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# DRM103 Designer Reference Manual

## Devices Supported:

**MMA7361L**
**MMA7455L**
**MMA7660FC**

Document Number: DRM103
Rev. 2
11/2009

Energy Efficient Solutions by Freescale™

freescale semiconductor™

Safety of Radio Frequency Energy

The manufacturer has evaluated the transmitter for safe operation for uncontrolled use in the general population. The measured power density at 1 cm is under the threshold established by the FCC and is not required to be tested for specific absorption rate. The manufacturer instructs the user that the transmitter should not be handled or placed near the body continuously for more than 30 minutes while operating.

USA:

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

– Reorient or relocate the receiving antenna.
– Increase the separation between the equipment and receiver.
– Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
– Consult the dealer or an experienced radio/TV technician for help.

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

The antenna(s) used for this transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

Canada:

This digital apparatus complies with Canadian ICES-003.

Cet appareil numérique est conforme à la norme NMB-003 du Canada.

Europe:

Compliant (CE)

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# Chapter 1
# Introduction

## 1.1 Introduction

This paper describes the next generation of a Wireless Sensing Triple Axis Reference Design (ZSTAR). This demo represents a wireless demonstration of the 3-axes accelerometer sensors, the MMA7455L (RD3172MMA7455L), the MMA7361L (RD3172MMA7361L) and the MMA7660FC (RD3172MMA7660FC) from Freescale. ZSTAR3 is the successor to the previous Freescale demo ZSTAR and is fully compatible with it. The Demo is built on a new generation of Freescale parts and brings some new extended functionalities.

The reference design will enable you to see how Freescale's accelerometers can add additional functionality to applications in various industries. The accelerometer measurements can be grouped into 6 sensing functions - Fall, Tilt, Motion, Positioning, Shock and Vibration - for multifunctional applications.

The RD3172MMA7455L / RD3172MMA7361L / RD3172MMA7660FC development tool offers robust wireless communication using the powerful, easy-to-use 2.4 GHz frequency transceiver and microcontroller in the one package MC13213. Without any changes on board, it can be made with pin to pin compatibility allowing implementation of the MC13214 for ZigBee® wireless applications.

Only the sensor board was updated completely, as the receiver used is still the USB stick from the previous generation of ZSTAR, but new software was developed that supports all the new functionalities.

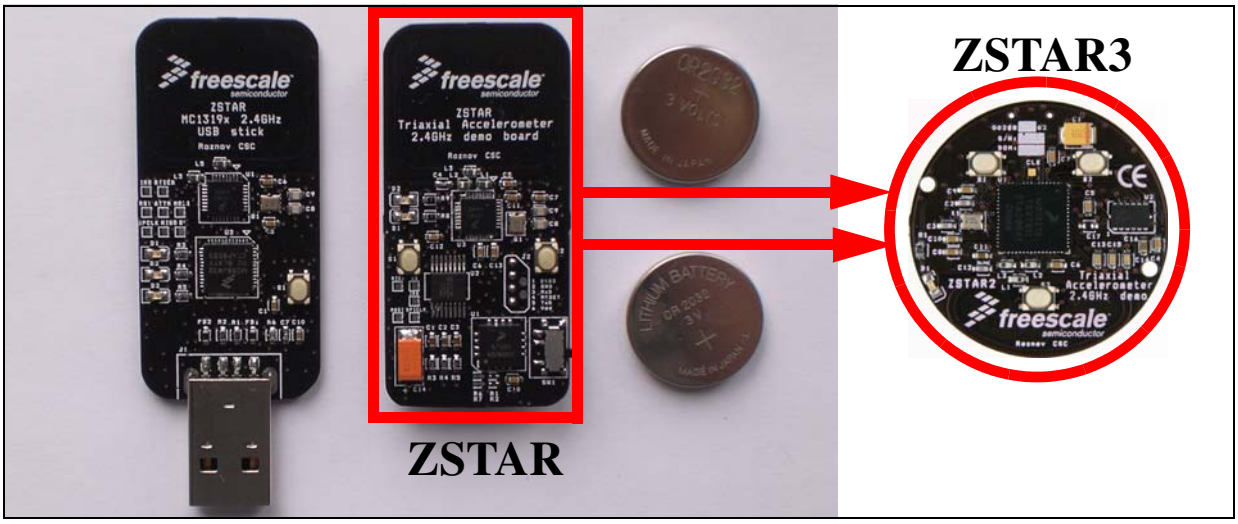



**Figure 1-1. The ZSTAR Demo Migration Photo (CR2032 batteries for comparison)**

# Chapter 2
# ZSTAR3 Wireless Sensing Triple Axis Reference Design Introduction

## 2.1 Introduction

The Wireless Sensing Triple Axis Reference Design (ZSTAR3) was designed as a new generation of the previous ZSTAR (RD3152MMA7260Q) demo. A 2.4 GHz Radio Frequency (RF) link is also used in this new demo and its based on the new solution modem and microcontroller in one package MC13213 family. It's used for connection between the sensor and PC, allowing visualization of key accelerometer applications as in the previous demo.

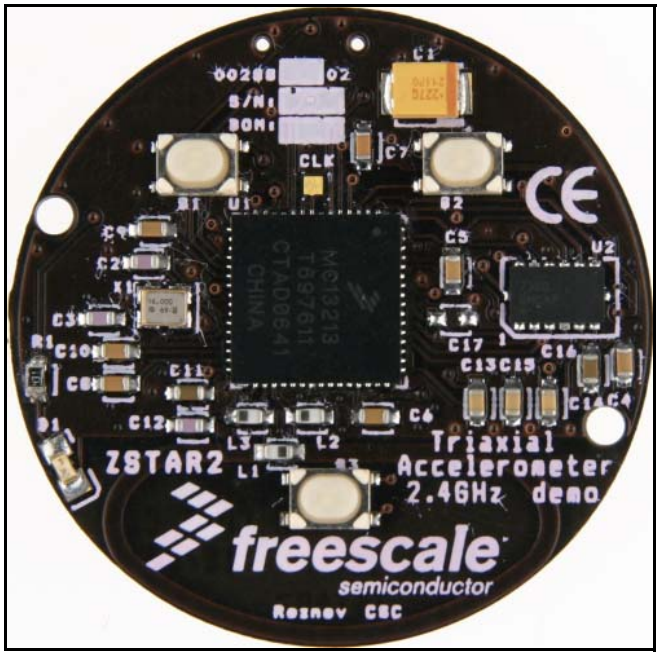



**Figure 2-1. ZSTAR3 Sensor Board**

The demo consists of two boards (a new one and an older one with new software):

- Sensor Board (or remote board) is a new board designed for demonstrating Freescale's new 3-axes accelerometer solution for digital (MMA7455L, MMA7660FC) and analog (MMA7361LT) accelerometric data sensing, and the 2.4 GHz RF modem with an HCS08 microcontroller in a one package solution as an easy design for remote sensors.
- USB stick, with the MC13191 RF front-end, and the HC08 family MCHC908JW32 for the USB communication. This board is used from the older ZSTAR demo, but with new software.

Both sides communicate over the RF medium utilizing the freely available lightly modified software stack Simple Media Access Control (SMAC) from Freescale.

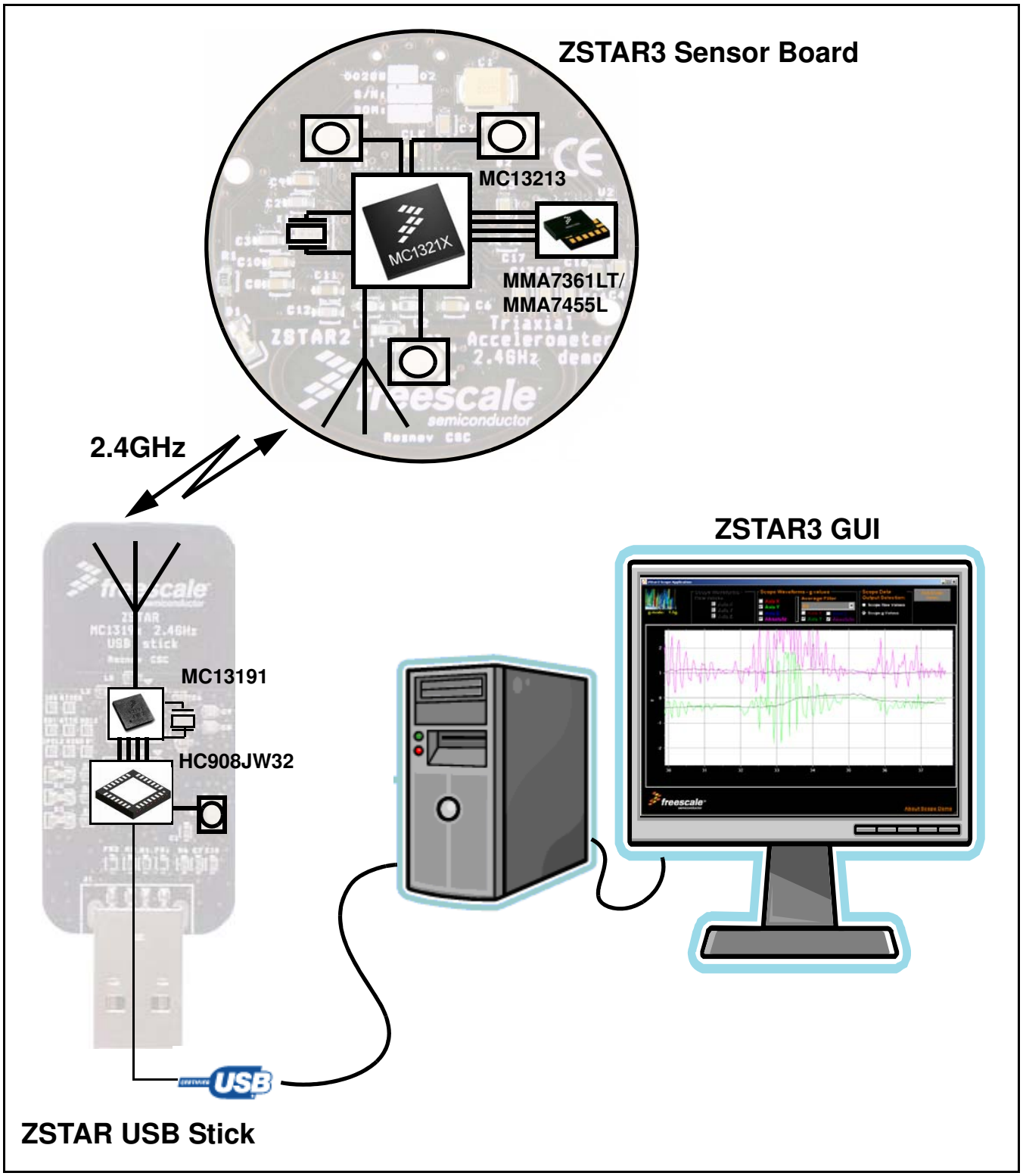



Figure 2-2. ZSTAR3 Block Diagram

## 2.2 Features of ZSTAR3

- Sensing acceleration in 3 axes
- Handles digital and analog sensors
- Wireless communication with sensors through the **2.4 GHz** band
- **RF protocol supports 16 sensors per one USB stick (receiver)**
- Star topology of the RF network
- Data rate of a sensor is 30, 60 or 120 Hz
- Typical wireless range is 20 m, two walls or one floor
- Auto calibration function of the sensor
- USB communication on the receiver part
  - Virtual serial port - interface for the GUI and serial port terminal
  - HID class - mouse for windows
  - HID class – keyboard (game controller)
- 8-bit/16-bit working modes
- 3 push buttons on the sensor board
- Current consumption:
  - in normal run mode: 1.8 - 3.9 mA, depending on the actual data rate
  - in sleep mode: less than 900 nA
- Power consumption depends on the current output values of the sensor. At a standstill, the board transmits only every 10th packet
- Sensor Board is powered by a coin-sized CR2032 3 V battery
- Small size board fits a circular plastic box.

## 2.3 Featured Products

This demo consists of several Freescale products whose main features are listed below. It is made up of two accelerometers, because the sensor board can be assembled with digital or analog Freescale accelerometers.

### 2.3.1 Triple Axis Analog Accelerometer MMA7361L

The MMA7361LT is a low power, low profile capacitive micromachined accelerometer featuring signal conditioning, a 1-pole low pass filter, temperature compensation, self-test, 0g-detect which detects linear freefall, and g-Select which allows for the selection between 2 sensitivities. Zero-g offset and sensitivity are factory set and require no external devices. The MMA7361LT includes a sleep mode that makes it ideal for handheld battery powered electronics.

**Features:**

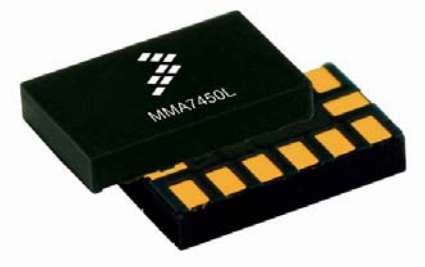
- 3 x 5 x 1.0 mm LGA-14-pin package
- Low current consumption: 400 µA
- Sleep mode: 3 µA
- Low voltage operation: 2.2 V - 3.6 V

- High sensitivity (800 mV/g at 1.5g)
- Fast turn on time (0.5 ms enable response time)
- Self-test for freefall detect diagnosis
- 0g-Detect for freefall protection
- Signal conditioning with low pass filter
- Robust design, high shocks survivability
- RoHS compliant
- Environmentally preferred product
- Low cost

### 2.3.2 Triple Axis Digital Accelerometer MMA7455L

The MMA7455L is a digital output ($I^2C$/SPI), low power, 3 x 5 x 0.8 mm low profile package capacitive micromachined accelerometer featuring signal conditioning, a low pass filter, temperature compensation, self-test, configured to detect 0g through interrupt pins (INT1 or INT2), and pulse (click) detect for quick motion detection. The 0g offset can be customer calibrated using assigned 0g registers and g-Select which allows for command selection of 3 sensitivities (2g/4g/8g). Zero-g offset and sensitivity are factory set and require no external devices. The MMA7455L includes a standby mode that makes it ideal for handheld battery powered electronics.

**Features:**




- Digital output ($I^2C$/SPI) for processor system performance
- Low-profile 14-pin 3 x 5 x 0.8 mm LGA package
- LGA volume is 77 percent smaller than a Quad Flat No-Lead (QFN) package
- XYZ: three axes of sensitivity in one device (2g, 4g, 8g)
- Low current consumption: 400 µA
- Standby mode: 5 µA
- Low-voltage operation: 2.4 V - 3.6 V
- Customer assigned registers for offset calibration
- Programmable threshold interrupt output
- Level detection for motion recognition (shock, vibration, freefall)
- Single or double click (pulse) recognition
- High sensitivity
  - 64 LSB/g at 2g
  - 64 LSB/g at 8g in 10-bit mode

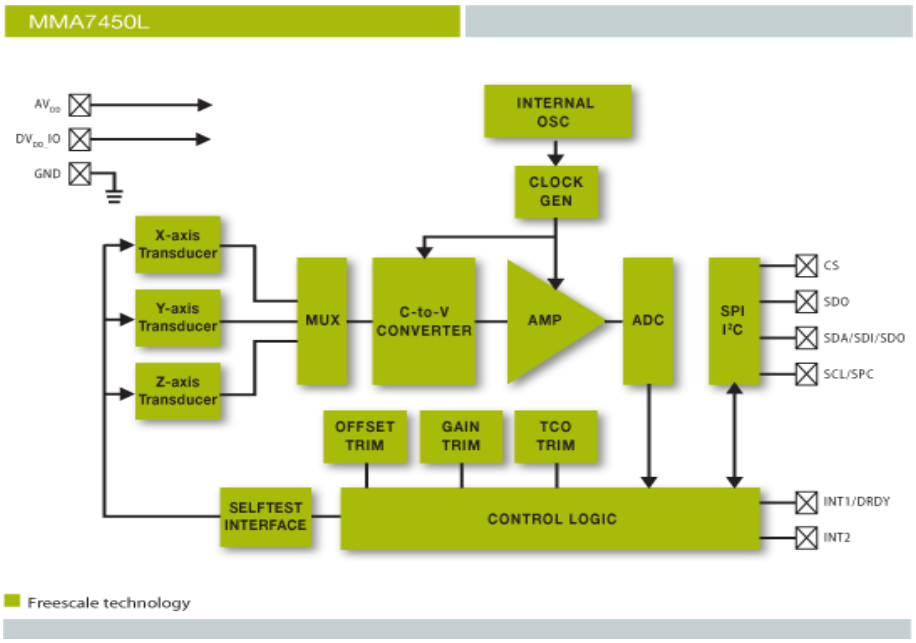



**Figure 2-3. Block diagram of MMA7455L**

### 2.3.3 Triple Axis Digital Accelerometer MMA7660FC

The MMA7660FC is a Digital Output ($I^2C$), very low power, low profile capacitive micro machined accelerometer featuring a low pass filter, compensation for 0g offset and gain errors, and conversion to 6-bit digital values at a user configured output data rate. The device can be used for sensor data changes, product orientation, and gesture detection through an interrupt pin (INT). The device is housed in an extremely small 3 x 3 x 0.9 mm DFN package.

**Features:**


- Digital Output ($I^2C$)
- 3 x 3 x 0.9 mm DFN package
- Low Power Current Consumption
  - Off Mode: 0.4 µA
  - Standby Mode: 2 µA
  - Active Mode: Configured down to 47 µA
- Low Voltage Operation: 2.4 V – 3.6 V
- 3-Axis ±1.5 g MEMS Sensor and CMOS Interface Controller Built Into One Package
- Configured Output Data Rate From 1 to 120 Samples A Second
- Auto Wake/Sleep Feature for Low Power Consumption
- Tilt Orientation Detection for Portrait/Landscape Capability
- Gesture Detection Including Shake Detection and Pulse Detection
- Robust Design, High Shocks Survivability (10,000 g)
- RoHS Compliant
- Environmentally Preferred Product
- Low Cost

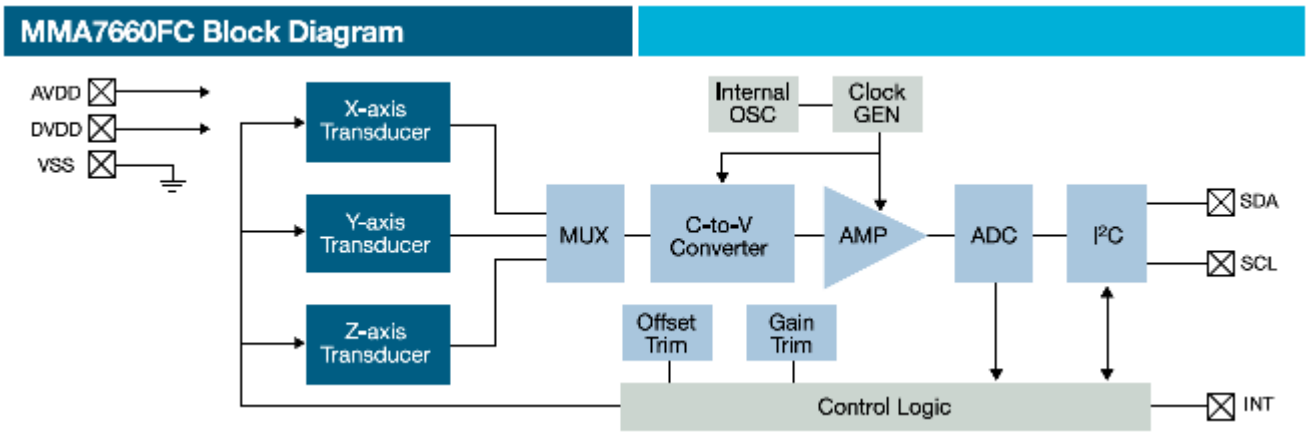



**Figure 2-4. Block diagram of MMA7660FC**

## 2.3.4 The SiP (System in Package) MC13213

The MC13213 System in Package (SiP) integrates the MC9S08GT MCU with the MC1320x transceiver into a single 9 x 9 mm LGA package. The MC13213 provides 60 K Flash memory and 4 K of RAM. By using the IEEE® 802.15.4 Compliant MAC, or BeeStack™ ZigBee Protocol Stack, the MC13213 is an ideal solution for sensing and control applications that require mesh networking.

**Features:**

- 40 MHz HCS08 low-voltage, low-power core
- 60 KB Flash and 4KB RAM memory
- Seven addressing modes for the CPU
- Multiple 16-bit timers
- 2 V to 3.4 V operating voltage with on chip voltage regulator
- -40 to +85 °C operating temperature
- Low external component count
- Requires a single 16 MHz crystal
- Programmable frequency clock output for MCU
- Auto-trim feature for crystal accuracy
- Eliminates the need for external variable capacitors
- Allows for automated production frequency calibration
- 9 x 9 x 1 mm 71-pin LGA package
- RoHS compliant
- Up to 38 GPIO's

- 8-bit port KeyBoard Interrupt (KBI)
- 8-channel 10-bit Analog-to-Digital Converter (ADC)
- Two independent Serial Communication Interfaces (SCI) supporting up to 115.2 kBaud
- Inter-integrated circuit ($I^2C$) with 100 kbps maximum bus loading
- Internal Clock Generator (ICG) at 100 kHz or 16 MHz (including internal reference generator)
- Low-voltage detection
- In-circuit debug and Flash programming available via on-chip background debug module (BDM)
- Programmable Low Voltage Interrupt (LVI)
- Common On-chip Processor (COP) watchdog timer
- Operates in the 2.4GHz band
- 250 kbps O-PQSK modulation
- 16 selectable channels
- 0 dBm nominal output power
- Programmable from -27 dBm to +3 dBm
- Receive sensitivity of -92 dBm (typical) at 1% PER
- Integrated transmit/receive switch
- Supports single-ended or full differential operation
- Supports external Low-Noise Amplifier (LNA) and/or Power Amplifier (PA)
- Three lower power modes for increased power life
- Supports streaming and data processing modes

**Software Features:**

- Simple MAC
  - Small memory footprint (< 4 KB)
  - Supports point-to-point and star network configurations
  - ANSI C source code
- IEEE 802.15.4 compliant MAC
  - Supports star, mesh and cluster tree topologies
  - Supports beaconed and non-beaconed networks
  - Supports Guaranteed Time Slots (GTS) for predicable latency
  - 128-bit Asymmetric Encryption Standard (AES)
  - Object Code
- BeeStack ZigBee Protocol Stack
  - ZigBee 2006 Compliant Platform
  - Object Code

# Chapter 3
# ZSTAR3 Sensor Board Description

## 3.1 Board Overview

The Sensor Board utilizes a small footprint size dual-layer Printed Circuit Board (PCB) containing all the necessary circuitry for both accelerometer sensors and transferring data over a Radio Frequency (RF).

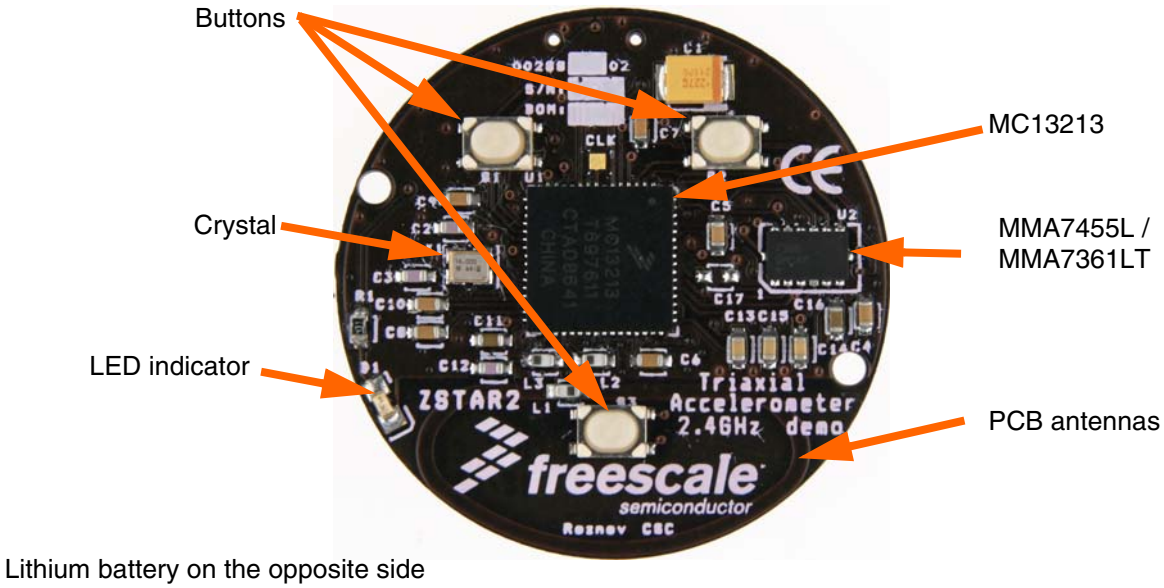



**Figure 3-1. ZSTAR3 Sensor Board Overview**[1]

1. This is valid for 00288_02 PCB revision (black edition). For new revision (00288_04) see chapter **3.4 New PCB Revision 00288_04**.

The board is powered by a Lithium coin-sized CR2032 battery. The block diagram of the board is as follows:

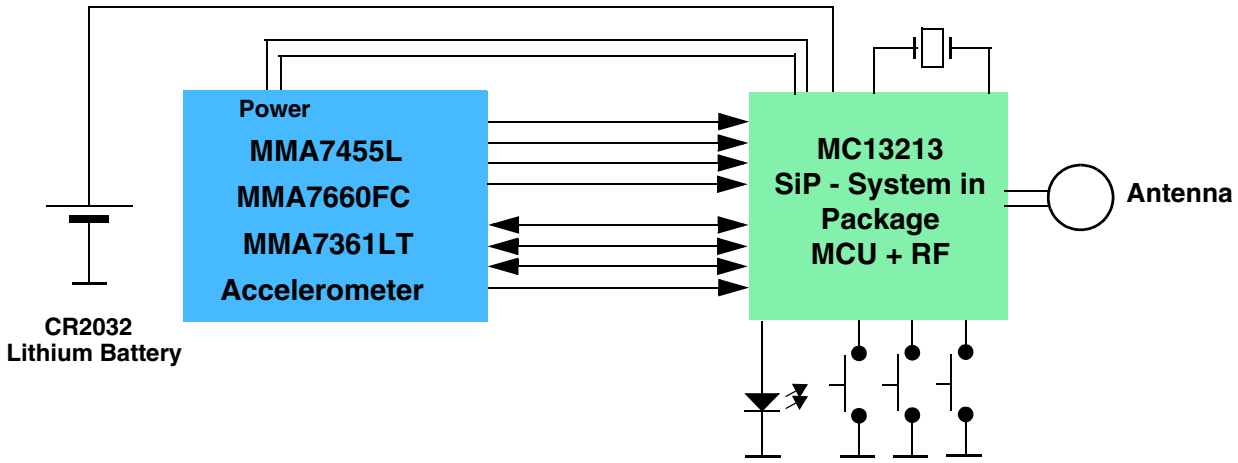



**Figure 3-2. Sensor Board Block Diagram[1]**

Figure 3-3 shows in more detail, how different software and hardware modules cooperate with each other. The main task of the Sensor Board is to:

- Periodically wake-up from power saving mode
- Measure all three XYZ acceleration values from the Sensor
- Compose a data frame using simple The ZSTAR3 RF Protocol
- Use Simple Media Access Controller (SMAC) to send this data frame over the RF link
- Go to sleep.

This basic loop repeats 30 times per second (period is 33.333 ms) providing nearly a real-time response from the Sensor.

1. The MMA7660FC is supported by new PCB with revision code 00288_04.

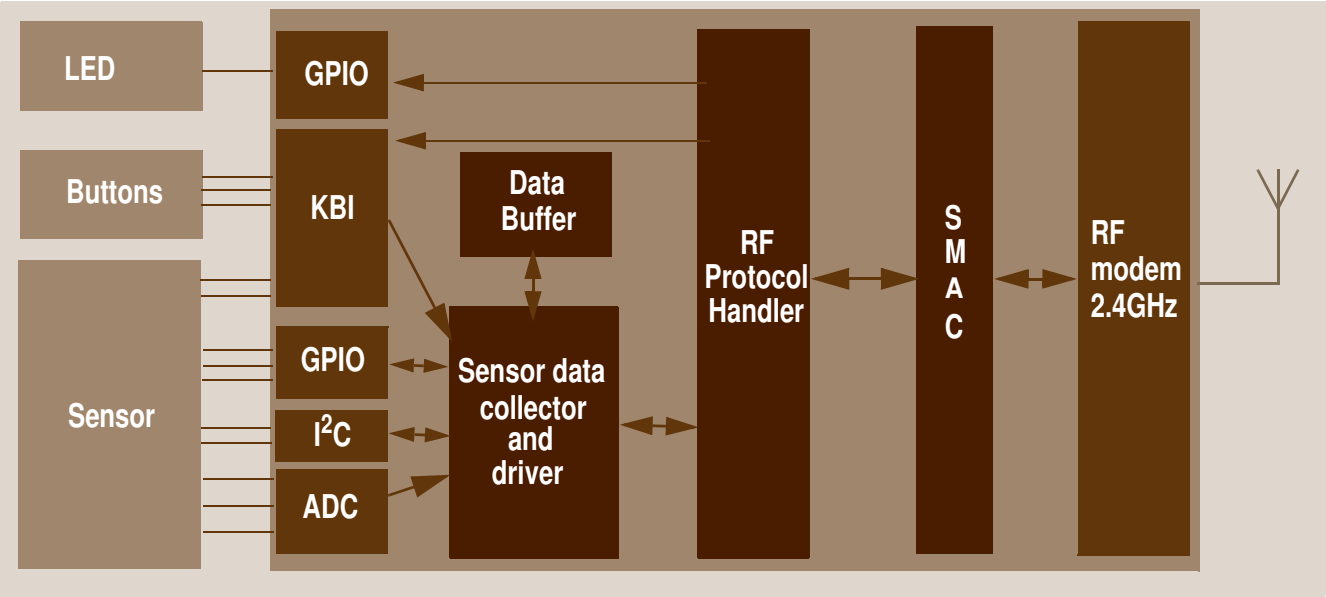



**Figure 3-3. ZSTAR3 Sensor Board Software Overview**

For the Sensor Board operation, several of the MC13213's hardware modules are used: Analog-to-Digital Converter (ADC), Synchronous Peripheral Interface (SPI), External Interrupt Request (IRQ), Keyboard Interrupts and General Purpose Input/Output (GPIO).

## 3.2 Accelerometric Sensor SW Controller

Reading of the XYZ levels and all other operations with sensor is dependent on the currently assembled sensor. The ZSTAR3 sensor board supports two types of Freescale accelerometric sensors, analog (MMA7361L) and digital (MMA7455L, MMA7660FC[1]). The assembled sensor is powered by the MCU I/O pins, because the solution achieves lowest power consumption in sleep mode.

### 3.2.1 Multi Sensor Support Software Model

All common sensor control functions are physically created as a single functions. Each type of sensor has own function designed for sensor needs. The main software only uses volatile pointers to these functions, which are assigned within program initialization, by the `Recognise_Sensor()` function. This function recognizes an assembled sensor and assigns the correct function address of functions to the volatile RAM pointers. For example, in this way the analog sensor uses the ADC to read XYZ sensor values of sensor and the digital sensor uses the digital interface, but in the source code there is only one line:

```
p_Read_Accelerometer((void*) &(accel_data[0].x)).
```

1. The MMA7660FC is supported by new PCB with revision code 00288_04.

### 3.2.2 Auto Calibration Process

The software uses for both types of sensor an auto calibration process to get the offset calibration values. It uses a simple 0g X, 0g Y, +1g Z auto calibration method. The sensor board runs the auto calibration process for each g scale of the sensor, and thus uses an individual set of calibration values for each g scale. For more details, see Freescale application note AN3447, “Implementing Auto-Zero Calibration Techniques for Accelerometers” at www.freescale.com.

### 3.2.3 Analog Sensor Software Support

The 3-axis accelerometer sensor MMA7361L provides three separate analog levels for the X, Y and Z axis. These outputs are ratiometric, which means that the output offset voltage and sensitivity will scale linearly with the applied supply voltage. This is a key feature when interfacing to a microcontroller with A/D converter reference levels tied to a power supply, because it provides a system level cancellation of supply induced errors in the analog-to-digital conversion process.

During the analog-to-digital conversion in the microcontroller, 10-bit resolution is used. MC13213 A/D channels 0, 1 and 2 are connected to X (channel 1), Y (channel 2) and Z (channel 0) outputs of the MMA7361L. The microcontroller’s `APCTL1` register enables these ADC channels for I/O pin control by the ADC module.

The `ADCCFG` register controls the selected mode of operation, clock source, clock divide, and configuration for low power or long sample times.

The MMA7361L sensor implements a digital output for the freefall detection module. This output is connected directly to the KeyBoard Interrupt (KBI) module and it’s used as the default source for freefall detection.

### 3.2.4 Digital Sensor Software Support

The ZSTAR3 sensor board provides support for sensors with digital interface. The interface contains pins routed to KBI, $I^2C$ and general GPIO pins. So the interface can handle hardware $I^2C$ bus[1], or any other standard that can be handled by GPIO pins controlled by software. Also the KBI interface can supports interrupt signals of used sensors.

1. This is valid for 00288_04 PCB revision (red edition). See chapter **3.4 New PCB Revision 00288_04**. The old one version of PCB 00288_02 doesn’t provide external pull-up’s on $I^2C$ bus.

### 3.2.5 Power Management

A CR2032 Lithium battery provides a fairly limited charge for such a real-time-like demo that demands frequent transmissions. Some sort of power management has to be implemented in order to keep the current consumption at a reasonable level.

Typically, current consumptions of the Sensor Board components are as follows:

- SiP - System in Pack MC13213
  - 2.4GHz transceiver of the MC13213
    - in Off mode, 200 nA
    - in Hibernate mode, 2.3 µA
    - in Doze mode, 35 µA
    - in Idle mode, 500 µA
    - in Transmit mode, 30 mA
    - in Receive mode, 37 mA
  - 8-bit microcontroller of the MC13213
    - in Stop3 mode, 700 nA
    - in Wait mode, 560 µA
    - in Run mode, 6.5 mA
- Tri-axial accelerometers
  - low-g tri-axial analog sensor MMA7361L
    - in Sleep mode, 3 µA
    - in Normal mode, 400 µA
  - low-g tri-axial digital sensor MMA7455L
    - in Sleep mode, 5 µA
    - in Normal mode, 400 µA
  - low-g tri-axial digital sensor MMA7660FC[1]
    - in Sleep mode, 2 µA
    - in Normal mode, Configurable down to 47 µA

It is obvious that in a battery operated application care must be taken to ensure the lowest possible current consumption, especially when the maximum current (provided by the battery) is somehow limited. A CR2032 Lithium battery cannot provide current in the range of 40 mA for long periods of time. To alleviate high current surges, an additional large capacitor has been designed.

For transmission and reception using the MC13213, a specific scheme has been used to ensure the battery is not depleted or overloaded, targeting a 30 samples per second (33 ms period) transmission rate. For better power management, the software uses a system of skipping transmission if sensor output data is the same or very similar to the last transmitted sample. The maximum count of skip transmissions is 10, then sensor data is always transmitted. Every received transmission from the sensor board clears the time-out counter in the USB stick. The ZSTAR3 sensor board typically opens a receive window every 10th period (~333 ms) to maintain synchronization with the USB stick (Communication Master) and to receive possible control data from the master.

1. The MMA7660FC is supported by new PCB with revision code 00288_04.