MEMS Motion Handling and Assembly Guide

PURPOSE AND SCOPE

This document provides general information and reference guidelines for handling and assembling TDK InvenSense Micro Electro-Mechanical Systems (MEMS) motion sensors. Design rules and soldering recommendations included in this document represent the best practices to achieve a high level of performance in terms of accuracy and stability.

MANUFACTURING RECOMMENDATIONS

State-of-the-art performances for the MEMS component in a plastic package can be obtained by implementing multiple strategies to ensure an adequate level of mechanical decoupling from the PCB to the sensor. Recommendations on PCB drawing, solder mask definition, and stencil design are just some of the factors that must be accounted for to achieve optimal sensor behavior. Setting a proper clearance between the PCB solder mask and the bottom of the package helps to improve the overall performance while avoiding any stress due to the mismatch between the Coefficient of Linear Thermal Expansion (CTE) of the package material and the PCB.

To avoid multiple reflow steps for the MEMS component, the side where the MEMS is placed must be soldered last.

Any material used in the surface-mount assembly process of the MEMS product should be free of restricted RoHS elements or compounds. Pb-free solders should be used for assembly.

For critical applications needing a superior level of accuracy, TDK InvenSense can provide support how to implement on-board calibration. Additional information is available upon request.

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TDK Corporation
1745 Technology Drive, San Jose, CA 95110 U.S.A.
Tel: +1 (408) 988-7339 Fax: +1 (408) 988-8104
Website: www.invensense.com

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TABLE OF CONTENTS

Component Placement

For accurate MEMS motion sensor placement, keep an adequate distance from sources of thermomechanical stress when possible.

Place large insertion components, such as keyboards or push buttons, connectors, shielding boxes, and mounting holes, at a minimum distance of 2 mm from the MEMS motion sensor. Apply the same distance to components that can generate PCB self-heating with high transient slope, like processors, batteries, power, and recharging circuits.

Maintain generally accepted industry design practices for component placement near the device to prevent noise coupling, avoiding the neighborhood of any vibration sources like a vibrator motor, speaker, buzzer, etc.

If a flexible PCB must be used, place the MEMS sensor in the most rigid location and preferably in a region that is not subjected to changes in deflection during the application use cases.

Place decoupling capacitors (if needed) as close as possible to the power supply lands of the MEMS sensors. Passive components values can be found into the MEMS datasheet specification.

PCB Design

To achieve optimal performance of MEMS motion devices, the PCB footprint design should be as symmetrical as possible to avoid tilt caused by asymmetrical solder paste quantity.

Apart from the lands, the top metal layer should not be below the sensor footprint (no traces, not ground plane, no exposed pad connection, no solder mask). The lands should be limited within the boundary of chip. PCB land sizes must be designed to match the component pad sizes that are listed in the Package Dimensions section of the datasheet.

All the traces must be routed straight to the lands. The lands that must be connected have to be shorted outside the perimeter of the package.

TDK InvenSense products have very low active and standby current consumption. The exposed pad is not internally connected, and it is not required for heat sinking. The exposed die pad must not be soldered to the PCB and must be left unconnected.

PCB vias must be placed outside the sensor footprint. No vias can be placed below the package or inside the lands area.

To avoid harmonic coupling, do not route active signals in non-shielded signal planes directly below the sensor package.

To achieve the best performance, the copper thickness should be at least 1 oz (35 µm).

Soldering Recommendation

TDK InvenSense recommends designing the PCB pad layout with Non-Solder Mask Defined pads (NSMD), rather than Solder Mask Defined (SMD) pads. NSMD contact pads have the solder mask pulled away from the solderable metallization. NSMD contact pads have several advantages over SMD pads. They provide a tighter tolerance for copper etching, provide a larger copper pad area, and allow the solder to anchor to the edges of the copper pads, which improves solder joint reliability.

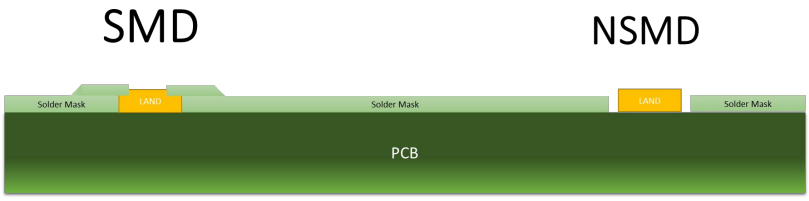

Figure 1: PCD pad layout for both SMD and NSMD

To achieve optimal performance of MEMS motion devices, TDK InvenSense strongly recommend not to place solder mask below the MEMS component. Should this not be possible, set the solder mask aperture to a maximum of 0.05 mm larger than the component solder pad per edge with blocked areas (as shown in Figure 2 on the left), or with individually outlined pads (as shown in Figure 2 on the right).

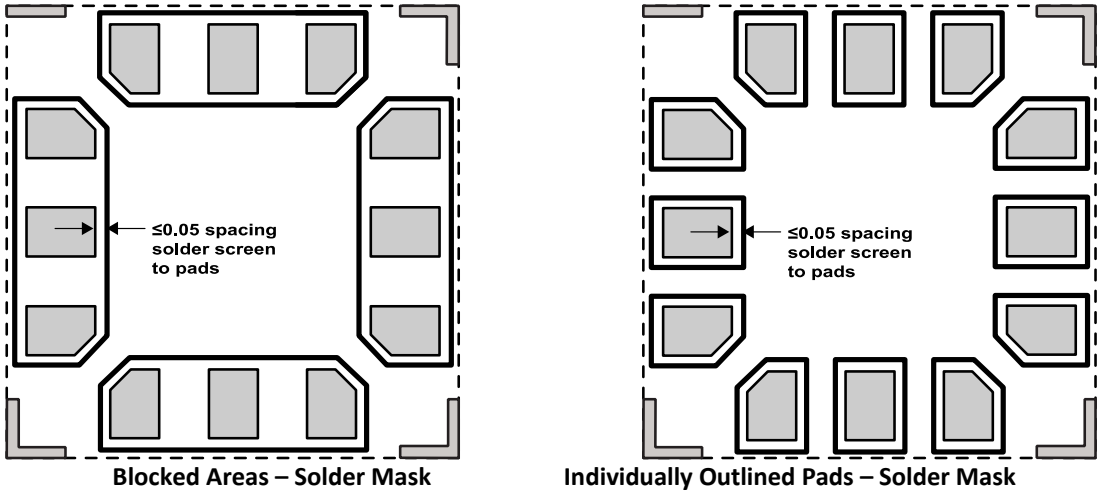

Figure 2. Solder Masks

Solder Paste Printing

Mechanical decoupling from the PCB to the sensor must be ensured in order to prevent any stress on the component. Contact from PCB resist and the package exposed pad must be avoided. Proper thickness definition for both solder paste and copper help set proper clearance below the package. No solder paste needs to be disposed below the exposed pad.

Solder paste disposition should be done by stencil screening. In standard conditions, TDK InvenSense recommends using a stencil opening to land ration of 90%. Stencil walls should be tapered to produce uniform release of the paste when the stencil is removed from the PCB. Stencil thickness should be at least 100 μm in respect to standard area ratio design rule.

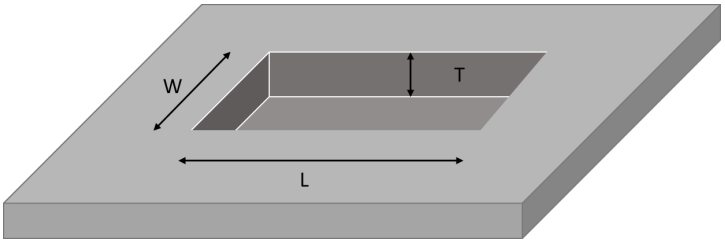

Figure 3: Stancil opening dimensions

Generic best practices for stencil design should be followed:

- Aspect Ratio
  - The width of aperture / thickness = W/T
  - The lowest acceptable aspect ratio is 1.5
- Area Ratio
  - Surface area of aperture / surface area of the aperture walls = (L x W)/ (2 x (L+W) x T)
  - The lowest acceptable area ratio is 0.66

Maximizing symmetry and balance for pad connection will help with component self-alignment and will lead to better control of solder paste reduction after reflow. At the end of the soldering process, the solder paste must be as uniform as possible to avoid unbalanced stress on the component.

Solder paste volume to be printed is greater than the final solder joint volume because solder paste decreases during reflow. Solder paste volume reduction factor is typically between 0.45 and 0.55. Being the pad area constant, in the worst case, the solder paste thickness can be assumed to be about 45% after the reflow:

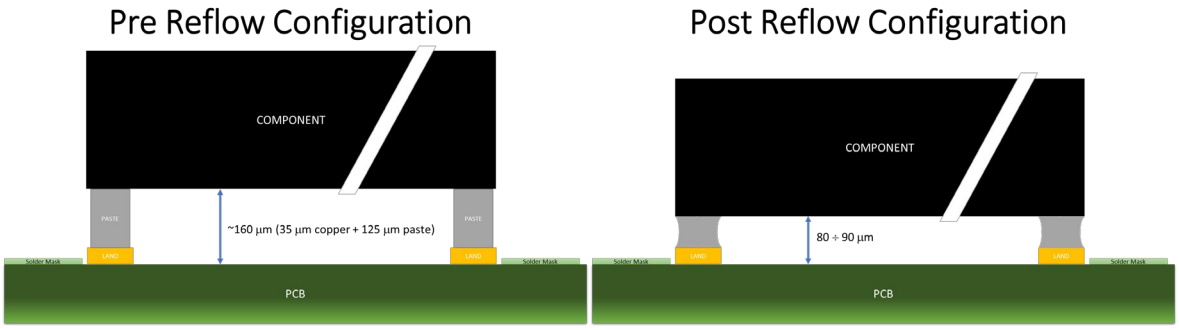

Figure 4: Pre and post reflow configuration

Solder paste thickness calculation example for 4.5 x 4.5 mm^2 QFN Package:

- Nominal W = 0.25 mm
- Nominal L = 0.53 mm
- Aspect Ratio T < 0.166 mm
- Area Ratio T < 0.129 mm
- Optimal T = 125 µm

Component Placement Pressure and Pick-and-Place Velocity

Use a typical pick-and-place machine with reflow equipment like an oven. Avoid any manual soldering process. Machines should be set up to slow down both the pick and the place operations, as much possible, to help minimize any shock impact to the device.

Sensor has been designed and tested to survive at shock up to the Absolute Maximum Rating (AMR) reported into the datasheet, shock above the AMR could damage the MEMS structure. Parts subjected to shock greater than AMR have to be discarded.

PCB Mounting and Cross-Axis Sensitivity

Even if the package tends to center itself and correct for slight placement errors during the reflow process due to surface tension of the solder joint, orientation errors of the gyroscope and accelerometer mounted on the PCB can cause cross-axis sensitivity in which one gyro or accel responds to rotation or acceleration about another axis, respectively. The orientation mounting error concept is illustrated in Figure 5:

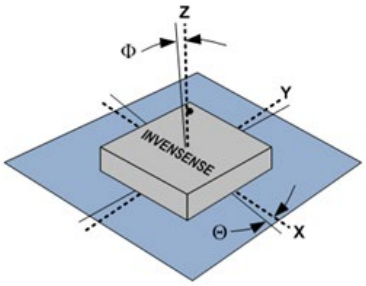

Figure 5. Package Gyro & Accel Axes (---) Relative to PCB Axes (—) with Orientation Errors (Θ and Φ)

Note: Please refer to the datasheet for actual orientation of the axis with respect to package.

Table 1 shows the cross-axis sensitivity as a percentage of the specified gyroscope or accelerometer's sensitivity for a given orientation error, respectively.

Orientation Error (θ or Φ)	Cross-Axis Sensitivity (sinθ or sinΦ)
0.0º	0.00%
0.5º	0.87%
1.0º	1.75%

Table 1. Cross-Axis Sensitivity vs. Orientation Error

The product specifications for cross-axis sensitivity include the effect of the die orientation error with respect to the package.

PCB MOUNTING OPTICAL INSPECTION

For production efficiency, multiple qualified assembly suppliers and lead frame vendors may be used on any given device. Therefore, variations in lead frame color or reflectivity can occur. Using a higher illumination source for optical inspection before PCB mounting is recommended.

MEMS HANDLING INSTRUCTIONS

Unlike conventional IC products in similar packages, MEMS devices contain moving micromechanical structures. Therefore, MEMS devices require different handling precautions than conventional ICs prior to mounting onto PCBs.

TDK InvenSense products have been qualified to a shock tolerance of 10,000 *g* , validated up to 20,000g. Detailed information for each component are reported into the product datasheet. Furthermore, the products are shipped in cushioned tape and reel packing (ref.: EIA-481) with additional "pizza box" (Figure 29) to protect them from potential damage induced by abnormal handling and shipping.

- Do not drop individually packaged sensors or trays of sensors. Components placed in trays could be subject to excessive *g*-forces and stress.
- PCBs that incorporate mounted sensors should not be separated by manually snapping them apart. This could create excessive *g*-forces and stress.
- Do not clean MEMS sensors in ultrasonic baths. Ultrasonic baths can induce MEMS damage if the bath energy causes excessive drive motion through resonant frequency coupling.
- Do not open and remove MEMS devices from the moisture barrier bag until you are ready to use them. The moisture barrier bag provides good protection to the MEMS sensors during storage and transfer.
- Do not use any devices that are dropped inadvertently during handling.

TAPE AND REEL HANDLING INSTRUCTIONS

TDK InvenSense devices are shipped in tape and reels. They are packaged to protect them from potential damage induced by normal handling and shipping. These are handling guidelines for the tape and reels populated with MEM's motion devices:

- Tape and reels (with devices) should not be dropped at any time or un-reeled manually.
- Precautions should be taken to minimize the amount of vibration that tape and reels (with devices) are subjected to while in pick and place machines.
- The slowest settings possible should be used on pick and place machines during the SMT process.
- Tape and reels should be kept in packaging as long as possible, until ready for use on pick and place machines
- Any carts used for internal transportation of tape and reels (with devices) should be padded with bumpers and have shock absorbing features.

ESD CONSIDERATIONS

Establish and use (Electrostatic Damage) ESD-safe handling precautions when unpacking and handling ESD-sensitive devices.

- Store ESD sensitive devices in ESD safe containers until ready for use. The Tape-and-Reel moisture-sealed bag is an ESD approved barrier. The best practice is to keep the units in the original moisture sealed bags until ready for assembly.
- TDK InvenSense products are qualified to meet at least 250V ESD-MM (Machine Model). Restrict all device handling to ESD protected work areas that measure less than 200V static charge. Ensure that all workstations and personnel are properly grounded to prevent ESD.

STORAGE SPECIFICATIONS

TDK InvenSense products conform to the storage specifications of IPC/JEDEC J-STD-020D.1:

Rating	After opening moisture-sealed bag
MSL 1	Unlimited (Storage Conditions: Ambient ≤30°C at 85%RH)
MSL 3	168 hours (Storage Conditions: Ambient ≤30°C at 60%RH)
MSL 5	48 hours (Storage Conditions: Ambient ≤30°C at 60%RH)

Figure 6: Handling Conditions for Different MSL Ratings

REFLOW SPECIFICATION

Qualification Reflow: TDK InvenSense products are qualified in accordance with IPC/JEDEC J-STD-020D.1. This standard classifies proper packaging, storage and handling in order to avoid subsequent thermal and mechanical damage during the solder-reflow attachment phase of PCB assembly.

The qualification preconditioning process specifies a sequence consisting of a bake cycle, a moisture soak cycle (in a temperature humidity oven), and three consecutive solder reflow cycles, followed by functional device testing.

The peak-solder reflow classification temperature requirement for package qualification is (260°C +5°C/-0°C) for lead-free soldering of components measuring less than 1.6 mm in thickness. The qualification profile and a table explaining the set-points are shown below.

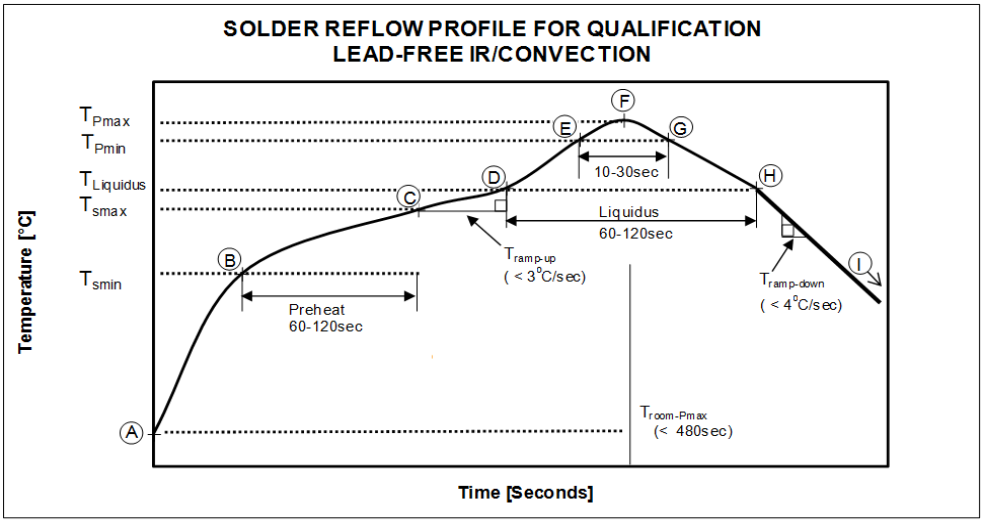

Figure 7. Solder Reflow Profile for Qualification

Step	Setting	CONSTRAINTS		
		Temp (°C)	Time (sec)	Max. Rate (°C/sec)
A	T_{room}	25		
B	T_{Smin}	150		
C	T_{Smax}	200	$60 < t_{BC} < 120$	
D	$T_{Liquidus}$	217		$r_{(TLiquidus-TPmax)} < 3$
E	$T_{Pmin\ [255°C,\ 260°C]}$	255		$r_{(TLiquidus-TPmax)} < 3$
F	$T_{Pmax\ [\ 260°C,\ 265°C]}$	260	$t_{AF} < 480$	$r_{(TLiquidus-TPmax)} < 3$
G	$T_{Pmin\ [255°C,\ 260°C]}$	255	$10< t_{EG} < 30$	$r_{(TPmax-TLiquidus)} < 4$
H	$T_{Liquidus}$	217	$60 < t_{DH} < 120$	
I	T_{room}	25		

Table 2. Temperature Set Points Corresponding to Reflow Profile Above

Notes: Customers must never exceed the Classification temperature (T_{Pmax} = 260°C).
All temperatures refer to the topside of the package, as measured on the package body surface.

STORAGE SPECIFICATIONS

TDK InvenSense products conform to the storage specifications of IPC/JEDEC J-STD-020D.1 Moisture Sensitivity Level (MSL) 1.

Calculated shelf-life in moisture-sealed bag	12 months -- Storage Conditions: <40°C and <90% RH
After opening moisture-sealed bag	Unlimited hours -- Storage Conditions: Ambient ≤30°C at 85%RH

TDK InvenSense products conform to the storage specifications of IPC/JEDEC J-STD-020D.1 Moisture Sensitivity Level (MSL) 3.

Calculated shelf-life in moisture-sealed bag	12 months -- Storage Conditions: <40°C and <90% RH
After opening moisture-sealed bag	168 hours -- Storage Conditions: Ambient ≤30°C at 60%RH

TDK InvenSense products conform to the storage specifications of IPC/JEDEC J-STD-020D.1 Moisture Sensitivity Level (MSL) 5.

Calculated shelf-life in moisture-sealed bag	12 months -- Storage Conditions: <40°C and <90% RH
After opening moisture-sealed bag	48 hours -- Storage Conditions: Ambient ≤30°C at 60%RH

Notes: A attain the MSL rating for motion-based products, please refer to the qualification report for the details.

PACKAGE MARKING SPECIFICATION

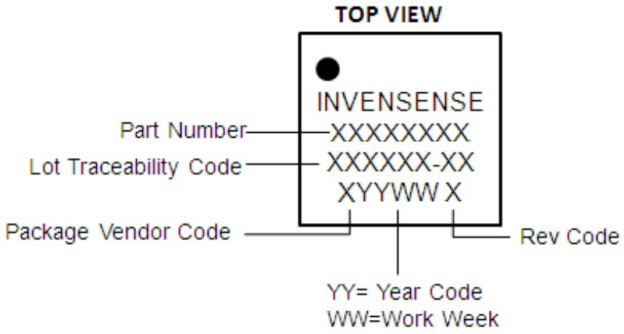

Figure 8. 4 x 4 mm² Package Marking Specification

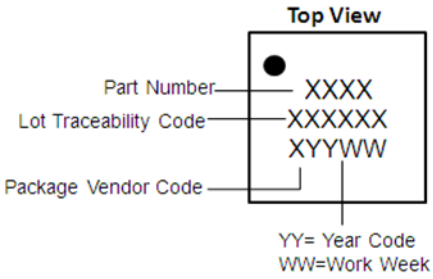

Figure 9. 3 x 3 mm² Package Marking Specification (TYPE I)

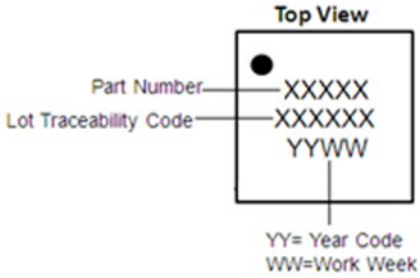

Figure 10. 3 x 3 mm² Package Marking Specification (TYPE II)

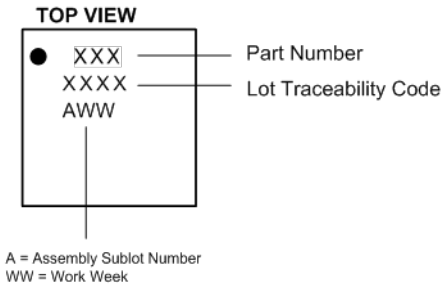

Figure 11. 3 x 3 mm² Package Marking Specification (TYPE III)

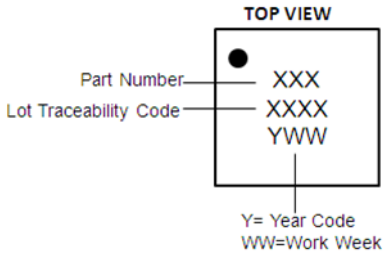

Figure 12. 2.3 x 2.3 mm² Package Marking Specification

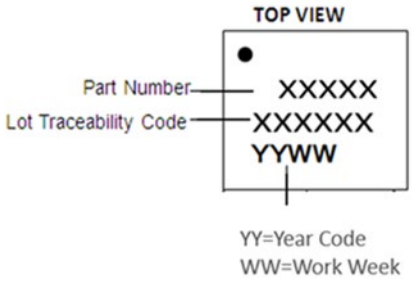

Figure 13. 2.5 x 3 mm² Package Marking Specification

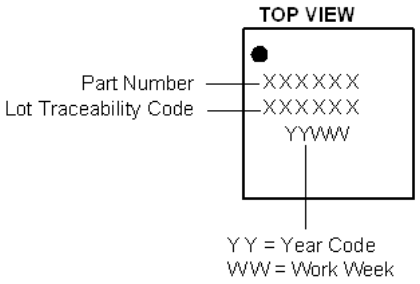

Figure 14. 4.5 x 4.5 mm² QFN Package Marking Specification

TAPE & REEL SPECIFICATION

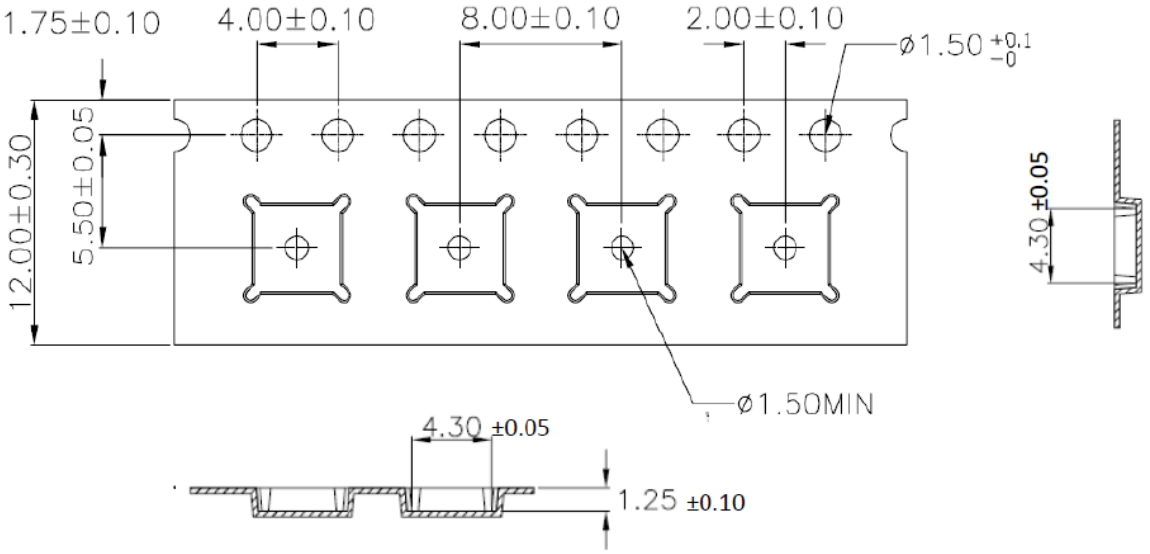

Figure 15. 4 x 4 mm² Tape Dimensions

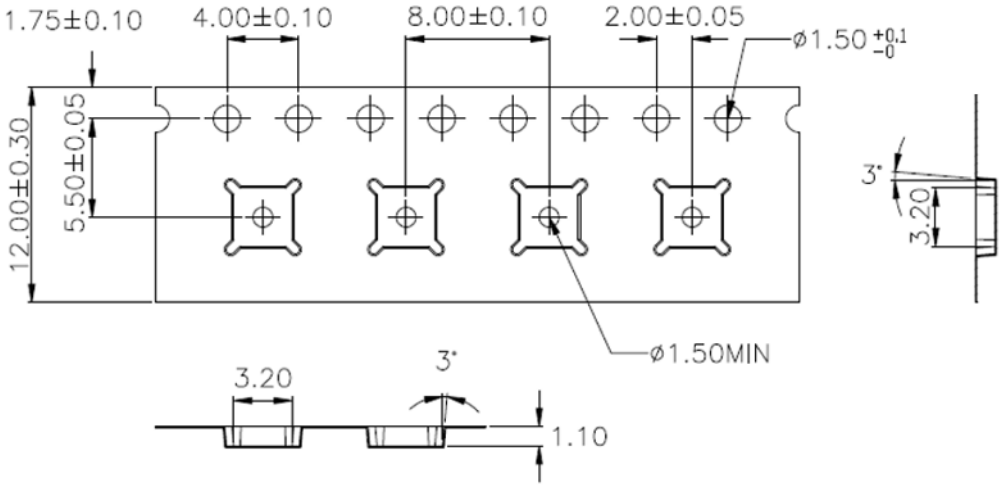

Figure 16. 3 x 3 mm² Tape Dimensions (TYPE I) (for package height 0.9 mm and 1.0 mm)

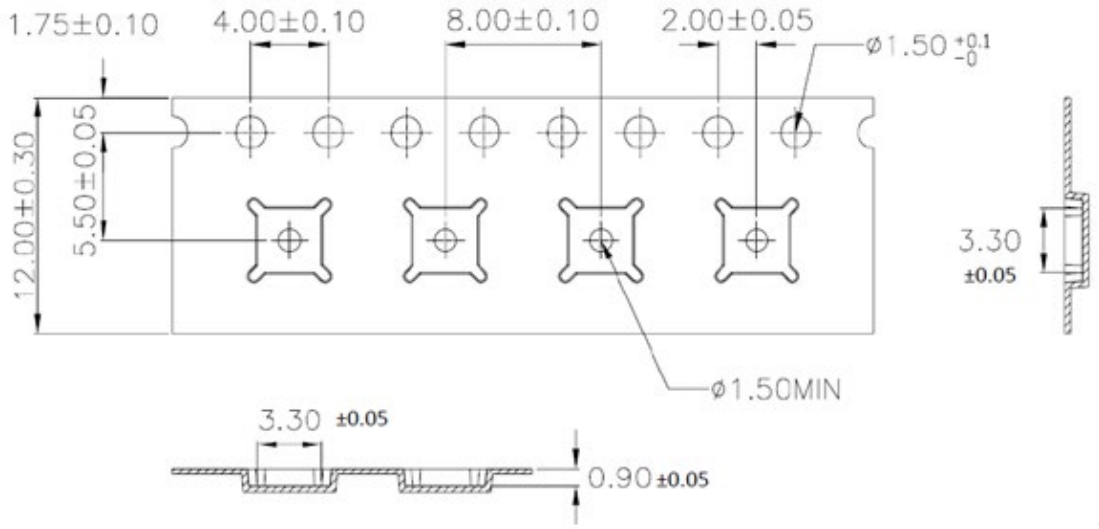

Figure 17. 3 x 3 mm² Tape Dimensions (TYPE II) (for package height 0.75 mm)

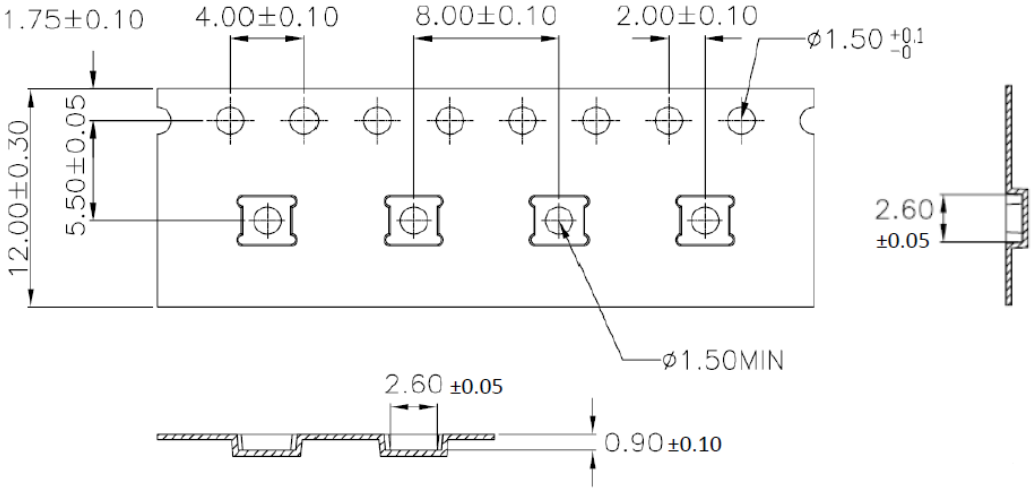

Figure 18. 2.3 x 2.3 mm² Tape Dimensions

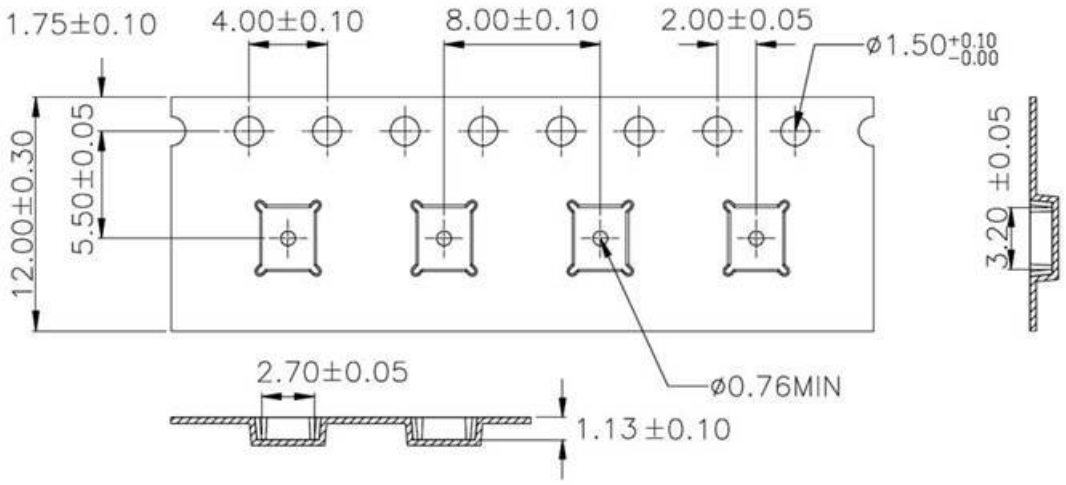

Figure 19. 2.5 x 3 mm² Tape Dimensions (TYPE I)

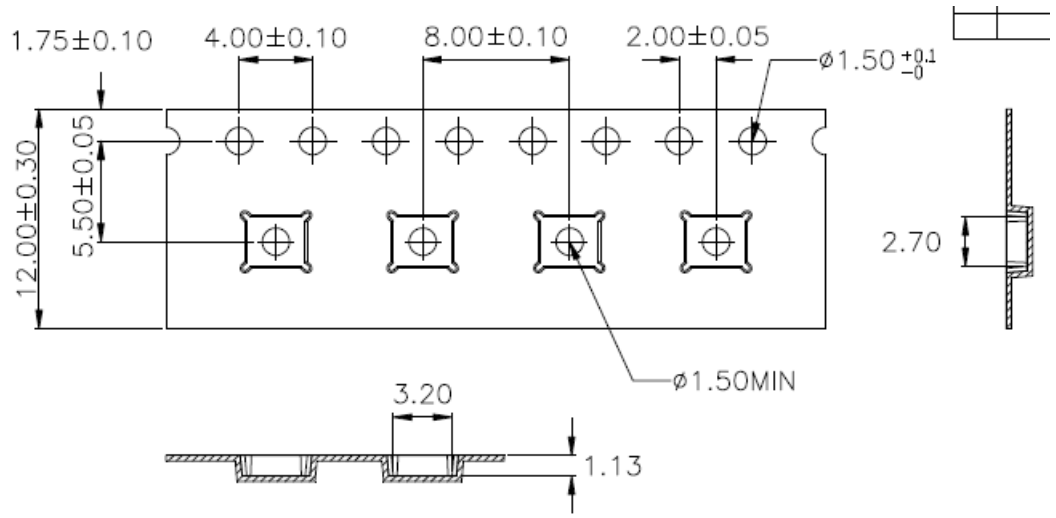

Figure 20. 2.5 x 3 mm² Tape Dimensions (TYPE II)

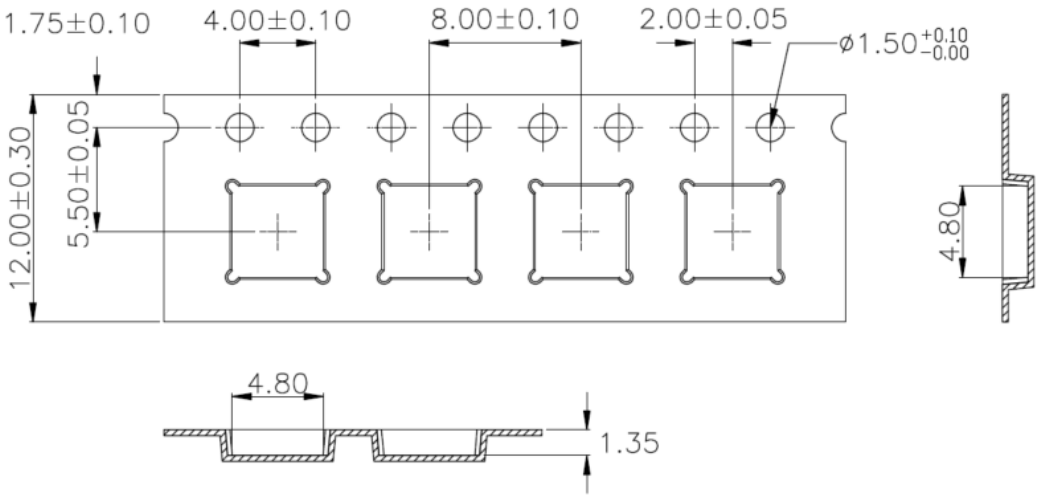

Figure 21. 4.5 x 4.5 mm² Tape Dimension (for package height 1.1 mm)

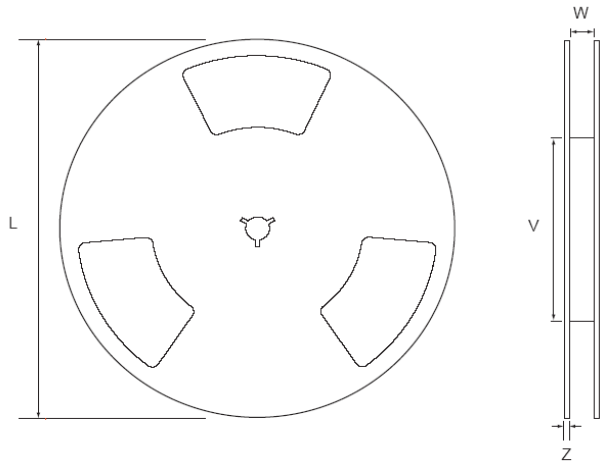

Figure 22. Reel Outline Drawing

REEL (mm)			
L	**V**	**W**	**Z**
330	**102**	**12.8**	**2.3**

Table 3. Reel Dimensions

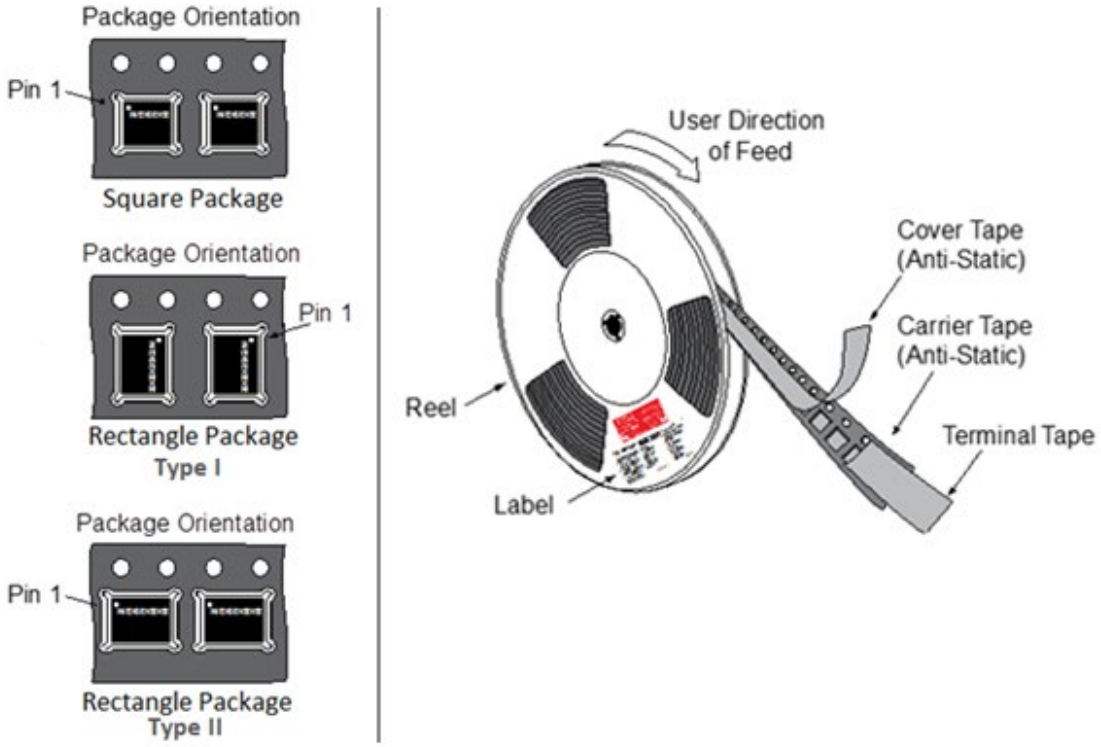

Figure 23. Tape and Reel – Package Orientation

Quantity Per Reel	5,000
Reels per Box	1
Boxes Per Carton (max)	5
Pcs/Carton (max)	25,000

Table 4. Reel Specifications for packages smaller than 4.5 x 4.5 mm²

Quantity Per Reel	4,000
Reels per Box	1
Boxes Per Carton (max)	5
Pcs/Carton (max)	20,000

Table 5. Reel Specification for Package 4.5 x 4.5 mm²

REEL & PIZZA BOX LABEL

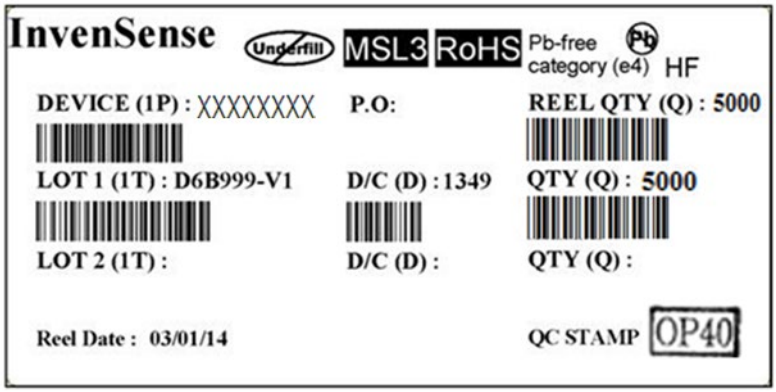

Figure 24. Barcode Label

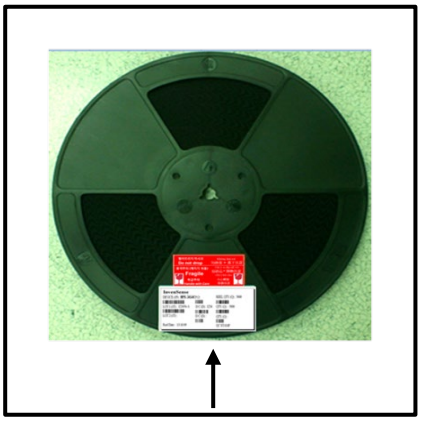

Figure 25. Location of Label on Reel

Figure 26. 2D Barcode Label on the Left of Pizza Box

PACKAGING

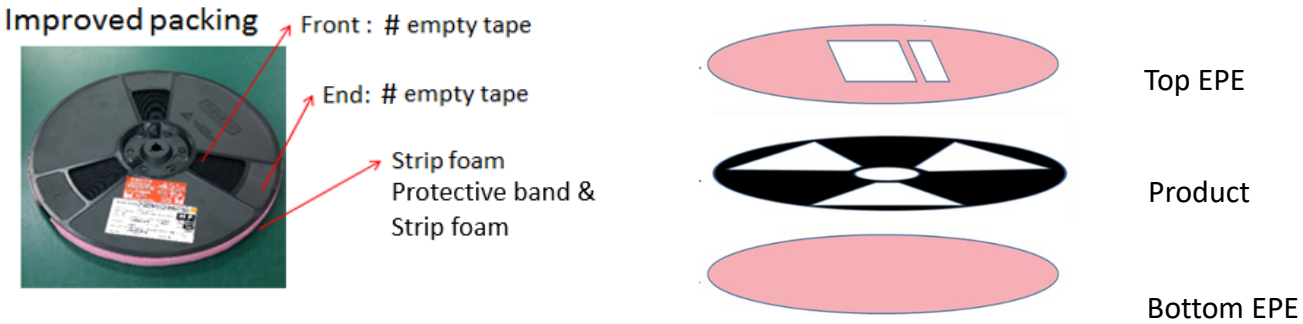

Figure 27. Improved Packing

Tape	Empty tape # Front	Empty tape # End
4x4,3x3,2.3x2.3,2.5x3.0	550	550
4.5x4.5	300	300

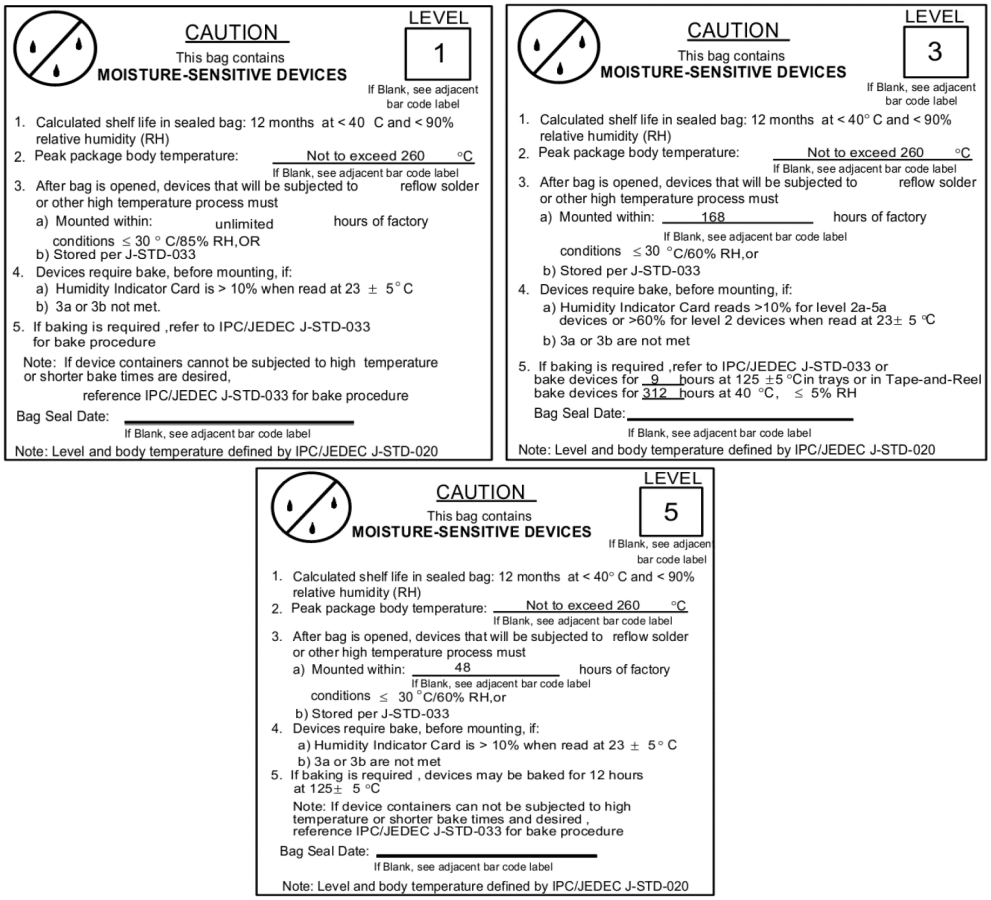

Figure 28. MSL Label (MSL 1, MSL 3 and MSL 5)

Current **New**

Figure 29. Reel now packed for shipping in bubble wrap and pizza box

Caution Label

ESD Label

Figure 30. Labels

Pizza Box

Pizza Boxes Placed in Foam-Lined Shipper Box

Outer Shipper Label

Figure 31. Boxes and Labels

Representative Shipping Carton Label:

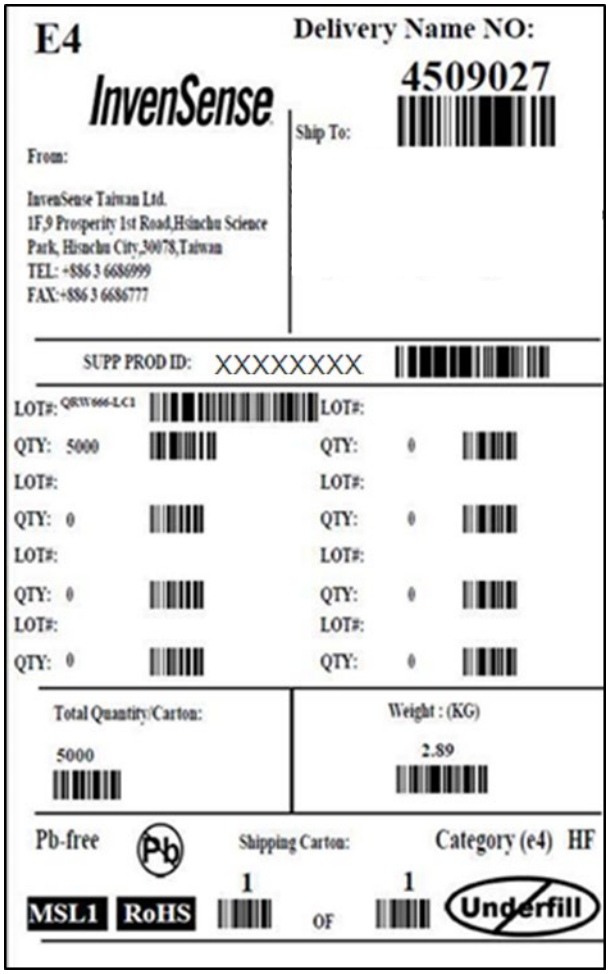

Figure 32. Outer Shipping Carton Label

REVISION HISTORY

Revision Date	Revision	Description
10/16/2013	1.0	Initial Release
01/13/2014	2.0	Revised sections 3.1.5, 3.3, 3.7, 3.8, 3.9, and 3.11.
02/11/14	2.1	Modified document format and updated shipping label.
05/29/14	2.2	Added tape and reel handling guidelines, updated 3x3mm tape and reel spec, updated packaging section for reels
07/07/14	2.3	Revised 3x3mm tape and reel spec to add tolerances
11/06/14	2.4	Added section on PCB Mounting Optical Inspection section
11/17/2014	2.5	Updated Storage Specifications
12/04/2014	2.6	Updated carrier pocket (Ao, Bo) tolerances to +/-0.05mm.
02/19/2015	2.7	Added storage specification back in. Added tape and reel spec 3x3x1.25mm.
03/01/2016	2.8	Added pizza box 2D label example picture.
05/03/2016	2.9	Added 2 type 3x3 top marking example. Updated the front/end empty pocket quantity from 550ea to 50ea for all package types.
05/26/2016	3.0	Change the front/end empty pocket quantity from 50ea back to 550ea
11/08/2016	3.1	Added the 2.5x3 tape and reel specifications.
11/09/2016	3.2	Formatting update
01/06/2017	3.3	Added the new tape and reel specifications for 2.5x3 Tape Dimensions TYPE II
07/27/2017	3.4	Updated the tape and reel specification 2.5x3 Tape Dimensions TYPE I
04/17/2018	3.5	Updated the manufacturing recommendations section
11/06/2018	3.6	1.Adjust PACKAGE MARKING SPECIFICATION of 3x3 to TYPE I~III (Figure 5~7) 2.Add PACKAGE MARKING SPECIFICATION of 2.5x 3 (Figure 9) 3. Remove special marking requirement of special code table 3~4. 4. Combine and revise 3x3 Tape Dimensions for package height 0.9 and 1.0. (Figure 11) 5. Revise Improved Packing (Figure 21.) 6. Add MSL1 label (Figure22)
11/13/2018	3.7	1.Tabel 3. Add 2.5x3 information 2.Remove product name from this document as general guide
12/19/2018	3.8	Remove Component Placement Pressure and Pick-and-Place Velocity/Mounter Force
06/14/2019	3.9	Added package 4.5 x 4.5 x 1.1. Updated mounting recommendations. Added MSL handling conditions
10/14/2019	4.0	1. Added the MSL details. 2. Added MSL 5 label. Updated PCB design section: no solder musk below the component, die pad must be left unconnected. Updated soldering recommendation: TDK InvenSense strongly recommend not to place solder mask below the MEMS component. Updated Figure 4

COMPLIANCE

ENVIRONMENTAL COMPLIANCE

TDK InvenSense products are RoHS and Green compliant.

TDK InvenSense products are in full environmental compliance as evidenced by our Materials Declaration Data Sheets (MDS). The MDS report, along with support documentation consisting of Material Safety Data Sheets (MSDS) and analytical reports for each homogeneous element of the product are available upon request.

DRC COMPLIANCE

TDK InvenSense products use materials that comply with DRC (Democratic Republic of the Congo) Conflict-Free Smelter and Mines requirements to meet the SEC implementation of Dodd–Frank Section 1502.

COMPLIANCE DECLARATION DISCLAIMER

TDK InvenSense believes this compliance information to be correct but cannot guarantee accuracy or completeness. Conformity documents for the above component constitutes are on file. TDK InvenSense subcontracts manufacturing and the information contained herein is based on data received from vendors and suppliers, which has not been validated by TDK InvenSense.

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