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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

>50 Year Legacy

>5,500 Engineers

>6,000 Patent Families

>18,000 Customers

Platform-Level Solutions
Three Trends Shaping Our Future

Connected Intelligence

Going Green

Health & Safety
Over One Billion Freescale MEMS Devices Shipped

1980
We manufacture our first uncompensated pressure sensor

Late 1980’s
Freescale begins developing the first surface micro-machined inertial sensors for the automotive airbag market

1992
Dedicated supplier to the critical care medical market through shipment of over 60 million units for the invasive blood pressure market

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
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

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
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

Strong foundation of multiple sensor types

Pressure  Magnetics  Inertial  Capacitive/Touch  Voltage  Temp

SENSING SYSTEM

Sensing platform

Sensing integration/fusion

Sensor with algorithm/logic
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: 105°C

**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
  - TRANSIENT 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***

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

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

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

Factor of Merit

Features & Features

power consumption and resolution

*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”

- 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

MPL3115A2
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

- Applications processor
- Intelligent Sensor
  - ROM
  - RAM
  - Microcontroller
  - Flash
  - ADC
  - Sensor/MEMS
    - External sensor 1
    - External sensor 2
    - External sensor 3

External sensors are connected to the Intelligent Sensor through a Digital Interface.
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
The intelligent motion sensor platform
Application example

MMA9550L

Applications processor

Mag  Cap Touch  Pressure

External Sensors

3- Axis Motion Sensor

FLASH

FLASH

ADC

RAM

MCU

SPI - I2C - GPIO

External Sensors

Applications processor

MMA9550L

FLASH

FLASH

ADC

RAM

MCU

SPI - I2C - GPIO

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

MMA9550L

Low-power mode: 0.15 mA

Applications Processor i.MX51 (Linux OS)

Low-power mode: 12 mA
Normal mode: 500 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

i.MX51 PLL Lock time: 100 µs
i.MX51 Interrupt latency: 1 µs
i.MX51 Wakeup latency: 5 µs

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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
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

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Intelligent Sensor Hub</th>
<th>ZigBee</th>
<th>Power saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Power mode</td>
<td>50µA LP</td>
<td>1.1mA Stby</td>
<td>95%</td>
</tr>
<tr>
<td>Full Running mode</td>
<td>3.5mA FR</td>
<td>6.2mA Stby</td>
<td>44%</td>
</tr>
<tr>
<td>Saving 1 transmit</td>
<td>3.5mA FR</td>
<td>27mA Stby</td>
<td>87%</td>
</tr>
</tbody>
</table>
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

FoR = Frame of Reference Mapping

FoR = Frame of Reference Mapping

MANY styles of sensor fusion are possible.

Many styles of sensor fusion are possible.
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

Physical Devices

- Ambient Light
- Barometer
- Thermometer
- 3D Accelerometer
- 3D Gyroscope
- 3D Magnetometer

Firmware Processing

- Pass-Through and Calibration
- Sensor Fusion

Windows Sensors

- Ambient Light
- Barometer
- Thermometer
- Accelerometer
- Gyrometer
- Compass
- Inclinometer
- Orientation
Windows 8 Xtrinsic Sensor Platform Block Diagram

- ColdFire+ Microcontroller
  - 128 K Flash
  - 32 K RAM
- USB to host
- I2C & Interrupts
  - Analog
  - Control
  - Ambient Light Sensor
  - Xtrinsic Accelerometer
  - Xtrinsic Magnetometer
  - Xtrinsic Barometer/Thermometer
  - Gyroscope
- USB to host
Enablement
The Sensor Toolbox
Unified Hardware, Software and Accessories

- 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
For Further Information

Sensors

- [www.freescale.com/sensors](http://www.freescale.com/sensors)
- [http://www.freescale.com/sensingplatform](http://www.freescale.com/sensingplatform)
- [http://www.freescale.com/sensordata](http://www.freescale.com/sensordata)
- [www.freescale.com/mems](http://www.freescale.com/mems)

Sensor Products

- [www.freescale.com/xyz](http://www.freescale.com/xyz)
- [www.freescale.com/magnetic](http://www.freescale.com/magnetic)
- [www.freescale.com/pressure](http://www.freescale.com/pressure)
- [http://www.freescale.com/sensortoolbox](http://www.freescale.com/sensortoolbox)

Blogs: Smart Sensors

  - 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”