SY24647

High- or Low-Side, Bidirectional, High Accuracy Current Sense Amplifier

General Description

The SY24647 is a current-sense amplifier, served as a voltage-output, current-shunt monitor. The device can sense a shunt voltage drop with a common mode voltage varying from -0.1V to 26V, independent of the supply voltage. The gain can be fixed at 200V/V. The SY24647 has a low offset zero-drift architecture, which can allow the device to function very well in measuring the low voltage drop in the power management unit.

The SY24647 operates from a 3V to 5.5V power supply. The device is provided in a SOT363 package, and specified over the extended industrial temperature range of -40°C to 125°C.

Ordering Information

SY24647□(□□□)

- Package Code
- Optional Spec Code

Ordering Number	Package type	Note
SY24647AHT	SOT363	

Features

- Voltage-output, Current-shunt Monitor
- Wide Common Mode Operation Range: -0.1V~26V
- Gain=200V/V
- Amplifier's Output Referenced to VREF input
- Shunt Drop Range:
  - -10mV to 10mV (VCC=5V，REF=2.5V)
  - 1mV to 24mV (VCC=5V，REF=0V)
- Low Offset Voltage: ±35µV (Maximum)
- 0.5µV/°C Offset Drift (Maximum)
- Accuracy: ±0.5% Gain Error (Maximum)
- 10ppm/°C Gain Drift (Maximum)
- Quiescent Current: 100µA (Maximum)
- Packages: SOT363

Applications

DC Bus Monitoring for:

- Body Control Module
- Valve Control
- Motor Control
- Electronic Stability Control
- Wireless Charging Transmitters

Typical Application

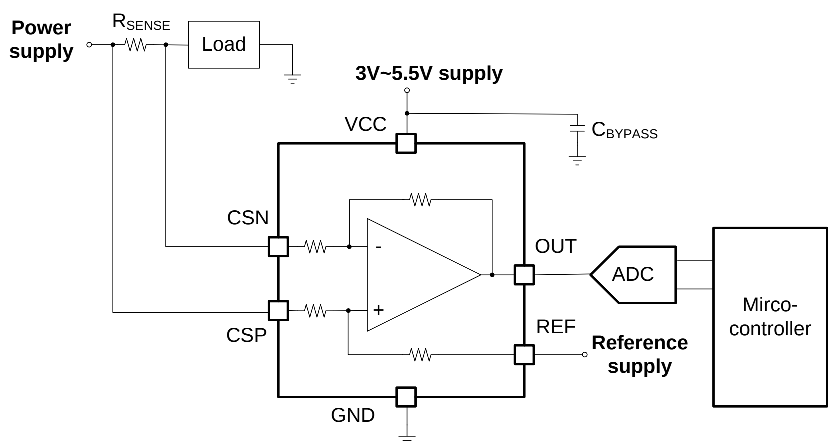
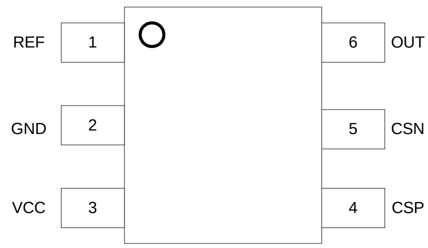


Figure 1. Typical application

Figure. 1 shows the basic connections of the SY24647. The two-input pin CSN and CSP should be connected to the shunt resistor as closely as possible to minimize any resistance in series with the sense resistor. A bypass capacitor connected to the power-supply is required for stability concern.

Pin out (Top View)



(SOT363)

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

Name	Number	Description
REF	1	Reference voltage input
GND	2	Ground
VCC	3	Power supply
CSP	4	Connect to supply side of shunt resistor
CSN	5	Connect to load side of shunt resistor
OUT	6	Output voltage

Block Diagram

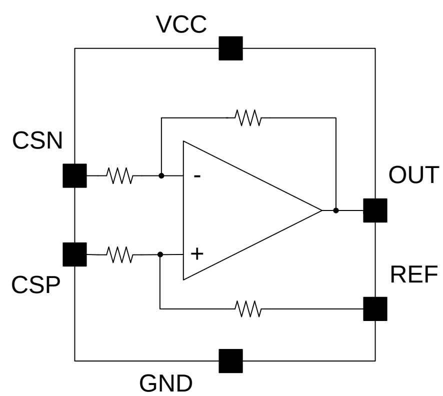


Figure 2. Block Diagram

Absolute Maximum Ratings

VCC --- -0.3V to 6V
CSP, CSN
Common-mode -- -0.3V to 29V
Differential --- -29V to 29V
REF -- -0.3V to VCC
OUT --- -0.3V to VCC
Package Thermal Resistance (Note 2)
θ_{JA} --- 321°C/W
$\theta_{JC(top)}$ --60°C/W
Junction Temperature --- -40°C to 150°C
Storage Temperature Range -- -65°C to 150°C
ESD Susceptibility
HBM (Human Body Mode) --- 4 kV
CDM (Charged Device Model) -- 1 kV

Recommended Operating Conditions

CSP, CSN (Differential) -- -10mV to +10mV
VCC -- 5V
REF -- 2.5V
Junction Temperature Range --- -40°C to +125°C

Electrical Characteristics

At T = 25°C, VCC = 5V, V_{SENSE} = CSP-CSN=0mV, CSP = 12V, and VREF = 2.5V, unless otherwise noted.

Parameter	Symbol	Test condition	Min	Typ	Max	Unit
INPUT						
Common-mode Input	V_{CM}	T = -40°C to 125°C(2)	-0.1		26	V
Common-mode Rejection Ratio	CMRR	CSP=CSN=0 V to 26 V, V_{SENSE} = 0mV, T = 25°C		125		dB
		CSP=CSN=0 V to 26 V, V_{SENSE} = 0mV, T = -40°C to 125°C(2)	110	125		
Offset Voltage, RTI(1)	V_{OS}	V_{SENSE} = 0 mV, T = 25°C		±0.5	±35	μV
Offset Voltage vs Temperature	dV_{OS}/dT	T = -40°C to 125°C(2)		0.1	0.5	μV/°C
Offset Voltage vs Power Supply	PSR	VCC = 3 V to 5.5V, CSP = 12 V, V_{SENSE} = 0 mV, T = 25°C		±0.1	±5	μV/V
Input Bias Current	I_B	V_{SENSE} = 0 mV, T = 25°C	30	38	45	μA
Input Offset Current	I_{OS}	V_{SENSE} = 0 mV, T = 25°C		±0.02		μA
OUTPUT						
Gain				200		V/V
Gain Error		VCC = 5V, VREF = 2.5V. V_{SENSE} = -10 mV to 10 mV, T = 25°C		±0.02%	±0.5%	
		VCC = 5V, VREF = 2.5V. V_{SENSE} = -10 mV to 10 mV, T = -40°C to 125°C(2)		±0.02%	±0.5%	
Gain Error vs Temperature		T = -40°C to 125°C(2)		3	10	ppm/°C
Nonlinearity Error		T = 25°C		±0.01%		
Maximum Capacitive Load(2)		No sustained oscillation, T = 25°C		1		nF
VOLTAGE OUTPUT						
Output Voltage Swing to V_{CC} Power-supply Rail		R_{LOAD} = 10kΩ to GND, T = 25°C		(V_{CC}) - 0.05	(V_{CC}) - 0.2	V
		R_{LOAD} = 10kΩ to GND, T = -40°C to 125°C(2)			(V_{CC}) - 0.2	
Output Voltage Swing to GND		R_{LOAD} = 10kΩ to GND, T = 25°C		(V_{GND})+ 0.005	(V_{GND})+ 0.05	V
		R_{LOAD} = 10kΩ to GND, T = -40°C to 125°C(2)			(V_{GND})+ 0.05	
FREQUENCY RESPONSE						
Bandwidth	BW	C_{LOAD} = 10pF, T = 25°C		14		kHz
Slew Rate(2)	SR	T = 25°C		0.4		V/μs
POWER SUPPLY						
Operation Voltage	V_{CC}		3		5.5	V
Quiescent Current	I_Q	V_{SENSE} = 0 mV, T = 25°C		78	96	μA
		V_{SENSE} = 0 mV, T = -40°C to 125°C(2)			100	μA

Note:
(1) RTI = referred to input
(2) Guaranteed by Design, not subject to test.

Applications Information

SY24647 is a 26V common-mode, zero-drift topology, current sense amplifier that can be used in both low-side and high-side configurations. It is commonly used for over-current detection, voltage feedback control loops, or as a power monitor.

This device is intended to operate as Analog Front END (AFE) for ADC or microcontroller requiring high-common mode signal translation to low-side referenced inputs.

REF Input

SY24647 device measures the voltage developed across a current-sensing resistor when current passes through the device. The transfer function of SY24647 is

$$OUT = 200 \times V_{SENSE} + V_{REF} \qquad (V_{SENSE} = V_{CSP} - V_{CSN})$$

It is means SY24647 applicable to unidirectional and bidirectional current sense.

For unidirectional current sense application, the REF pin can be connected to ground directly as Figure 3 shown. The output rises above 0V for positive differential input signals linearly.

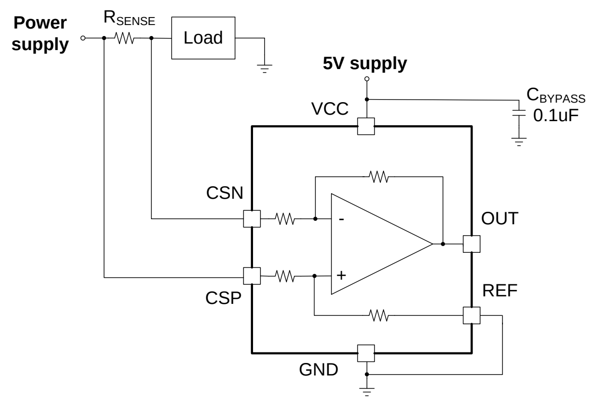


Figure 3. Unidirectional Current Sense Application

For bidirectional current sense application, the REF pin can be connected to a reference voltage (for example 0.5×VCC) as Figure 4 shown. The output rises above the reference voltage for positive differential input signals and falls below the reference voltage for negative differential input signals linearly.

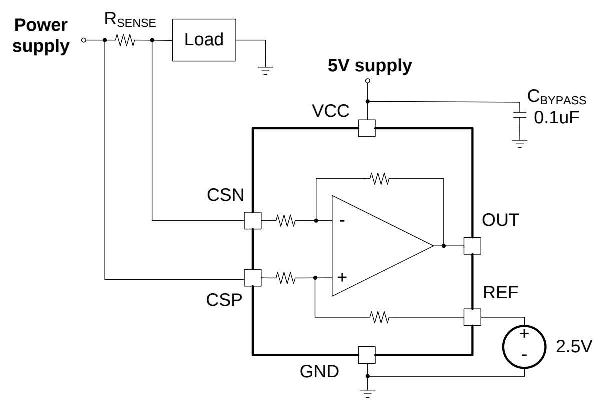


Figure 4. Bidirectional Current Sense Application

As with any difference amplifier, the SY24647's common-mode rejection ratio is affected by any impedance present at the REF input. This concern is not a problem when the REF pin is connected directly to most references or power supplies. When using resistive dividers from the power supply or a reference voltage, the REF pin must be buffered by an op amp.

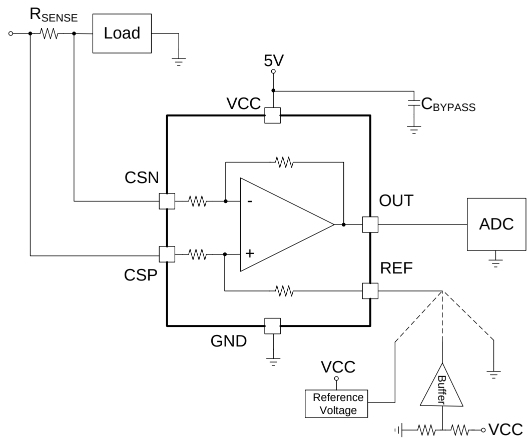


Figure 5. REF Pin Drive

In systems where the SY24647 output can be sensed differentially, such as by a differential input analog-to-digital converter (ADC) or by using two separate ADC inputs, the effects of external impedance on the REF input can be cancelled. Figure 6 depicts a method of taking the output from the SY24647 by using the REF pin as a reference.

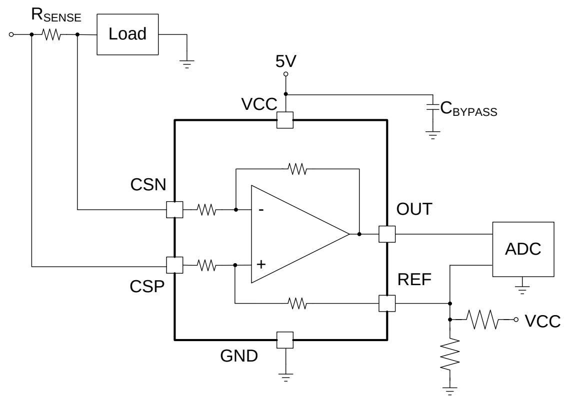


Figure 6. Sensing the SY24647 to Cancel the Effects of Impedance on the REF Input

Input Filtering

To improve the de-glitch ability and the system SNR (Signal to Noise Ratio), a RC filter placed at the inputs pins is recommended as below shows.

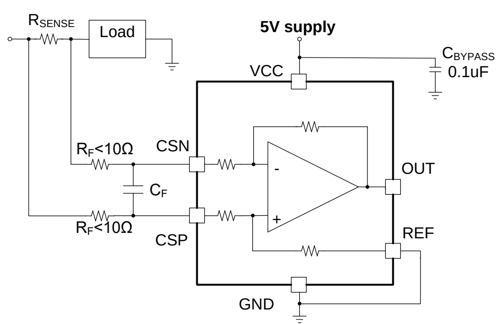


Figure 7. Filter at Input Pins

However, the addition of external series resistance will create an additional error in the measurement so the value of these series resistors must be kept to 10 Ω (or less, if possible) to reduce impact to accuracy. A mismatch in input bias currents present when a differential voltage is applied between the input pins of SY24647 cause the internal bias network. When additional external series filter resistors are added to the circuit, the mismatch in bias currents results in a mismatch of voltage drops across the filter resistors. This mismatch creates a differential error voltage that subtracts from the voltage developed at the shunt resistor.

This error results in a voltage at the device input pins that is different than the voltage developed across the shunt resistor. Without the additional series resistance, the mismatch in input bias currents has little effect on device operation. The amount of error these external filter resistors add to the measurement can be calculated using Equation 1.

$$GainError = (\frac{1000}{0.79 \times R_F + 1000} - 1) \times 100\%$$

For example, using R_F =10Ω for external series resistance will results in a Gain error = -0.78%.

Selecting R_{SENSE}

The design of the current-sensing resistor R_{SENSE} is dependent of the measured current, the maximum current-sensing voltage range between CSP and CSN, the reference voltage VREF and the power voltage VCC.

For the unidirectional current application, assuming the measured current range is 0A ~ I_{maxP}, because the maximum current-sensing voltage range of pins CSP and CSN is 1mV ~ 24mV, the maximum current-sensing resistor R_{max1} for the input limit is 24mV/I_{maxP}.

But because pin OUT output voltage is clamped between GND and VCC-0.2V, the maximum current-sensing resistor R_{max2} for the output limit is (VCC-0.2V-V_{REF})/200/I_{maxP}.

So the smaller value of R_{max1} and R_{max2} can be chosen as the maximum available current-sensing resistor value.

Unidirectional Application R_{SENSE} Design Table

1.Measured current range	0A ~ I_{maxP}
2.Maximum current-sensing voltage range	1mV ~ 24mV
3.Maximum sensing resistor for input limit	R_{max1}=24mV/I_{maxP}
4.Maximum OUT pin output range	GND ~ VCC-0.2V
5.Maximum sensing resistor for output limit	R_{max2}= (VCC-0.2V -V_{REF})/200/I_{maxP}
6.Maximum available current-sensing resistor	$R_{SENSE,max}$=MIN[R_{max1}, R_{max2}]

For the bidirectional current application, assuming the measured current range is -I_{maxN} ~ I_{maxP}, the maximum current-sensing resistor R_{max1} for the input limit is the smaller value of 10mV/I_{maxN} and 10mV/I_{maxP}.

But because pin OUT output voltage is clamped between GND and VCC-0.2V, the maximum current-sensing resistor R_{max2} for the output limit is the smaller value of V_{REF}/200/I_{maxN} and (VCC-0.2V-V_{REF})/200/I_{maxP}.
So the smaller value of R_{max1} and R_{max2} can be chosen as the maximum available current-sensing resistor value.

Bidirectional Application R_{SENSE} Design Table

1.Measured current range	-I_{maxN} ~ I_{maxP}
2.Maximum current-sensing voltage range	-10mV ~ 10mV
3.Maximum sensing resistor for input limit	R_{max1}=MIN[10mV/I_{maxN}, 10mV/I_{maxP}]
4.Maximum OUT pin output range	GND ~ VCC-0.2V
5.Maximum sensing resistor for output limit	R_{max2}= MIN[V_{REF}/200/I_{maxN}, (VCC-0.2V-V_{REF})/200/I_{maxP}]
6.Maximum available current-sensing resistor	$R_{SENSE,max}$=MIN[R_{max1}, R_{max2}]

A quick design table are shown as below:

Unidirectional Application (V_{REF}=0V)			**Bidirectional Application (V_{REF}=0.5*VCC)**		
I_{SENSE} range	Recommended R_{SENSE}		I_{SENSE} range	Recommended R_{SENSE}	
	VCC=5V	VCC=3.3V		VCC=5V	VCC=3.3V
0A ~ 1A	20 mΩ	15 mΩ	-1A ~ 1A	10 mΩ	7 mΩ
0A ~ 2A	10 mΩ	7 mΩ	-2A ~ 2A	5 mΩ	3 mΩ
0A ~ 3A	7 mΩ	5 mΩ	-4A ~ 4A	2.5 mΩ	1.5 mΩ
0A ~ 5A	4 mΩ	3 mΩ	-5A ~ 5A	2 mΩ	1.4 mΩ
0A ~ 10A	2 mΩ	1.5 mΩ	-10A ~ 10A	1 mΩ	0.7 mΩ

Layout Guidelines

Connect the input pins to the sensing resistor using a Kelvin or 4-wire connection. This connection technique ensures that only the current-sensing resistor impedance is detected between the input pins. Poor routing of the current-sensing resistor commonly results in additional resistance present between the input pins. Given the very low ohmic value of the current resistor, any additional high-current carrying impedance can cause significant measurement errors.

Place the power-supply bypass capacitor as closely as possible to the supply and ground pins. The recommended value of this bypass capacitor is 0.1µF. Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.

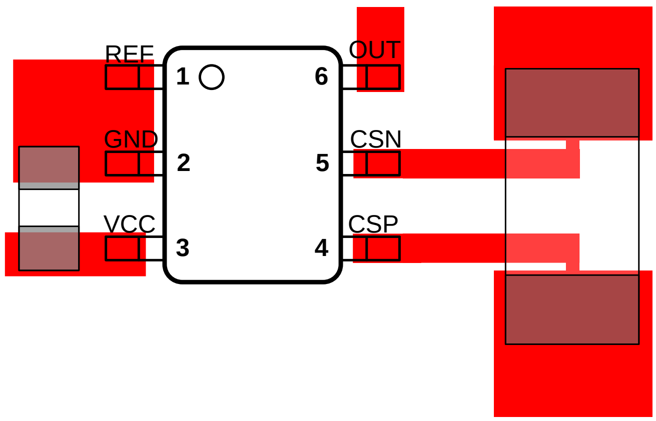
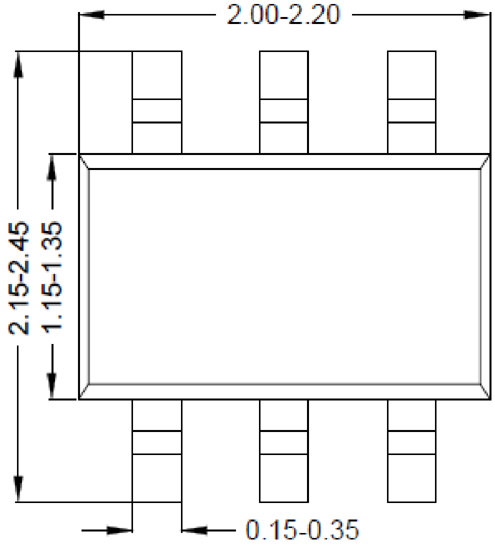
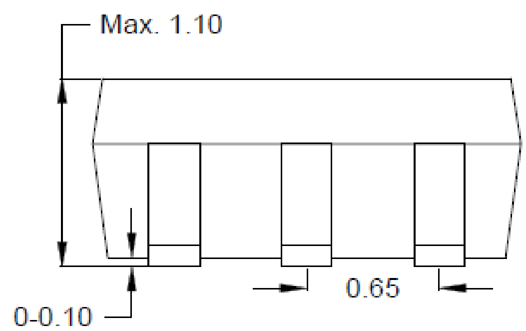


Figure 8. Recommended Layout

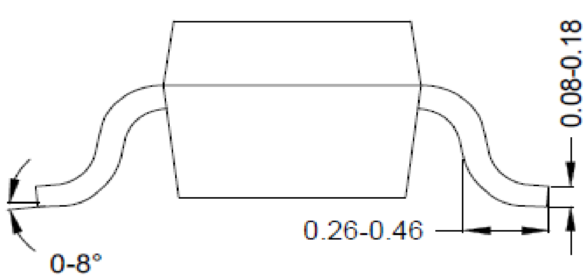
SOT363 Package Outline Drawing



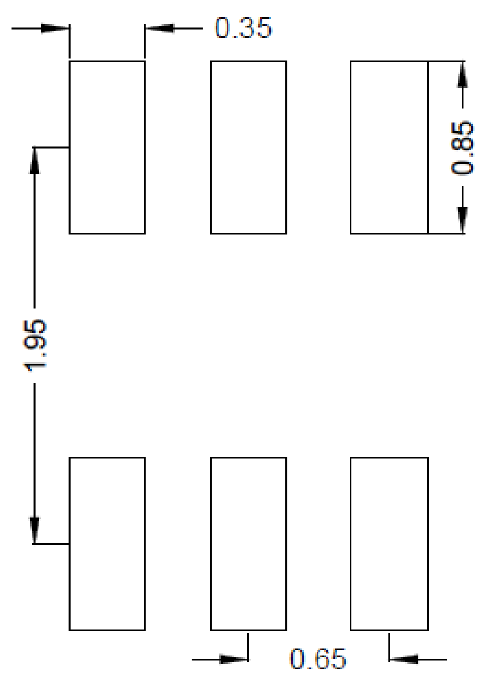
Top view



Side view A



Side view B



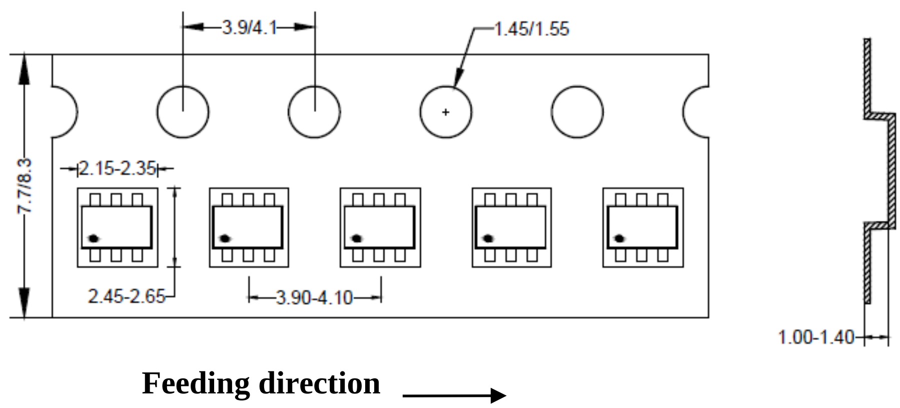
Recommended PCB layout (Reference only)

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

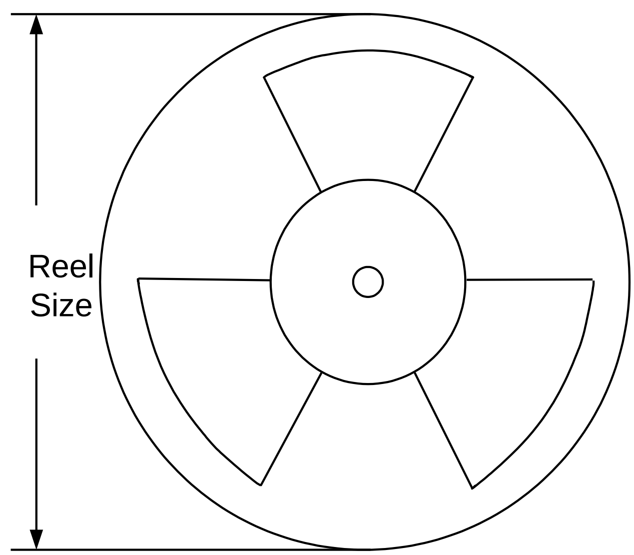
Taping & Reel Specification

1. Taping orientation

SOT363



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
SOT363	8	4	7"	280	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
Jun. 14, 2023	Revision 0.9	Initial Release

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