Xtrinsic Sensing: Industrial Automation and Building Control Applications

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Abstract

Learn about the future of MEMS in Industrial Automation and Building Controls

Easy to Manage/Configure  High Reliability  Fast Response  Intuitive

Three Foundational Xtrinsic Sensing Technologies

Learn about Xtrinsic sensors that specifically support industrial and building control applications. These can maximize content collected from your environment to make intelligent decisions for controlling a wide range of systems, such as home thermostats, building elevators, bank kiosks, gas pumps, manufacturing operator panels and data access terminals. The following sensors will be discussed: FXAS21000 Xtrinsic 3-axis digital gyroscope, FXLC95000CL Xtrinsic intelligent motion-sensing platform and MMA955xL Xtrinsic motion sensing platform.
Agenda

• Industrial Automation and Building Control Applications
• Use Cases Today and Future
• 3 Foundational Sensor Technologies
• Freescale’s Reference Design
• Power Efficiency and Industrial Automation
• Sensor Resources
Industrial Automation and Building Control Applications

Market, Use Cases today and Future
Limitless Sensor and IoT Opportunities

Vision
Industrial Automation to Home Automation

- Appliance Control
- Smart Thermostat
- Room Occupancy
- Doors Open/Close
- Garage Door Control
- Air conditioning Control
- Turning on lights when home
- Smart Power Meter
- Proximity Detection for Occupancy detection
- Home Automation: Door/Window Control
Industrial Control and Monitoring

• Current Solutions
  - Statistical analysis
  - Trained employees
  - Monitor when broken to fix

• With Sensor Monitoring and Control
  - True real-time analysis
  - Real-time monitoring
  - Predictive failure
2006/42/EC Machine Directive

European Union
Harmonized Standards Supersede All others from End 2011 onwards (see Official Journal of the European Union for list)

EN ISO 13849-1/-2
(PLa – PLe) can be applied to pneumatic, hydraulic, mechanical as well as electrical systems

EN IEC 61508
"Functional safety of electrical/electronic/programmable electronic safety-related systems",
A product-oriented (hardware/software) functional safety standard

EN IEC 62061
(SIL1 – SIL3) limited to electrical systems

United States of America
ISO 26262
Functional Safety
Freescale Functional Safety in Industrial

- Recent industrial disasters have highlighted the need for improved safety, and an increasing number of industrial control systems are requiring IEC 61508 safety certification.

- Functional safety also is becoming more prevalent and stringent in markets such as solar energy and aviation, as well as FDA Class III medical. Electronics in industrial markets typically must operate with minimal faults in harsh environments. System designers can count on the solutions included in our SafeAssure functional safety program to stand up to rugged industrial conditions and be supported by the necessary documentation and safety expertise.
Home Automation Use Cases

• Turn up thermostat when on your way home
• Turn on the lights when on entering the room
• Turn down hot water heater when on vacation
• Turn off air conditioning when windows opened
• Warning when garage door is left open
• Warning when windows are left open, left unlocked.
Trends in Home Appliance Market

• Water and energy conservation
  – Increase MEMS / electronic solution
  – Higher resolution and accurate water consumption
  – Noise limitation
• Regulation and Standards

  EU Legislation on efficiency of Appliances

  US introduced the Energy Star program

  Energy Efficiency Standards and an Energy Label Program

  IEC 60730 Product Safety – “Class B”
Robotics Automation and Control

- Low-cost, low-power control in personal robots (vacuums, floor washers, mowers, pool cleaners)
- Control and motion in service robots for dangerous, strenuous or repetitive tasks (handling warehouse inventory, assisting nurses, security, construction, mining, industrial cleaning, waste handling, firefighting, rescue)
- Control, vision and motion in factory robots
- Navigation and communication in unmanned vehicles for air, ground and underwater defense, search and rescue
- Collision avoidance and safety in manned vehicles
Asset Tracking and Automation

- Equipment tracking for efficiencies, handling, location
- Staff tracking for efficiencies, safety, documentation of patient treatment
- First responders tracking with indoor navigation for faster response, location guidance, context and condition feedback
Sensor Monitoring and Control System

**Sensors**
- Continuous Monitoring
- Report State

**Sensor Module**

**Processing**
- Process Sensor Signatures
- Determine Safety Issue for shut-off
- Send Local Predictive Failure Messages

**Local Actuator**
- Actuate Motors as needed

**Wireless System Module**
- Monitor Processed Sensor Signatures
- Addition Safety Monitoring for shut-off
- Send Predictive Failure Message

Wireless Signals

Field Bus

External Use | 13
Sensors are now pervasive as a result of the portable revolution and advent of the Internet of Things (IoT).

**Freescale Sensors Timeline**

**One Billion and Counting**

From 1969 to 2012 Freescale has designed, produced and shipped innovative sensor products to global customers.

- **1969** - Manufacture our first unpatterned pressure sensor.
- **1990** - Begin increased pressure sensor production.
- **1995** - Introduce pressure sensors for fuel injection equipment.
- **1999** - Launch the SCD400 series of pressure sensors.
- **2000** - Launch a line of engine control sensors.
- **2001** - Launch compact, low cost, plastic pressure sensors.
- **2003** - Develop increased pressure sensors for automotive electronic systems.
- **2005** - Launch the SCD400 series of pressure sensors.
- **2007** - Launch a line of pressure sensors for automotive electronic systems.
- **2009** - Launch a line of pressure sensors for automotive electronic systems.
- **2011** - Launch a line of pressure sensors for automotive electronic systems.
- **2012** - Launch a line of pressure sensors for automotive electronic systems.

**Freescale Sensors has pioneered the development of innovative sensor products for over 32 years.**
Sensors at the Root of an IoT Device

Increasing Levels of Intelligence
- Decision making
- Software
- Programmability
- Applications
- Third-party Software

Increasing Levels of Integration
- Acceleration Sensors
- Battery Sensors
- Magnetic Sensors
- Pressure Sensors
- Radar Technology
- Touch Sensors

Market Leadership
>1 BILLION MEMs Sensors
#1 Independent Automotive MEMs Sensor Supplier

Sensing
Accelerometer
Magnetometer
Gyroscope
Pressure
Altimeter
Temperature etc.

Embedded Processing
MCU
MPU
Hybrid MCU/MPU
Network Processor

Connectivity
NFC
6LoPAN
Sub-Gig
ZigBee
GPS
BT/BLE
Wi-Fi
RFID
Cellular

Technology

Applications

Software

Many Other Services

Smart Lighting
Pedestrian Navigation
Smart Cars
M2M
Auto Safety
Smart Tags

Smart Homes
BLDG Automation
Remote Appliance Avoidance

Smart Energy
Air Quality Control
Supply Chain Automation

Smart Parking

Smart Grid

Technology Innovations

NXP

Freescale
Success Factor for Sensor Systems and Networks

• **Smart Sensors**
  - Sensor fusion and advanced algorithms
  - Complete solution

• **Intelligent Sensing Framework**
  - Proven platform to facilitate sensor firmware
  - Power management and communications services
  - Scalable over MCU and sensor families

• **Sensors**
  - Stability of temperature/media
  - Low power
  - Broad portfolio
  - Sensor integrated MCUs
Foundational Sensing Technologies

Xtrinsic Sensors
Review of the devices, technology, strengths and weaknesses that Sensor Fusion utilizes
MEMS & Sensor Technology

- eCompass
- Magnetometers
- Accelerometers
- Touch Sensors
- Gyroscope
- Altimeter / Pressure
## Sensor Strengths & Weaknesses

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Strengths</th>
<th>Weaknesses</th>
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<tbody>
<tr>
<td><strong>Accelerometer</strong></td>
<td>• Inexpensive</td>
<td>• Measures the difference of gravity and acceleration. We need them separate.</td>
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<tr>
<td></td>
<td>• Extremely low power</td>
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<td></td>
<td>• Very linear</td>
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<tr>
<td></td>
<td>• Very low noise</td>
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<tr>
<td><strong>Magnetometer</strong></td>
<td>• The only sensor that can orient itself with regard to “North”</td>
<td>• Subject to magnetic interference</td>
</tr>
<tr>
<td></td>
<td>• Insensitive to linear acceleration</td>
<td>• Not “spatially constant”</td>
</tr>
<tr>
<td><strong>Gyro</strong></td>
<td>• Independent of linear acceleration</td>
<td>• Power hog</td>
</tr>
<tr>
<td></td>
<td>• Can be used to “gyro-compensate” the magnetometer</td>
<td>• Long startup time</td>
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<td></td>
<td>• Zero rate offset drifts over time</td>
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<tr>
<td><strong>Pressure Sensor</strong></td>
<td>• The only stand-alone sensor that can give an indication of altitude</td>
<td>• A “relative” measurement</td>
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<td>• Subject to many interferences and environmental factors</td>
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MEMS and Sensor Fusion
“The Whole Is Greater Than the Sum of Its Parts”

- Individual sensors have inherent limitations and/or errors that can be corrected or compensated for by complementary sensing nodes:
  - **Accelerometer**: x, y & z linear motion sensing - sensitive to vibrations
  - **Gyroscope**: pitch, roll & yaw rotational sensing - zero bias drift
  - **Magnetometer**: x, y & z axis magnetic field sensing - sensitive to magnetic interference

- Fused sensor information is more accurate and reliable than individual sensor data:
  - e.g., Gyros suffer from offset drifts over time. A companion accelerometer’s data compensates for the offset drift.
Industrial Automation Examples
Challenges and Solutions
Passive Tamper Detection

**Motion or Magnetic Tamper Detection**

- Anti-tamper detection can be implemented by placing sensors on the casing of the meter to trigger a tamper during any of the following conditions:
  - Magnetic jamming detection (MAG3110)
  - Shock detection for force detection
  - TAMPER inputs are filtered to reject noise

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![Sensor Hub MMA955x Signal Conditioning](image1)

**MAG3110**

**FXLN8371**
Condition Monitoring

The process of monitoring data that is collected from sensors on industrial equipment
- Vibration Signatures and Changes
- Pressure
- Flow
- Acoustic
- Location
- Shock Detection
- Machine operating characteristics
- Installation process or motion signature

• Prevent unexpected equipment breakdowns
• More effectively schedule maintenance activities
• Improve operation efficiency
• Increases return on assets
Vibration Data Monitoring

- Accelerometers measure vibrations which can be processed with an FFT for vibration data
- Provides very detailed information on the machine condition
- Helps to identify specific problems within a machine
- Track developing faults. By tracking changes in a vibration signature it is possible to know which component is having a problem and estimate approximate time to failure.

Some applications will not require FFT since their dominant frequencies are well known. An example of this would be a 120 Hz AC motor or a 60 Hz appliance. However, most applications will require some form of vibration characterization to be successful.
Monitoring the Bearings

• Most machines involve rotary mechanisms. Motors, pumps, compressors, fans, belt conveyors, gearboxes, all involve rotary mechanisms and are frequently used in machines.

• Most rotary mechanisms in turn have bearings that support the weight of rotating parts and bear the forces associated with rotary motion and vibration. In general, large amounts of force are borne by bearings. It is not surprising that bearings are often the place where damage occurs and where symptoms first develop.
Absolute Acceleration Measurements

- Stabilizing feedback signals
- Orientation correction
- Control the level and spectral content of motion
- Perfecting the structural behavior
- Shock Detection for Warranty
Xtrinsic FXLC95000CL
32-bit MCU Sensor Fusion Hub with Accelerometer

• **Differentiating Points**
  - System in Package: 32-bit MCU and 3-axis accelerometer
  - Open MCU architecture enables differentiated creativity
  - First open programming model with library support
  - Compute and actuate locally
  - Best in class accelerometer noise & resolution performance

• **When to choose FXLC9500CL**
  - Sensor hub managing multiple sensors
  - Pass through data as needed i.e., heading
  - Perform 6-axis fusion
  - Mag/accel cal/ecompass
  - Gyro/accel

• **Typical Applications**
  - Mobile: Phones, Tablets, eReaders
  - Controllers: Remotes, Games
  - Sports Monitoring
  - Motion enabled accessories
Xtrinsic Intelligent Sensing Framework (ISF)

- **Differentiating Points**
  - Industry’s First open Intelligent Motion Platform Framework
  - Significantly reduce time to market
  - Scalable from intelligent sensor and through Kalman filter
  - Power management features enabling low power modes

- **Product Features**
  - Provides a single unified interface for sensor data regardless of sensor types
  - Enables developer to concentrate on using sensor data, not getting sensor data
  - Eliminates intensive sensor integration effort
  - Provides power management of the platform to achieve lowest power mode of operation
  - Known good framework to rely on

- **Typical Applications**
  - Mobile: Phones, Tablets, eReaders
  - Controllers: Remotes, Gaming
  - Sports Monitoring Performance Monitoring
  - Augmented Reality
Wireless Sensor Monitoring Demo

Xtrinsic Sensor Fusion
Sensor Fusion Development Hardware

Sensor Area Networks will utilize various radios and protocols depending on energy efficiency and compatibility requirements.
Freescale Xtrinsic Vibration Monitoring

• 512 point FFT computed locally on FRDM-KL25Z Freedom Board
• Sensor readings from attached FRDM-FXS-Multi-B sensor board
• FFT coefficients transmitted to PC for demo display and further analysis
• Targeted at IoT machine monitoring
Vibration Detection Capability

- **Example – FXLS8471Q**
  - 3-axis accelerometer with selectable ODR= 1.56 Hz to 800 Hz, Less than 150 μg/√Hz low-noise, 14-bit resolution
  - 800Hz sampling gives 400Hz bandwidth.
  - Resolution within that bandwidth is unlimited and depends only on how big (how long in time) an FFT you perform.

- **Measurement of motor**
  - Absolute vibration levels often do not provide a satisfactory indication of the condition of a machine; only changes in level are relevant.

- **Examples of motor predictive failure with detected frequencies:**
  - 5.4 Hz (repetition rate of forced lubrication system on actual bearing, and harmonics)
  - 6.4 Hz (repetition range of the forced lubrication system on adjacent bearings, and harmonics)
  - 15.43 Hz (ie ball-passing frequency for an outer raceway defect and its harmonics).
Power Efficiency and Industrial Automation

Power Efficient Products and Solutions
Sensor Algorithms Developed using most efficient MCU’s Power Modes

MKL25Z
ARM® Cortex™- M0+
48MHz core clock
24MHz bus clock
24MHz flash
IDD_{RUN} has peripherals disabled

Regulator on CPU on Peripherals on
High speed clock
Wake via interrupt

Regulator on
CPU off
Peripherals disabled
High speed clock
Wake via interrupt

Regulator on
CPU off
Peripherals off
High speed clock
Wake via interrupt

Regulator in low power
CPU off
Peripherals on
CPU=4MHz max, flash<800KHz

Regulator in low power
CPU on
Peripherals on
CPU=4MHz max, flash<800KHz

Chip in static mode with LVD off
Regulator in low power mode

Chip in state retention mode

FLL acquisition time = 1ms
PLL lock time ~ .69ms
PLL IDD adder = 600 μA @ 48MHz
PLL IDD adder = 1060 μA @ 96MHz

ARM and Cortex are trademarks or registered trademarks of ARM Ltd or its subsidiaries.
Including power efficient Analog Solutions

- **Analog Products for the Industrial Market**
  - Leveraging a legacy of automotive analog leadership, we also provide industrial solutions designed for safety, reliability and performance.
  - Freescale provides robust, reliable high-performance analog mixed-signal and power solutions that bridge real world signals with connected processor intelligence enabling complete embedded system solutions.
  - Analog products designed for a broad array of applications including factory automation systems, industrial networking and power management equipment, portable medical products, smart home and building controls as well as energy storage systems.
Industrial Longevity and Quality
Providing long-term production support
Freescale Longevity Program

• The embedded market needs long-term product support
• Freescale has a longstanding track record of providing long-term production support for our products
• Freescale is pleased to introduce a formal product longevity program for the market segments we serve
  – Automotive and medical segments: Freescale will make a broad range of program devices available for a minimum of 15 years
  – All other market segments in which Freescale participates, Freescale will make a broad range of devices available for a minimum of 10 years
  – Life cycles begin at the time of launch
• A list of participating Freescale products is available at: www.freescale.com/productlongevity
# Application/Qualification Tiers

<table>
<thead>
<tr>
<th>Tier</th>
<th>Typical Application Use-Time</th>
<th>Power-On Hours</th>
<th>Examples of Typical Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;blank&gt;</td>
<td></td>
<td></td>
<td>No tier level currently defined (to be determined) or tier level not applicable for this product.</td>
</tr>
<tr>
<td>Commercial</td>
<td>5 years</td>
<td>Part-time/Full-time</td>
<td>PCs, consumer electronics, portable telecom products, PDAs, etc.</td>
</tr>
<tr>
<td>Industrial</td>
<td>10 years</td>
<td>Part-time/Full-time</td>
<td>Installed telecom equipment, work stations, servers, routers, etc. Can also be used in Commercial applications.</td>
</tr>
<tr>
<td>Automotive</td>
<td>10-20 years</td>
<td>Part-time/Full-time</td>
<td>&quot;under the hood&quot;, drive train control, safety equipment, etc. Can also be used in Commercial and Industrial applications.</td>
</tr>
</tbody>
</table>

* Please refer to product data sheets for operating temperature ranges, since they are independent of tier and will vary per product.
More Information on Freescale Sensor Solutions

Visit us on Freescale.com:
- http://www.freescale.com/sensors
- http://www.freescale.com/sensortoolbox
- http://www.freescale.com/xyz
- http://www.freescale.com/magnetic
- http://www.freescale.com/gyroscope
- http://www.freescale.com/pressure
- http://www.freescale.com/ISF

Blogs: Smart Mobile Devices
- Xtrinsic Related Blogs
  - Magnetometer placement – where and why
  - Hard and soft iron magnetic compensation explained
  - Magnetic sensor makes electronic compass design easy
  - Online data sets for inertial & magnetic sensors (part 1)

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- Xtrinsic Sensor Fusion Toolbox

Watch our Xtrinsic Sensor Videos on YouTube
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