IDG-300 Hardware Design Guide

Table of Contents

1. Introduction 3

2. Block Diagram 3

3. Zero Rate Output (ZRO)/Drift 4

4. Amplitude Gain Control Filter 4

5. Internal Low Pass Filter 4

6. External Low Pass Filter 5

7. No Connect (NC) and Reserved (RESV) Pins 5

8. Power Supply and LDO 5

9. Exposed Die Pad 6

10. Board Layout Design Techniques 6

11. PCB Pad Layout Dimensions 7

12. Cross Axis Sensitivity 7

13. MEMS Handling Instructions 8

1. Introduction

This application note is intended to assist system designers in motion sensing applications when using the InvenSense IDG-300 dual-axis gyroscope. The IDG-300 device can be used in a wide range of applications and each specific design will have various degrees of customization.

These general guidelines will address some of the common design questions when using the IDG-300 device. Topics covered in this application note include:
- Zero Rate Output
- Power Supply design
- Internal and External Filters circuit behavior
- PCB Mounting and Pin connections

For further details regarding product performance and specifications, please refer to the IDG-300 datasheet.

2. Block Diagram

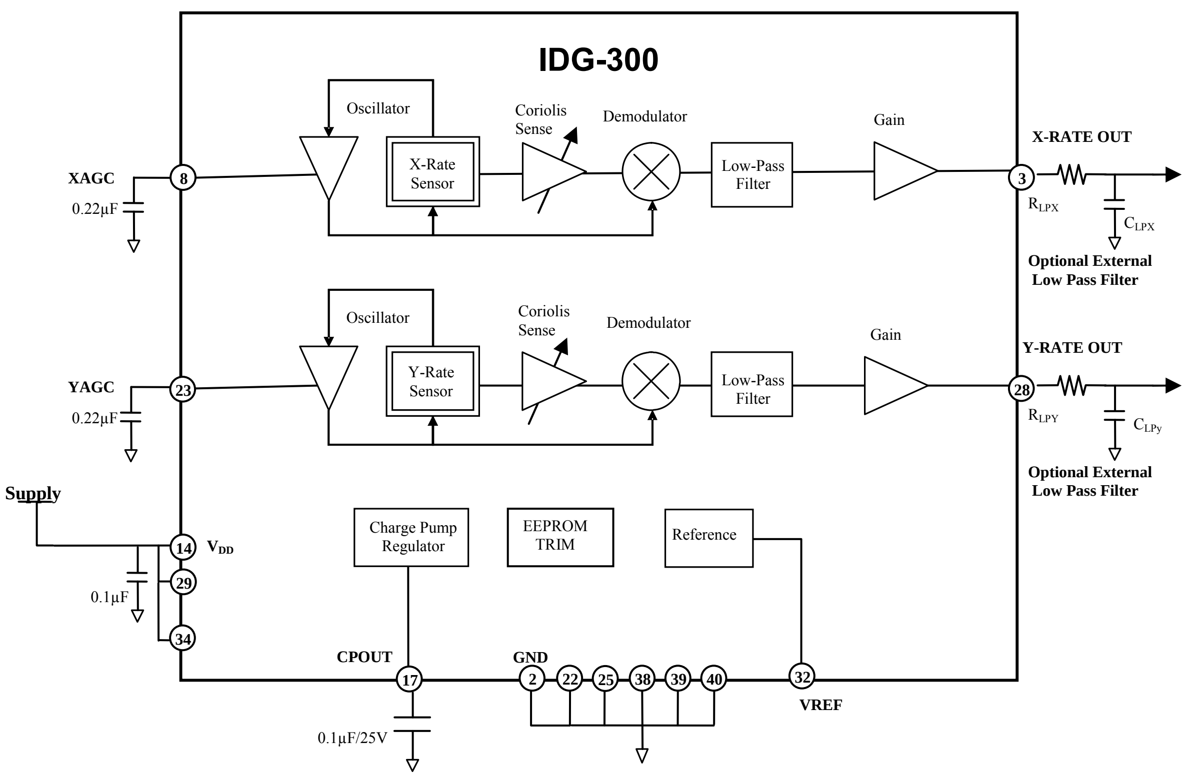


Figure 1: IDG-300 Block Diagram

Figure 1 shows the functional block diagram for the IDG-300 that will commonly be referred to within the contents of this Application Note.

3. Zero Rate Output (ZRO)/Drift

Zero Rate Output (ZRO) is the static output of the analog voltage signal with no motion or external vibration. The IDG-300 has an expected ZRO DC output level of 1.5V for both the X-axis and Y-axis gyroscopes and the amount of variation under normal operating range is shown in the IDG-300 datasheet. The X and Y axes are independent functions within the device and it is important to note that when monitoring the analog output signals on an oscilloscope there might be some slight offset between the two analog outputs.

Applications are designed to get periodic measurements from the gyroscope and it is important to differentiate between changes in ZRO levels and actual motion. Analog to Digital Converters (ADC) will track the voltage levels of the analog outputs to determine when rotation is applied on an axis of the IDG-300.

The power supply voltage (Vdd) under normal operating conditions will not have a direct affect on the ZRO output level since this value is not based off of an internal resistor divider network however it is recommended that the power supply (Vdd) for the IDG-300 have tight stability through external power supply circuitry using a Low Drop Output Regulator (LDO).

It is important to note that all gyroscopes will experience drift over time due to environmental conditions such as temperature. The gyroscope's angle of measurement will be based on the previous angle measured and the difference between the gyroscope's output and the measured gyroscope bias. The IDG-300 does not have a linear relationship between temperature and ZRO level.

4. Amplitude Gain Control Filter

AGC (Amplitude Gain Control) is used as the initial amplification stage from the movement of the gyroscope device. The oscillation circuit controls the amplitude to maintain constant sensitivity over the specified temperature range.

Each axis has separate filters located at Pin 8 for X-Axis AGC (XAGC) and Pin 23 Y-Axis AGC (YAGC) which require 0.22µF, ±10% capacitor values as compensation capacitors for the amplitude control loops. These capacitors should be placed close to the device.

These AGC pins 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 excess flux or solder and should be cleanly mounted onto the PCB.

5. Internal Low Pass Filter

An internal low pass filter within the IDG-300 device will have a direct impact on the system performance as well as set the bandwidth for motion detection. The internal low pass filter (LPF) is used after the demodulation stage to attenuate noise and high frequency artifacts before amplification. The internal LPF is set at 140Hz and cannot be changed.

6. External Low Pass Filter

An external low pass filter is recommended to attenuate high-frequency noise. The external LPF is set by the resistor and capacitor values on the PCB with recommended cutoff frequency value of ~ 2kHz to attenuate signals above 10kHz.

7. No Connect (NC) and Reserved (RESV) Pins

RESV pins are the test pins and used for internal purposes. It is important that the layout does not connect them to other signals such as Vdd and GND. Customer schematics should have these RESV pins remain as No Connect (NC) or floating on the board. The design can connect the NC pins to each other since they are not bonded internally.

8. Power Supply and LDO

Analog circuits and devices can have noise within a specific frequency content that could pass through filters in the design and affect the analog blocks of the design.

The IDG-300 gyroscope 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 and external filtering. Above 100Hz, the PSRR is determined by the characteristics of the on-chip low pass filter and the external low pass filter. A spectrum analyzer may be used to capture the noise content by frequency.

The IDG-300 gyroscope can 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 2 shows a typical configuration for this external power circuit.

A Low Drop Output Regulator (LDO) should be used for power supply rejection. It will also maintain the Vdd level to be more stable and has tight tolerance of the output. Low cost LDO devices are available in the market with more than 60dB of rejection.

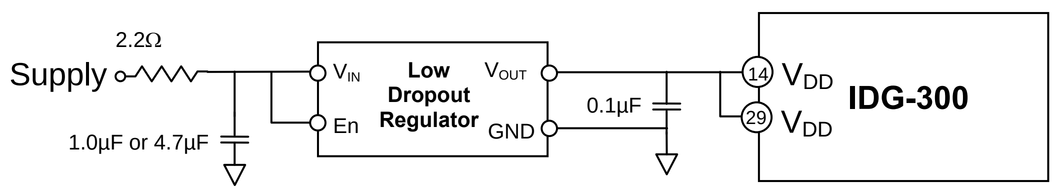


Figure 2: Reference External Power Circuit

It is also important to note that the IDG-300 will require the power supply voltage (VDD) rise time (10% - 90%) to be less than 20ms at VDD (Pin 14) for proper device operation.

9. Exposed Die Pad

The bottom of the QFN package for the IDG-300 has an exposed die pad area as shown in Figure 3. It is important that designs have no connection to this keep out region and that proper device placement is used to minimize the excessive solder underneath the device.

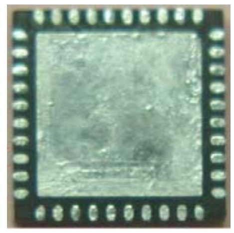


Figure 3: Bottom View of the IDG-300 QFN package

There is no electrical requirement to solder the exposed die pad of the IDG-300 gyroscope to the PCB. The IDG-300 gyroscope does not rely on the exposed die pad for thermal conduction, electrical connection, or electromagnetic shielding.

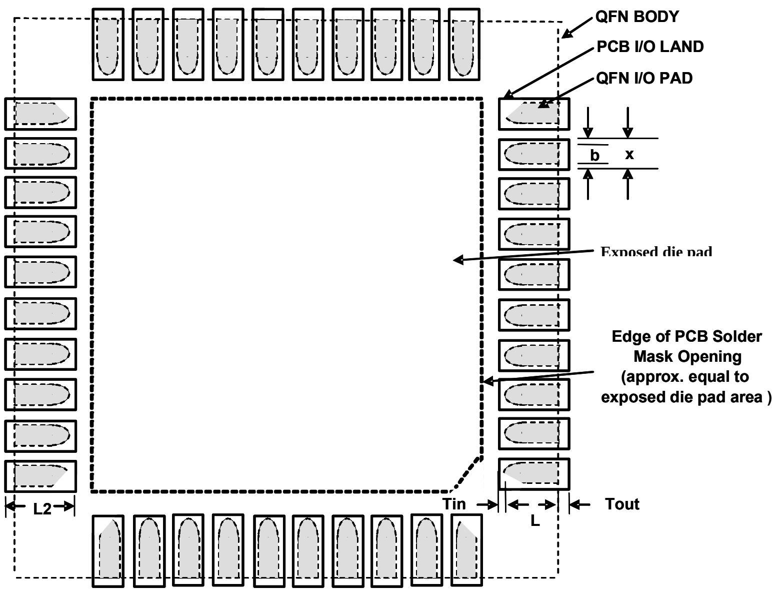
If the QFN package is mounted onto a board with any object underneath – it could put high package stress on the device affecting performance and in extreme cases causing permanent damage to the die. This stress on the package can affect the MEMS within the gyroscope in addition to making the device more sensitive to temperature changes.

10. Board Layout Design Techniques

Common details that should be considered during the PCB design should include:
- Mechanical shielding through enclosures
- Choice in PCB material selection
- Proper PCB layout
- Surface mounting process in manufacturing
- Impedance matching
- Signal layers
- Power/Ground plane shielding
- Trace Routing of low and high-speed signals
- Selection of Stripline and Microstrip for trace routing

11. PCB Pad Layout Dimensions

Figure 4 below gives a footprint recommendation for the IDG-300 QFN leads.



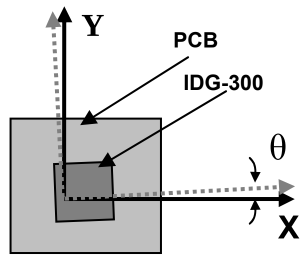
NOMINAL PACKAGE I/O PAD DIMENSIONS (mm)	
Pad Pitch	0.50
Pad Width (b)	0.25
Pad Length (L)	0.40
I/O LAND DESIGN DIMESNIONS GUIDELINES (mm)	
Land Width (X)	0.30
Outward Extension (Tout)	0.05
Inward Extension (Tin)	0.05
Land Length (L2)	0.50
Sq. Stencil Openings (c)	0.5 x 0.5
Maximum Dimension (Zmax)	6.9 x 6.9

Figure 4: I/O Pads of the IDG-300 QFN package

12. Cross Axis Sensitivity

The orientation of the device should also be highly controlled for the X and Y axes to prevent motion in one direction to impact the unaffected direction of motion. In some cases of improper orientation, the device might provide improper measurements of movement due to 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 5.



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

Figure 5

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 the datasheet includes the effect of the die orientation error with respect to the package.

13. MEMS Handling Instructions

MEMS (Micro Electro-Mechanical Systems) are a time-proven, robust technology used in tens 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 5000*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 5000*g*.
2. Printed circuit boards with mounted gyroscopes should not be separated by manually snapping apart. This could create g-forces in excess of 5000*g*.