## Introduction

The purpose of this application note is to illustrate how the Kionix KXG07 accelerometer-gyroscope can replace an existing Kionix KX023, KX123, or KX124 accelerometer.

## Pin Compatibility

The KX023, KX123, and KX124 accelerometer can easily be replaced by a KXG07 accelerometer-gyroscope for either an I2C or SPI interface application. In some existing KX023, KX123, and KX124 applications; the KXG07 may be drop in replaceable (hardware only).

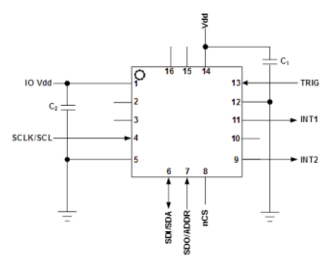
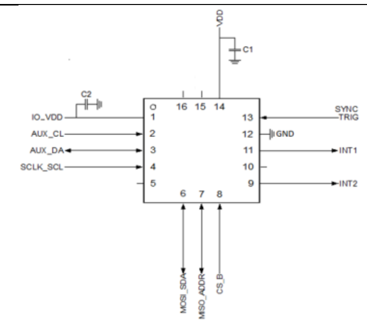
| KX023, KX123, and KX124 | | | KXG07 | | |
|---|---|---|---|---|---|
|  | | |  | | |
| **Pin** | **Name** | **Description** | **Pin** | **Name** | **Description** |
| 1 | IO_VDD | The power supply input for the digital communication bus. Optionally decouple this pin to ground with a 0.1uF ceramic capacitor. | 1 | VDDIO | External supply for IO ring. Optional Bypass capacitor C2 |
| 2 | NC | Not Internally Connected – Can be connected to VDD, IO_VDD, GND or leave floating | 2 | AUX_CL | Auxiliary I2C master serial clock. |
| 3 | NC | Not Internally Connected – Can be connected to VDD, IO_VDD, GND or leave floating | 3 | AUX_DA | Auxiliary I2C master serial data. |
| 4 | SCLK/SCL | SPI and I$^2$C Serial Clock | 4 | SCLK_SCL | SPI/I2C serial clock.[1] |
| 5 | GND | Ground | 5 | NC | Leave unconnected or connect to GND |
| 6 | SDI/SDA | SPI Data input / I2C Serial Data | 6 | MOSI_SDA | SPI MOSI / I2C serial data. [1] |
| 7 | SDO/ADDR | Serial Data Out pin during 4 wire SPI communication and part of the device address during I2C communication. | 7 | MISO_ADDR | SPI MISO / I2C slave_addr[0] |
| 8 | nCS | SPI enable / I2C mode select. Connect to GND for SPI enabled, I2C communication disabled. Connect to IO_VDD for SPI disabled, I2C communication enabled. Do not leave floating. | 8 | CS_B | SPI mode CS_B = 0 / I2C mode CS_B = 1 |
| 9 | INT2 | Physical Interrupt 2. Leave floating if not used. | 9 | INT2 | Programmable interrupt output.[2] |
| 10 | NC | Not Internally Connected – Can be connected to VDD, IO_VDD, GND or leave floating | 10 | NC | Leave unconnected or connect to GND or IO_VDD |
| 11 | INT1 | Physical Interrupt 1. Leave floating if not used.0 | 11 | INT1 | Programmable interrupt output. |
| 12 | GND | Ground | 12 | VSS | GND. |
| 13 | TRIG | Trigger pin for FIFO buffer control – Connect to GND when not using external trigger option. | 13 | SYNC_TRIG | SYNC input/output. External TRIG input for buffer function.[2,3] |
| 14 | VDD | The power supply input. Decouple this pin to ground with a 0.1uF ceramic capacitor. | 14 | VDD | External supply with Bypass capacitor C1 |
| 15 | NC | Not Internally Connected – Can be connected to VDD, IO_VDD, GND or leave floating | 15 | NC | Leave unconnected or connect to GND |
| 16 | NC | Not Internally Connected – Can be connected to VDD, IO_VDD, GND or leave floating | 16 | NC | Leave unconnected or connect to GND |

**Figure 1: Pin Description KX023, KX123, and KX124 vs. KXG07**

## Key Differences

- KXG07 additionally offers:
  - Accelerometer-Gyroscope combination (6-axis)
  - Temperature sensor
  - Timestamping
  - Larger sample buffer (4096 bytes)
  - ±16g Full Scale range selection
  - Auxiliary I2C master interface to control up to 2 additional auxiliary sensors
- KXG07 internal register definitions do not align exactly with the KX023/123/124. Since the KXG07 contains the same engines within the KX023/123/124, many of the register names are the same (bit locations may differ). Software changes are required in the user's application.
- KXG07 (highlighted notes 2, 3 in Figure 1):
  - Care must be taken with external connection of the SYNC pin. The reset state of the SYNC pin is tri-stated. If pin is not used in application, connect to IO_VDD or GND and ensure the state of the pin is never changed to output through register write to FSYNC_CTL register. If pin is configured as Output in the application, the pin must be left floating to avoid internal short circuit to IO_VDD or GND.
  - The INT2 and SYNC_TRIG pins are multifunction pins. The pin configuration changes based on the state of fsync_trig and fsync_mode[1:0] control fields per below table:

| fsync_trig | fsync_mode | INT2 | SYNC_TRIG | Notes |
|---|---|---|---|---|
| 0 | 0 | interrupt 2 | trigger | Fsync function is not enabled. |
| 0 | >0 | interrupt 2 | sync | Fsync function is enabled. |
| 1 | x | sync | trigger | |

**Figure 2: Multifunctional Pin Operation**

## Side-by-Side Comparison

The following are key similarities and differences in hardware and software between the KX023, KX123, KX124 accelerometer and the KXG07 accelerometer-gyroscope:

### Package Information

| Parameter | Units | KX023 | KX123 | KX124 | KXG07 |
|---|---|---|---|---|---|
| Sensing Axis (Accel) | | XYZ 3-axis | XYZ 3-axis | XYZ 3-axis | XYZ 3-axis |
| Sensing Axis (Gyro) | | | | | XYZ 3-axis |
| Package Size | mm | 3x3x0.9 | 3x3x0.9 | 3x3x0.9 | 3x3x0.9 |
| Package Type | | LGA | LGA | LGA | LGA |
| Pins | | 16 | 16 | 16 | 16 |

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## Features

| Parameter | Units | KX023 | KX123 | KX124 | KXG07 |
|---|---|---|---|---|---|
| Low Power Mode | | Yes | Yes | Yes | Yes |
| Self-test | | Yes | Yes | Yes | Yes |
| Wake-up | | Yes | Yes | Yes | Yes |
| Back-to-Sleep | | Yes | Yes | Yes | Yes |
| Freefall Detection | | Yes | Yes | Yes | Yes |
| Tap, Double Tap Detection | | Yes | Yes | Yes | Yes |
| Tilt Orientation Detection | | Yes | Yes | Yes | Yes |
| Sample Buffer (FIFO) | Bytes | 256 | 2048 | 2048 | 4096 |
| Accelerometer Sensor | | Yes | Yes | Yes | Yes |
| Temperature Sensor | | No | No | No | Yes |
| Gyroscope | | No | No | No | Yes |
| Timestamp | | No | No | No | Yes |
| Auxiliary I2C | | No | No | No | Yes |

## Electrical Specifications

| Parameter | | | Units | KX023 | KX123 | KX124 | KXG07 |
|---|---|---|---|---|---|---|---|
| Supply Voltage (Vdd) | | | V | 1.71–3.6 | 1.71–3.6 | 1.71–3.6 | 1.71–3.6 |
| I/O Pads Supply Voltage (IOVdd) | | | V | 1.7–Vdd | 1.7–Vdd | 1.7–Vdd | 1.7–Vdd |
| Current Consumption | Low Power | Operating (Accel Only) | µA | 10 | 10 | 10 | 15 |
| | | Operating (Gyro Only) | µA | | | | 185 |
| | | Operating (Gyro + Accel) | µA | | | | 200 |
| | High Res | Operating (Accel Only) | µA | 145 | 145 | 145 | 150 |
| | | Operating (Gyro Only) | µA | | | | 500 |
| | | Operating (Gyro + Accel) | µA | | | | 600 |
| | Standby | | µA | 0.9 | 0.9 | 0.9 | 1.5 |
| I2C Communication Rate (max) | | | MHz | 3.4 | 3.4 | 3.4 | 3.4 |
| SPI Communication Rate (max) | | | MHz | 10 | 10 | 10 | 10 |

## Environmental

| Parameter | Units | KX023 | KX123 | KX124 | KXG07 |
|---|---|---|---|---|---|
| Supply Voltage (VDD) | V | -0.3–3.63 | -0.3–3.63 | -0.3–3.63 | -0.3–3.6 |
| Operating Temperature Range | °C | -40–85 | -40–85 | -40–85 | -40–85 |
| Storage Temperature Range | °C | -55–150 | -55–150 | -55–150 | -55–150 |
| Mechanical Shock (powered and unpowered) | g | 5000 for 0.5ms<br>10000 for 0.2ms | 5000 for 0.5ms<br>10000 for 0.2ms | 5000 for 0.5ms<br>10000 for 0.2ms | 5000 for 0.5ms<br>10000 for 0.2ms |
| ESD (HBM) | V | 2000 | 2000 | 2000 | 2000 |

## Accelerometer Mechanical

| Parameter | | Units | KX023 | KX123 | KX124 | KXG07 |
|---|---|---|---|---|---|---|
| Operating Temperature Range | | °C | -40–85 | -40–85 | -40–85 | -40–85 |
| Zero-g Offset | | mg | ±25 | ±25 | ±25 | ±25 |
| Zero-g Offset Variation from RT over Temp. | | ± mg/ºC | 0.2 | 0.2 | 0.2 | 0.25 |
| Sensitivity | GSEL1=0, GSEL0=0 (±2g) | counts/g | 16384 | 16384 | 16384 | 16384 |
| | GSEL1=0, GSEL0=1 (±4g) | counts/g | 8192 | 8192 | 8192 | 8192 |
| | GSEL1=1, GSEL0=0 (±8g) | counts/g | 4096 | 4096 | 4096 | 4096 |
| | GSEL1=1, GSEL0=1 (±16g) | counts/g | | | | 2048 |
| Sensitivity Variation from RT over Temp. | | %/°C | 0.01 | 0.01 | 0.01 | 0.01 (xy)<br>0.03 (z) |
| Self-Test Output change on Activation | | g | 0.5 | 0.5 | 0.5 | 0.5 |
| Mechanical Resonance (-3dB)[1] | | Hz | 3500 (xy)<br>1800 (z) | 3500 (xy)<br>1800 (z) | 3500 (xy)<br>1800 (z) | 3500 (xy)<br>1800 (z) |
| Non-Linearity | | % of FS | 0.6 | 0.6 | 0.6 | 0.5 |
| Cross Axis Sensitivity | | % | 2 | 2 | 2 | 2 |
| Noise (RMS at 50Hz) | | mg | 0.75 | 0.75 | 0.75 | TBD |

1. Resonance as defined by the dampened mechanical sensor.

## Sensor Output Registers (Primary)

| Addr (hex) | KX023, KX123, KX124 | | KXG07 | |
|---|---|---|---|---|
| | Name | Description | Name | Description |
| 00 | XHP_L | X-axis high pass filter output low | TEMP_OUT_L | Temperature output low byte |
| 01 | XHP_H | X-axis high pass filter output high | TEMP_OUT_H | Temperature output high byte |
| 02 | YHP_L | Y-axis high pass filter output low | GYRO_XOUT_L | Gyro X-axis output low byte |
| 03 | YHP_H | Y-axis high pass filter output high | GYRO_XOUT_H | Gyro X-axis output high byte |
| 04 | ZHP_L | Z-axis high pass filter output low | GYRO_YOUT_L | Gyro Y-axis output low byte |
| 05 | ZHP_H | Z-axis high pass filter output high | GYRO_YOUT_H | Gyro Y-axis output high byte |
| 06 | XOUT_L | X-axis output low | GYRO_ZOUT_L | Gyro Z-axis output low byte |
| 07 | XOUT_H | X-axis output high | GYRO_ZOUT_H | Gyro Z-axis output high byte |
| 08 | YOUT_L | Y-axis output low | ACC_XOUT_L | Accel X-axis output low byte |
| 09 | YOUT_H | Y-axis output high | ACC_XOUT_H | Accel X-axis output high byte |
| 0A | ZOUT_L | Z-axis output low | ACC_YOUT_L | Accel Y-axis output low byte |
| 0B | ZOUT_H | Z-axis output high | ACC_YOUT_H | Accel Y-axis output high byte |
| 0C | | | ACC_ZOUT_L | Accel Z-axis output low byte |
| 0D | | | ACC_ZOUT_H | Accel Z-axis output high byte |

## The Kionix Advantage

Kionix technology provides 6 Degrees-of-Freedom inertial sensor system on a single, silicon chip, which is designed to strike a balance between current consumption and noise performance with excellent bias stability over temperature. A gyroscope accelerometer can be used to enable a variety of simultaneous features including, but not limited to:

Hard Disk Drive protection
Vibration analysis
Tilt screen navigation
Sports modeling
Theft, man-down, accident alarm
Image stability, screen orientation & scrolling
Computer pointer
Navigation, mapping
Game playing
Automatic sleep mode
Remote controls
Toys

## Theory of Operation

During operation, the gyroscope sensor elements are forced into vibration. When angular velocities are applied about the sensing axes, vibration is transferred to sensing elements, causing capacitance changes at the sensor electrodes. Acceleration sensing is based on the principle of a differential capacitance arising from acceleration-induced motion of the sense element, which utilizes common mode cancellation to decrease errors from process variation, temperature, and environmental stress. Capacitance changes are amplified and converted into digital signals which are processed by a dedicated digital signal processing unit. The digital signal processor applies filtering, bias and sensitivity adjustment, as well as temperature compensation. The DSP also feeds back the driving signal to ensure the proper sensor excitation.

For product summaries, specifications, and schematics, please refer to the Kionix MEMS accelerometer product catalog at [http://www.kionix.com/parametric/6-Axis Combo Parts And 9-Axis Solutions](http://www.kionix.com/parametric/6-Axis Combo Parts And 9-Axis Solutions)