

## **1 INTRODUCTION**

### **1.1 PURPOSE AND SCOPE**

This document is a product specification, providing a description, specifications, and design related information on the ICM-42688-P Single-Interface MotionTracking device. The device is housed in a small 2.5x3x0.91 mm 14-pin LGA package.

### **1.2 PRODUCT OVERVIEW**

The ICM-42688-P is a 6-axis MotionTracking device that combines a 3-axis gyroscope, and a 3-axis accelerometer in a small 2.5x3x0.91 mm (14-pin LGA) package. It also features a 2K-byte FIFO that can lower the traffic on the serial bus interface, and reduce power consumption by allowing the system processor to burst read sensor data and then go into a low-power mode. ICM-42688-P, with its 6-axis integration, enables manufacturers to eliminate the costly and complex selection, qualification, and system level integration of discrete devices, guaranteeing optimal motion performance for consumers.

The gyroscope supports eight programmable full-scale range settings from  $\pm 15.625\text{dps}$  to  $\pm 2000\text{dps}$ , and the accelerometer supports four programmable full-scale range settings from  $\pm 2\text{g}$  to  $\pm 16\text{g}$ .

ICM-42688-P also supports external clock input for highly accurate 31kHz to 50kHz clock, that helps to reduce system level sensitivity error, improve orientation measurement from gyroscope data, reduce ODR sensitivity to temperature and device to device variation.

The device includes industry first 20-bits data format support in FIFO for high-data resolution. This FIFO format encapsulates 19-bits of gyroscope data and 18-bits of accelerometer data for high precision applications. Other industry-leading features include on-chip 16-bit ADCs, programmable digital filters, an embedded temperature sensor, and programmable interrupts. The device features I3C<sup>SM</sup>, I<sup>2</sup>C and SPI serial interfaces, a VDD operating range of 1.71 V to 3.6 V, and a separate VDDIO operating range of 1.71 V to 3.6 V.

The host interface can be configured to support I3C<sup>SM</sup> slave, I<sup>2</sup>C slave, or SPI slave modes. The I3C<sup>SM</sup> interface supports speeds up to 12.5MHz (data rates up to 12.5Mbps in SDR mode, 25Mbps in DDR mode), the I<sup>2</sup>C interface supports speeds up to 1 MHz, and the SPI interface supports speeds up to 24 MHz.

By leveraging its patented and volume-proven CMOS-MEMS fabrication platform, which integrates MEMS wafers with companion CMOS electronics through wafer-level bonding, InvenSense has driven the package size down to a footprint and thickness of 2.5x3x0.91 mm (14-pin LGA), to provide a very small yet high performance low cost package. The device provides high robustness by supporting 20,000g shock reliability.

### **1.3 APPLICATIONS**

- AR/VR Controllers
- Head Mounted Displays
- Wearables
- Sports
- Robotics

## 2 FEATURES

### 2.1 GYROSCOPE FEATURES

The triple-axis MEMS gyroscope in the ICM-42688-P includes a wide range of features:

- Digital-output X-, Y-, and Z-axis angular rate sensors (gyroscopes) with programmable full-scale range of  $\pm 15.625$ ,  $\pm 31.25$ ,  $\pm 62.5$ ,  $\pm 125$ ,  $\pm 250$ ,  $\pm 500$ ,  $\pm 1000$ , and  $\pm 2000$  degrees/sec
- Low Noise (LN) power mode support
- Digitally-programmable low-pass filters
- Factory calibrated sensitivity scale factor
- Self-test

### 2.2 ACCELEROMETER FEATURES

The triple-axis MEMS accelerometer in ICM-42688-P includes a wide range of features:

- Digital-output X-, Y-, and Z-axis accelerometer with programmable full-scale range of  $\pm 2g$ ,  $\pm 4g$ ,  $\pm 8g$  and  $\pm 16g$
- Low Noise (LN) and Low Power (LP) power modes support
- User-programmable interrupts
- Wake-on-motion interrupt for low power operation of applications processor
- Self-test

### 2.3 MOTION FEATURES

ICM-42688-P includes the following motion features, also known as APEX (Advanced Pedometer and Event Detection – neXt gen)

- Pedometer: Tracks Step Count, also issues Step Detect interrupt
- Tilt Detection: Issues an interrupt when the Tilt angle exceeds  $35^\circ$  for more than a programmable time
- Raise to Wake/Sleep: Gesture detection for wake and sleep events. Interrupt is issued when either of these two events are detected
- Tap Detection: Issues an interrupt when a tap is detected, along with the tap count
- Wake on Motion: Detects motion when accelerometer data exceeds a programmable threshold
- Significant Motion Detection: Detects Significant Motion if Wake on Motion events are detected during a programmable time window

### 2.4 ADDITIONAL FEATURES

ICM-42688-P includes the following additional features:

- External clock input supports highly accurate clock input from 31kHz to 50kHz, helps to reduce system level sensitivity error, improve orientation measurement from gyroscope data, reduce ODR sensitivity to temperature and device to device variation
- 2K byte FIFO buffer enables the applications processor to read the data in bursts
- 20-bits data format support in FIFO for high-data resolution
- User-programmable digital filters for gyroscope, accelerometer, and temperature sensor
- 12.5MHz I3C<sup>SM</sup> (data rates up to 12.5Mbps in SDR mode, 25Mbps in DDR mode) / 1 MHz I<sup>2</sup>C / 24 MHz SPI slave host interface
- Digital-output temperature sensor
- Smallest and thinnest LGA package for portable devices: 2.5x3x0.91 mm (14-pin LGA)
- 20,000 *g* shock tolerant
- MEMS structure hermetically sealed and bonded at wafer level
- RoHS and Green compliant

### 3 ELECTRICAL CHARACTERISTICS

#### 3.1 GYROSCOPE SPECIFICATIONS

Typical Operating Circuit of section 4.2, VDD = 1.8 V, VDDIO = 1.8 V, T<sub>A</sub>=25°C, unless otherwise noted.

| PARAMETER   | CONDITIONS                                | MIN  | TYP     | MAX   | UNITS     | NOTES |
|---|---|------|---------|-------|-----------|-------|
| <b>GYROSCOPE SENSITIVITY</b>                        |   |      |         |       |           |       |
| Full-Scale Range                                    | GYRO_FS_SEL=0                             |      | ±2000   |       | °/s       | 2     |
|   | GYRO_FS_SEL =1                            |      | ±1000   |       | °/s       | 2     |
|   | GYRO_FS_SEL =2                            |      | ±500    |       | °/s       | 2     |
|   | GYRO_FS_SEL =3                            |      | ±250    |       | °/s       | 2     |
|   | GYRO_FS_SEL =4                            |      | ±125    |       | °/s       | 2     |
|   | GYRO_FS_SEL =5                            |      | ±62.5   |       | °/s       | 2     |
|   | GYRO_FS_SEL =6                            |      | ±31.25  |       | °/s       | 2     |
|   | GYRO_FS_SEL =7                            |      | ±15.625 |       | °/s       | 2     |
| Gyroscope ADC Word Length                           | Output in two's complement format         |      | 16      |       | bits      | 2, 5  |
| Sensitivity Scale Factor                            | GYRO_FS_SEL=0                             |      | 16.4    |       | LSB/(°/s) | 2     |
|   | GYRO_FS_SEL =1                            |      | 32.8    |       | LSB/(°/s) | 2     |
|   | GYRO_FS_SEL =2                            |      | 65.5    |       | LSB/(°/s) | 2     |
|   | GYRO_FS_SEL =3                            |      | 131     |       | LSB/(°/s) | 2     |
|   | GYRO_FS_SEL =4                            |      | 262     |       | LSB/(°/s) | 2     |
|   | GYRO_FS_SEL =5                            |      | 524.3   |       | LSB/(°/s) | 2     |
|   | GYRO_FS_SEL =6                            |      | 1048.6  |       | LSB/(°/s) | 2     |
|   | GYRO_FS_SEL =7                            |      | 2097.2  |       | LSB/(°/s) | 2     |
| Sensitivity Scale Factor Initial Tolerance          | Component and Board-level, 25°C           |      | ±0.5    |       | %         | 1     |
| Sensitivity Scale Factor Variation Over Temperature | 0°C to +70°C                              |      | ±0.005  |       | %/°C      | 3     |
| Nonlinearity  | Best fit straight line; 25°C              |      | ±0.1    |       | %         | 3     |
| Cross-Axis Sensitivity                              | Board-level                               |      | ±1.25   |       | %         | 3     |
| <b>ZERO-RATE OUTPUT (ZRO)</b>                       |   |      |         |       |           |       |
| Initial ZRO Tolerance                               | Board-level, 25°C                         |      | ±0.5    |       | °/s       | 3     |
| ZRO Variation vs. Temperature                       | 0°C to +70°C                              |      | ±0.005  |       | °/s/°C    | 3     |
| <b>OTHER PARAMETERS</b>                             |   |      |         |       |           |       |
| Rate Noise Spectral Density                         | @ 10 Hz                                   |      | 0.0028  |       | °/s /√Hz  | 1     |
| Total RMS Noise                                     | Bandwidth = 100 Hz                        |      | 0.028   |       | °/s-rms   | 4     |
| Gyroscope Mechanical Frequencies                    |   | 25   | 27      | 29    | KHz       | 1     |
| Low Pass Filter Response                            | ODR < 1kHz                                | 5    |         | 500   | Hz        | 2     |
|   | ODR ≥ 1kHz                                | 42   |         | 3979  | Hz        | 2     |
| Gyroscope Start-Up Time                             | Time from gyro enable to gyro drive ready |      | 30      |       | ms        | 3     |
| Output Data Rate                                    |   | 12.5 |         | 32000 | Hz        | 2     |

**Table 1. Gyroscope Specifications**

**Notes:**

1. Tested in production.
2. Guaranteed by design.
3. Derived from validation or characterization of parts, not tested in production.
4. Calculated from Rate Noise Spectral Density.
5. 20-bits data format supported in FIFO, see section 6.1.

### 3.2 ACCELEROMETER SPECIFICATIONS

Typical Operating Circuit of section 4.2, VDD = 1.8 V, VDDIO = 1.8 V, T<sub>A</sub>=25°C, unless otherwise noted.

| PARAMETER                                  | CONDITIONS                        | MIN          | TYP    | MAX  | UNITS | NOTES  |   |
|--|-----------------------------------|--------------|--------|------|-------|--------|---|
| ACCELEROMETER SENSITIVITY                  |                                   |              |        |      |       |        |   |
| Full-Scale Range                           | ACCEL_FS_SEL =0                   |              | ±16    |      | g     | 2      |   |
|  | ACCEL_FS_SEL =1                   |              | ±8     |      | g     | 2      |   |
|  | ACCEL_FS_SEL =2                   |              | ±4     |      | g     | 2      |   |
|  | ACCEL_FS_SEL =3                   |              | ±2     |      | g     | 2      |   |
| ADC Word Length                            | Output in two's complement format |              | 16     |      | bits  | 2, 5   |   |
| Sensitivity Scale Factor                   | ACCEL_FS_SEL =0                   |              | 2,048  |      | LSB/g | 2      |   |
|  | ACCEL_FS_SEL =1                   |              | 4,096  |      | LSB/g | 2      |   |
|  | ACCEL_FS_SEL =2                   |              | 8,192  |      | LSB/g | 2      |   |
|  | ACCEL_FS_SEL =3                   |              | 16,384 |      | LSB/g | 2      |   |
| Sensitivity Scale Factor Initial Tolerance | Component and Board-level, 25°C   |              | ±0.5   |      | %     | 1      |   |
| Sensitivity Change vs. Temperature         | -40°C to +85°C                    |              | ±0.005 |      | %/°C  | 3      |   |
| Nonlinearity                               | Best Fit Straight Line, ±2g       |              | ±0.1   |      | %     | 3      |   |
| Cross-Axis Sensitivity                     | Board-level                       |              | ±1     |      | %     | 3      |   |
| ZERO-G OUTPUT                              |                                   |              |        |      |       |        |   |
| Initial Tolerance                          | Board-level, all axes             |              | ±20    |      | mg    | 3      |   |
| Zero-G Level Change vs. Temperature        | -40°C to +85°C                    |              | ±0.15  |      | mg/°C | 3      |   |
| OTHER PARAMETERS                           |                                   |              |        |      |       |        |   |
| Power Spectral Density                     | @ 10 Hz                           | X and Y-axis |        | 65   |       | μg/√Hz | 1 |
|  |                                   | Z-axis       |        | 70   |       | μg/√Hz | 1 |
| RMS Noise                                  | Bandwidth = 100 Hz                | X and Y-axis |        | 0.65 |       | mg-rms | 4 |
|  |                                   | Z-axis       |        | 0.70 |       | mg-rms | 4 |
| Low-Pass Filter Response                   | ODR < 1kHz                        |              | 5      |      | 500   | Hz     | 2 |
|  | ODR ≥ 1kHz                        |              | 42     |      | 3979  | Hz     | 2 |
| Accelerometer Startup Time                 | From sleep mode to valid data     |              |        | 10   |       | ms     | 3 |
| Output Data Rate                           |                                   |              | 1.5625 |      | 32000 | Hz     | 2 |

**Table 2. Accelerometer Specifications**

**Notes:**

1. Tested in production.
2. Guaranteed by design.
3. Derived from validation or characterization of parts, not tested in production.
4. Calculated from Power Spectral Density.
5. 20-bits data format supported in FIFO, see section 6.1.