IDG-650 Dual-Axis Gyro Product Specification

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1. Revision History

Revision Date	Revision	Description
10/22/08	01	Initial Release
02/04/09	02	Updated to highlight capability of 2nd stage analog output, enhanced performance of AZ, and added functionality of VREF output. Necessary changes were made to electrical specifications, pin out, functional block diagram, reference circuit, package diagram, and design considerations section to describe these changes.
07/28/09	03	Updated tape and reel specification; reflow specification and profile; qualification test policy; and several formatting and textual changes. Removed environmental compliance section.
04/13/10	04	Removed confidentiality mark
05/20/10	05	Updated AutoZero section to include pin connection recommendation when AZ function not used.

2. Purpose

The purpose of this document is to provide a detailed product description and design-related information regarding the IDG-650 dual-axis gyroscope.

3. Product Overview

The IDG-650 is a state-of-the-art dual-axis gyroscope designed specifically for complex motion sensing in 3D-input devices and gaming controllers. The IDG-650 gyroscope utilizes state-of-the-art MEMS fabrication with wafer-scale integration technology. This technology combines completed MEMS wafers and completed CMOS electronic wafers together using a patented and proprietary wafer-scale bonding process that simultaneously provides electrical connections and hermetically sealed enclosures. This unique and novel fabrication technique is the key enabling technology that allows for the design and manufacture of high performance, multi-axis, integrated MEMS gyroscopes in a very small and economical package. Integration at the wafer-level minimizes parasitic capacitances, allowing for improved signal-to-noise over a discrete solution. With the addition of the new patented Auto Zero feature for minimizing bias drift over temperature, the IDG-650 offers unparalleled gyroscope performance in 3D-input and gaming applications.

4. Features

By integrating the control electronics with the sensor elements at the wafer level, the IDG-650 gyroscope supports a rich feature set including:

- Integrated X- and Y-axis gyros on a single chip
- Two separate outputs per axis for high-speed gaming applications and higher-precision menu navigation

  X-/Y-Out Pins: 2000°/s full scale range
  0.5mV/°/s sensitivity

  X/Z4.5Out Pins: 440°/s full scale range
  2.27mV/°/s sensitivity
- Integrated amplifiers and low-pass filters
- Auto-Zero function
- On-chip temperature sensor
- High vibration rejection over a wide frequency range
- High cross-axis isolation by proprietary MEMS design
- 3V single-supply operation
- Hermetically sealed for temp and humidity resistance
- 10,000 *g* shock tolerant
- Smallest dual axis gyro package at 4 x 5 x 1.2mm
- RoHS and Green Compliant

5. Functional Block Diagram

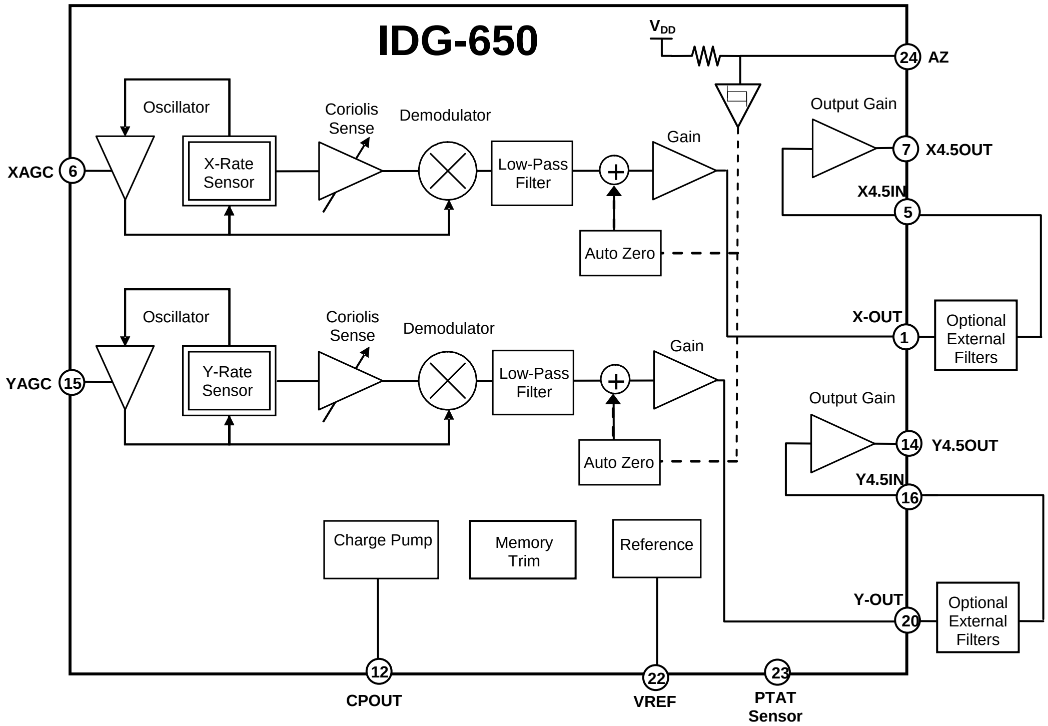


Figure 1

6. Functional Description

6.1 Overview

The IDG-650 gyroscope consists of two independent vibratory MEMS gyroscopes. One detects rotation about the X-axis; the other detects rotation about the Y-axis.

The gyroscope's proof-masses are electrostatically oscillated at resonance. An internal automatic gain control circuit precisely controls the oscillation of the proof masses. When the sensor is rotated about the X- or Y-axis, the Coriolis Effect causes a vibration that can be detected by a capacitive pickoff. The resulting signal is amplified, demodulated, and filtered to produce an analog voltage that is proportional to the angular rate.

6.2 Rate Sensors

The mechanical structures for detecting angular rate about the X- and Y-axes are fabricated using InvenSense's proprietary bulk silicon technology. The structures are covered and hermetically sealed at the wafer level. The cover shields the gyro from electromagnetic and radio frequency interferences (EMI/RFI). The dual-mass design inherently rejects any signal caused by linear acceleration. The X-gyro and the Y-gyro have different resonant frequencies to prevent undesired coupling.

6.3 Oscillator Circuit

The oscillator circuit generates electrostatic forces to vibrate the structure at resonance. The circuit detects the vibration by measuring the capacitance between the oscillating structure and a fixed electrode. The oscillator circuit switches in quadrature phase with the capacitance measurement in order to vibrate at resonance.

6.4 Amplitude Control

The scale factor of the gyroscope depends on the amplitude of the mechanical motion and the trim setting of the internal programmable gain stages. The oscillation circuit precisely controls the amplitude to maintain constant sensitivity over the temperature range. The capacitors (0.22µF ±10%) connected to Pin 6 (XAGC) and Pin 15 (YAGC) are compensation capacitors for the amplitude control loops.

6.5 Coriolis Sense

Rotating the sensor about the X- or Y-axis results in a Coriolis force on the corresponding X- or Y-rate sensor. The Coriolis force causes the mechanical structure to vibrate in-plane. The resulting vibration is detected by measuring the capacitance change between the mechanical structure and fixed electrodes. This signal is converted to a voltage waveform by means of low-noise charge integrating amplifier and amplification stages.

6.6 Demodulator

The output of the Coriolis sense is an amplitude modulated waveform. The amplitude corresponds to the rotation rate, and the carrier frequency is the mechanical drive frequency. The synchronous demodulator converts the Coriolis sense waveform to the low-frequency, angular rate signal.

6.7 Low-Pass Filter

After the demodulation stage, there is a low-pass filter. This filter attenuates noise and high frequency artifacts before final amplification.

6.8 Auto Zero

The Auto Zero function is used to reduce DC offset caused by bias drift. The use of this function will vary by application requirement. Pin 24 (AZ) is used to set the Auto Zero function, resetting the bias to approximately VREF.

6.9 Temperature Sensor

A built-in Proportional-To-Absolute-Temperature (PTAT) sensor provides temperature information on Pin 23.

6.10 Charge Pump

The on-chip charge pump generates the voltage required to oscillate the mechanical structure.

6.11 Memory Trim

The on-chip memory is used to select the gyro's sensitivity, calibrate the sensitivity, null DC offsets and select the low-pass filter option

6.12 Scale Factor

The Rate-Out of the gyros is not ratiometric to the supply voltage. The scale factor is calibrated at the factory and is nominally independent of supply voltage.

6.13 Reference Voltage

The gyro includes a bandgap reference circuit. The output voltage is typically 1.35V and is nominally independent of temperature. The zero-rate signal is nominally equal to the reference value.

6.14 Analog Outputs

The IDG-650 gyro has two X-outputs (X-OUT and X4.5OUT), and two Y-outputs (Y-OUT and Y4.5OUT), with scale factors and full-scale sensitivities that vary by a factor of 4.5, as detailed in Section 8.2.7.

Having two sensitivities and two full-scale ranges per axis allows the end user to have one output that can be used for faster motions (over a full scale range of ±2000º/sec), and a second output that can be used for slower motions (over a full scale range of ±440º/sec). Thus a lower-resolution analog-to-digital converter (ADC) may be used to digitize the motion, with the gain of 4.5 in the X4.5OUT and Y4.5OUT outputs effectively giving the user an additional two-plus bit of resolution.

7. Specification

7.1 Specified Parameters

All parameters specified are @ VDD = 3.0 V and T_A = 25°C. External LPF @ 2kHz. All specifications apply to both axes.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
SENSITIVITY					
Full-Scale Range	At X-OUT and Y-OUT		±2000		°/s
	At X4.5OUT and Y4.5OUT		±440		°/s
Sensitivity	At X-OUT and Y-OUT		0.5		mV/°/s
	At X4.5OUT and Y4.5OUT		2.27		mV/°/s
Initial Calibration Tolerance	At X-OUT and Y-OUT		±6		%
Calibration Drift Over Specified Temperature	At X-OUT and Y-OUT		±10		%
Nonlinearity	At X-OUT and Y-OUT, Best Fit Straight Line		<1		% of FS
Cross-axis Sensitivity			±1		%
REFERENCE					
Voltage (VREF)			1.35		V
Tolerance			±50		mV
Load Drive			100		µA
Capacitive Load Drive	Load directly connected to VREF		100		pF
Power Supply Rejection	VDD= 2.7V to 3.3V		1		mV/V
Reference Drift Over Specified Temperature			±5		mV
ZERO-RATE OUTPUT (ZRO)					
Static Output (Bias)	Factory Set		1.35		V
Initial Calibration Tolerance	Relative to VREF, With Auto Zero		±20		mV
	Relative to VREF, Without Auto Zero		±150		mV
ZRO Drift Over Specified Temperature			±20		mV
Power Supply Sensitivity	@ 50 Hz		10		°/sec/V
FREQUENCY RESPONSE					
High Frequency Cutoff	Internal LPF -90°		140		Hz
LPF Phase Delay	10Hz		-4.5		°
MECHANICAL FREQUENCIES					
X-Axis Resonant Frequency		20	24	28	kHz
Y-Axis Resonant Frequency		23	27	31	kHz
Frequency Separation	X and Y Gyroscopes		3		kHz
NOISE PERFORMANCE					
Total RMS Noise	Bandwidth 1Hz to 1kHz, At X-OUT and Y-OUT		0.3		mV rms
OUTPUT DRIVE CAPABILITY					
Output Voltage Swing	Load = 100kΩ to Vdd/2	0.05		Vdd-0.05	V
Capacitive Load Drive			100		pF
Output Impedance			100		Ω
POWER ON-TIME					
Zero-rate Output	Settling to ±3°/s		50	200	ms
AUTO ZERO CONTROL					
Auto Zero Logic High	Rising Input		1.9		V
Auto Zero Logic Low	Falling Input		0.9		V
Auto Zero Pulse Duration		2		1500	µsec
Offset Settle Time After Auto Zero			7		msec

7.2 Specified Parameters, continued

All parameters specified are @ VDD = 3.0 V and T_A = 25°C. External LPF @ 2kHz. All specifications apply to both axes.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
POWER SUPPLY (VDD)					
Operating Voltage Range		2.7	3.0	3.3	V
Quiescent Supply Current			7		mA
Supply Current Change Over Specified Temperature			±2		mA
TEMPERATURE SENSOR					
Sensitivity	Range -20 to +85°C		4		mV/°C
Offset			1.25		V
Output Impedance			12		kΩ
TEMPERATURE RANGE					
Specified Temperature Range		-20		+85	°C

7.3 Recommended Operating Conditions

Parameter	Min	Typ	Max	Unit
Power Supply Voltage (VDD)	2.7	3.0	3.3	V
Power Supply Voltage (VDD) Rise Time (10% - 90%)			20	ms

7.4 Absolute Maximum Ratings

Stress above those listed as “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device under these conditions is not implied. Exposure to the absolute maximum rating conditions for extended periods may affect device reliability.

Parameter	Rating
Supply Voltage	-0.3V to +3.6V
Acceleration (Any Axis, unpowered)	10,000*g* for 0.3ms
Operating Temperature Range	-40 to +105°C
Storage Temperature Range	-40 to +125°C

7.5 Reference Circuit

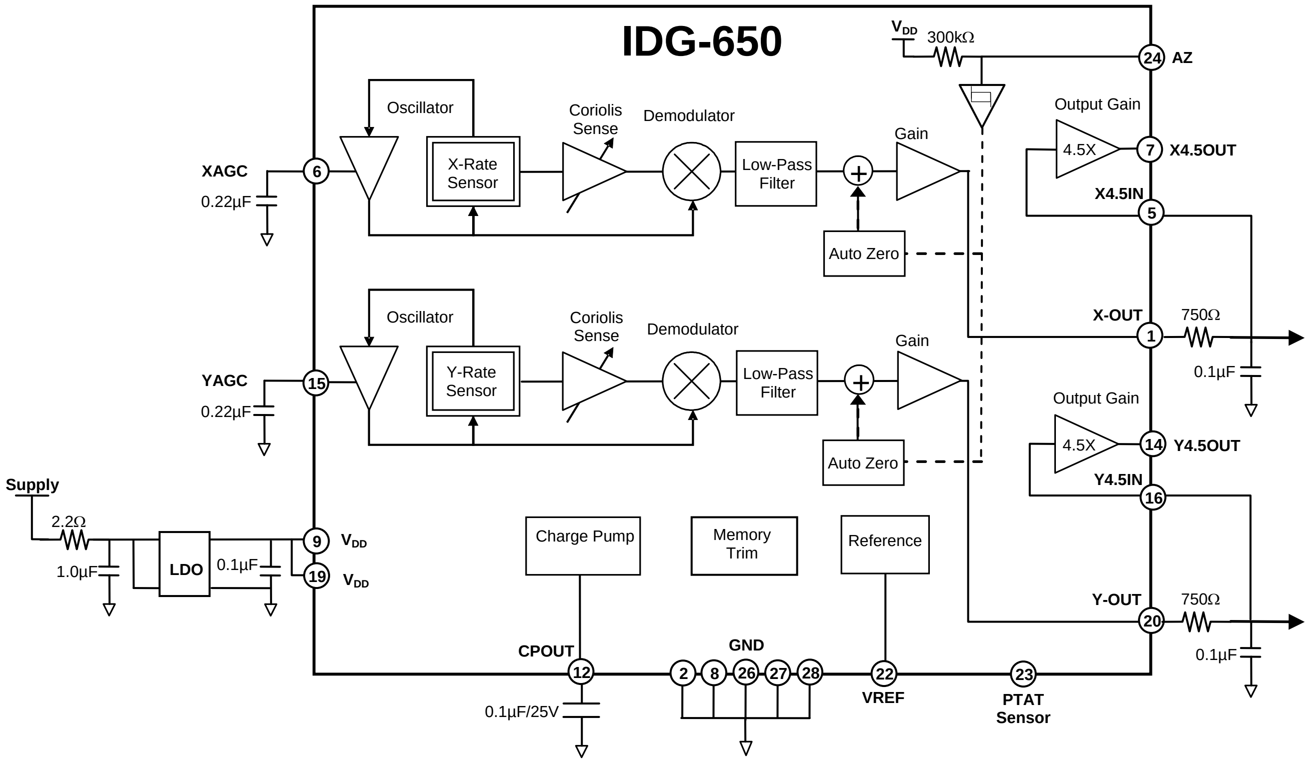


Figure 2

7.5.1 Bill of Material for External Components

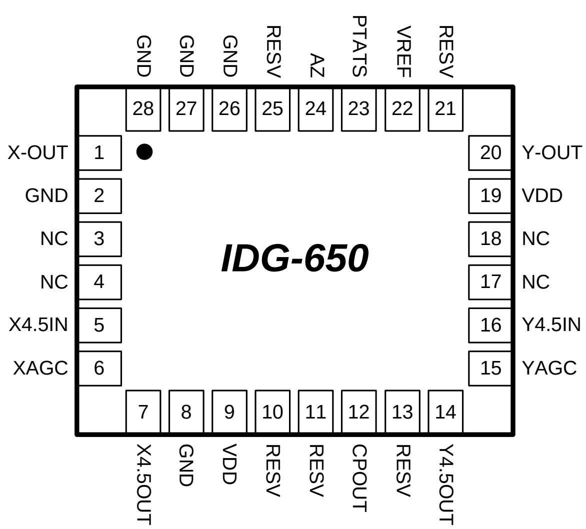
Component	Specification
Low Pass Filter Capacitors	0.1µF ±20% / 10V
AGC Capacitors	0.22µF ±10% / 10V
VDD Bypass Capacitor	0.1µF ±20% / 10V
Charge Pump Capacitor	0.1µF ±20% / 25V
LDO Input Filter Capacitor	1.0µF / Ratings Dependent upon Supply Voltage
LDO Input Filter Resistor	2.2Ω ±1%
Low Pass Filter Resistors	750Ω ±1%
VDD Bypass Capacitor	0.1µF ±20% / 10V

8. Application Information

8.1 Pin Out and Signal Description

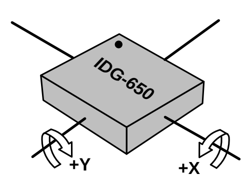
Number	Pin	Description
2, 8, 26, 27, 28	GND	Ground
9, 19	VDD	Positive supply voltage
1	X-OUT	Rate output for rotation about the X-axis
5	X4.5IN	X-axis input to the 4.5X amplifier
6	XAGC	Amplitude control capacitor connection
7	X4.5OUT	X-axis output of the 4.5X amplifier
12	CPOUT	Charge pump capacitor connection
14	Y4.5OUT	Y-axis output of the 4.5X amplifier
15	YAGC	Amplitude control capacitor connection
16	Y4.5IN	Y-axis input to the 4.5X amplifier
20	Y-OUT	Rate output for rotation about the Y-axis
22	VREF	Precision reference output
23	PTATS	Temperature Sensor Output
24	AZ	X & Y Auto Zero control pin
10, 11, 13, 21, 25	RESV	Reserved. Do not connect.
3, 4, 17, 18	NC	Not internally connected. May be used for PCB trace routing.

Top View



28-pin, 4mm x 5mm x 1.2mm QFN Package

This is a dual-axis rotational-rate sensing device. It produces a positive output voltage for rotation about the X- or Y-axis, as shown in the figure below.



Orientation of Axes of Sensitivity and Polarity of Rotation

Figure 3

8.2 Design Considerations

8.2.1 Power Supply Rejection Ratio

The gyro is most susceptible to power supply noise (ripple) at frequencies less than 100Hz. At less than 100Hz, the PSRR is determined by the overall internal gain of the gyroscope. Above 100Hz, the PSRR is determined by the characteristics of the on-chip low-pass filter. Above 1kHz, the PSRR is relatively constant except for two narrow frequency ranges corresponding to the resonant frequencies of the X and Y gyroscopes.

8.2.2 Power Supply Filtering

The power supply voltage (VDD) rise time (10% - 90%) must be less than 20ms at VDD (Pin 9, 19) for proper device operation.

The IDG-650 gyroscope should be isolated from system power supply noise by a combination of an RC filter that attenuates high frequency noise and a Low Drop Out power supply regulator (LDO) that attenuates low frequency noise. Figure 4 shows a typical configuration.

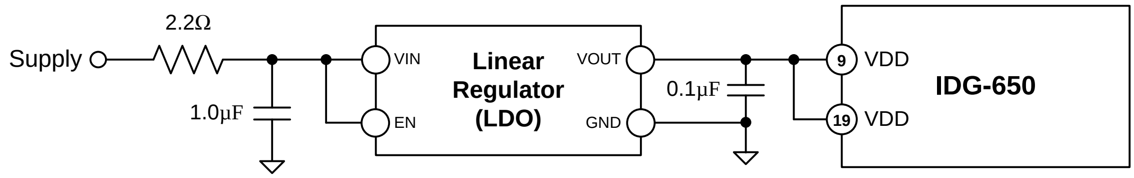


Figure 4

The low-pass RC filter should be chosen such that it provides significant attenuation of system noise at high frequencies. The LDO should be a low noise regulator (<100μV/rtHz) that exhibits good noise rejection at low frequencies.

8.2.3 Amplitude Control

The scale factor of the gyroscope depends on the amplitude of the mechanical motion and the trim setting of the internal programmable gain stages. The oscillation circuit controls the amplitude to maintain constant sensitivity over the specified temperature range. The capacitors connected to Pin 6 (XAGC) and Pin 15 (YAGC) are compensation capacitors for the amplitude control loops.

8.2.4 Temperature Sensor

A built-in Proportional-To-Absolute-Temperature (PTAT) sensor provides temperature information on Pin 23 (PTATS). The temperature sensor output signal is analog, and has a bias of approximately 1.25V at room temperature, and increases at a rate of 4mV/ºC. The output impedance is nominally 12kΩ and is therefore not designed to drive low impedance loads. If necessary, the output can be externally buffered with a low offset-drift buffer, and optionally a low-pass filter to minimize noise.

8.2.5 Internal Low-Pass Filter

After the demodulation stage, there is a low-pass filter. This filter limits noise and high frequency artifacts from the demodulator before final amplification. The following graph shows the typical gain and phase response. The low-pass filter has been designed for a nominally flat gain up to the cutoff frequency while still achieving a low phase delay at 10Hz and 30Hz.

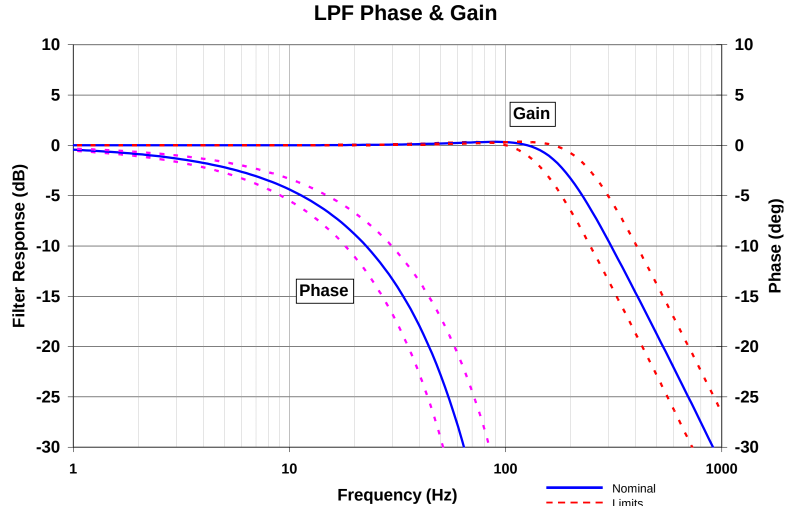


Figure 5

8.2.6 External Low-Pass Circuitry

To further attenuate high-frequency noise, an optional external low-pass filter may be used.

8.2.7 Gyro Outputs

The IDG-650 gyro has two X-outputs and two Y-outputs, with scale factors and full-scale sensitivities as summarized below.

Axis	Gyro Output	Sensitivity (mV/º/s)	Full-Scale Range (±º/s)
X	X-OUT	0.5	2000
	X4.5OUT	2.27	440
Y	Y-OUT	0.5	2000
	Y4.5OUT	2.27	440

Having two sensitivities and two full-scale ranges per axis allows the end user to have one output that can be used for faster motions such as full-motion gaming (over a full scale range of ±2000º/sec), and a second output that can be used for slower motions such as for gesture and menu-navigation functionality (over a full scale range of ±440º/sec). Thus a lower-resolution analog-to-digital converter (ADC) may be used to digitize the motion, with the gain of 4.5 in the _4.5OUT output effectively giving the user an additional two-plus bits of resolution.

The IDG-650 gyro outputs are independent of supply voltage (i.e. they are not ratiometric).

Gyro rotation rate is calculated as:

(Gyro Output Voltage – Gyro Zero-Rate Out) / Sensitivity

where the Zero-Rate Output (ZRO) is nominally VREF. There is a temperature dependence to ZRO, and an initial accuracy to ZRO.

8.2.8 Auto Zero

Auto Zero (AZ) is a function that is used to maximize the gyro's dynamic range when using the X4.5OUT and Y4.5OUT outputs.

AZ works by keeping the gyro's Zero-Rate Output (ZRO) close to VREF, and thus allows the user to achieve a wider usable signal range, without using external analog high pass filters.

When activated, the Auto Zero circuit internally nulls the ZRO to VREF. The typical usage of Auto Zero is in conditions where:

1. The gyro's motion is known, such as when:
    a. The gyro is stationary.
    b. Other sensors can report angular rotation rate.
2. The DC value of the gyro output is not important, but only the AC value is. In this case, a digital ac filter may be used to extract the gyro data, which provides a higher-quality output than is possible with an analog R-C filter.

The Auto Zero function is initiated on the rising edge of the AZ pin. The Auto Zero settling time is typically 7ms. This time includes the time required for nulling the ZRO and for the settling of the internal low pass filter (LPF). If the external LPF bandwidth is less than 200Hz, the Auto Zero settling time will be longer than specified.

The AZ pulse width should meet the specified minimum time requirement of 2µs to start the Auto Zero function, and should be shorter than the maximum specified time of 1,500µs. The Auto Zero pulse should occur after the start-up period to cancel any initial calibration error.

If the AutoZero function is not used, the AZ pin (pin 24) should be connected to ground.

8.2.9 High Impedance Nodes

XAGC (pin 6) and YAGC (pin 15) pins are high impedance (>1Mohm) nodes. Any coating, glue or epoxy on these pins or on the capacitors connected to these pins, will affect part performance and should be avoided.

8.2.10 Charge Pump

The on-chip charge pump requires a bypass capacitor for stable operation. This capacitor should be 0.1µF and rated for 25V.

8.2.11 Proper Interface Cleaning

Proper cleaning of PCB solder pads prior to assembly is recommended. PCB surface contaminants at XAGC (pin 6) or YAGC (pin 15) device interfaces may affect part performance.

8.2.12 Acoustic Noise Sensitivity

The IDG-650 gyroscope is insensitive to acoustic vibration except for a narrow frequency range near the gyro's resonant frequency. The typical bandwidth of the acoustic sensitivity is 200Hz. It is recommended that products using the IDG-650 gyroscope be designed such that the acoustic noise in the 20kHz to 31kHz range be attenuated by the product's enclosure.

8.2.13 Electrostatic Discharge Sensitivity

The IDG-650 gyroscope can be permanently damaged by an electrostatic discharge. ESD precautions for handling and storage are recommended.

9. Assembly

9.1 Orientation

The diagram below shows the orientation of the axes of sensitivity and the polarity of rotation.

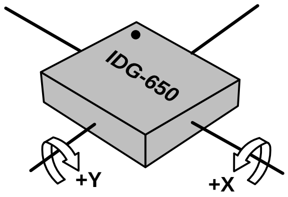
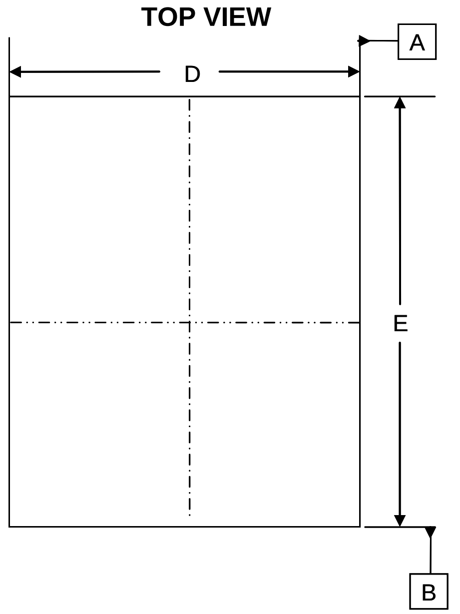
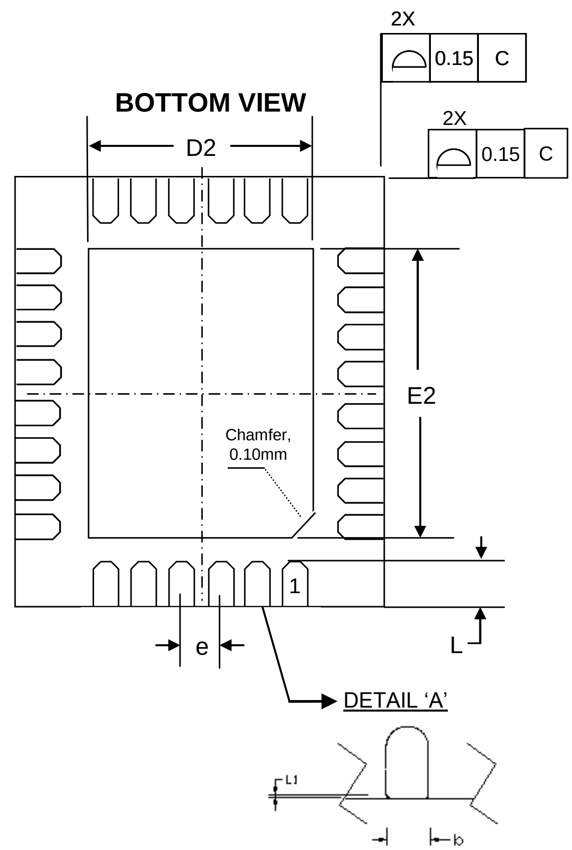
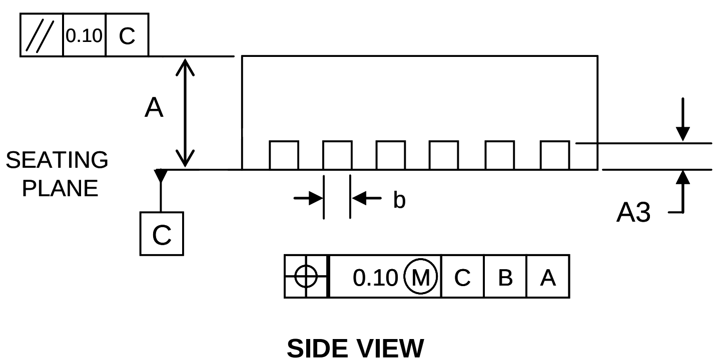


Figure 6

9.2 Package Dimensions







SYMBOL	COMMON					
	DIMENSIONS MILLIMETERS			DIMENSIONS INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX
A	1.10	1.15	1.20	0.042	0.044	0.046
A3		0.203 BSC			0.008 BSC	
b	0.18	0.25	0.30	0.007	0.009	0.011
D	3.85	4.00	4.15	0.150	0.156	0.161
D2	2.65	2.80	2.95	0.103	0.109	0.115
E	4.85	5.00	5.15	0.189	0.195	0.200
E2	3.50	3.65	3.80	0.137	0.142	0.148
e		0.50 BSC			0.019 BSC	
L	0.30	0.35	0.40	0.011	0.013	0.015
L1	0.00	0.08	0.15	0.000	0.003	0.006

Figure 7

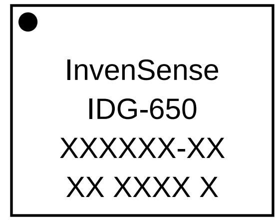
9.3 Package Marking Specification

Line 1 = Company Name

Line 2 = Part Number

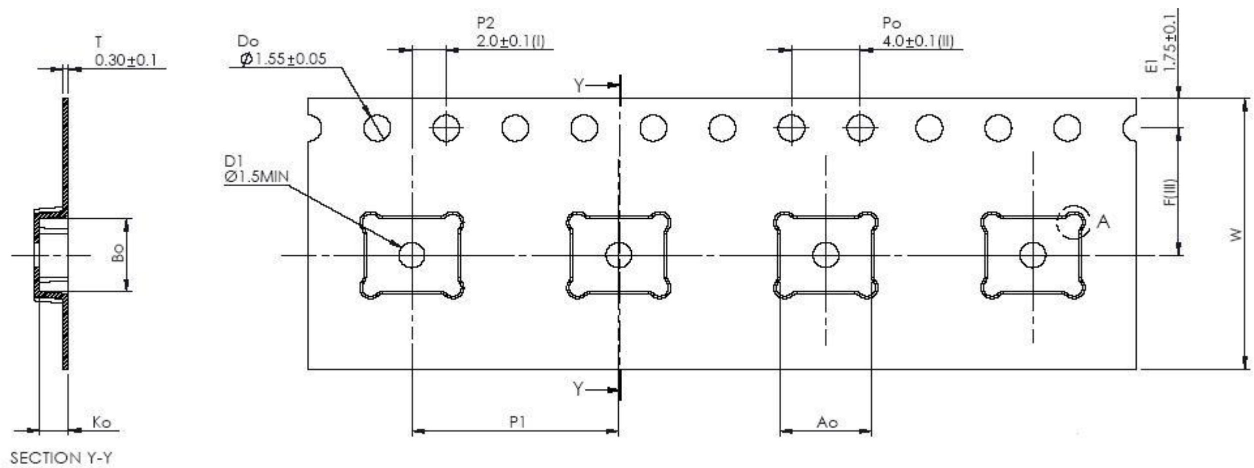
Line 3 = Lot Traceability Code

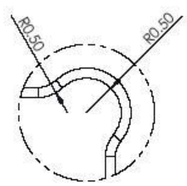
Line 4 = Fabricator, Assembly, Date Code, Revision



Top View

9.4 Tape & Reel Specification



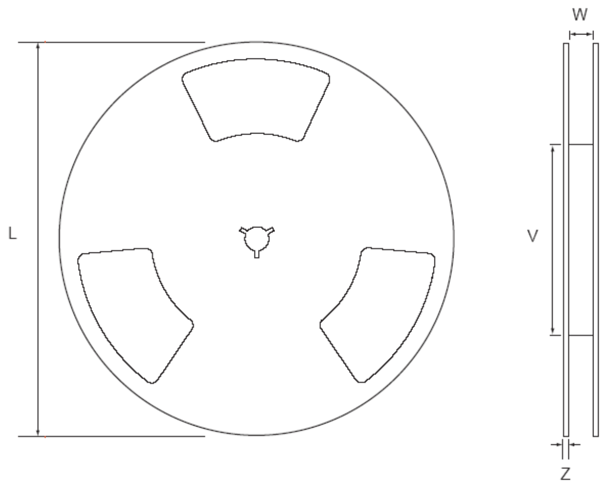


DETAIL 'A'

(I) Measured from centerline of sprocket hole to centerline of pocket.
(II) Cumulative tolerance of 10 sprocket holes is ± 0.20.
(III) Measured from centerline of sprocket holes to centerline of pocket.
(IV) Other material available.
ALL DIMENSIONS IN MILLIMETERS UNLESS OTHERWISE STATED.

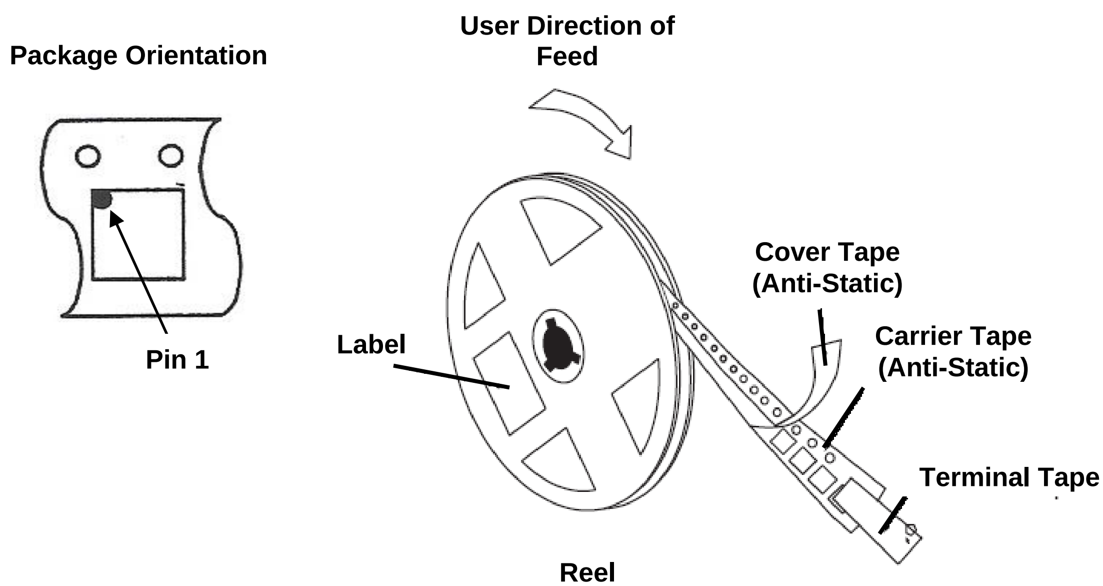
PKG SIZE	CARRIER TAPE (mm)							
	Tape Width (W)	Pocket Pitch (P1)	Ao	Bo	Ko	F	Leader Length (Min.)	Trailer Length (Min.)
4x5	16.00 ±0.3	12.00 ±0.1	5.30 ±0.1	4.30 ±0.1	1.65 ±0.1	7.50 ±0.1	300	300

Figure 8



PKG SIZE	REEL (mm)			
	L	V	W	Z
4x5	330	100	16.4	3.0

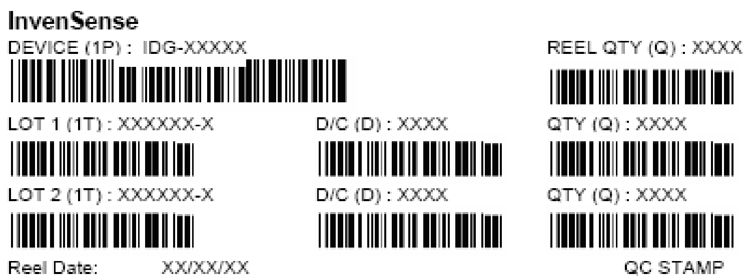
Figure 9

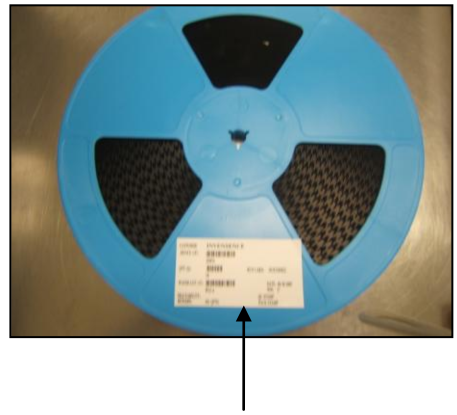


Quantity Per Reel	5000
Reels per Pizza Box	1
Pizza Boxes Per Carton (max)	3 full pizza boxes packed in the center of the carton, buffered by two empty pizza boxes (front and back).
Pieces/Carton (max)	15,000

Figure 10

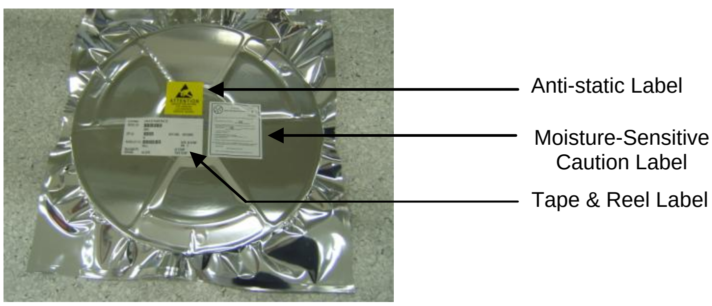
9.4.1 Label



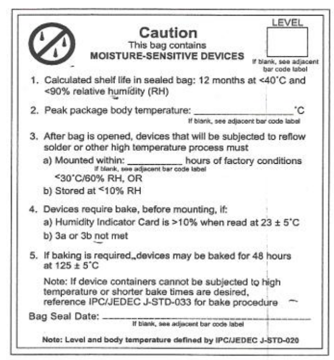


Location of Label

9.4.2 Packing



Moisture Barrier Bag With Labels



Caution
This bag contains
MOISTURE-SENSITIVE DEVICES

LEVEL
If blank, see adjacent bar code label

1. Calculated shelf life in sealed bag: 12 months at <40˚C and <90% relative humidity (RH)
2. Peak package body temperature: ______________ ˚C
   If blank, see adjacent bar code label
3. After bag is opened, devices that will be subjected to reflow solder or other high temperature process must
   a) Mounted within: ________ hours of factory conditions
   If blank, see adjacent bar code label
   <30˚C/60% RH, OR
   b) Stored at <10% RH
4. Devices require bake, before mounting, if:
   a) Humidity Indicator Card is >10% when read at 23 ± 5˚C
   b) 3a or 3b not met
5. If baking is required, devices may be baked for 48 hours at 125 ± 5˚C

Note: If device containers cannot be subjected to high temperature or shorter bake times are desired, reference IPC/JEDEC J-STD-033 for bake procedure

Bag Seal Date: ______________
If blank, see adjacent bar code label

Note: Level and body temperature defined by IPC/JEDEC J-STD-020

Moisture-Sensitive Caution Label

Reel in Pizza Box

Pizza Box with Tape & Reel Label

9.5 Trace Routing

Routing traces or vias under the gyro package such that they run under the exposed die pad is prohibited.

9.6 Soldering Exposed Die Pad

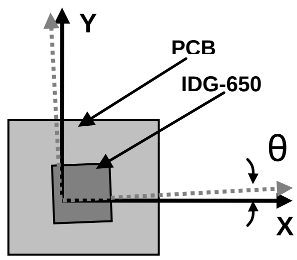
The exposed die pad is internally connected to VSS. The exposed die pad should not be soldered to the PCB since soldering to it contributes to performance changes due to package thermo-mechanical stress.

9.7 Component Placement

Testing indicates that there are no specific design considerations other than generally accepted industry design practices for component placement near the IDG-650 gyroscope to prevent noise coupling, and thermo-mechanical stress.

9.8 PCB Mounting and Cross-Axis Sensitivity

Orientation error of the gyroscope mounted to the printed circuit board can cause cross-axis sensitivity in which one gyro responds to rotation about the other axis, for example, the Y-axis gyroscope responding to rotation about the X-axis. The orientation mounting error is illustrated in Figure 12.



Packaged Gyro Axis (-----) Relative to PCB Axes (——) with Orientation Error *θ*.

Figure 11

The table below shows the cross-axis sensitivity as a percentage of the specified gyroscope's sensitivity for a given orientation error.

Orientation Error	Cross-Axis Sensitivity
Theta (θ)	**|sinθ|**
0º	0%
0.5º	0.87%
1º	1.75%

The specification for cross-axis sensitivity in Section 7.1 includes the effect of the die orientation error with respect to the package.

9.9 AGC Nodes

The gyro pins marked XAGC and YAGC are high impedance nodes that are sensitive to current leakage, which can impact gyroscope performance. Care should be taken to ensure that these nodes are not contaminated by residue such as flux and are clean.

9.10 MEMS Handling Instructions

MEMS (Micro Electro-Mechanical Systems) are a time-proven, robust technology used in hundredstens of millions of consumer, automotive and industrial products. MEMS devices consist of microscopic moving mechanical structures. They differ from conventional IC products even though they can be found in similar packages. Therefore, MEMS devices require different handling precautions than conventional ICs prior to mounting onto printed circuit boards (PCBs).

InvenSense's dual-axis gyroscopes utilize MEMS technology which consists of microscopic moving silicon structures to sense rotations and have a shock tolerance of 10,000*g*. InvenSense packages its gyroscopes as it deems proper for protection against normal handling and shipping. It recommends the following handling precautions to prevent potential damage.

1. Individual or trays of gyroscopes should not be dropped on hard surfaces. Components in trays if dropped could be subjected to *g*-forces in excess of 10,000*g.*

2. Printed circuit boards with mounted gyroscopes should not be separated by manually snapping apart. This could create *g*-forces in excess of 10,000*g.*

9.11 Gyroscope Surface Mount Guidelines

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

In order to assure gyroscope performance, several industry standard guidelines need to be considered for surface mounting. These guidelines are for both printed circuit board (PCB) design and surface mount assembly and are available from packaging and assembly houses.

When using MEMS gyroscope components in plastic packages, package stress due to PCB mounting and assembly could affect the output offset and its value over a wide range of temperatures. This is caused by the mismatch between the Coefficient Temperature Expansion (CTE) of the package material and the PCB. Care must be taken to avoid package stress due to mounting.

9.12 Reflow Specification

The approved solder reflow curve shown in the figure below conforms to IPC/JEDEC J-STD-020C (reflow) with a maximum peak temperature (255 +5/-0°C). This is specified for component-supplier reliability qualification testing using lead-free solder. All temperatures refer to the topside of the QFN package, as measured on the package body surface. Customer solder-reflow processes should use the solder manufacturer's recommendations, making sure to never exceed the constraints listed in the table and figure below, as these represent the maximum tolerable ratings for the device. For optimum results, production solder reflow processes should use lower temperatures, reduced exposure times to high temperatures, and lower ramp-up and ramp-down rates than those listed below.

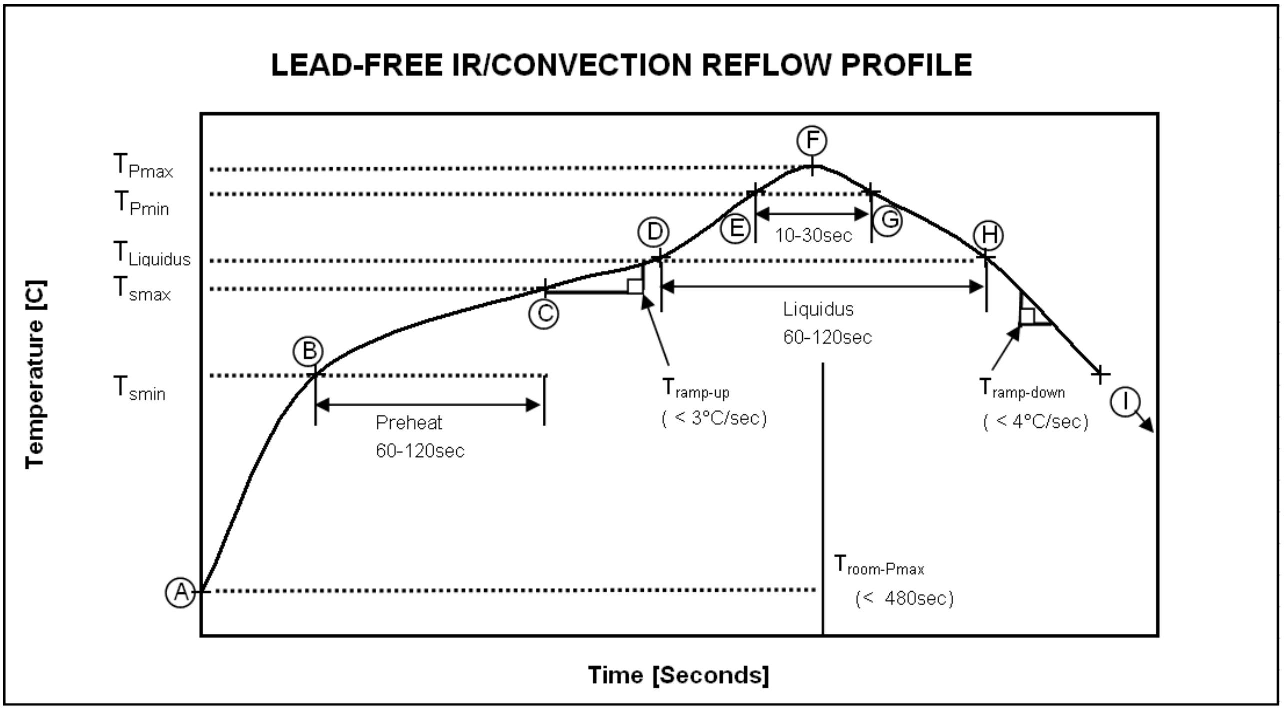


Figure 12. Approved IR/Convection Solder Reflow Curve

Temperature Set Points for IR / Convection Reflow Corresponding to Figure Above

Step	Setting	CONSTRAINTS		
		Temp (°C)	**Time (sec)**	**Rate (°C/sec)**
A	Troom	25		
B	TSmin	150		
C	TSmax	200	60 < tBC < 120	
D	TLiquidus	217		r(TLiquidus-TPmax) < 3
E	TPmin [< TPmax-5°C, 250°C]	255		r(TLiquidus-TPmax) < 3
F	TPmax [< TPmax, 260°C]	260	tAF < 480	r(TLiquidus-TPmax) < 3
G	TPmin [< TPmax-5°C, 250°C]	255	tEG < 30	r(TPmax-TLiquidus) < 4
H	TLiquidus	217	60 < tDH < 120	
I	Troom	25		

9.13 Storage Specifications

The storage specification of the IDG-650 gyroscope conforms to Moisture Sensitivity Level (MSL) 3, as defined by IPC/JEDEC J-STD-020D.01.

Storage Specifications for IDG-650

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

10. Reliability

10.1 Qualification Test Policy

InvenSense's products complete a Qualification Test Plan before being released to production. The Qualification Test Plan follows the JEDEC 47D Standards, "Stress-Test-Driven Qualification of Integrated Circuits," with the individual tests described below.

10.2 Qualification Test Plan

Accelerated Life Tests

Test	Method/Condition	Lot Quantity	Samples / Lot	Accept / Reject Criteria
High Temperature Operating Life (HTOL/LFR)	JEDEC JESD22-A108C, 3.63V biased, Tj>125°C [read-points 168, 500, 1000 hours]	3	77	(1/2)
Steady-State Temperature Humidity Unbiased Life (1)	JEDEC JESD22-A101C, 85°C/85%RH [read-points 168, 500, 1000 hours]	3	77	(1/2)
High Temperature Storage Life	JEDEC JESD22-A103C, Cond. A, 125°C Non-Bias Bake [read-points 168, 500, 1000 hours]	3	77	(1/2)

Device Component Level Tests

Test	Method/Condition	Lot Quantity	Samples / Lot	Accept / Reject Criteria
ESD-HBM	JEDEC JESD22-A114F, Class 2 (2KV)	1	15	(0/1)
ESD-MM	JEDEC JESD22-A115-A, Class B (200V)	1	12	(0/1)
Latch Up	JEDEC JESD78B Class 1 (25°C), Level 1 (+/- 100mA)	1	6	(0/1)
Mechanical Shock	JEDEC JESD22-B104C, Mil-Std-883, method 2002, Cond. D, 10,000*g's*, 0.3ms, ±X,Y,Z – 6 directions, 5 times/direction	3	5	(0/1)
Vibration	JEDEC JESD22-B103B, Variable Frequency (random), Cond. B, 5-500Hz, X,Y,Z – 4 times/direction	3	5	(0/1)
Temperature Cycling (1)	JEDEC JESD22-A104D Condition N, -40°C to +85°C, Soak Mode 2, 100 cycles	3	77	(1/2)

Tests are preceded by MSL3 Preconditioning in accordance with JEDEC JESD22-A113F