Introduction

There is a growing interest in 6 Degree-of-Freedom inertial sensor solutions for purpose of enhancing end user experience. This application note will help developers quickly implement proof-of-concept designs using Kionix's KMX62, a tri-axis accelerometer and tri-axis magnetometer single chip combo solution. Please refer to the KMX62 data sheet for additional implementation guidelines. Kionix strives to ensure that our sensors will meet design expectations by default, but it is not possible to provide default settings to work in every environment. Depending on the intended application, it is very likely that some customization will be required in order to optimize performance. The information provided here will help the developer get the most out of the KMX62 combo sensor.

Circuit Schematic

This section shows recommended wiring for the KMX62, based on proven operation of the part. Specific applications may require modifications from these recommendations. Please refer to the KMX62 Data Sheet for all pin descriptions.

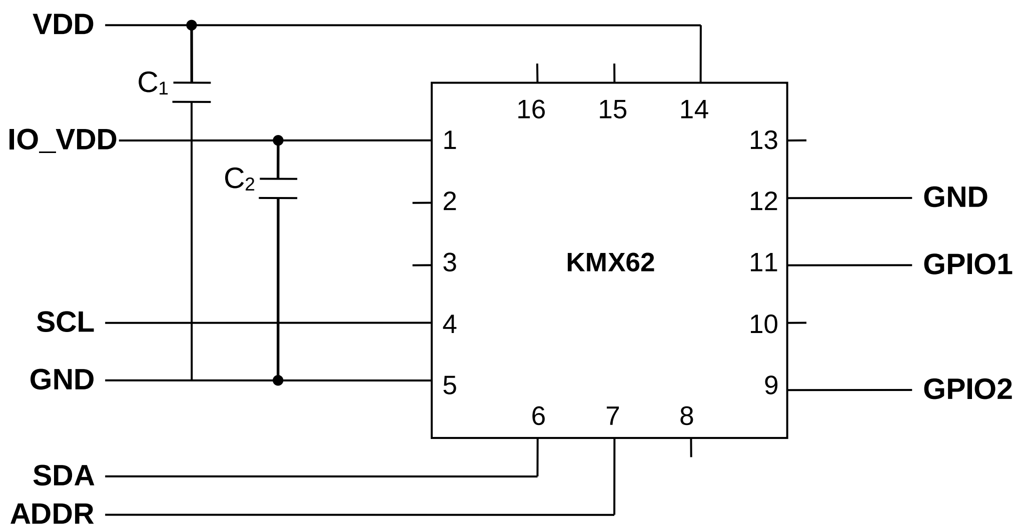

Figure 1. Application Schematic

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Implementation

Here we present several basic ways to initialize the part. These can vary based on desired operation, but generally the initial operations a developer wants to do are: 1) read back acceleration and magnetic field data asynchronously, 2) read back acceleration and magnetic field data when next data is ready via interrupt, 3) use the Wake Up function of accelerometer to place magnetic sensor from stand-by to operating mode. These cursory solutions are provided as a means for configuring the part to a known operational state. Note that these conditions just provide a starting point, and the values may vary as developers refine their application requirements.

1. Asynchronous Read Back of Acceleration and Magnetic Field Data

a) Write 0x00 to Control Register 2 (CNTL2) to set the register to its default value.

Register Name	Address	Value
CNTL2	0x3A	0x00

b) Write 0x22 to Data Control Register (ODCNTL) to set the Output Data Rate (ODR) of the accelerometer and magnetometer to 50 Hz. (Note: This is also the default value.)

Register Name	Address	Value
ODCNTL	0x2C	0x22

c) Write 0x0F to Control Register 2 (CNTL2) to (1) disable the temperature sensor, (2) set the G-range to ±2g, (3) enable full resolution mode, and (4) set the accelerometer and magnetometer into operating mode.

Register Name	Address	Value
CNTL2	0x3A	0x0F

d) Acceleration and Magnetic field data can now be read asynchronously from the ACCEL_XOUT_L, ACCEL_XOUT_H, ACCEL_YOUT_L, ACCEL_YOUT_H, ACCEL_ZOUT_L, ACCEL_ZOUT_H, MAG_XOUT_L, MAG_XOUT_H, MAG_YOUT_L, MAG_YOUT_H, MAG_ZOUT_L, and MAG__ZOUT_H registers in 2's complement format.

2. Synchronous Hardware Interrupt Read Back of Acceleration and Magnetic Field Data

a) Write 0x00 to Control Register 2 (CNTL2) to set the register to its default value.

Register Name	Address	Value
CNTL2	0x3A	0x00

b) Write 0x18 to Interrupt Control Register 1 (INC1) to enable reporting availability of new accelerometer and magnetometer data via physical interrupt pin INT1 (GPIO1)

Register Name	Address	Value
INC1	0x2A	0x18

c) Write 0x04 to Interrupt Control Register 3 (INC3) to configure the physical interrupt pin to push/pull, active high, and latched operation.

Register Name	Address	Value
INC3	0x2C	0x04

d) Write 0x22 to Data Control Register (ODCNTL) to set the Output Data Rate (ODR) of the accelerometer and magnetometer to 50 Hz. (Note: This is also the default value.)

Register Name	Address	Value
ODCNTL	0x38	0x22

e) Write 0x0F to Control Register 2 (CNTL2) to (1) disable the temperature sensor, (2) set the G-range to ±2g, (3) enable full resolution mode, and (4) set the accelerometer and magnetometer into operating mode.

Register Name	Address	Value
CNTL2	0x3A	0x0F

f) Acceleration and Magnetic field data can now be read synchronously from the ACCEL_XOUT_L, ACCEL_XOUT_H, ACCEL_YOUT_L, ACCEL_YOUT_H, ACCEL_ZOUT_L, ACCEL_ZOUT_H, MAG_XOUT_L, MAG_XOUT_H, MAG_YOUT_L, MAG_YOUT_H, MAG_ZOUT_L, and MAG__ZOUT_H registers in 2's complement format.

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3. *Motion Detection Function*

a) Write 0x00 to Control Register 2 (CNTL2) to set the register to its default value.

Register Name	Address	Value
CNTL2	0x3A	0x00

b) Write 0x02 to Interrupt Control Register 1 (INC1) to enable reporting of the new accelerometer motion detection via physical interrupt pin INT1 (GPIO1)

Register Name	Address	Value
INC1	0x2A	0x02

c) Write 0x04 to Interrupt Control Register 3 (INC3) to configure the physical interrupt pin to push/pull, active high, and latched operation.

Register Name	Address	Value
INC3	0x2C	0x04

d) Write 0x3F to Interrupt Control Register 4 (INC4) to define the direction of detected motion for all positive and negative directions: x positive (x+), x negative (x-), y positive (y+), y negative (y-), z positive (z+), z negative (z-) directions.

Register Name	Address	Value
INC4	0x2D	0x3F

e) Write 0x08 to Accelerometer Motion Control Register 1 (AMI_CNTL1) to set the level to 0.5g. The following formula is used:

AMITH (counts) = Desired Threshold (g) x 16 (counts/g)

AMITH (counts) = 0.5 x 16 = 8 counts

Note that this threshold is differential with respect to the previous reading.

Register Name	Address	Value
AMI_CNTL1	0x2F	0x08

f) Write 0x05 to Accelerometer Motion Control Register 2 (AMI_CNTL2) to set the time motion must be present before a wake-up interrupt is set to 0.1 second. The following formula is used:

AMICT (counts) = Desired Delay Time (sec) x OWUF (Hz)

AMICT (counts) = 0.1 x 50 = 5 counts

Since the desired delay time is 0.1 second and the OWUF will be set to 50 Hz (next step), then the motion detection timer is 5 counts (0x05).

Register Name	Address	Value
AMI_CNTL2	0x30	0x05

g) Write 0x86 to Accelerometer Motion Control Register 3 (AMI_CNTL3) to enable the motion interrupt engine, set the interrupt to latched mode, and set the Output Data Rate of the motion detection (OAMI) to 50 Hz.

Register Name	Address	Value
AMI_CNTL3	0x31	0x86

h) Write 0x01 to Control Register 2 (CNTL2) to enable the accelerometer. The accelerometer must be enabled for motion detection.

Register Name	Address	Value
CNTL2	0x3A	0x01

i) Monitor the physical interrupt INT1 of the accelerometer, if the acceleration input profile satisfies the criteria previously established for the 0.5g motion detect threshold level in both positive and negative directions of the X, Y, Z axis for more than 0.1 second, then there should be positive latched interrupt present and the magnetometer portion of the sensor will be place into full operation.

j) Read Interrupt Release (INL) register to unlatch (clear) the output interrupt created by the motion detection function.

Register Name	Address	Value
INL	0x05	n/a

Timing Requirements

There are several timing requirements that developers should keep in mind when working with the KMX62.

I²C Clock - The I²C Clock can support Fast Mode up to **400 KHz** and High Speed mode up to **3.4 MHz**.

Power Up to Communication - After the part is powered up, it takes maximum **50 ms** before it is ready for I²C communication.

Enable to Valid Outputs - After the part is enabled ACT_STBY or MAGSTBY bit in STBY_REG is asserted), it takes from **3.4 ms** to **80 ms** depending on the ODR before valid data is available. (See KMX62 Product Specification for details)

Software Reset/Power On Reset Delay - After a Software or Power On Reset, the part takes maximum of **50ms** before it is ready for I²C communication.

Interrupt Configuration

Each physical interrupt (GPIO1 and GPIO2) have 6 possible configurations, based on two states for each of the three customizable variables located in Interrupt Control Register 3:

Latched/Pulsed (IEL)

0 – Latched mode – When an interrupt is triggered, it will remain active on the pin until cleared.

1 – Pulse mode – When an interrupt is triggered, it will cause a short (~50µs) pulse on the pin and clear itself.

Polarity (IEA)

0 – Active Low – The interrupt pin will normally be HIGH, but will transition to LOW when an interrupt is triggered.

1 – Active High – The interrupt pin will normally be LOW, but will transition to HIGH when an interrupt is triggered.

Enable/Disable (IEN)

0 – Disabled – Interrupt conditions will not be reflected on the physical interrupt pin.

1 – Enabled – Interrupt conditions will be reflected on the physical interrupt pin.

A Few Interrupt Tips

Read the Interrupt Release Register to Clear

In latched mode, the INL register must be read in order to clear the physical interrupt pin. This will also clear the Interrupt Source Registers and the INT bit (0x10) in the Status Register.

Microcontroller/GPIO Interrupt Handling –

GPIO configuration is based solely on the connected hardware. The KMX62 can be configured to issue interrupts depending on how the GPIO is programmed to catch them (if this is not the case, please contact your Kionix Sales Representative). Generally, when an interrupt is triggered, the developer should take the following steps:

1- Disable GPIO interrupt
2- Clear GPIO interrupt and generate desired functionality
3- Enable GPIO interrupt

These steps should be taken without calling any digital communication transactions if done in an interrupt context, because the operating system or kernel will not allow busy-waiting on an I/O operation during an interrupt service routine.

Interrupt Polling - If physical interrupts are not used, a polling mechanism can be devised, which checks the INT bit in INS1 (Interrupt Source Register 1) to be set. In addition, this mechanism can also look at the remaining bits in INS1 to determine which function caused the interrupt and what steps should be taken before clearing the interrupt source information by reading the INL register.

Troubleshooting

All Interrupt Issues

- Make sure the KMX62 is configured to issue interrupt signals in the way that your GPIO is programmed to handle them.
- An oscilloscope on the physical interrupt pin can be a valuable tool to confirm physical interrupt operation.
- Double check the AMI Mask bits in Interrupt Control 3 (INC3)
- The AMI Timer is based on the AMI Output Data Rates, so make sure the correct cycle time is used when calculating the expected timer length (please refer to the KMX62 product specification).

AMI (Active Motion Interrupt) Not Working

- Make sure that the AMI engine is enabled (AMI_EN bit in Active Motion Control Register 3).
- Try altering the threshold requirements to achieve desired operation. If the part is waking up too easily, try increasing the threshold. If the interrupt is not firing at all, the threshold may be set too high.
- Try shortening the timer requirements, and make sure the acceleration on an unmasked axis is above the threshold until the expiration of the WUF Timer.

Placement and Orientation

Placement

- It is important to note that the placement of the KMX62 within the target device can especially have a significant effect on the magnetometer portion of the sensor. Please refer to AN043 Preliminary Review for Magnetometer Integration for further guidance on magnetometer integration.

The Kionix Advantage

Kionix technology provides for X, Y, and Z-axis sensing on a single, silicon chip. One 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

Theory of Operation

Kionix MEMS linear tri-axis accelerometers function on the principle of differential capacitance. Acceleration causes displacement of a silicon structure resulting in a change in capacitance. A signal-conditioning CMOS technology ASIC detects and transforms changes in capacitance into an analog output voltage, which is proportional to acceleration. These outputs can then be sent to a micro-controller for integration into various applications.

Magnetic sensing is based on the principle of magnetic impedance. The magnetic sensor detects very small magnetic fields by passing an electric pulse through a special electron spin aligned amorphous wire. Due to the high Curie temperature of the wire, the sensor's thermal performance shows excellent stability.

For product summaries, specifications, and schematics, please refer to the Kionix MEMS 6-axis combo parts and 9-axis solutions product catalog at http://www.kionix.com/parametric/6-Axis Combo Parts And 9-Axis Solutions