Smart & Intelligent Sensors

SENSORDEVICES - WISH 2012

Workshop on the Intelligent Sensor Hub

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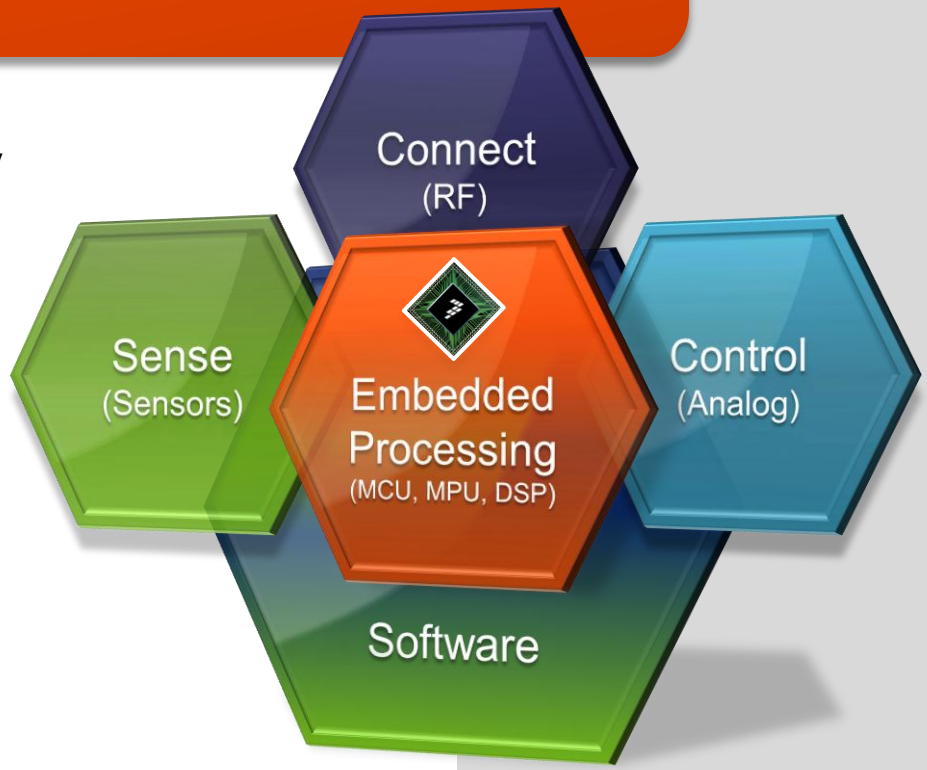
A Global Leader of
Embedded Processing Solutions

Two Core Product Groups

- Automotive, Industrial & Multi-Market Solutions
  - Microcontrollers
  - Sensors
  - Analog
- Networking and Multimedia Solutions
  - Communications Processors
  - Applications Processors
  - RF Power

Four Primary Markets

- Automotive
- Industrial
- Networking
- Consumer



Platform-Level Solutions

>50 Year Legacy

>5,500 Engineers

>6,000 Patent Families

>18,000 Customers

freescale™

Three Trends Shaping Our Future

Connected Intelligence

Going **Green**

Health & **Safety**

freescale™

Over One Billion Freescale MEMS Devices Shipped

100 Million

200 Million

400 Million

800 Million

1 Billion Units Shipped

1992

Dedicated supplier to the critical care medical market through shipment of over 60 million units for the invasive blood pressure market

Late 1980's

Freescale begins developing the first surface micro-machined inertial sensors for the automotive airbag market

1980

We manufacture our first uncompensated pressure sensor

Early 2000s

Inertial sensor portfolio expands with X-, XY- and Z-axis low-g products for the consumer market

Nov. 2008

Synerject announces its ongoing use of Freescale pressure sensors for robust, cost-effective ECUs for two- and four-stroke engine management

April 2009

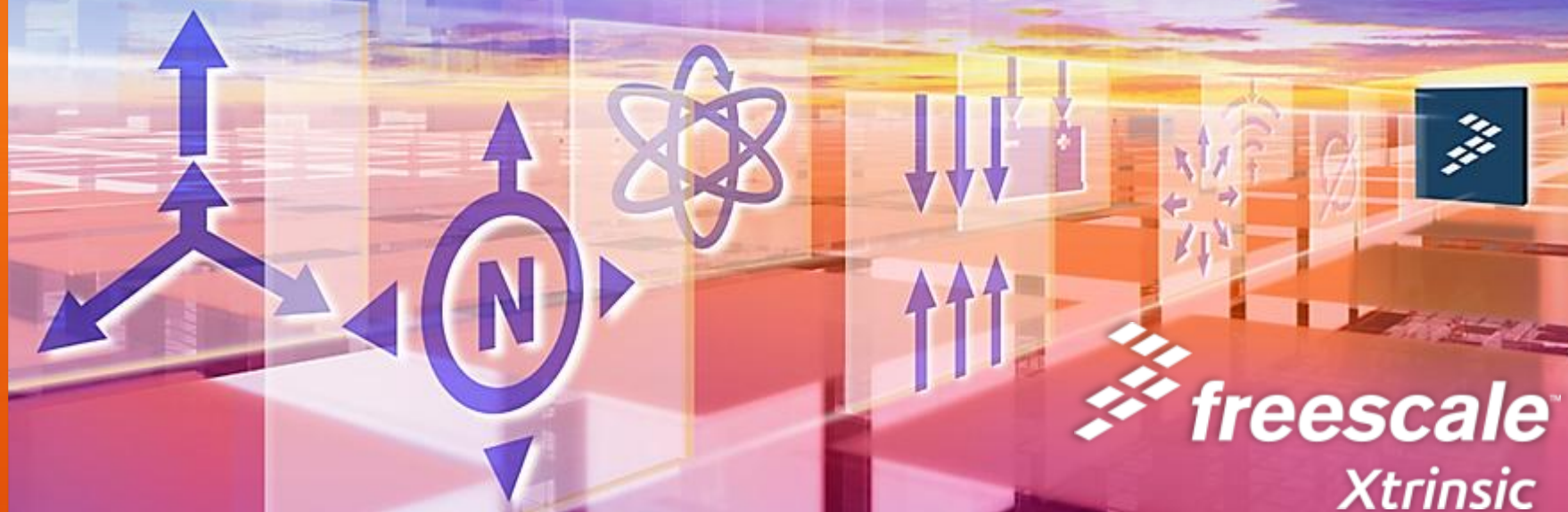
MMA7660FC
Intelligent 3-axis digital accelerometer introduced for advanced mobile phone interfaces

30 Years of Commercial MEMS Design and Production Expertise

*iSuppli 2011

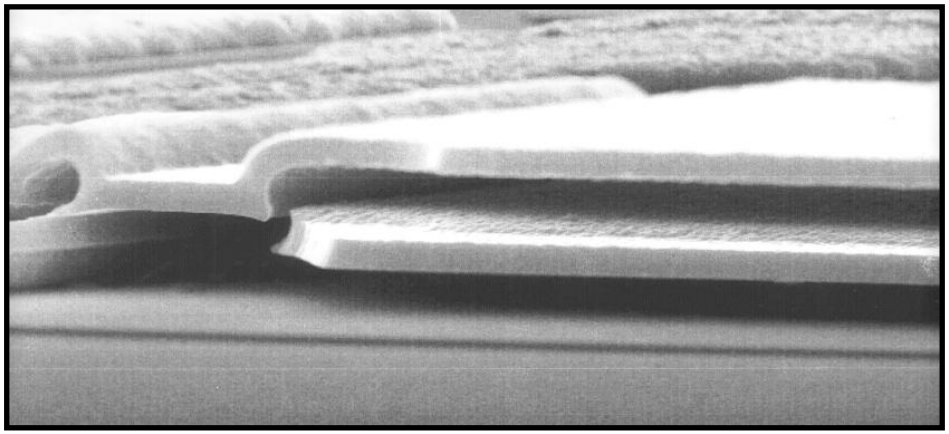
freescale™

MEMS and Sensors: Market and Applications



MEMS as Sensors

- MEMS trend
  - Lower power
  - Smaller sizes
  - Economy of scale
  - Sensors types
  - Easier integration
  - Higher embedded functionalities



Sensors: Applications Trend

- Location-Based-Services
- Intuitive User Interface
- Consumer medical
- Wireless Sensor Networks (WSN)
- Automotive safety

Freescale Offers a Full Portfolio of MEMS & Sensors

eCompass

Magnetometers

Accelerometers

Touch Sensors

Altimeter

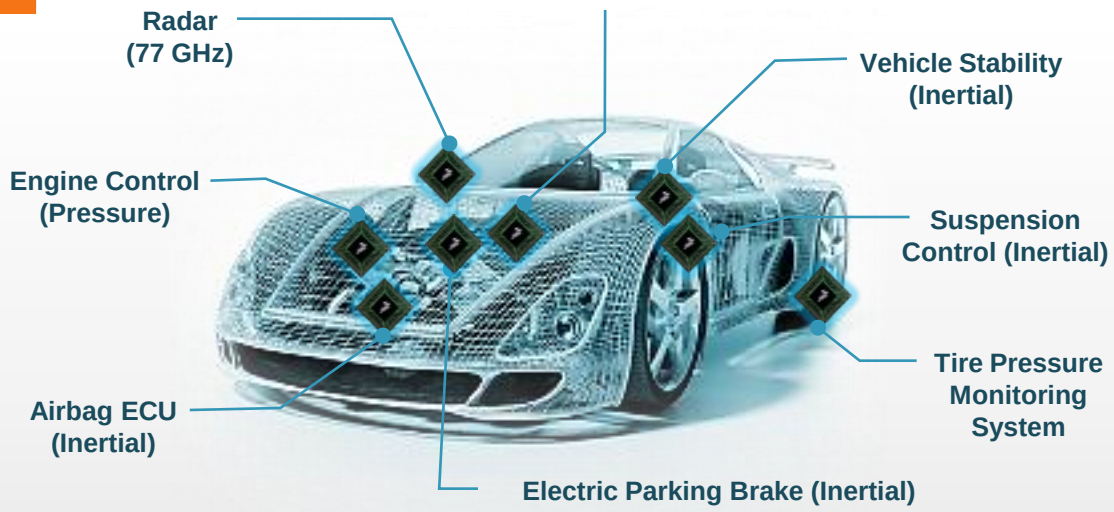
Pressure

Freescale Commitment to Automotive Sensors

FREESCALE SENSORS 30 Year ANNIVERSARY 1 BILLION UNITS SHIPPED

Peripheral Sensor Interface 5 (PSI5) DSI

Inertial & Pressure Side Crash Satellite



Market Leader

Freescale is the largest non-captive supplier of automotive MEMS accelerometers
Broad standard portfolio

- **Convergence of Active Safety Systems Around 77GHz Radar**
- **Airbag installation: AP**
- **Recent Government Mandates:**
  - TPMS Korea - Jan 2013
  - ECS Korea - Jan 2012
  - Front Airbag India - 2013
  - Emissions China-5/Euro-5 - 2015

Autoliv BYD Continental DELPHI DENSO KEIHIN MAGNETI MARELLI MOBIS TAKATA TRW BMW Ford GM HONDA The Power of Dreams PEUGEOT TOYOTA

freescale Xtrinsic

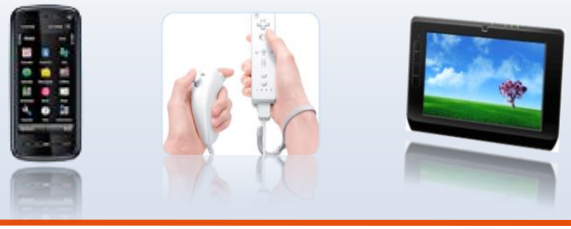
Sensor Consumer & Industrial Market Focus

Mobile Phones

- Orientation detection
- Tilt to scroll
- Gesture detection
- Pedometer/ position detection

Gaming

- Orientation detection
- Tilt to control
- Tap to select/button replacement
- Gesture detection



Medical Applications

- Blood pressure monitors
- Sleep apnea (CPAP machines)
- Inhalers and ventilators

Industrial Applications

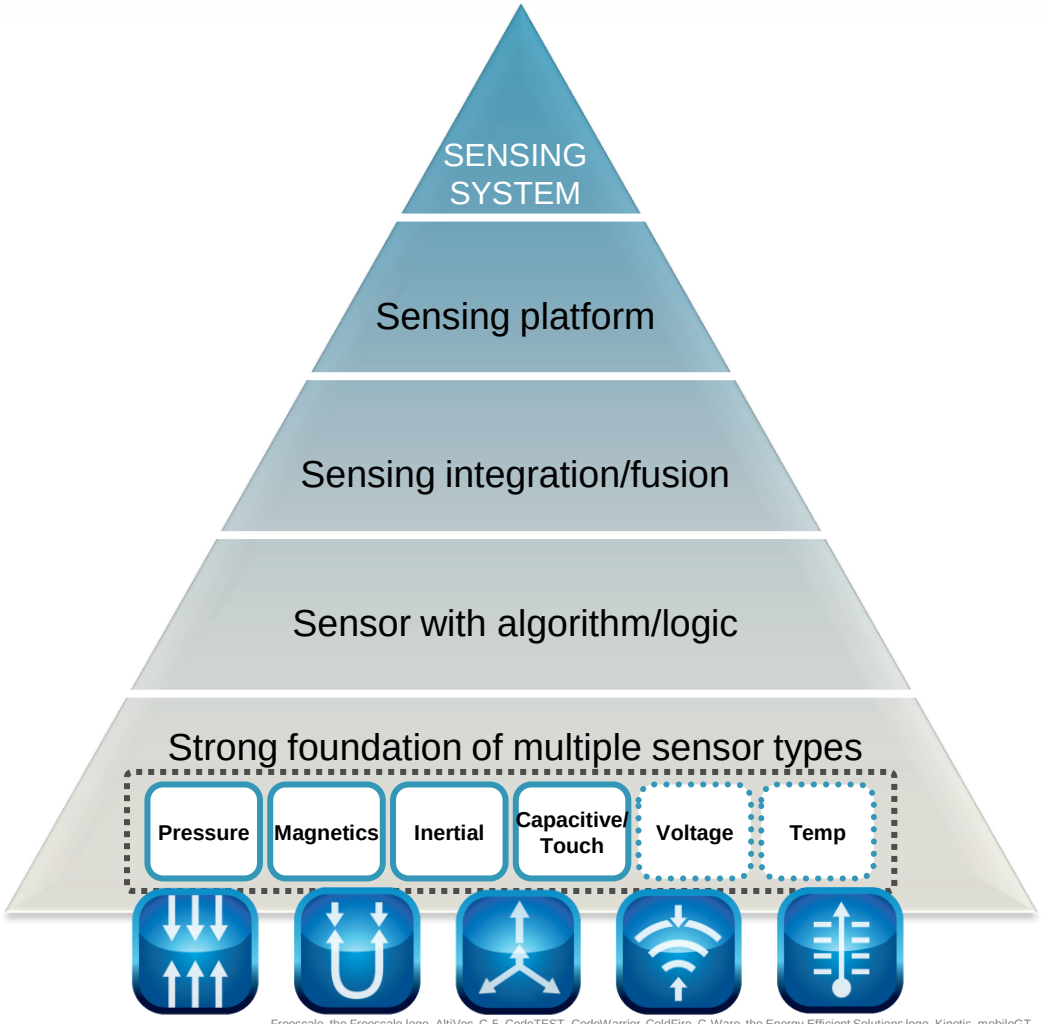
- Energy metering
- Fleet monitoring/tracking
- Power tools
- Small appliances

Freescale's New Era of Xtrinsic Sensing

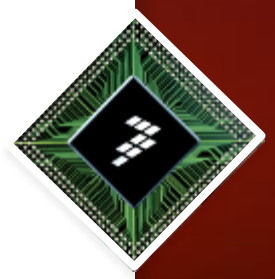
Intelligent Contextual Sensing – *more than translating a signal*

Xtrinsic Sensing Solutions

- **Increasing levels of intelligence**
- **Increasing levels of integration**

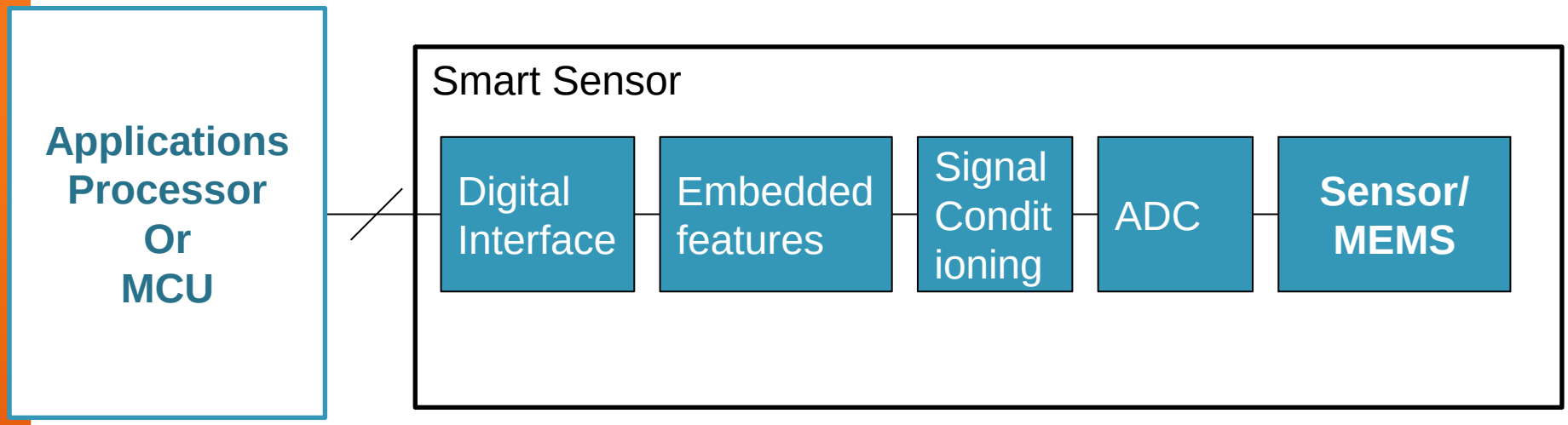


Smart Sensors



Standard Sensor Structure

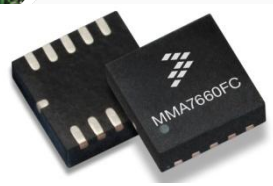
Ex.: Accelerometer, magnetometer, pressure sensors…



Advantages of Smart Sensors

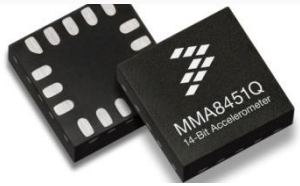
- Reduction of the data communication with the main applications processor for some preset functions with a specific expected value
- Lower system power consumption since some data is filtered and not all of the processing needs to be done by the main processor
- Easier integration due to standard digital interface and pre-defined functions, avoiding developing all applications from raw data

C&I Accelerometer Family



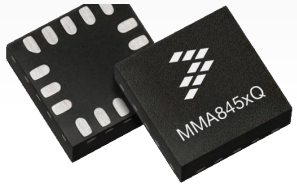
MMA865x

- Digital Output
- Cost Efficient
  - 1mg/count sensitivity
- High Performance
- Rich Features
  - P/L detection
  - High Pass Filter
  - Transient Detect



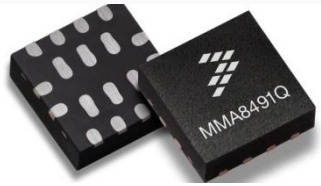
MMA845x

- Digital Output
- Extreme Performance
  - .25mg/count sensitivity
- Extended Features
  - FIFO
  - Configurable P/L trip angles
  - High Pass Filter
  - Transient Detect



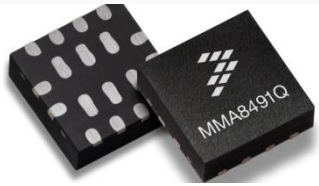
MMA8450

- Digital Output
- Low Voltage
  - 1.71-1.89V



MMA8491

- Digital Output
- Extreme Low Power
  - 0.35uA/Hz
- Cost Efficient
  - 1mg/count sensitivity
- Industrial Package



MMA837x

- Analog Output
- High Bandwidth
  - 4.9kHz
- Low Voltage
  - 1.71-3.6V
- Industrial Package
- Extended Temp Range: 105C

Consumer

Industrial

Xtrinsic MMA845xQ 14/12/10-bit 3-axis Accelerometer Family Low Power High Level of Embedded Function

Saving Power and Increasing Efficiency: Key Features in Smart Sensors (Accelerometer)

- Embedded features

TILT orientation | TAP 2TAP detection | HIGH PASS FILTER | MOTION threshold | FREE FALL detection | TRANS-IENT detection

- Power management

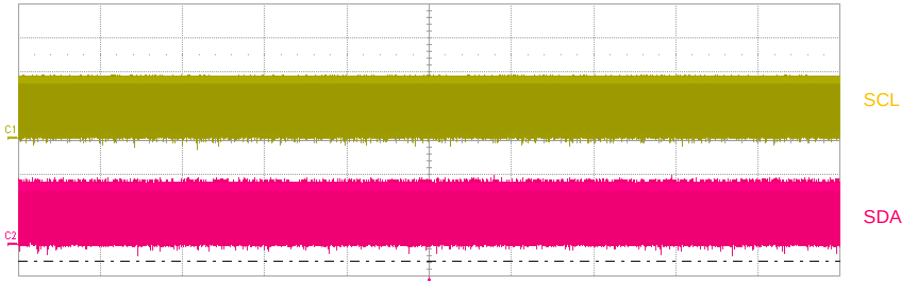
POWER SELECT | SYSTEM POWER SAVE | AUTO WAKE | AUTO SLEEP | SLEEP

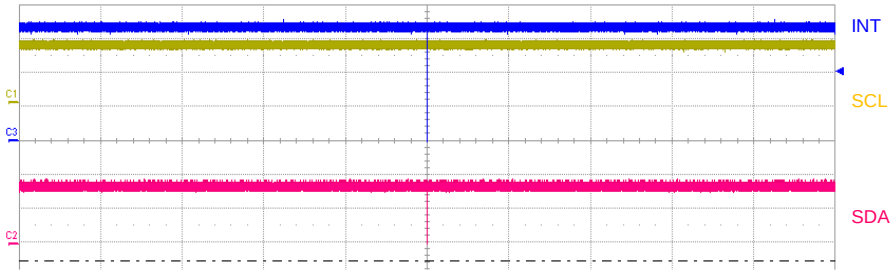
- Smart communication

Interrupts | 32 SAMPLE FIFO

Ex.: Smarter Accelerometer

Portrait/landscape detection (100 samples per second ODR)





⇒**10 500** data **per second***

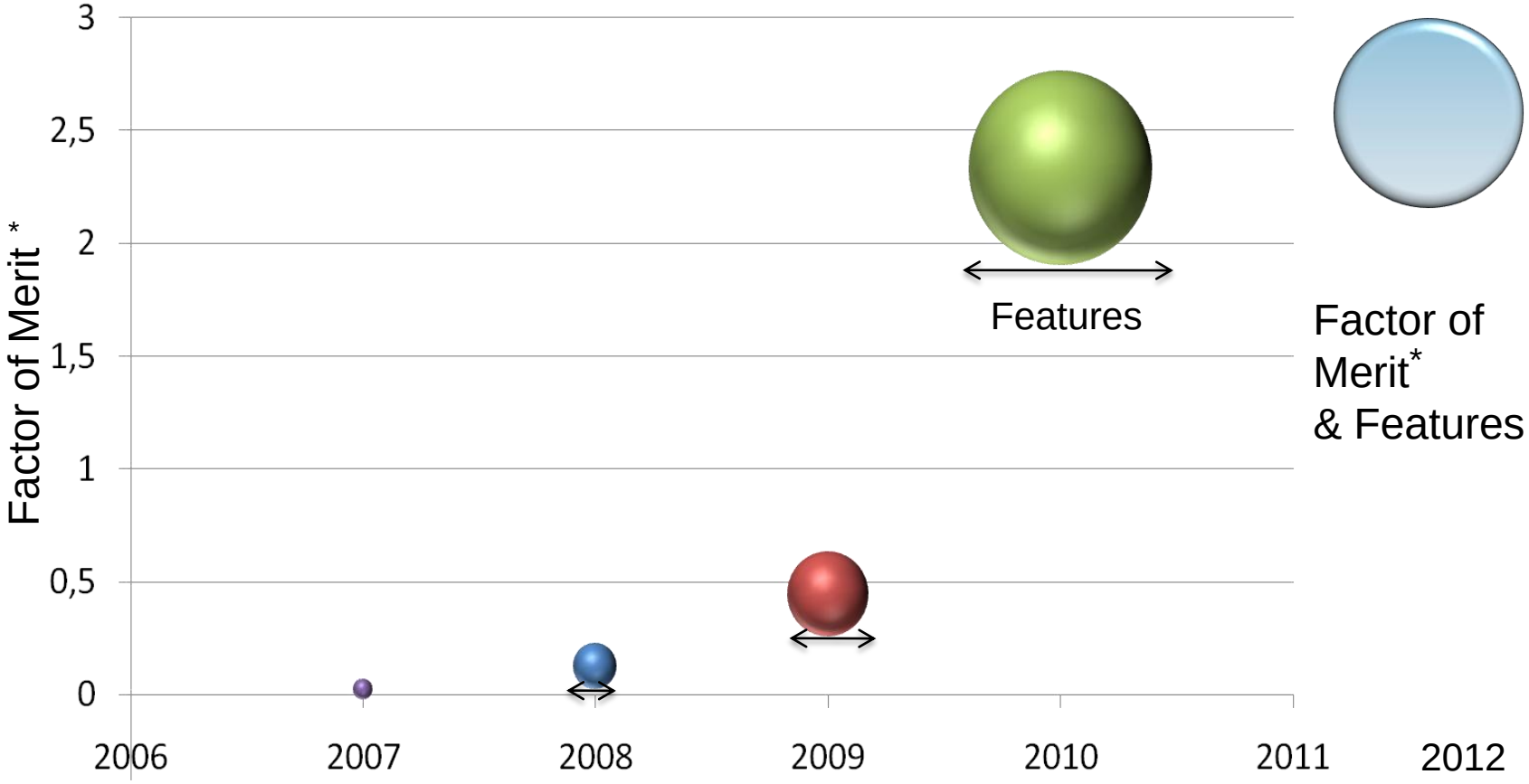
⇒ **41** data **only**
regardless of the ODR **

* 3-axis, 12 bit, I2C communication
Generic accelerometer

** 3-axis, 12 bit, I2C communication + interrupt pin. Embedded algorithm, MMA8452Q, portrait/landscape feature

Sensor Performance Improvement

3-axis MEMS accelerometer



*power consumption and resolution

3-Axis Magnetometers

Xtrinsic MAG3110

3-Axis Magnetometer

Differentiating Points

- High accuracy compass function
- Decimator allows for lowest noise implementation with oversampling to remove RF noise and Idd induced mag fields

Product Features

- 1.95V to 3.6V supply voltage
- Maximum field of 10G (1000 uT)
- Output data rates (ODR) from 1.25Hz to 80Hz
- Magnetometer resolution of 0.1uT
- Current Consumption as low as 24uA at 1.25Hz
- I²C digital interface
- Extended temperature range of -40°C to +85°C.

Typical Applications

- Electronic Compass
- Enhanced User Interface
- Dead-reckoning GPS assist for Location Based Services

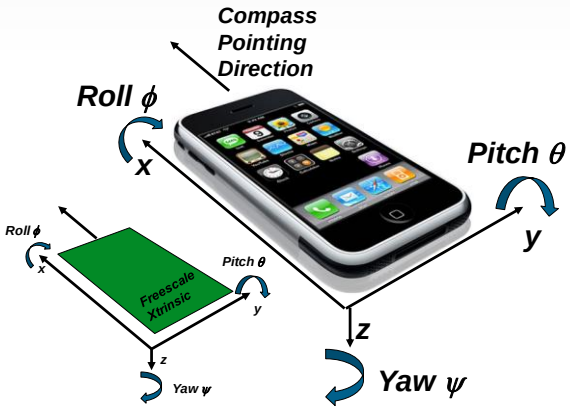
Package

2 x 2 x 0.85mm QFN

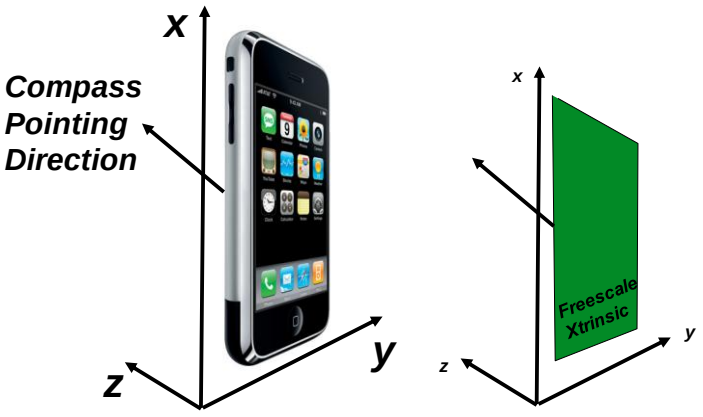
Availability

In Production
Online Sample Program
Buy Direct
Distribution Stocked

Magnetometer with Auto-Calibration and Tilt Compensation



- Hard Iron Offset:
  - DC offset from permanent magnetism
  - PCB and from test magnets



- Soft Iron Offset:
  - Uncalibrated gain differences on each axis
  - Directional soft iron effects of PCB

Xtrinsic FXOS8700CQ (Gauss)

6DOF (3-axis Accelerometer + 3-axis Magnetometer)

Differentiating Points

- Lowest noise gcell and mcell
- Embedded Functionality to allow system fast response and power savings
- 32 sample FIFO with burst read

Product Features

- 1.95V to 3.6V supply voltage, I/O 1.6V – 3.6V
- ±2g/±4g/±8g accelerometer, ±15 Gauss Field range
- Output data rate (ODR) from 1.563Hz to 800Hz , 400Hz hybrid
- 14-bit gcell data, 800 counts per Gauss
- Low Offset Drift: 0.1mG per deg
- 4 channel motion detect ion- FF, Pulse, Transient, HPF, Tap
- Vector Magnitude for mcell, gcell

Typical Applications

- Electronic Compass
- Enhanced User Interface
- Dead-reckoning GPS assist for Location Based Services

Package

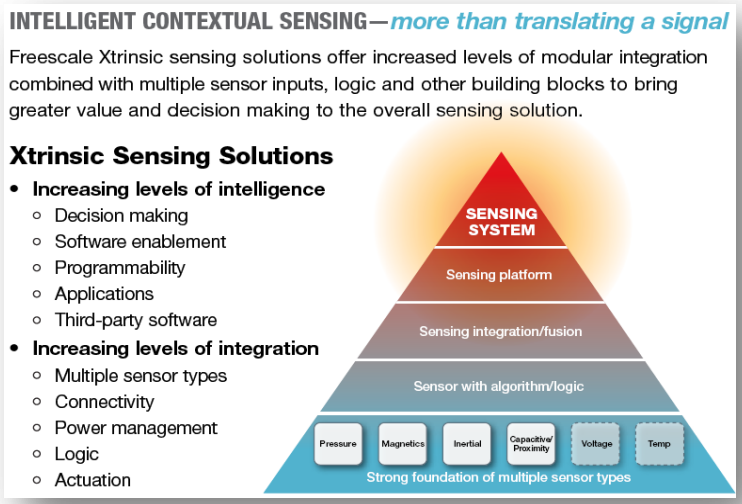
3 x 3 x 1.2mm QFN

Availability

- Dev Tool orderable – Sept'12
- Production – Sept'12

Xtrinsic eCompass Software Enablement

- **First supplier** to provide any level of eCompass calibration and compensation software without significant cost and using direct click thru web access
- **Market leading** calibration and compensation software that provides high accuracy heading information. Calibration is done in the background with minimal/no intervention from the user as with competing solutions.
- **Click thru license** on freescale.com /eCompass
- **Reference C source code** for the calibration can NOW be licensed free of charge from Freescale for use in any product using a Freescale magnetometer or Xtrinsic sensor (p/n: FXxxxxxxx).



NOW available for the expansive breadth of Freescale customers!
www.freescale.com/eCompass

Pressure Sensors

Xtrinsic MPL3115A2
Precision Digital Altimeter

Differentiating Points

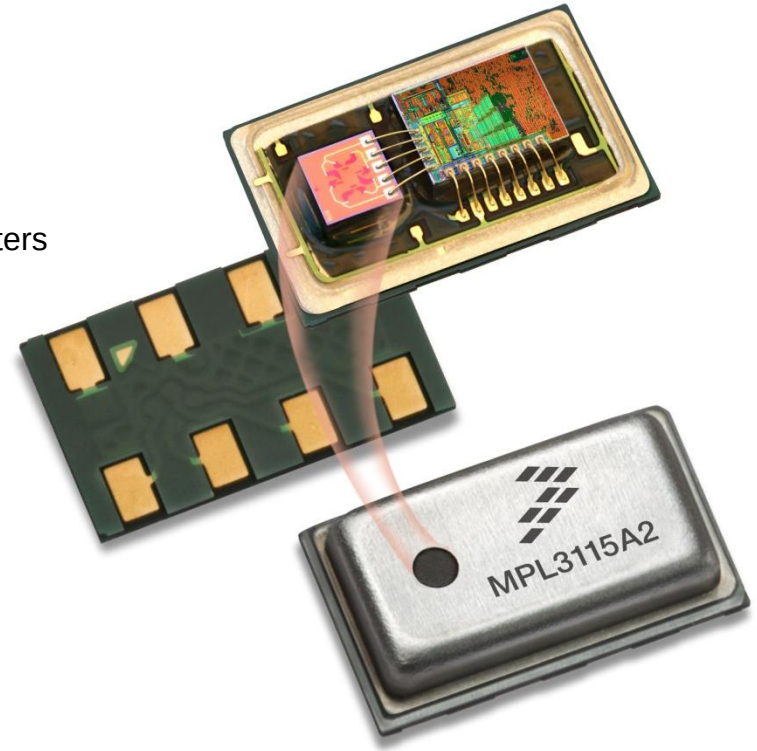
- Internally compensated, software is not needed
- Direct reading pressure in Pascals and altitude in meters
- On-board intelligence

Product Features

- Altitude resolution : < 1 foot / 0.3 m
- Pressure resolution: 1.5 Pa
- Pressure range: 20 – 110 kPa
- Calibrated pressure range: 50 – 110 kPa
- 1.95V to 3.6V supply voltage
- Variable output sampling rate (OST) up to 140 Hz
- Current Consumption:
  - Standby mode: 2 µA
  - Low-power mode: 8.5 µA at 1 Hz
- I²C digital interface

Typical Applications

- High Accuracy Altimeter
- Smartphones / Tablets
- GPS Enhancement for Location Based Services

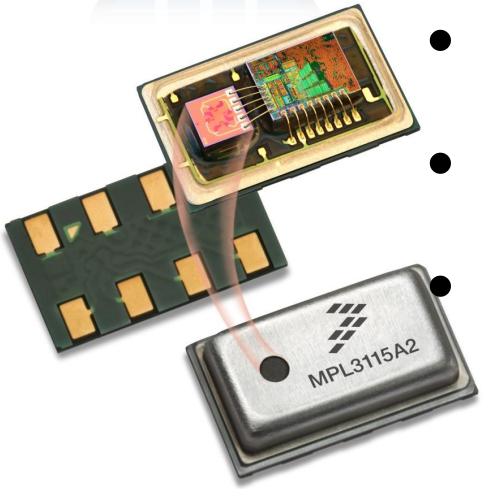


Package

3 x 5 x 1.1 mm LGA

In Production

Xtrinsic™ Pressure sensors:
"Meters to Centimeters"



MPL3115A2

- Few meters → 30 cm accuracy
- Pressure → Altitude
- Some 1000 µA → less than 10 µA
- 2 chips → 3 x 5 mm SiP
- Analog → Digital interface
- Passive → Smart interface

Key Limitations of Smart Sensors

- Sensor data aggregation & fusion :
  - More data to be processed in real time,
  - Higher ratio of unnecessary collected data and useful data,
  - Lack of data aggregation before processing.

- Power consumption of the system is increasing at the sensor and processing levels by adding more sensors

- Level of complexity to implement more sensors

- Design of Software adapting to each new sensor (calibration, specific data management, interface, data sampling rate, and sequence)

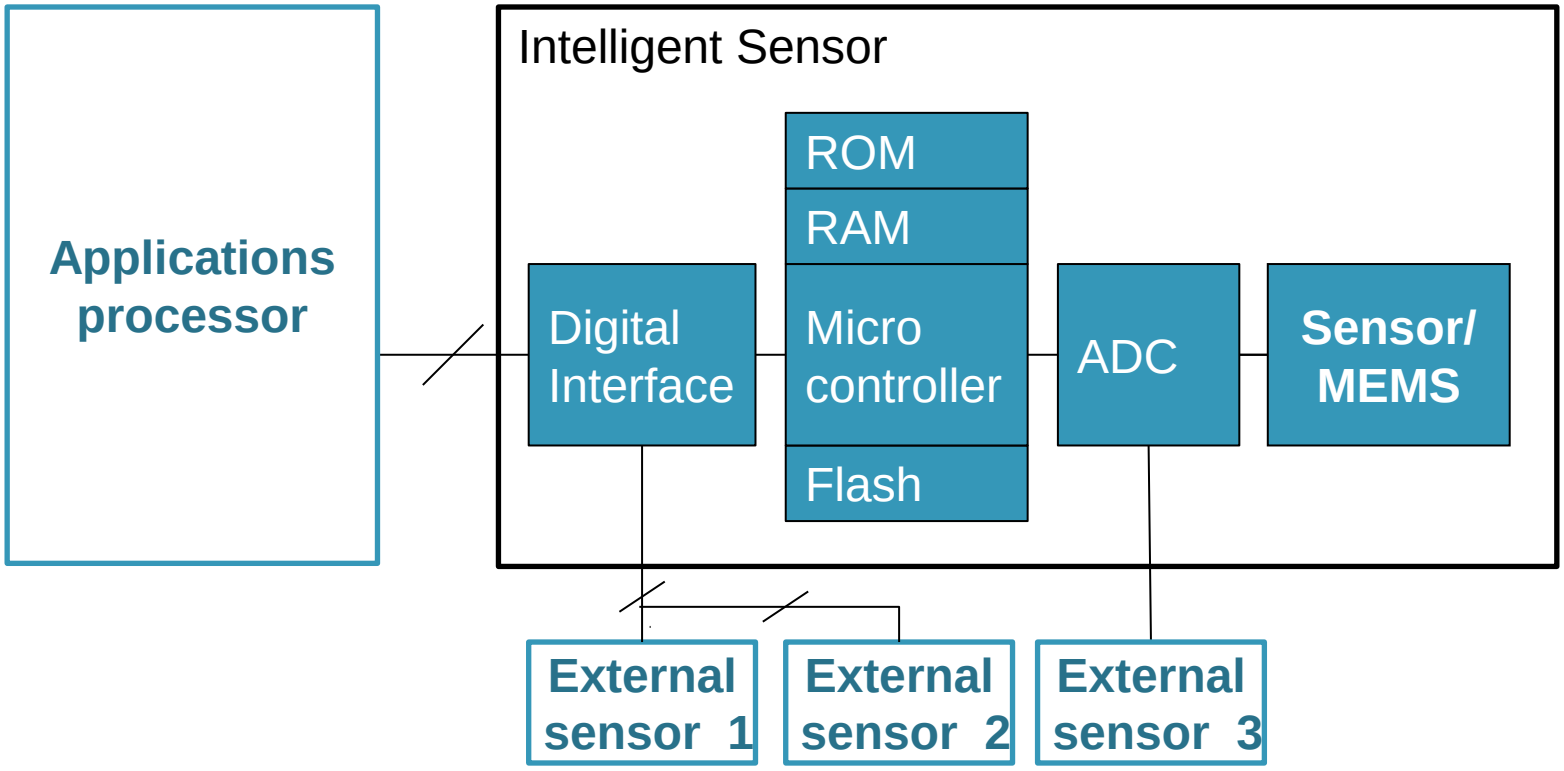
The Intelligent Sensor Concept

- Combination of:
  - Processing the sensor data,
  - Flexibility to reconfigure embedded functions
  - Aggregate external sensors data.

- Constraints:
  - Not to exceed the form factor of an existing sensor,
  - Minimize the extra cost,
  - Equivalent inner power consumption

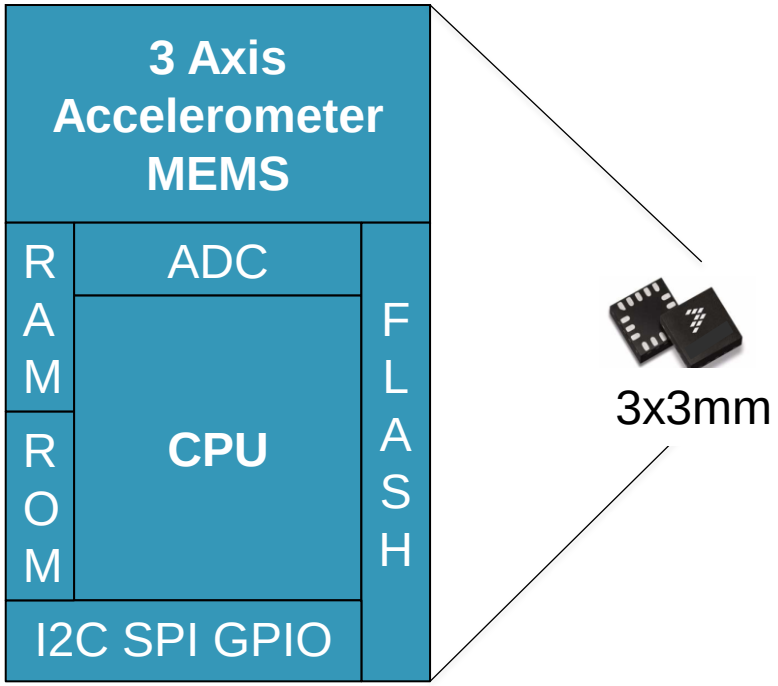
- Outcome Implementation:
  - Sensor
  - Small microcontroller,
  - Memory – flash, RAM and ROM
  - Optimized architecture for sensor applications

Intelligent Sensor structure



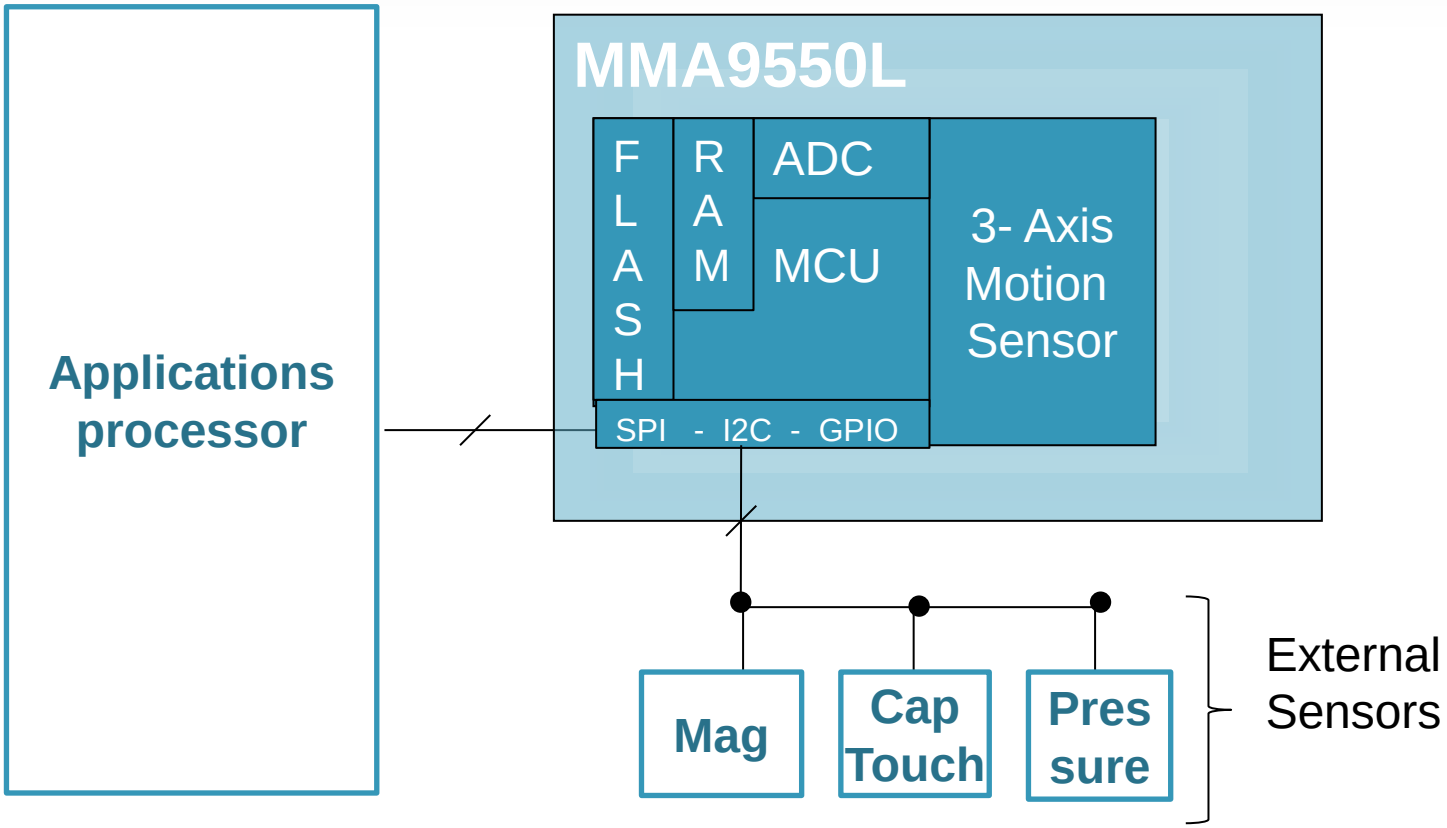
The Implementation: Intelligent Motion Sensor

- MEMS (3-axis accelerometer)
- 14 bit ADC
- Coldfire® V1 (a compact 32-bit RISC microcontroller)
- ROM
- RAM
- Flash
- SPI and I2C interfaces
- PWM (Pulse Width Modulation)
- GPIO

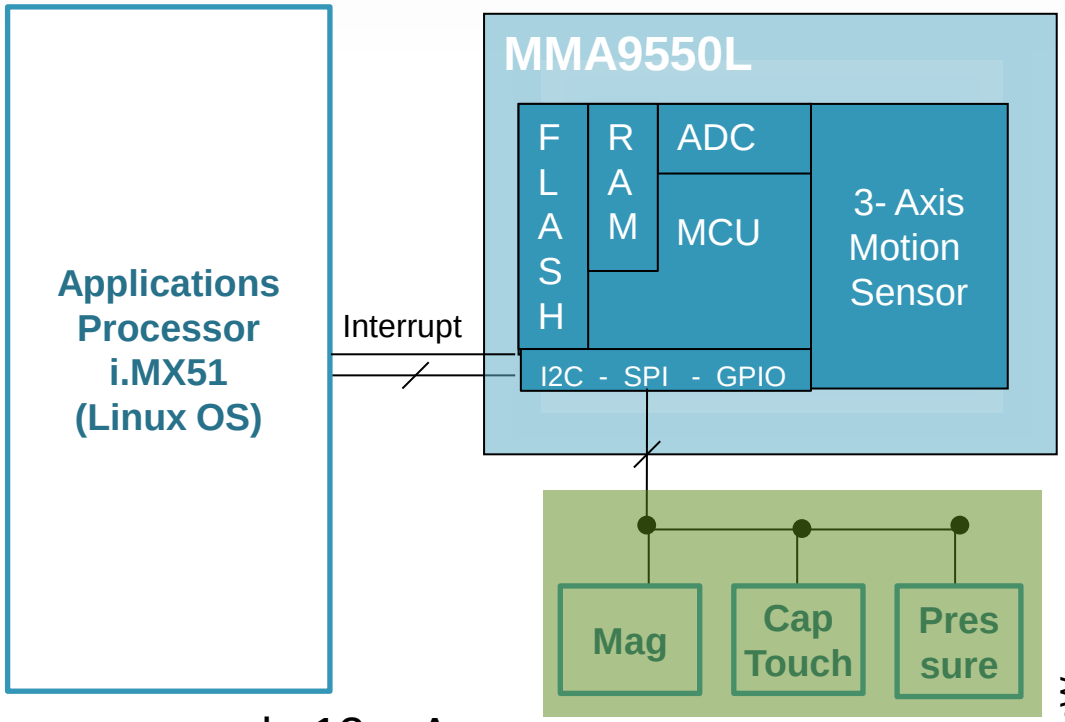


MMA9550L

The intelligent motion sensor platform Application example



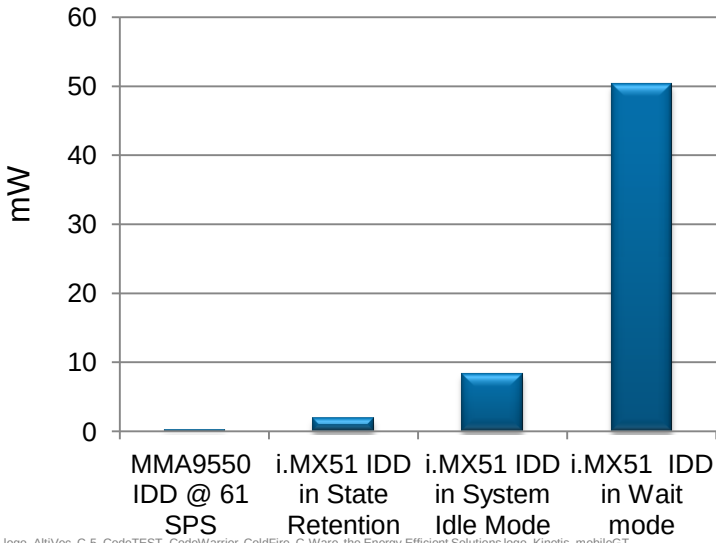
Distributed/Asymmetric Processing Advantages: Can Save More than 90% of the System Power



Low-power mode:12 mA
Normal mode: 500 mA

Low-power mode:
0.15 mA

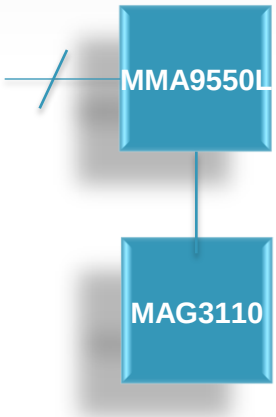
1000 cycles/sample i.MX51 estimated
i.MX51 PLL Lock time: 100 µs
i.MX51 Interrupt latency: 1 µs
i.MX51 Wakeup latency: 5 µs



Advantages of the Intelligent Sensor Platform

- Reduce system power consumption
- Reduce data communication
- Aggregate data from different sensors: sensor fusion
- Continuous calibrating and monitoring of the sensors
- Enable customization of each sensor node through SW
- Shorter software development time
- External sensor agnostic at system level

eCompass: Comparison with a Standard Solution



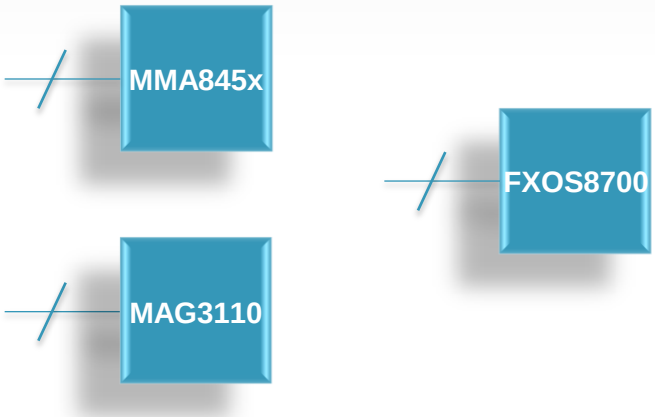
Only one digital interface

One set of drivers

Embedding:

. Magnetometer calibration*
. Tilt compensation
. Automatic sampling rate

0.16Kbps of processed data



Two digital interfaces

Two drivers

Need to add:

. Magnetometer calibration *
. Tilt compensation

3.36Kbps of unprocessed data

* soft and hard iron

Combining sensors and WSN/BSN

WSN/BSN Mass Adoption Challenges

- Cost
- Sensor size
- Sensor network deployment
- Power efficiency
- Computation and communication tradeoff

⇒ (Only) Partly addressed by ZigBee™/Bluetooth and MEMS

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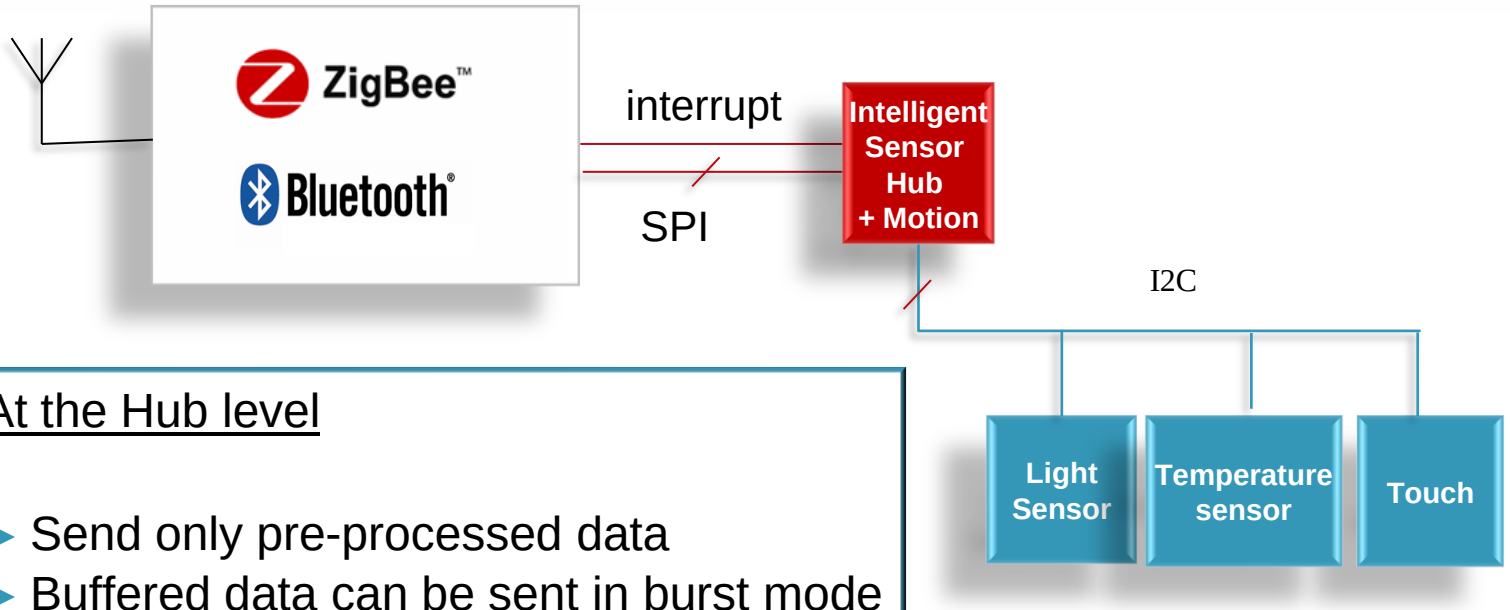
WSNs
Home Control with Intelligent Sensor Hub



At the Hub level

- Send only pre-processed data
- Buffered data can be sent in burst mode
- Reconfigurable by software
- Automatic wake-up/sleep with the accelerometer
- Aggregate sensor data

Power Consumption Saving

Use Case	Intelligent Sensor Hub	ZigBee	Power saving
Low-Power mode	*50µA* LP	*1.1mA* Stby	95%
Full Running mode	*3.5mA* FR	*6.2mA* Stby	44%
Saving 1 transmit	*3.5mA* FR	*27mA* Stby	87%

WSN/BSN Implementations: Key Issues Addressed by the Intelligent Sensor Hub

- Node heterogeneity

⇒ **Adaptation through the dedicated interfaces and software**

- Design and implementation of efficient power-saving algorithms for the communication

⇒ **Automatic wake-up/sleep, buffer, pre-processed data, aggregation…**

- Implementation cost

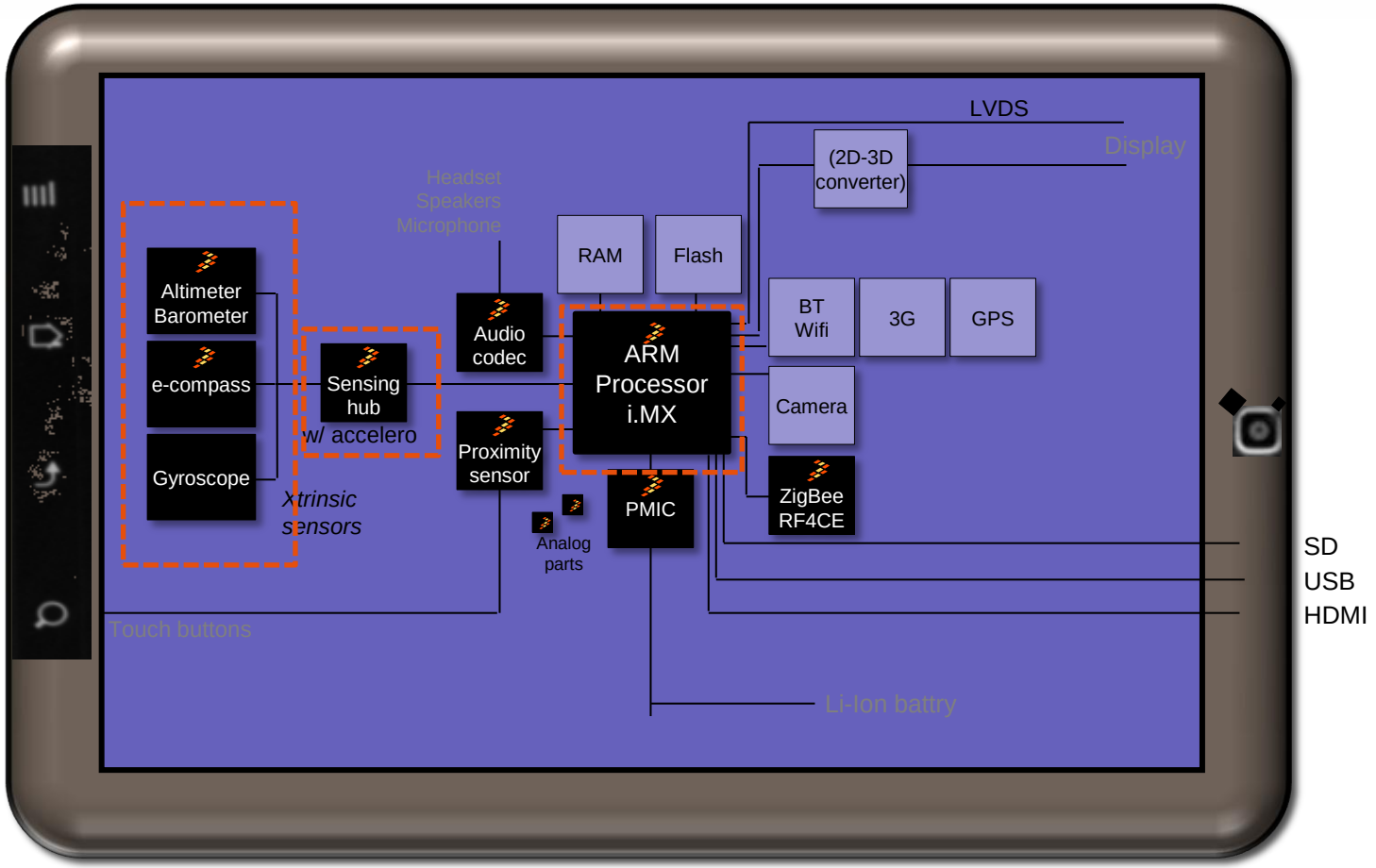
⇒ **Lower development efforts, lower cost than discrete solution, SW flexibility allowing re-usability and increasing life cycle**

- Sensor data aggregation

⇒ **Enabled at the sensors level**

Xtrinsic Sensing Solutions

Where does Sensor Fusion happen?



Sensor Fusion: Multiple Dimensions

- One Sensor:
  X, Y, Z → aggregated data
- Multiple Sensors:
  Ex: 3-axis accelerometer + 3-axis magnetometer = eCompass
- Software:

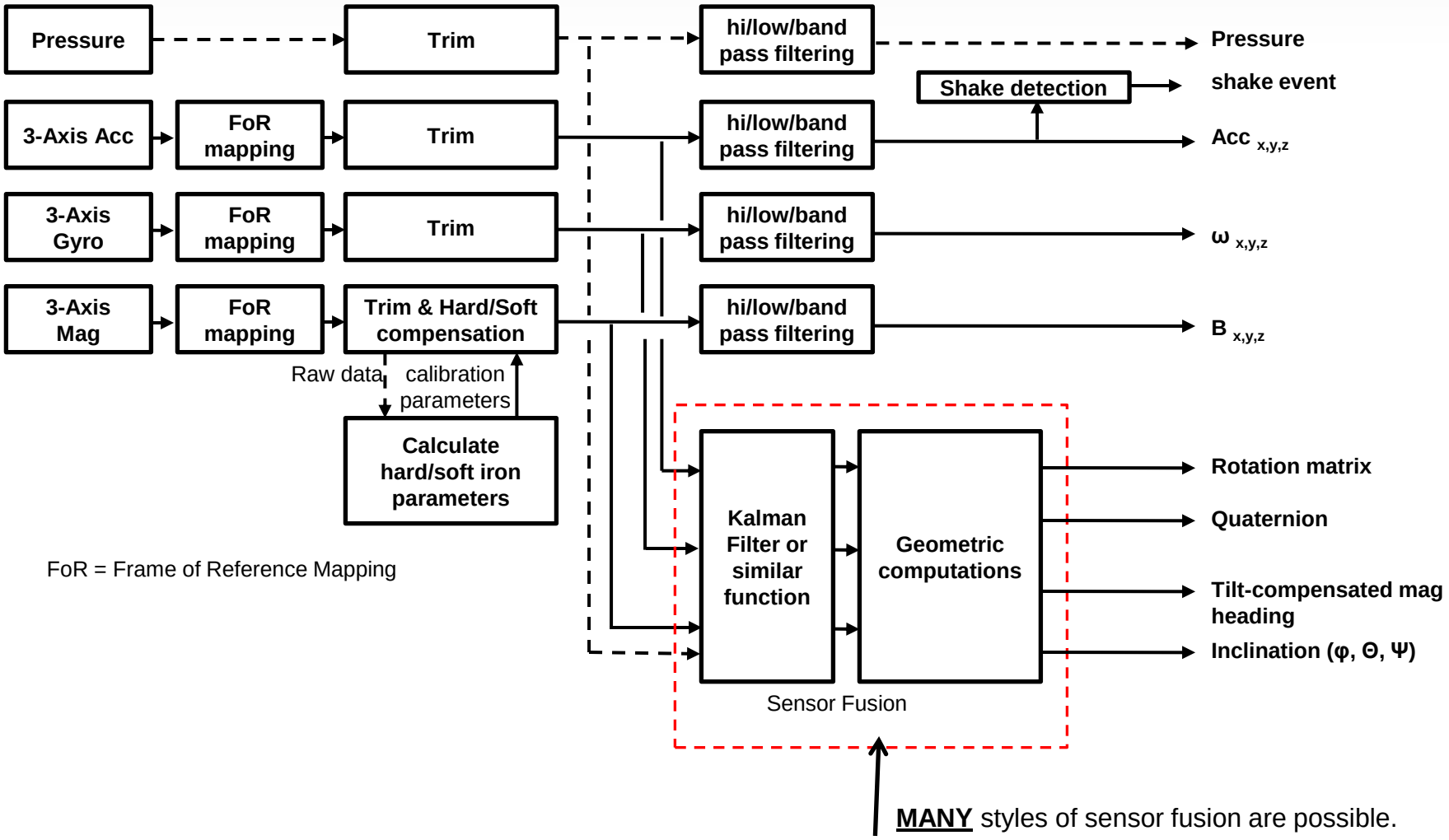
  Ex: Tilt compensation + calibration = “useable” eCompass

- Operating systems and API

  Android, Windows 8…
- Application software

  Gesture recognition, heading, navigation, positioning…

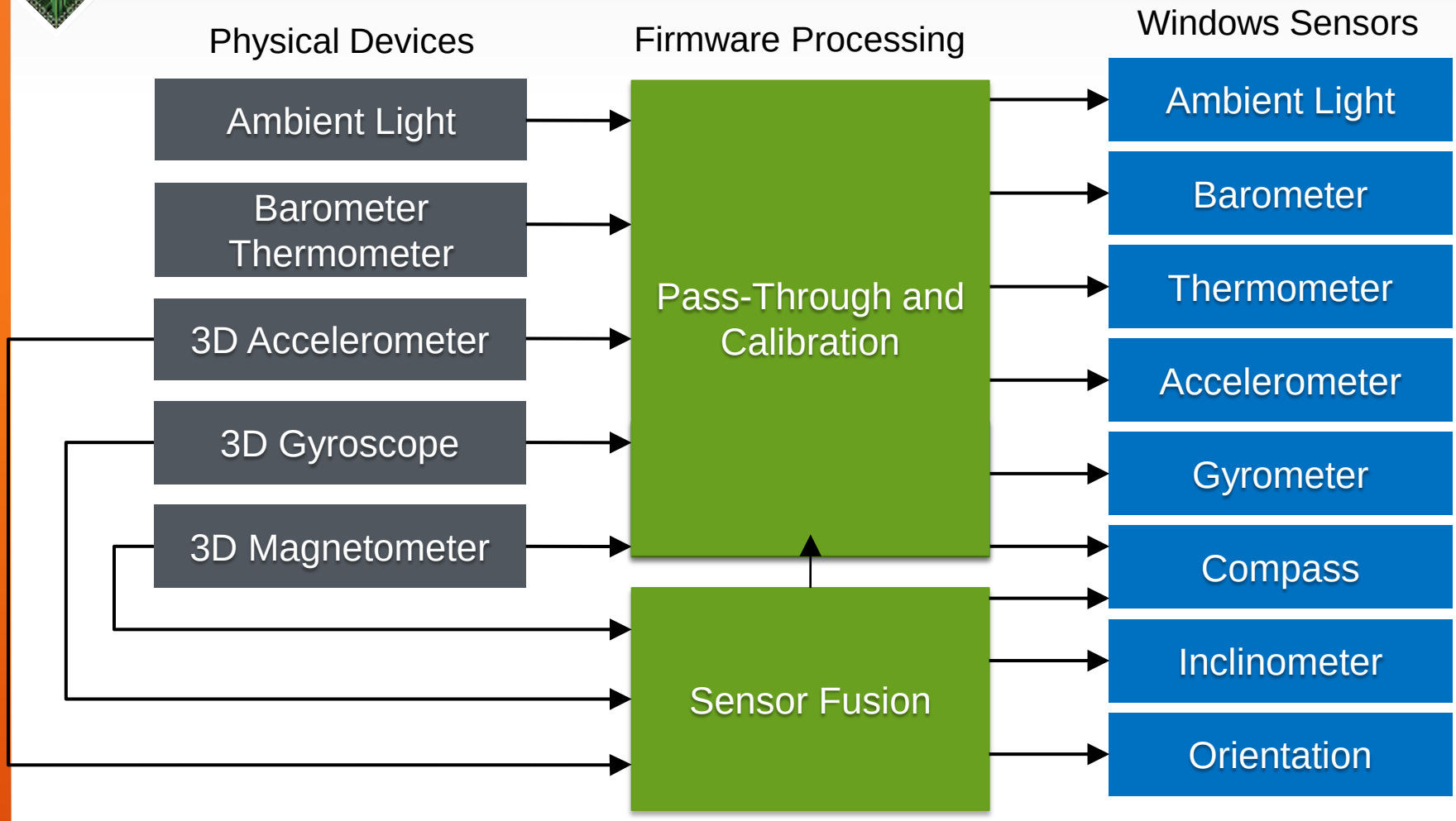
Baseline Sensor Fusion for Consumer Devices



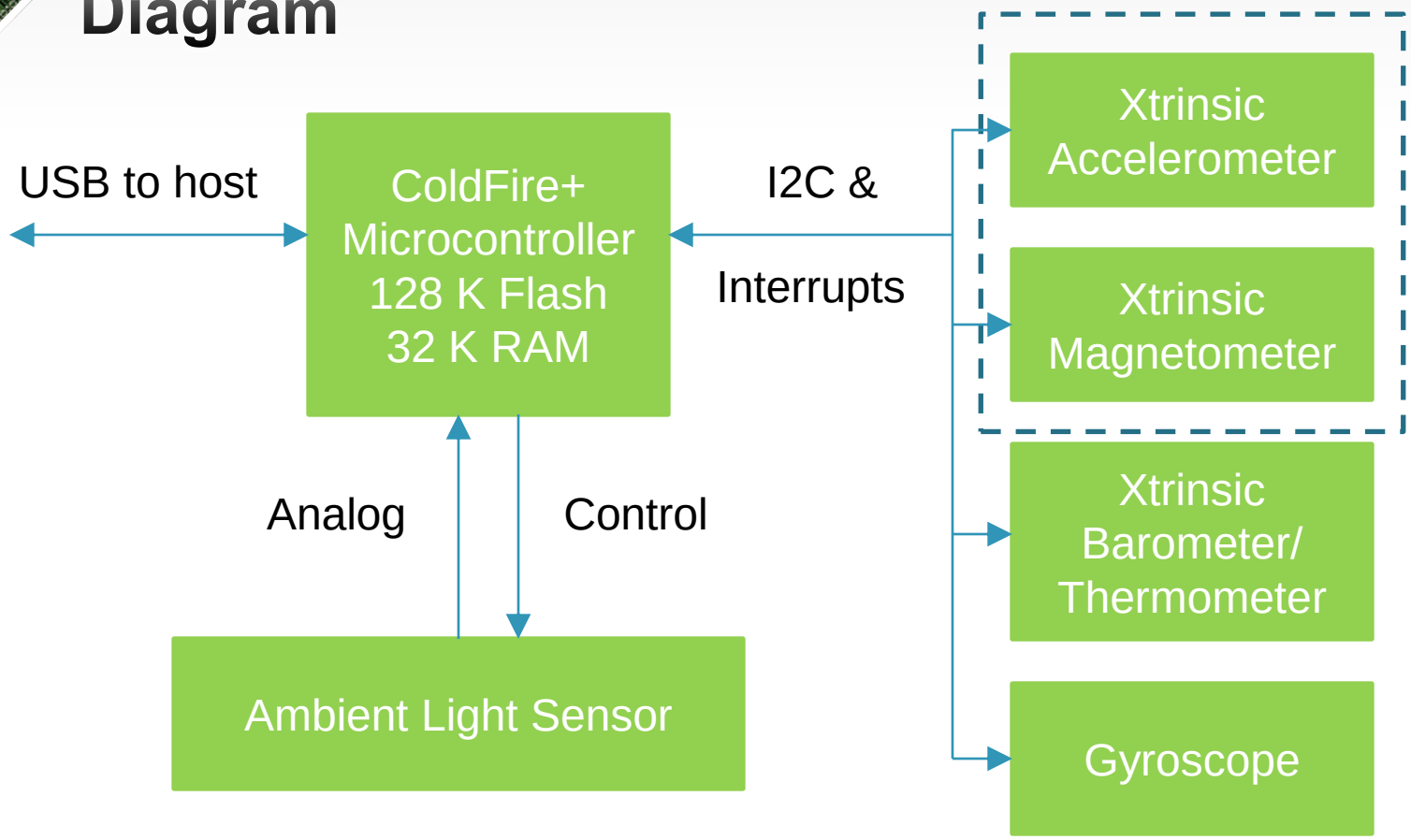
Windows 8 Freescale 12-Axis Xtrinsic Sensor Platform

Xtrinsic sensor fusion in tablets, slates, convertible/non-convertible laptops and other portable devices

Windows 8 Xtrinsic Sensor Data Flow



Windows 8 Xtrinsic Sensor Platform Block Diagram



Enablement

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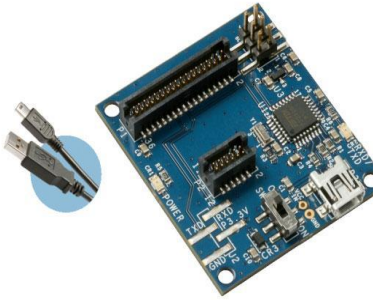
The Sensor Toolbox
Unified Hardware, Software and Accessories

KITMPR121EVM

KITMPL115A1EVB

LFSTBEB845x



LFSTBUSB

KITMMA9550LEVM

- Development tool definitions:
  - Power boards – 3V and 9V battery boards
  - Interface boards – communication boards
  - Development boards – for part evaluation
  - Kits – includes both board types
  - Electrodes – specific to touch sensors
- GUI software
  - Easy access through http://www.freescale.com/sensortoolbox
- Packaging includes:
  - Board(s)
  - Cable(s)
  - Quick start guide
  - Schematics (Web site)
  - Board diagram

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For Further Information

- **Sensors**
  - www.freescale.com/**sensors**
  - http://www.freescale.com/**sensingplatform**
  - http://www.freescale.com/**sensordata**
  - www.freescale.com/**mems**

- **Sensor Products**
  - www.freescale.com/**xyz**
  - www.freescale.com/**magnetic**
  - www.freescale.com/**pressure**
  - http://www.freescale.com/**sensortoolbox**

- **Blogs: Smart Sensors**
  - http://blogs.freescale.com/2011/06/06/location-based-services-sensors-go-beyond-the-navigation/?tid=NL_2311
  - http://blogs.freescale.com/author/michaelestanley/
    - What in the World is Contextual Sensing?
    - Evolving intelligence with sensors
    - Magnetic sensor makes electronic compass design easy

Perspectives

Innovation

Entrepreneurship

“Necessity is the mother of all inventions”

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