SY21238

Low Noise High Efficiency 850kHz Step Up Regulator with Accurate Input Current Limit

General Description

The SY21238 high efficiency step-up regulator operates using current mode control over a wide input voltage range from 3.5V to 30V. The high efficiency is achieved with a low $R_{DS(ON)}$ internal switch, and EMI performance is improved by using spread spectrum modulation of the internal clock. The SY21238 also features optional input overvoltage protection.

The SY21238 is available in a compact SOT23-6 package.

Features

- Wide 3.5V to 30V Input Range
- 30V Maximum Output Voltage
- 150 µA Iq (Typ.)
- Low 200mΩ $R_{DS(ON)}$ for Internal Switch
- 850kHz Switching Frequency
- Minimum On-Time: 100ns Typical
- Minimum Off-Time: 100ns Typical
- Optional Input Overvoltage Protection
- RoHS-Compliant and Halogen-Free
- Compact SOT23-6 Package

Targeted Applications

- GPS Navigation Systems
- Handheld Devices
- Portable Media Player

Typical Application

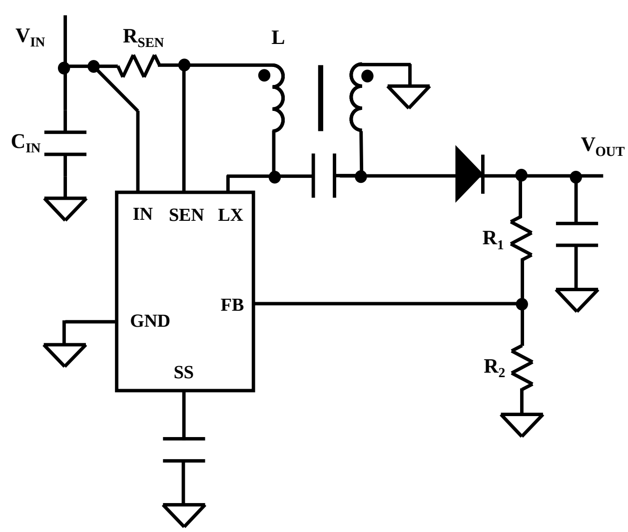


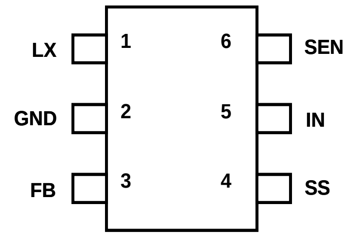
Figure 1. Typical Schematic Diagram

Ordering Information

Ordering Part Number	Package Type	Top Mark
SY21238ABC	SOT23-6 RoHS Compliant and Halogen Free	**HE*xyz***

x = year code, y = week code, z = lot number code

Pinout (top view)



Pin Name	Pin Number	Pin Description
LX	1	Inductor node. Connect an inductor from the power input to the LX pin.
GND	2	Ground pin
FB	3	Feedback pin. Connect a resistor R_1 between V_{OUT} and FB, and a resistor R_2 between FB and GND to program the output voltage: $V_{OUT}=1V\times(R1/R2+1)$
SS	4	External soft-start pin. Add a capacitor Css to this pin to program the soft-start time (tss) to limit the inrush current. tss=2.4ms×Css/10nF
IN	5	Input pin. Decouple this pin to the GND pin with a 1μF ceramic capacitor. Also used as the positive current sense pin. The device features a 7V input over voltage protection (OVP) function when the SS pin is floating or connected to a soft-start capacitor. Connect the SS to the IN to disable the input OVP function.
SEN	6	Negative current sense pin. Connect current sense resistor R_{SEN} between the IN pin and the SEN pin to program the input current limit: $I_{INLIM}=96mV/R_{SEN}$.

Block Diagram

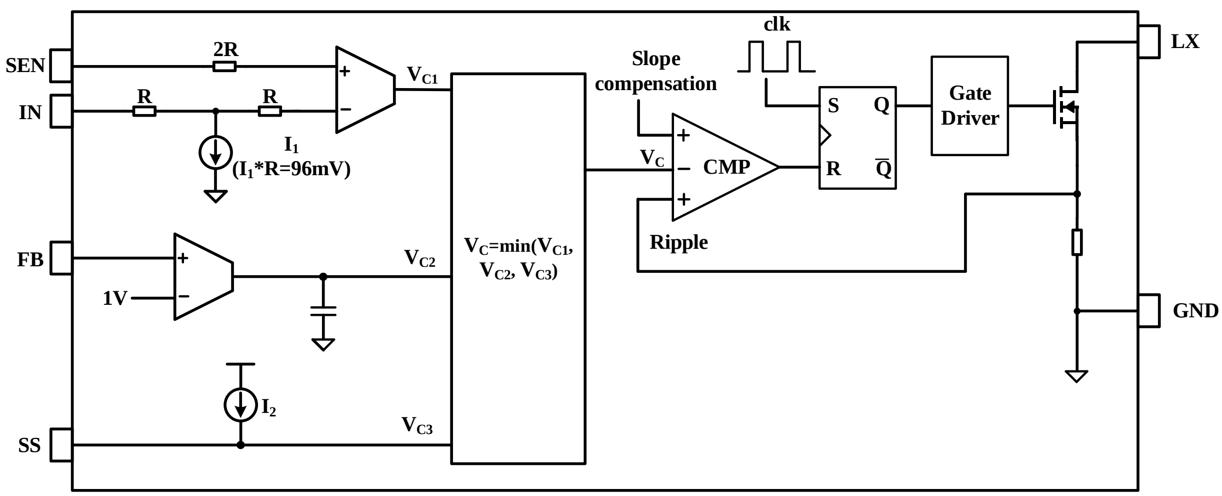


Figure 2 Block Diagram

Absolute Maximum Ratings

Parameter (Note 1)	Min	Max	Unit
LX, IN, SEN, SS	-0.3	33	V
FB	-0.3	4	
Lead Temperature (Soldering, 10s)		260	°C
Junction Temperature, Operating	-40	150	
Storage Temperature	-65	150	

Thermal Information

Parameter (Note 2)	Typ	Unit
θ_{JA} Junction-to-Ambient Thermal Resistance	170	°C/W
θ_{JC} Junction-to-Case Thermal Resistance	130	
P_D Power Dissipation T_A = 25°C	0.6	W

Recommended Operating Conditions

Parameter (Note 3)	Min	Max	Unit
IN, SEN, LX, SS	3.5	30	V
FB	0	3.6	
Junction Temperature, Operating	-40	125	°C
Ambient Temperature	-40	85	

Electrical Characteristics

(V_{IN} = 5V, V_{OUT}=12V, I_{OUT}=100mA, TA = 25°C unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Voltage Range	V_{IN}		3.5		30	V
Quiescent Current	I_Q	FB=1.1V		150		µA
Low Side Main FET RON	$R_{DS(ON)}$			200		mΩ
Main FET Current Limit	I_{LIM}		2			A
Switching Frequency	f_{SW}			850		kHz
Frequency Jittering Range	f_{JET}			±12.5		$\%f_{SW}$
Feedback Reference Voltage	V_{REF}		0.98	1	1.02	V
Current Sense Limit	IN-SEN	FB>500mV	94	96	98	mV
		FB<150mV		30		mV
IN UVLO rising threshold	$V_{IN,UVLO}$				3	V
UVLO hysteresis	V_{HYS}			0.1		V
IN OVLO rising threshold	$V_{IN,OV}$	SS is floating or connected to a soft-start capacitor	7			V
IN OVLO hysteresis				0.3		V
Thermal Shutdown Temperature	T_{SD}			150		°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.

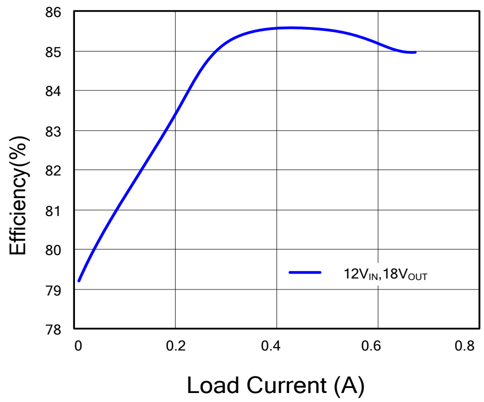
Note 2: θ JA is measured in the natural convection at TA = 25°C on a low effective single layer thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

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

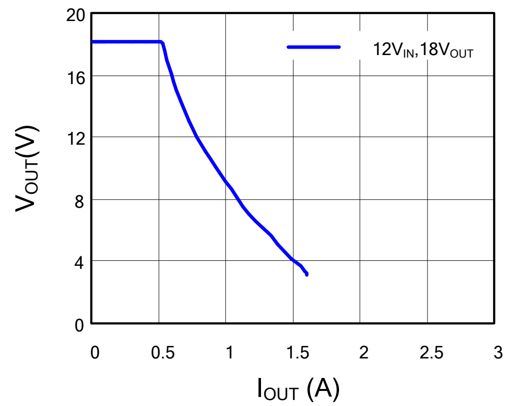
Typical Performance Characteristics

(T_A= 25℃, V_{IN}=5V, V_{OUT} = 12V, L = 6.8μH, C_{OUT}= 44μF, unless otherwise specified)

Efficiency VS Load Current

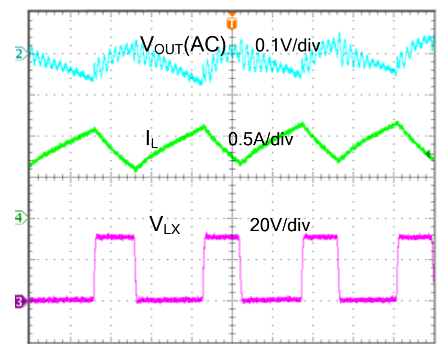


VOUT vs IOUT



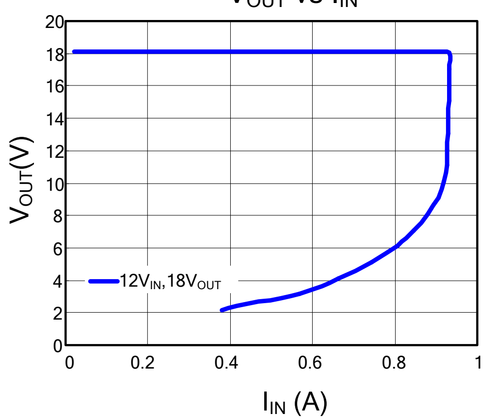
Output Ripple

(V_{IN}=12V, V_{OUT}=18V, I_{OUT}=0.5A)



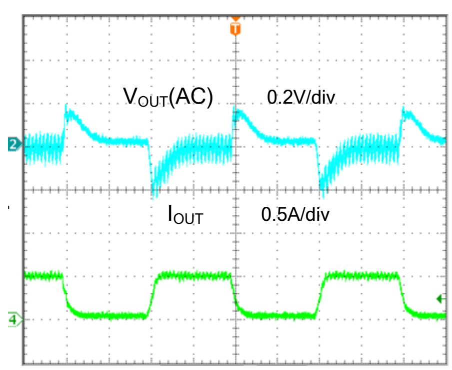
Time(400ns/div)

VOUT vs IIN



Load Transient

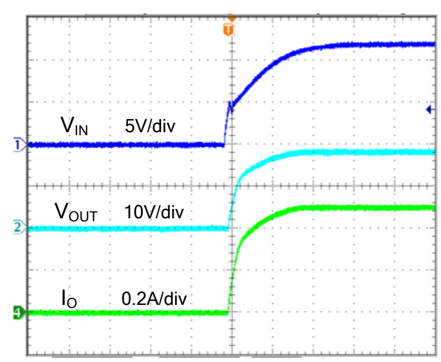
(V_{IN}=12V, V_{OUT}=18V,I_{OUT}=0.5A)



Time(100us/div)

Startup

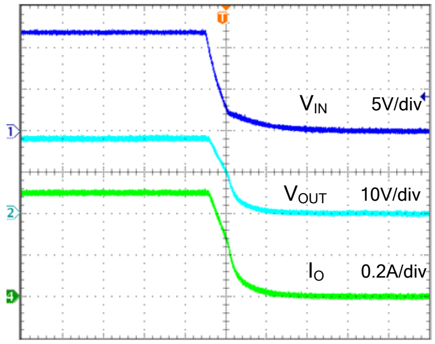
(V_{IN}=12V, V_{OUT}=18V, I_{OUT}=0.5A)



Time(2ms/div)

Shutdown

(V_{IN}=12V, V_{OUT}=18V, I_{OUT}=0.5A)



Time(2ms/div)

Detailed Description

The SY21238 is a fully integrated Boost/SEPIC regulator with input current limit. The device uses peak-current-mode control to ensure reliable overcurrent protection and cycle-by-cycle switch current limiting. The input current limit control senses the DC input current via a sense resistor and compares it against the internal threshold. If the input current is below the threshold, the device will operate in constant output voltage (CV) mode, and the output voltage will be regulated by the feedback voltage sensed on the V_{OUT}. If the input current goes above the threshold, the device operates in constant input current mode, and the average input current will be regulated to a level programmed by the input current sense resistor.

Soft Start Programming

The SY21238 provides an external soft-start pin that gradually raises the output voltage. The soft-start time can be programmed by the external capacitor across SS pin and GND. The soft start time is calculated as:

$$t_{SS} = 2.4ms \times \frac{C_{SS}}{10nF}$$

If a 10nF capacitor is used, the typical soft-start time will be 2.4ms.

When the SS pin is connected to IN pin, the SY21238 will disable VIN_OV protection so as to extend working condition to high VIN.

Fault Protection Modes

Input Over Voltage Protection

The input voltage is sensed by the IN pin. When the voltage on this pin exceeds 7V, the IC will shut down. To disable this function, connect the SS to the IN directly.

Thermal protection

The SY21238 includes over temperature protection circuitry to prevent overheating due to excessive power dissipation. This will shut down the device when the junction temperature exceeds 150°C. When the junction temperature cools down, the device will resume normal operation after a complete soft-start cycle. For continuous operation, provide adequate cooling so that the junction temperature does not exceed the thermal protection threshold.

Overcurrent Protection

The SY21238 provides a cycle-by-cycle overcurrent protection and turns off the main power MOSFET once the inductor current reaches the overcurrent limit threshold. During the overcurrent protection, the output voltage drops as a function of the load. As soon as the overload condition is removed, the converter resumes operation.

Applications Information

The following paragraphs describe the selection process for the feedback resistors (R1 and R2), current sense resistor R_{SEN}, input capacitor C_{IN}, output capacitor C_{OUT}, output inductor L, and diode D.

Feedback Resistor Dividers R_1 and R_2

Choose R_1 and R_2 to program the output voltage under the CV mode. Choose large resistance values between 1kΩ and 100kΩ for both R1 and R2 to minimize power consumption under light loads. If a value is chosen for R2, then R1 can be calculated as:

$$R_1 = \frac{(V_{OUT} - 1V) \times R_2}{1V}$$

Input Capacitor C_{IN}

A ceramic capacitor of 1μF minimum value is recommended to decouple the IN pin to GND.

Output Capacitor C_{OUT}

Select the output capacitor 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, use an X7R or better grade ceramic capacitor with proper rating and 22μF minimum capacitance.

For applications where the design must meet stringent ripple requirements, the following considerations must be followed:

The output voltage ripple at the switching frequency is caused by the inductor current ripple (ΔI_L) on the output capacitor's ESR (ESR ripple), as well as the stored charge (capacitive ripple). When calculating total ripple, both should be considered.

$$V_{RIPPLE,\ ESR1} = I_{LPEAK} \times ESR$$

$$V_{RIPPLE,\ ESR2} = I_{LVALLEY} \times ESR$$

$$V_{RIPPLE,CAP} = \frac{I_{OUT} \times (1\text{-}D)}{C_{OUT} \times f_{SW}}$$

The capacitive ripple might be higher because the effective capacitance for ceramic capacitors decreases with the voltage across the terminals. The voltage derating is usually included as a chart in the capacitor datasheet, and the ripple can be recalculated after taking the target output voltage into account.

Input Current Sense Resistor R_{SEN}

For a given input current limit, $I_{IN,MAX}$, the current sense resistor is selected to be

$$R_{SEN} = \frac{0.096}{I_{IN,MAX}}$$

Output Inductor L for SEPIC Design

Coupled inductor is recommended for SEPIC design to minimize the overall solution size. There are several considerations in choosing this inductor.

1) Choose the inductance to provide a ripple current that is approximately 40% of the maximum output current. The recommended inductance is calculated as::

$$\mathrm{L} = \frac{V_{IN} \times V_O}{40\% \times f_{SW} \times (I_{OUT,MAX} + I_{IN})(V_{IN} + V_O)}$$

Where fsw is the switching frequency and Iout,max is the maximum load current.

The SY21238 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 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<30mΩ to achieve a good overall efficiency.

Diode Selection

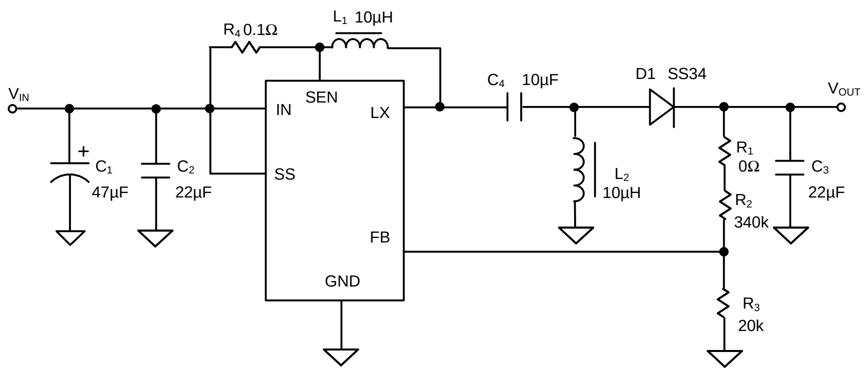
A Schottky diode is a good choice for high efficiency operation because of its low forward voltage drop and fast reverse recovery. The current rating of the diode must be higher than the value calculate using the following equation:

$$\mathrm{I_D(RMS)} \approx \sqrt{(\mathrm{I_{OUT}} \times \mathrm{I_{PEAK}})}$$

The Schottky diode reverse-breakdown voltage should be larger than the output voltage.

Typical Design

Typical Schematic



Design Specifications

Input Voltage (V)	Output Voltage (V)	Input Current Limit (A)
10-15	18	1

BOM List

Reference Designator	Description	Part Number	Manufacturer
U_1	2A, Step Up Regulator (SOT23-6)	SY21238ABC	
L_1, L_2	10μH /VLP6045LT-100M		TDK
C_1	47μF/16V Electrolytic Capacitor		TDK
C_2, C_3	22μF/X7R/25V/1206		TDK
C_4	10μF/X5R/25V/1206		TDK
R_1, R_5	0Ω, 0603		
R_2	340kΩ,5%, 0603		
R_3	20kΩ, 5%, 0603		
R_4	0.1Ω, 1%, 0603		
D1	SS34 (40V/3A)		

Recommend Table for Typical Applications

V_{OUT}(V)	R_2(kΩ)	R_3(kΩ)	L(μH)	C_{OUT}
18	340	20	10	22μF/25V/X7R,1206

Layout Design

The layout design of SY21238 regulator is relatively simple. For optimal design, follow these PCB layout considerations:

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 connecting to the FB pin must NOT be adjacent to the LX net on the PCB layout to avoid the noise problem.

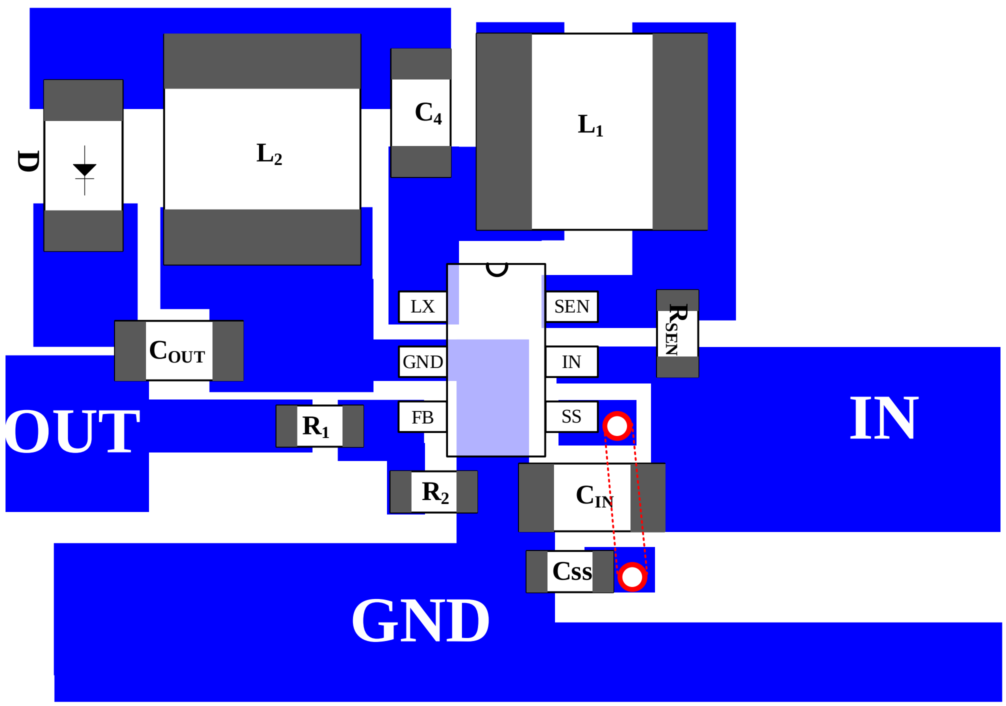
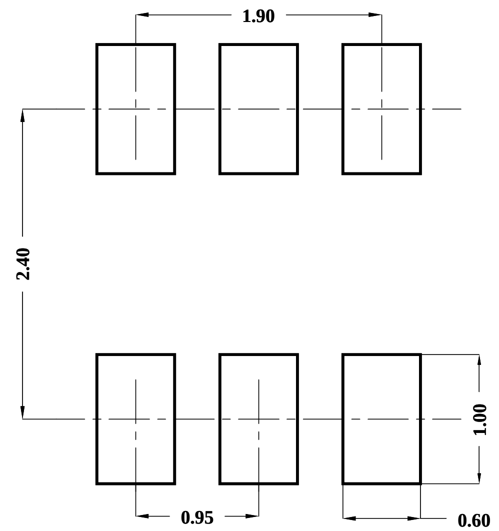
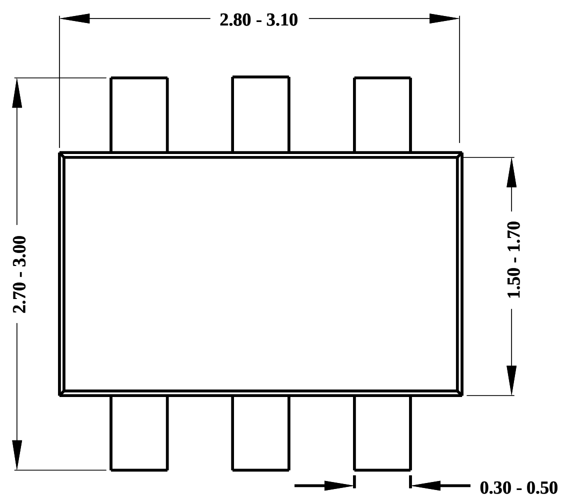


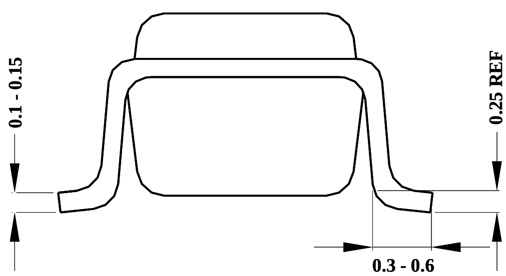
Figure.4 PCB Layout Suggestion

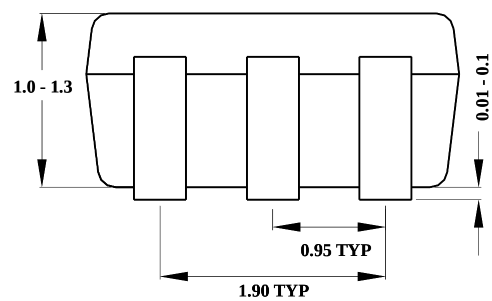
SOT23-6 Package outline & PCB layout design



Recommended Pad Layout



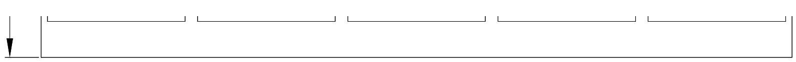




Notes: All dimensions are in millimeters.
All dimensions don’t include mold flash & metal burr.

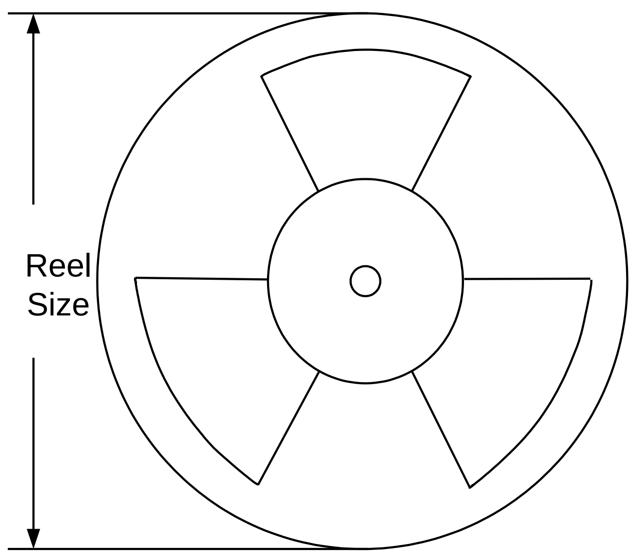
Taping & Reel Specification

1. 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

Revision History

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

Date	Revision	Change
Aug.24, 2023	Revision 1.0	Language improvements for clarity
Feb.01, 2012	Revision 0.9	Initial Release

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