# SY24631

## 36V High-Speed Zero-Drift Voltage Output Current-Shunt Monitor with High-Speed Overcurrent Comparator

## General Description

The SY24631 includes a high common-mode, current-sensing amplifier, as well as a high-speed comparator that can be configured to detect over-current conditions. The Current Sense Amplifier is used to accurately measure a small voltage developed across a shunt resistor and provide a proportional analog value at its output.

The built-in comparator measures the voltage developed at the output of the Current Sense Amplifier and compares that voltage with an externally configured threshold. When the voltage at the Amplifier output is higher than the threshold, its open-drain output will be driven low, effectively enabling fast over-current detection in a system. A single external resistor can be used to configure the over-current threshold. This current-shunt monitor can measure differential voltage signals on common-mode voltages that can vary from 0V up to 36V, independent of the supply voltage.

The open-drain Alert Output can be configured to operate in either transparent mode or latched mode. The device alert response time is under 0.75µs, which allows for quick detection of over-current events.

The SY24631 operates from a single 2.7V to 5.5V supply, drawing a maximum supply current of 400µA.The device is specified over the extended operating temperature range (-40°C to +125°C), and is available in an 8-pin MSOP package.

## Features

- Wide Common-mode Range: 0V to 36V
- Dual Output: Amplifier and Comparator Output
- High-Accuracy Amplifier:
  - Offset Voltage: 125µV (Max)
  - Offset Voltage Drift: 0.5µV/°C (Max)
  - Gain Error: 0.1% (Max)
  - Gain Error Drift: 10ppm/°C (Max)
- Available Amplifier Gain: 20V/V
- Programmable Alert Threshold Setting through a Single Resistor
- Total Alert Response Time: 0.75µs
- Open-drain Output with Latching Mode
- Package: MSOP8

## Applications

- Over-current Protection
- Power-Supply Protection
- Circuit Breakers
- Computers and Servers
- Telecom Equipment
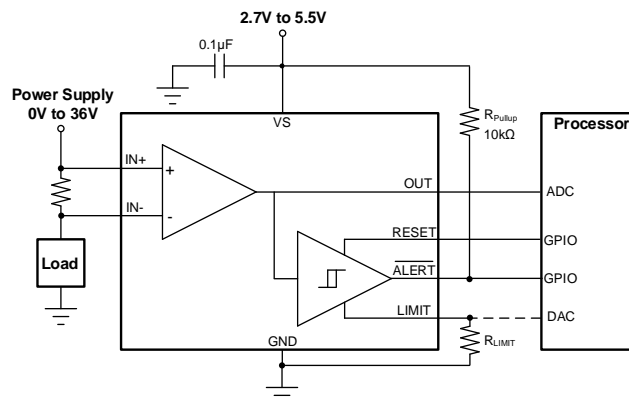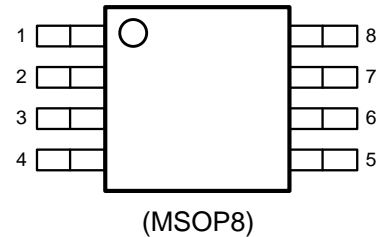- Battery Management

## Typical Application



*Figure 1. Schematic Diagram*

## Ordering Information

| Ordering Part Number | Package Type | Top Mark |
|---|---|---|
| SY24631CAP | MSOP8 | **DYT**xyz |

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

## Pinout (Top View)



(MSOP8)

## Pin Description

| Pin No | Pin Name | Pin Description |
|---|---|---|
| 1 | $V_S$ | Power supply, 2.7V to 5.5V. |
| 2 | OUT | Output voltage. |
| 3 | LIMIT | Alert threshold limit input. |
| 4 | GND | Ground. |
| 5 | RESET | Transparent or latch mode selection input. |
| 6 | ALERT | Over limit alert; active-low, open-drain output. |
| 7 | IN- | Connect to load side of shunt resistor. |
| 8 | IN+ | Connect to supply side of shunt resistor. |

## Absolute Maximum Ratings

| Parameter (Note 1) | Min | Max | Unit |
|---|---|---|---|
| $V_S$ | -0.3 | 6 | |
| $V_{IN+}$ - $V_{IN}$ (Differential) | -40 | 40 | |
| $V_{IN+}$, $V_{IN}$ (Common-Mode) | -0.3 | 40 | V |
| Alert Output $V_{ALERT}$ | -0.3 | 6 | |
| Input Voltage at Any Pin | -0.3 | $V_S$+0.3 | |
| Maximum Junction Temperature | | 150 | °C |
| Storage Temperature Range | -65 | 150 | |
| ESD: HBM (Human Body Model) | ± 2000 | | V |
| ESD: CDM (Charged Device Model) | ± 1000 | | V |

## Thermal Information

| Parameter (Note 2) | Max | Unit |
|---|---|---|
| $\theta_{JA}$ Junction-to-Ambient Thermal Resistance | 175 | °C/W |
| $\theta_{JC}$ Junction-to-Case Thermal Resistance (top) | 40 | |

## Recommended Operating Conditions

| Parameter (Note 3) | Min | Max | Unit |
|---|---|---|---|
| $V_S$ | | 5 | V |
| Common-mode, $V_{IN+}$, $V_{IN-}$ | | 12 | |
| Operation Temperature | -40 | 125 | °C |

## Electrical Characteristics

$T_A$ = 25°C, $V_{IN}$=$V_{IN+}$–$V_{IN-}$=10mV, $V_S$=5V, $V_{IN+}$=12V and $V_{LIMIT}$=2V, unless otherwise noted.

| Parameter (Note 4) | Symbol | Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| **Input** | | | | | | |
| Input Voltage | $V_{CM}$ | | 0 | | 36 | V |
| Differential Input Voltage | $V_{IN}$ | $V_{IN}$ = $V_{IN+}$ - $V_{IN-}$ | 0 | | 250 | mV |
| Common-Mode Rejection | CMR | $V_{IN}$ = 0V to 36V, $T_A$ = -40°C to +125°C | 100 | 110 | | dB |
| Offset Voltage, RTI (Note 5) | $V_{OS}$ | | | $\pm$25 | $\pm$125 | µV |
| Offset Voltage Drift, RTI | $dV_{OS}/dT$ | $T_A$ = -40°C to +125°C | | 0.1 | 0.5 | µV/°C |
| Power Supply Rejection Ratio | PSR | $V_S$ = 2.7V to 5.5V, $V_{IN+}$ = 12V, $T_A$ = -40°C to +125°C | | $\pm$0.1 | $\pm$10 | µV/V |
| Input Bias Current (Note 6) | $I_B$ | | | 125 | | µA |
| Input Offset Current (Note 7) | $I_{OS}$ | | | $\pm$0.1 | | µA |
| **Output** | | | | | | |
| Gain | G | | | 20 | | V/V |
| Gain Error | | $V_{OUT}$ = 0.5V to $V_S$ - 0.5V | | $\pm$0.03 | $\pm$0.1 | % |
| | | $T_A$ = -40°C to +125°C | | 3 | 10 | ppm/°C |
| Nonlinearity Error | | $V_{OUT}$ = 0.5V to $V_S$ - 0.5V | | $\pm$0.01 | | % |
| Maximum Capacitive Load | | No sustained oscillation | | 1 | | nF |
| **Voltage Output** | | | | | | |
| Swing to $V_S$ Power Supply Rail | | $R_L$ = 10kΩ to GND, $T_A$ = -40°C to +125°C | | $V_S$ - 0.05 | $V_S$ - 0.1 | V |
| Swing to GND | | $R_L$ = 10kΩ to GND, $T_A$ = -40°C to +125°C | | $V_{GND}$ + 20 | $V_{GND}$ + 30 | mV |
| **Frequency Response** | | | | | | |
| Bandwidth | BW | | | 500 | | kHz |
| Slew Rate | SR | | | 4 | | V/µs |
| **Noise, RTI** | | | | | | |
| Voltage Noise Density | | | | 30 | | nV/$\sqrt{Hz}$ |
| **Comparator** | | | | | | |
| Total Alert Propagation Delay | $t_p$ | Input overdrive = 1mV (Note 8) $V_{IN}$ to alert propagation | | 0.75 | | µs |
| Slew-Rate-Limited $t_p$ | | $V_{OUT}$ step = 0.5V to 4.5V, $V_{LIMIT}$ = 4V | | 1 | | |
| Limit Threshold Output Current | $I_{LIMIT}$ | | 79.4 | 80 | 80.6 | µA |
| | | $T_A$ = -40°C to +125°C | 78.8 | | 81.2 | |
| Comparator Offset Voltage | $V_{OS}$ | | | 1 | 3.5 | mV |
| Hysteresis | HYS | | | 20 | | mV |
| High-Level Input Voltage | $V_{IH}$ | | 1.4 | | $V_S$ + 0.3 | V |
| Low-Level Input Voltage | $V_{IL}$ | | 0 | | 0.4 | V |
| Alert Low-Level Output Voltage | $V_{OL}$ | $I_{OL}$ = 3mA | | 70 | 300 | mV |
| ALERT Terminal Leakage Input Current | | $V_{OH}$ = 3.3V | | 0.1 | 1 | µA |
| Digital Leakage Input Current | | 0 < $V_{IN}$ < $V_S$ | | 1 | | µA |
| **Power Supply** | | | | | | |
| Operating Supply Range | $V_S$ | $T_A$ = -40°C to +125°C | 2.7 | | 5.5 | V |
| Quiescent Current | $I_Q$ | $V_{IN}$ = 0mV, $T_A$ = 25°C | | 300 | 380 | µA |
| | | $T_A$ = -40°C to +125°C | | | 400 | |

**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:** Package thermal resistance is measured in the natural convection at $T_{A=}25°C$ on an 8.5cm × 8.5cm single-layer Silergy Evaluation Board.

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

**Note 4:** Production testing is performed at 25°C; limits at -40°C to +125°C are guaranteed by design, test, or statistical correlation.

**Note 5:** RTI = Referred to Input.

**Note 6:** Input bias current is decided by the average of the input currents of the pin IN+ and IN-.

**Note 7:** Input offset current is decided by the error between the input currents of the pin IN+ and IN-.

**Note 8:** Overdrive= $(V_{OUT}- V_{LIMIT})$/Gain.

# Application Information

## Operation

The SY24631 is a fixed-gain, zero-drift current-sense amplifier that amplifies the differential voltage across an external shunt resistor to create an output voltage.

The device features a 0V to 36V common-mode independent of its supply voltage in applications that use low-side or high-side configurations. The SY24631 can withstand, without sustaining damage, the full 36V common-mode voltage at the input pins when the supply voltage is removed.

The zero-drift topology enables high-precision measurements with typical input offset voltages as low as 125µV, and with a temperature contribution of only 0.5µV/°C over the full temperature range of -40°C to +125°C. The low total offset voltage of the SY24631 allows smaller current-sensing shunt resistor values to be used, minimizing the power loss across it.

The built-in comparator uses a single external resistor to set the corresponding current threshold level that is used for signaling over-current conditions. Combining the precise measurement of the current-sensing amplifier with the comparator enables creating a fast acting overcurrent-detection device.

## Alert Output

The ALERT pin is an active-low, open-drain output that is designed to be pulled low when the monitored current exceeds the configured threshold. This open-drain output pin should be connected to supply voltage through a 10kΩ pull-up resistor. The ALERT pin can be pulled up to a voltage beyond the supply voltage $V_S$, but the value must not exceed 5.5 V.

When the output voltage of the amplifier is lower than the voltage developed at the LIMIT pin, the comparator output will be in the default high state. When the amplifier output voltage exceeds the threshold voltage set using the LIMIT pin, the comparator output will become active and be pulled low, indicating that an over-current condition has occurred.

## Alert Mode

Using the RESET pin, the output can be configured to operate in either Transparent or Latched mode. This will change the behavior of the output when the over-current condition is removed, as described in the following paragraphs.

## Transparent Output Mode

The device will be set to Transparent Mode when the RESET pin is pulled low. In this mode, the Alert output changes state following the input signal with respect to the programmed alert threshold. For example, when the differential input signal rises above the alert threshold, the ALERT output pin will be pulled low. As soon as the differential input signal drops below the alert threshold, the output will return to the default high output state.

When connect the ALERT pin to a hardware interrupt input on a microcontroller, the output state change of the ALERT pin in Transparent Mode can be directly detected and over-current conditions can be handled.

## Latch Output Mode

The latch mode is designed to accommodate applications which do not have the functionality available to continuously monitor the state of the output ALERT pin.

The device can be configured to operate in Latch Mode by connecting the RESET pin to a HIGH level. In this mode when an over-current condition is removed, the ALERT pin will not return to the default high state.

To clear the alert, the RESET pin must be pulled low for at least 100ns. Pulling the RESET pin low allows the ALERT pin to return to the default high level, provided that the differential input signal has dropped below the alert threshold. If the input signal is still above the threshold limit when the RESET pin is pulled low, the ALERT pin will remain low.

After processing the over-current condition the external controller can return the device to Latch Mode by setting the RESET pin by to logic high.

## Transparent Output vs. Latch Output

The SY24631 is placed into the corresponding output mode by driving the voltage level at the RESET pin, as shown in Table 1.

*Table 1. Output Mode Settings*

| Output Mode | RESET Terminal Setting |
|---|---|
| Transparent mode | RESET = low |
| Latch mode | RESET = high |

The Alert pin behavior is shown in Figure 2 for the Latch and Transparent Modes.

When $V_{OUT}$ drops below the $V_{LIMIT}$-Hysteresis threshold for the first time, the RESET pin will be pulled high by the external resistor.

When the RESET pin is pulled high, the device will be set to Latch mode. In this mode the Alert output state will not return to high when the $V_{OUT}$ drops below the $V_{LIMIT}$-Hysteresis threshold.

When the RESET pin is pulled low, the ALERT pin will return to the default high level, indicating that the $V_{OUT}$ is below the $V_{LIMIT}$- Hysteresis threshold. When the $V_{OUT}$ drops below the $V_{LIMIT}$-Hysteresis threshold for the second time, the RESET pin will already be pulled low. The device is set to transparent mode at this point, and the ALERT pin is pulled back high as soon as the $V_{OUT}$ drops below the $V_{LIMIT}$-Hysteresis threshold.
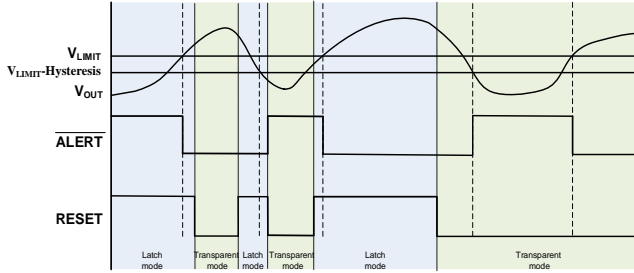
*Figure 2. Transparent vs. Latch Mode*

**Current-Limit Threshold Setting**

The SY24631 will determine if an overcurrent event is present by comparing the amplified measured voltage developed across the current-sensing shunt resistor with the corresponding voltage configured using the LIMIT pin. The threshold voltage for the LIMIT pin can be set using a single external resistor, or by connecting an external voltage source to the LIMIT pin.

**Resistor-Controlled Current Limit**

One approach for setting the limit threshold voltage is to connect a resistor from the LIMIT pin to ground. The value of this resistor $R_{LIMIT}$ will be chosen to create a corresponding voltage at the LIMIT pin that is equivalent to the output voltage $V_{OUT}$, when the maximum desired load current is flowing through the current-sensing resistor. An internal 80μA current source is connected to the LIMIT pin to configure the desired threshold by choosing the value of the $R_{LIMIT}$ resistor.

**Voltage Source Controlled Current Limit**

An alternate method for setting the over-current threshold is to connect the LIMIT pin to a programmable DAC (digital-to-analog converter). The benefit of this method is the ability to adjust the threshold, as the system operating conditions change.
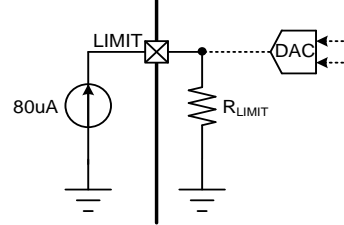


*Figure 3. Typical Circuit for Setting $V_{LIMIT}$*

**Hysteresis**

The onboard comparator in the SY24631 is designed to reduce the possibility of oscillations when the measured current is near the over-current threshold. A hysteresis level (HYS) of 20mV is utilized for proper operation.as shown in Figure 4.
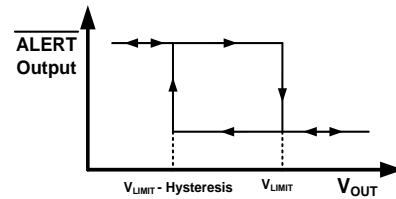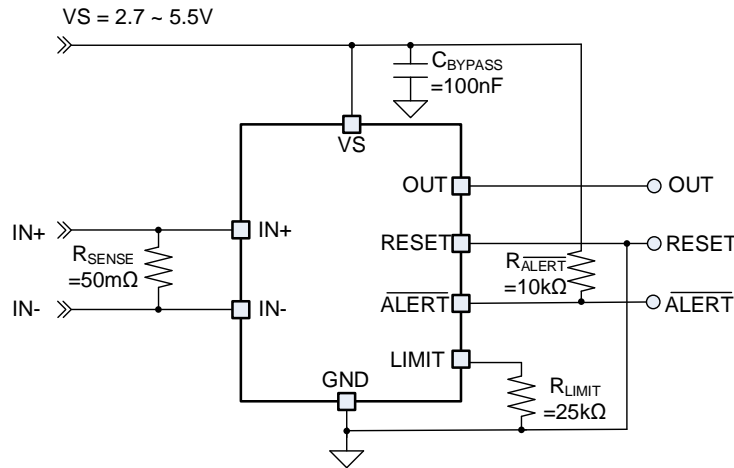


*Figure 4. $V_{LIMIT}$ Hysteresis*

## Application Schematic

VS = 2.7 ~ 5.5V

$C_{BYPASS}$ =100nF

VS

OUT ○ OUT

IN+

IN+

$R_{SENSE}$ =50mΩ

IN-

IN-

RESET

$R_{\overline{ALERT}}$ =10kΩ

○ RESET

$\overline{ALERT}$

○ $\overline{ALERT}$

LIMIT

$R_{LIMIT}$ =25kΩ

GND

## BOM List

| Designator | Description | Part Number | MFR |
|---|---|---|---|
| $C_{BYPASS}$ | 100nF/50V/X7R, 0603 | GCJ188R71H104KA12D | muRata |
| $R_{SENSE}$ | 50mΩ/1W, 1%, 2512 | RL2512FK-070R01L | YAGEO |
| $R_{LIMIT}$ | 25kΩ, 1%, 0603 | | |
| $R_{ALERT}$ | 10kΩ, 1%, 0603 | | |

## Layout Design

For optimal design, follow these PCB layout considerations:

- Using a Kelvin connection to connect the input pins to the current-sensing resistor $R_{SENSE}$. Due to the low resistance values of $R_{SENSE}$, poor PCB routing often leads to additional parasitic resistance between input pins, resulting in additional errors that cannot be ignored, this connection technique ensures that only $R_{SENSE}$ impedance is detected between the input pins. Minimizing the loop formed by these connections.
- Place the bypass capacitor (a 0.1μF MLCC is recommended) very near VCC and GND.
- To limit the generation of additional capacitance on this node, connect the $R_{LIMIT}$ to the GND pin as directly as possible.
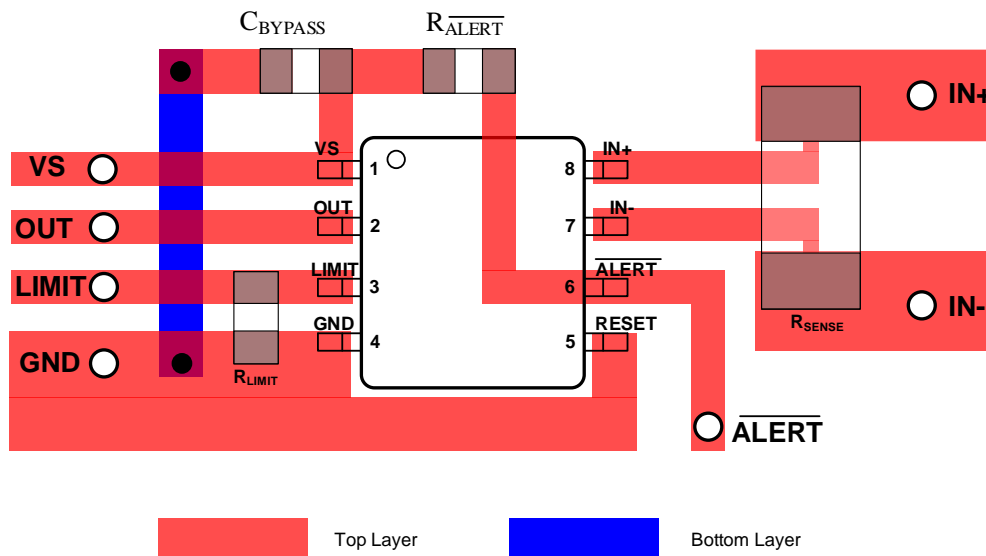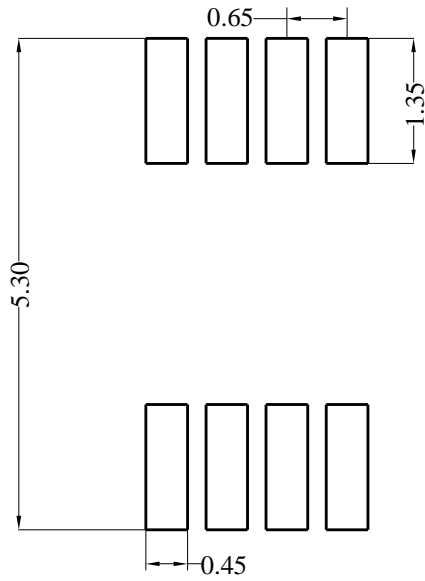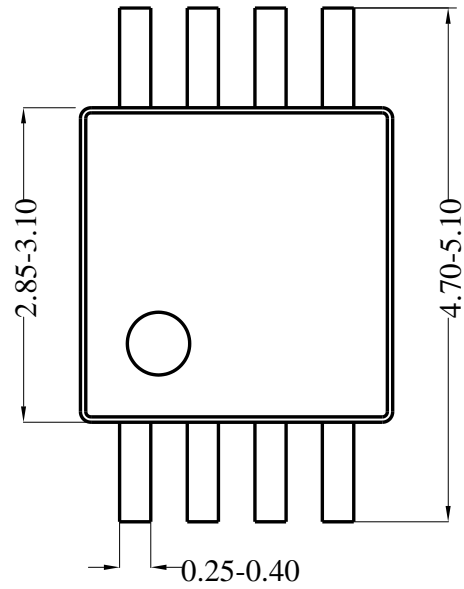


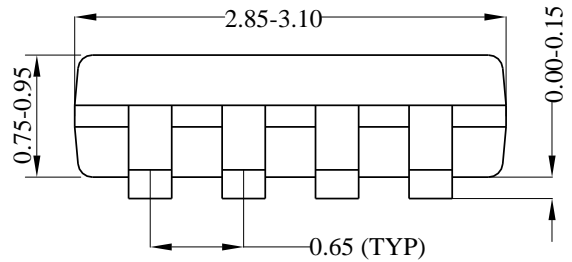| | Top Layer | | Bottom Layer |

*Figure 5. Recommended Layout*

# MSOP8 Package Outline Drawing

0.65

1.35

5.30

0.45

**Recommended pad layout**

2.85-3.10

4.70-5.10

0.25-0.40

**Top view**

0.10-0.25

0.40-0.80

0.25 base

**Side view A**

2.85-3.10

0.00-0.15
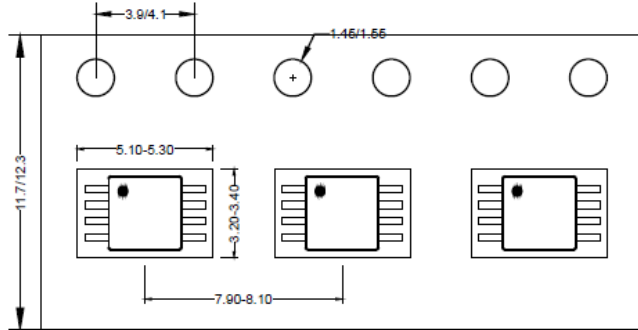
0.75-0.95

0.65 (TYP)
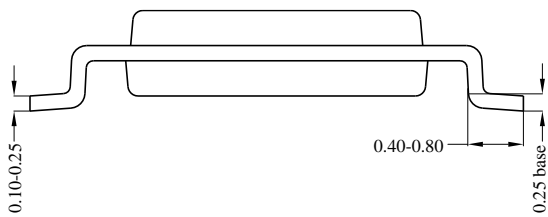
**Side view B**

*Note:* *All dimensions are in millimeters and exclude mold flash and metal burr.*

# Taping and Reel Specification

**Package orientation**



**Feeding direction**  →

**Carrier tape and reel specification for packages**
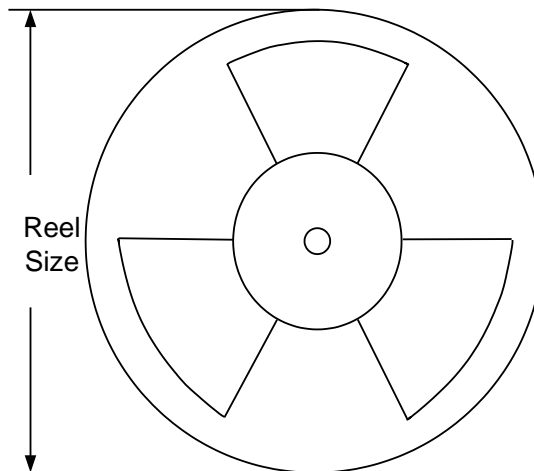


Reel Size

| Package types | Tape width (mm) | Pocket pitch(mm) | Reel size (Inch) | Trailer length(mm) | Leader length (mm) | Qty per reel |
|---|---|---|---|---|---|---|
| MSOP8 | 12 | 8 | 13" | 400 | 400 | 3000 |

**Others: N/A**

# 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 |
|---|---|---|
| Sept.6, 2022 | Revision 0.9 | Initial Release |
| Sept.6, 2023 | Revision 1.0 | Production Release |

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