{UVLO}				4.5	V
Switching Frequency	F_{SW}			1.2		MHz
Switching Frequency Accuracy			-20		20	$\%F_{SW}$
Min ON Time				100		ns
Min Off Time				80		ns
Soft-start Time	t_{SS}			1.4		ms
Thermal Shutdown Temperature	T_{SD}			150		°C
Thermal Shutdown Hysteresis	T_{HYS}			15		°C

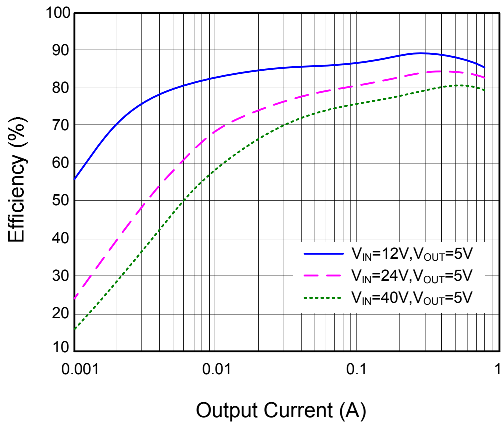
Note 1: Stresses beyond "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute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

Note 2: θJA is measured in the natural convection at T_A = 25°C on a high effective thermal conductivity four-layer test board per JESD51-7. Pin 2 of SOT-23-6 packages is the case position for θJC measurement.

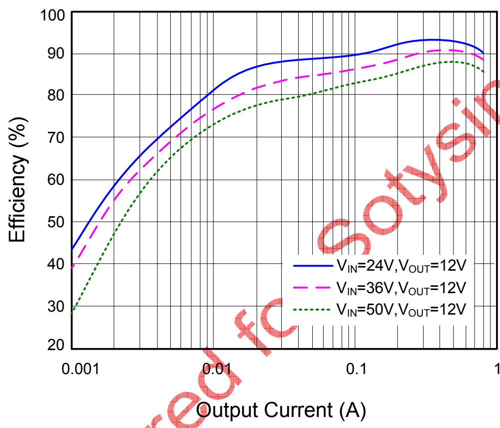
Note 3: The device is not guaranteed to function outside its operating conditions.

Typical Performance Characteristics

Efficiency vs. Output Current

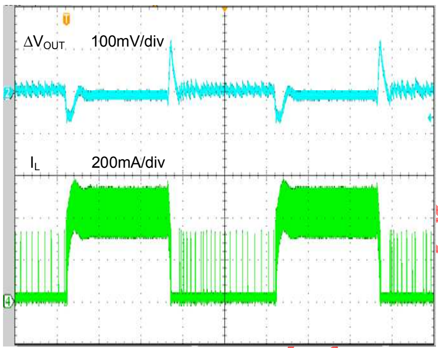


Efficiency vs. Output Current



Load Transient

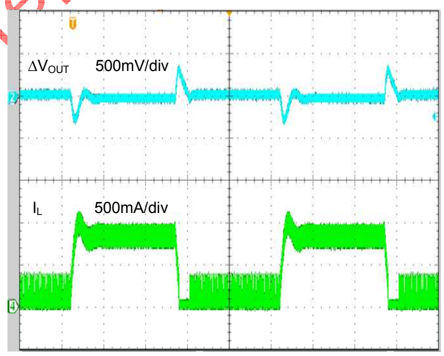
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0A~0.4A)



Time (200μs/div)

Load Transient

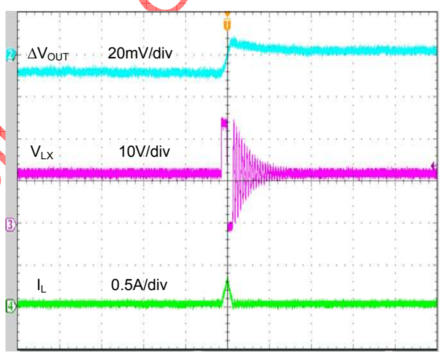
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.08A~0.8A)



Time (200μs/div)

Output Ripple

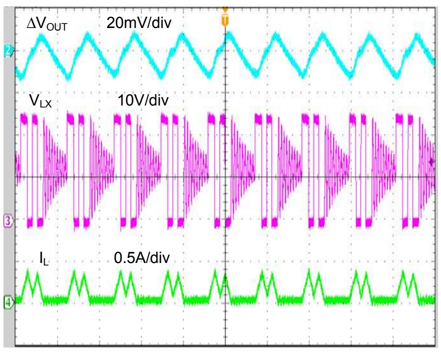
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0A)



Time (4μs/div)

Output Ripple

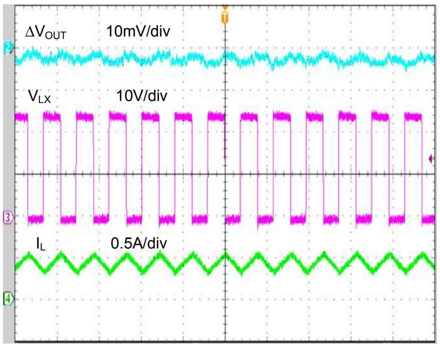
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.08A)



Time (4μs/div)

Output Ripple

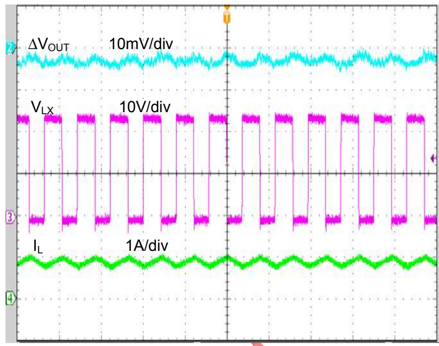
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.4A)



Time (1μs/div)

Output Ripple

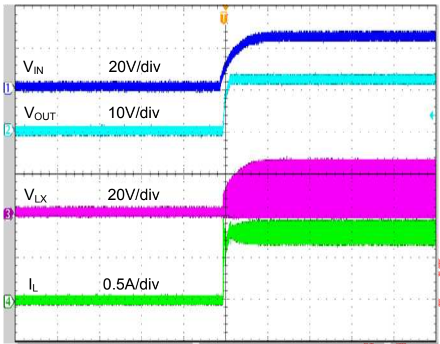
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.8A)



Time (1μs/div)

Startup from V_{IN}

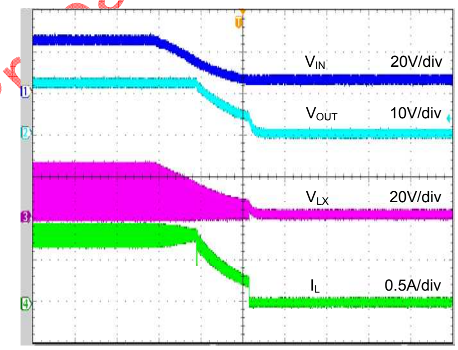
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.8A)



Time (10ms/div)

Shutdown from V_{IN}

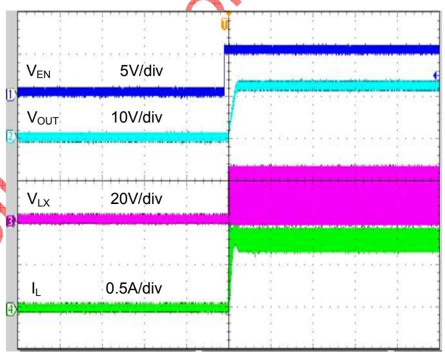
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.8A)



Time (4ms/div)

Startup from Enable

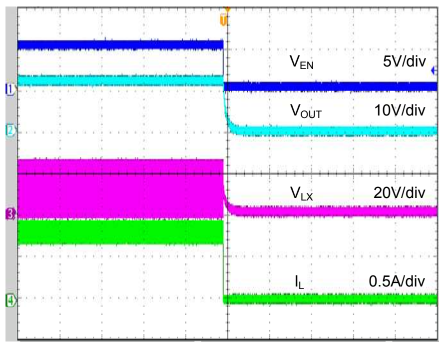
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.8A)



Time (4ms/div)

Shutdown from V_{IN}

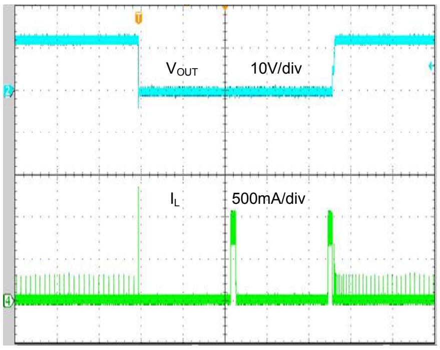
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.8A)



Time (4ms/div)

Short Circuit Protection

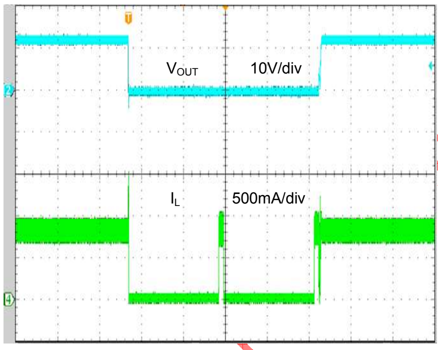
(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0A~Short)



Time (20ms/div)

Short Circuit Protection

(V_{IN}=24V, V_{OUT}=12V, I_{OUT}=0.8A~Short)



Time (20ms/div)

Operation

The SY8401 develops a high efficiency asynchronous step-down DC-DC converter which is capable of delivering 0.8A output current. The device adopts current mode adaptive constant off time control. The SY8401 operates over a wide input voltage range from 4.5V to 50V and integrates main switch with very low $R_{DS(ON)}$ to minimize the conduction loss.

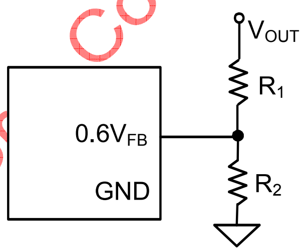
Low output voltage ripple and small external inductor and capacitor sizes are achieved with 1.2MHz switching frequency.

Applications Information

Because of the high integration in the SY8401 IC, the application circuit based on this regulator IC is rather simple. Only input capacitor C_{IN}, output capacitor C_{OUT}, output inductor L_1 and feedback resistors (R_1 and R_2) need to be selected for the targeted applications specifications.

Feedback Resistor Dividers R1 and R2:
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 Vout is 1.2V, R_1=100k is chosen, then using following equation, R_2 can be calculated to be 100kΩ:

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



Input Capacitor CIN:
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 10uF low ESR ceramic capacitor is recommended.

Output Capacitor COUT:
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 most applications, an X5R or better grade ceramic capacitor greater than 22uF capacitance can work well. The capacitance derating with DC voltage must be considered.

Output Inductor L1:
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 SY8401 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.

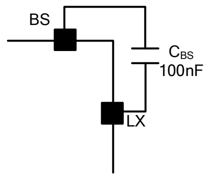
$$I_{SAT,MIN} > I_{OUT,MAX} + \frac{V_{OUT}(1 - V_{OUT}/V_{IN,MAX})}{2 \cdot F_{SW} \cdot L}$$

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.

Enable Operation
Pulling the EN pin low (<0.94V) will shut down the device. During shutdown mode, the SY8401 shutdown current drops to lower than 10uA, Driving the EN pin high (>1.26V) will turn on the IC again.

External Bootstrap Cap

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



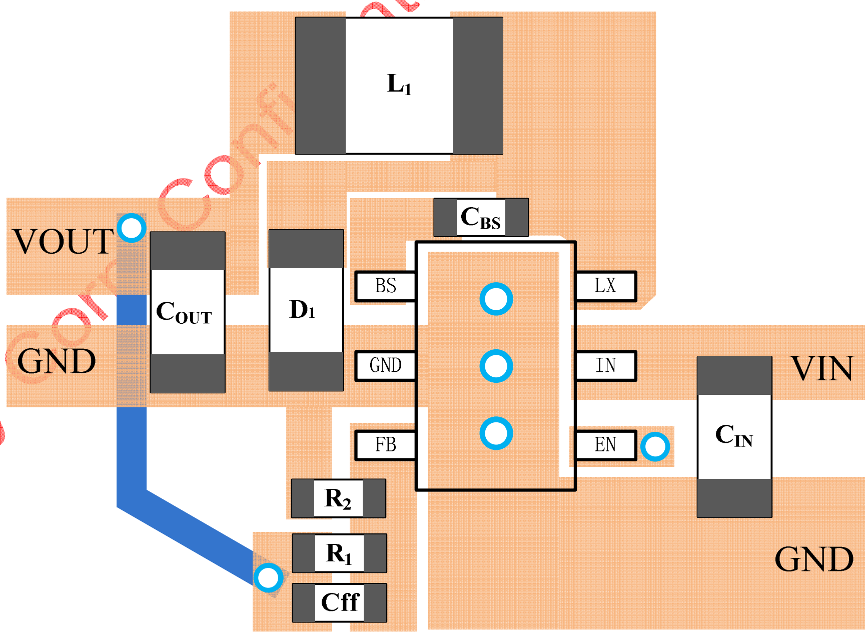
Load Transient Considerations:

The SY8401 regulator IC integrates the compensation components to achieve good stability and fast transient responses. In some applications, adding a 22pF ceramic cap in parallel with R1 may further speed up the load transient responses and is thus recommended for applications with large load transient step requirements.

Layout Design:

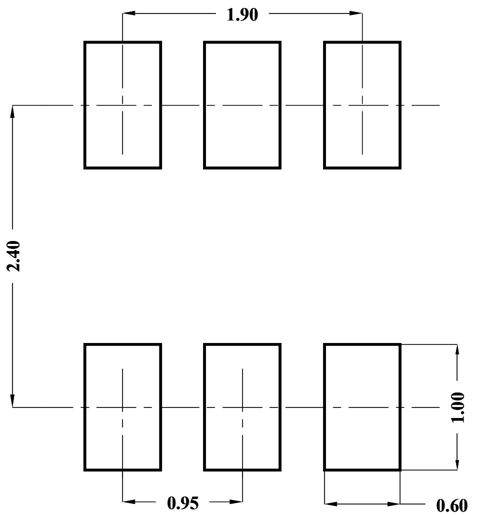
The layout design of SY8401 regulator is relatively simple. For the best efficiency and minimum noise problem, we should place the following components close to the IC: C_{IN}, L1, D1, R1 and R2.

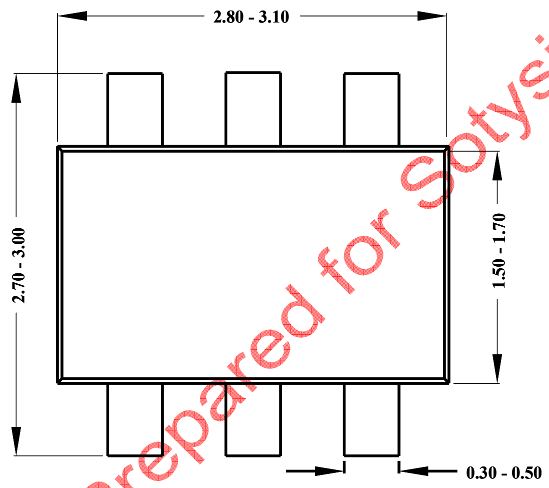
1) It is desirable to maximize the PCB copper area connecting to GND pin to achieve the best thermal and noise performance. If the board space allowed, a ground plane is highly desirable.
2) C_{IN} must be close to Pins IN and GND. The loop area formed by C_{IN} and GND must be minimized.
3) The PCB copper area associated with LX pin must be minimized to avoid the potential noise problem.
4) The components R1 and R2, and the trace connecting 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.



PCB Layout Suggestion

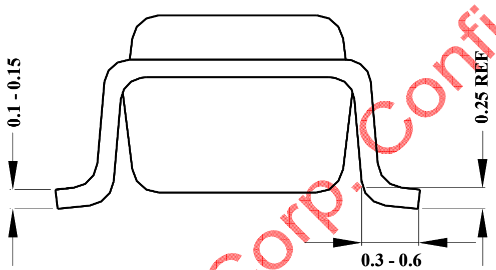
SOT23-6 Package Outline & PCB layout

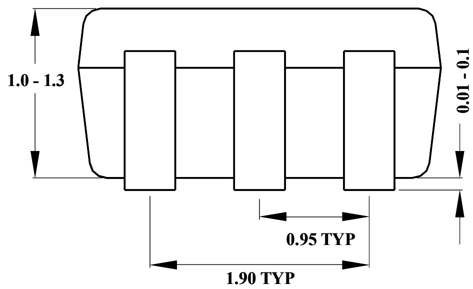




Recommended Pad Layout

Top View



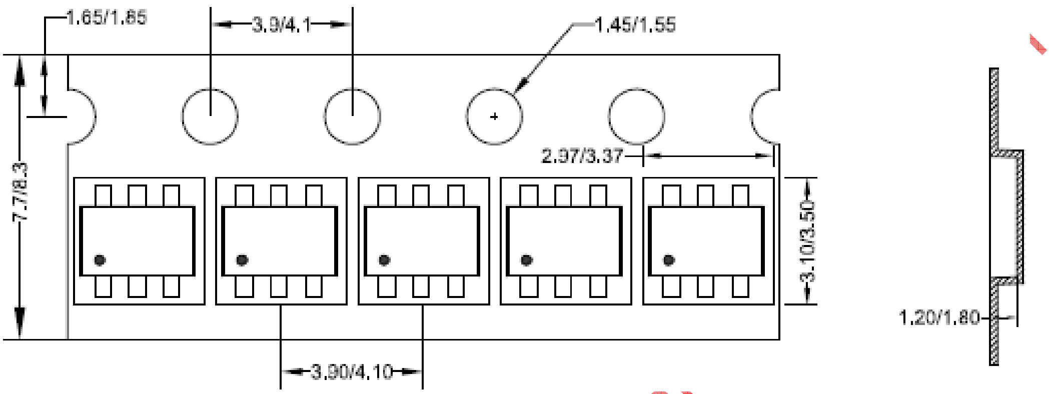


Notes: **All dimension in millimeter and exclude mold flash & metal burr.**

Taping & Reel Specification

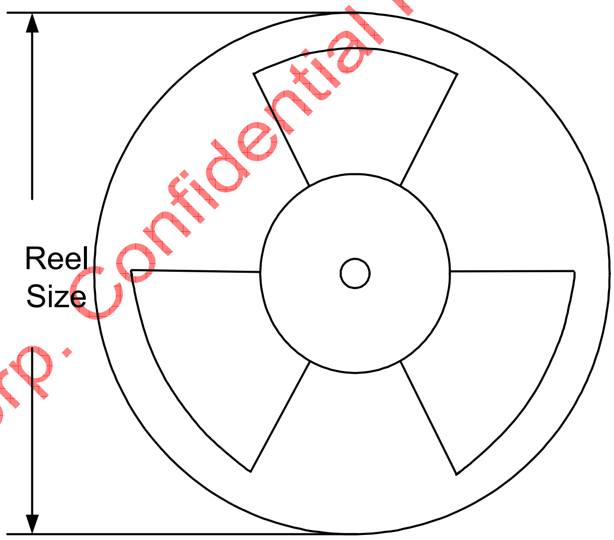
1. Taping orientation

SOT23-6



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
SOT23-6	8	4	7"	280	160	3000

3. Others: NA