Using NXP Sensors in Smart Home Applications

Michelle Kelsey

Motion Sensor PL

Sensor Business Line

June 2019 | Session #AMF-SMH-T3705

NXP

SECURE CONNECTIONS
FOR A SMARTER WORLD

Agenda

- Overview of NXP Sensor Business Line

- Insights into the Smart Home Market

- Requirements of Sensor Use Cases for Smart Home Market

- Overview of NXP Sensor Enablement for Smart Home Applications

- More Information/Q&A

NXP Sensors Overview

- Low power

- Small size

- High performance

- Precision sense and control

- Broad sensor portfolio

- Robust and reliable designs over temperature and harsh media

- Functional safety and 30+ year auto experience

- Software and algorithm enablement

- NXP portfolio for complete system solutions

- Trusted supplier with long term product commitments

Applications

Safety Systems
- Airbag deployment sensors
- Tire pressure monitoring sensor system

Automotive Systems
- Wheel rotation speed sensing
- Power train and engine management
- Steering angle and BLDC rotor position detection

Industrial & Medical
- Industrial IoT applications
- Surveillance & monitoring
- Telehealth
- Medical devices and hearables

Performance Consumer
- Activity and asset tracking
- Intuitive human interface
- Quantified wellness and personal fitness
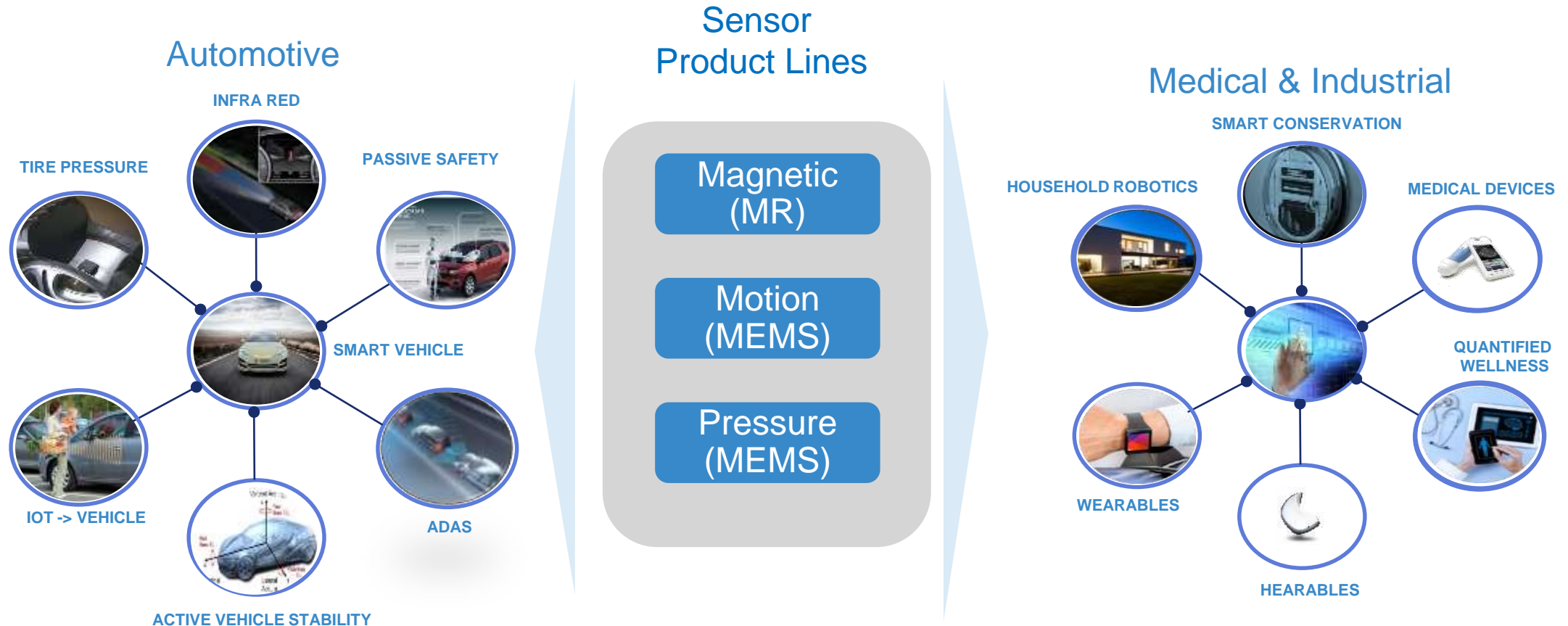- Connected and smart home

Market Leadership

#1	Merchant Automotive MEMS
#4	Inertial and Pressure MEMS sensors

NXP Sensor Technology Supports Key Applications

Automotive

- INFRA RED
- PASSIVE SAFETY
- TIRE PRESSURE
- SMART VEHICLE
- IOT -> VEHICLE
- ADAS
- ACTIVE VEHICLE STABILITY

Sensor Product Lines

- Magnetic (MR)
- Motion (MEMS)
- Pressure (MEMS)

Medical & Industrial

- SMART CONSERVATION
- HOUSEHOLD ROBOTICS
- MEDICAL DEVICES
- QUANTIFIED WELLNESS
- WEARABLES
- HEARABLES

3+ billion units shipped

Smart Home Applications

Global Smart Home Market

- **Home Security**
  - Authenticated Access (fingerprint, NFC)
  - Theft prevention and home monitoring
  - Security Cameras

- **Efficiency**
  - HVAC
  - Smart Metering
  - Plumbing

- **Appliances**
  - Various Appliances

- **Comfort and Convenience**
  - Smart beds
  - Small Appliances

- **Home Automation**
  - Lighting
  - Garage Door opening
  - Thermostat control
  - Robotic Vacuums
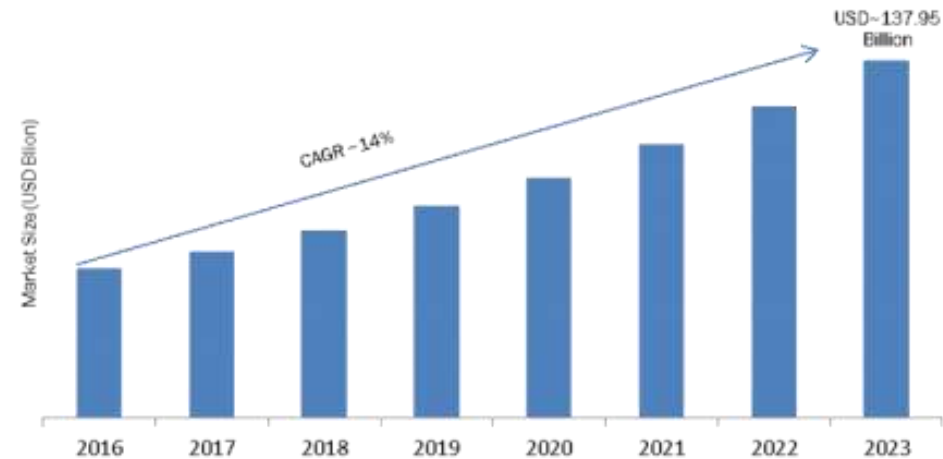
Smart Home Market 2019 Global Analysis by Region, Business Availability, Development, Industry Size, Growth and Trends by Forecast to 2023
Mon Jan 21, 2019 - 14:30pm UTC

Home Security

Home Security Market

System Type

- Professionally Installed & Monitored Systems
- Self-Installed & Professionally Monitored Systems
- Do-It-Yourself (DIY) Systems

Product Offering

- Fire Detection Systems
- Video Surveillance Systems
- Access Control Systems
- Intruder Alarms
- Other Systems

Home Type

- Independent Homes
- Apartments and Condominiums

Market Growth

- Expected to grow from USD 33.47 billion in 2017 to USD 55 billion by 2023
- CAGR of 9% during the forecast period 2018–2023
- Increasing criminal activities increase adoption
- Advancement in remote monitoring and connectivity technology increase home security systems market.
- High initial installation cost limit the market growth
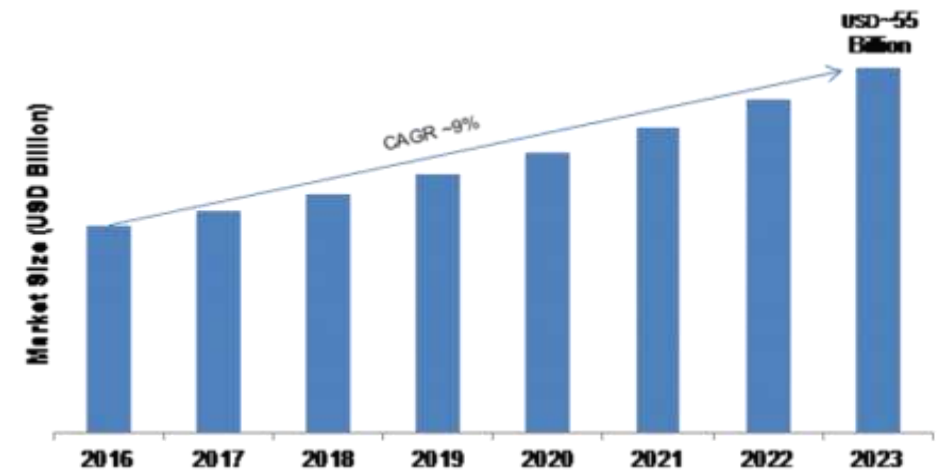
Home Security Systems Market 2019 Global Industry Analysis, Development, Growth Status, Opportunities, Key Strategies, Future Plans and Trends by Forecast 2023
Thu Mar 14, 2019 - 11:30am UTC

# Smart Connected Door and Window Monitoring

Use Case

- Accelerometer to detect door knock, door/window tamper and shock
- Accelerometer to avoid magnetic jamming for door open/close detection
- Magnetometer to determine door position for door open/close detection

Critical Parameters

- Always 'ON' Accelerometer
- Low Active power for battery powered products
- Transient Detection, Motion Detection
- Auto wake Sleep for power savings
- Magnetometer Sensitivity
- Efficient Magnetic calibration
- Parameter change with temperature (TCO, TCS)

Enabled by Accelerometers and Magnetic Sensors

- FXOS8700CQ 6-axis sensor high resolution (14/16 bit), low noise and low power hybrid mode
- MMA8451 high performance 3-axis accelerometer with low noise, 14-bit resolution, and TCO performance.
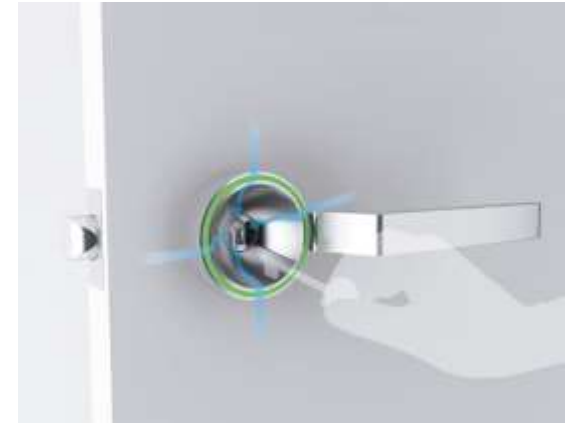
Home Security Cameras

Sensors Use Case

- An accelerometer is used to detect heading information, angle along with tamper and vibration detection
- Magnetometer for tilt compensation

Critical Parameters

- Accurate compass heading
- Yaw detection
- Accurate magnetic calibration
- Tilt compensation
- Offset change with temperature
- Sensitivity change with temperature

Enabled by Accelerometer + Magnetometer

- FXOS8700, for orientation, motion, vibration, shock, fall, g-force, altitude changes etc. are present
- MMA8451 High performance 3-axis accelerometer with low noise, 14-bit resolution, and TCO performance
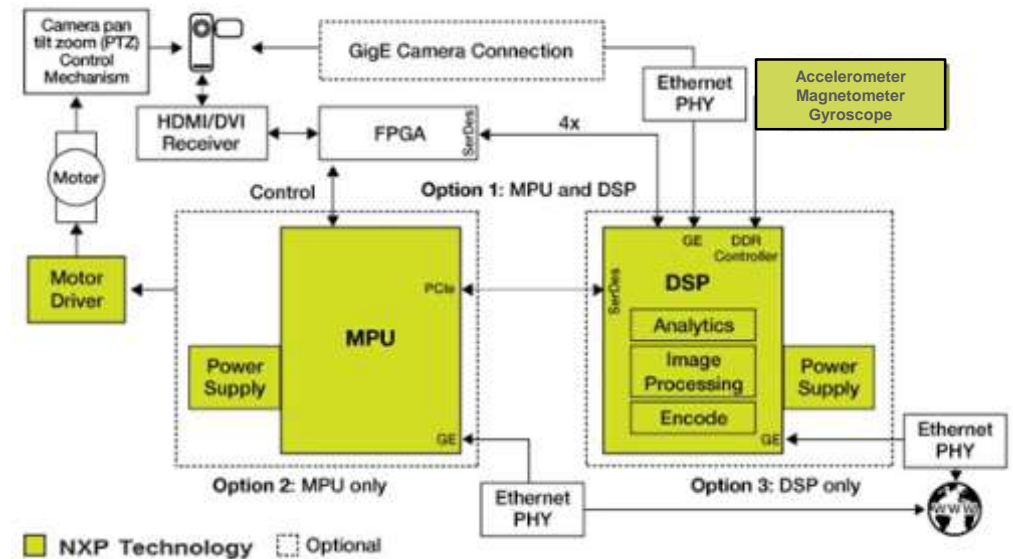
Home Efficiency

Heating, Ventilation, and Air Conditioning Market

Market Segmentation

- Heating controls
- Humidity controls
- Ventilation controls
- Integrated controls

Market Growth Factors

Climatic fluctuations in many countries, continued urbanization, growing e-commerce retail, population growth, and growing awareness about environmental protection

Market Trends

The Electric Power Research Institute (EPRI) has received a US $ 4.7 mn grant from the California Strategic Growth Council to develop advanced residential HVAC systems with low global warming potential (GWP) refrigerants. EPRI will also conduct community studies to bring technology to low-income and disadvantaged Californians. 28 JAN 2019
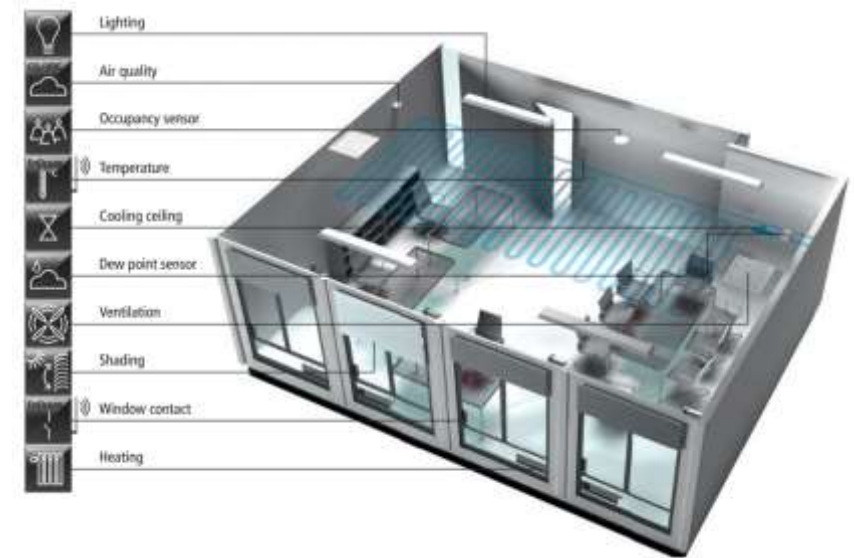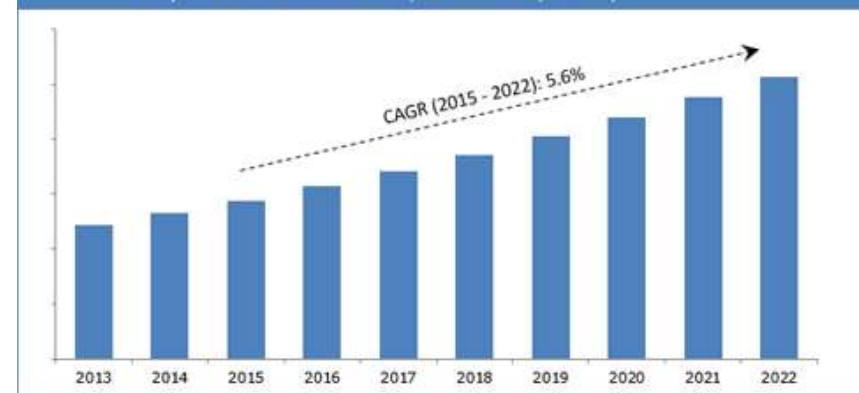

FIG. 1 — Global HVAC (Heating, Ventilation, and Air Conditioning) Market Revenue and Compound Annual Growth Rate, 2013 – 2022 (US$ Bn)

CAGR (2015 - 2022): 5.6%

2013 2014 2015 2016 2017 2018 2019 2020 2021 2022

# Intelligent HVAC Smart Filter Monitoring

Use Case

- A differential sensor can be used as a system monitoring device to regulate fan speed, fan performance and filter life in a Variable Air Volume (VAV) system. The device is typically located inside the duct work, filter housing or fan housing.

- Two pressures sources are measured as for example pre-filter and post-filter to determine filter performance.

Critical Factors

- Pressure range
- Resolution
- Repeatability
- Gauge/differential
- Sensitivity

Enabled by Pressure Sensors

- MPX2010 high performance
- MPX10
- NPS30 family currently in development
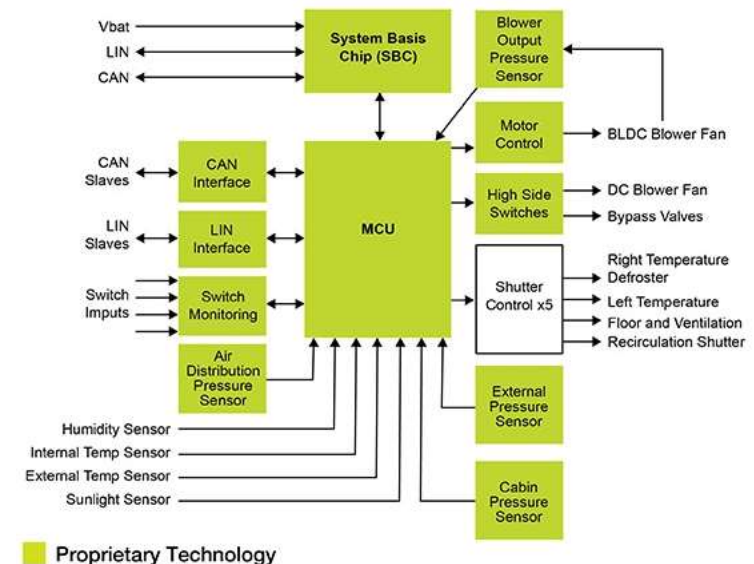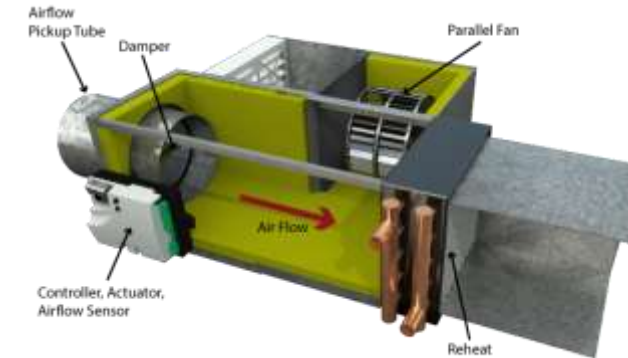
Smart Metering and Tamper Detection

Sensor Use Case

- Motion Sensors for Tamper detection or damage from storm

- Accelerometers to detect orientation detection to confirm correct installation

- Gas Meters: Absolute pressure sensors are able to derive the actual pressure and temperature at the inlet of the gas meter. Allowing the utility company to more accurately compute the standard volume, at the meter, and wirelessly transmit the reading to the utility company

Critical Parameters

- Standby power (minimum power draw from the meter)

- Low active power for always on application

- Zero-g offset change with temperature

- Preconfigured tilt detection trigger

Enabled By

- MPL3115A2 barometric measurement for standard volume delivered to customer

- MPVZ4006 media resistant differential flow sensor

- MMA8491 for tamper detection

Electronic Tamper Detection Smart Meter Reference Design
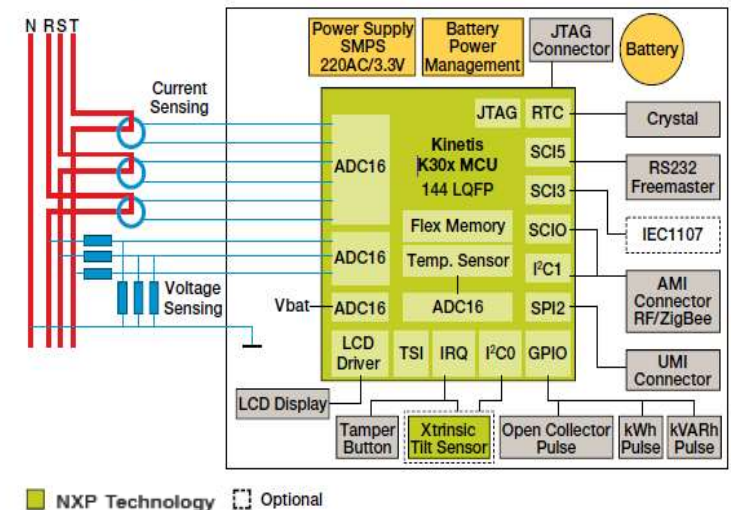
# Plumbing Monitoring

- ## Sensor Use Case
  - Monitor vibration signatures of all major pipes
  - Monitor water leaks in a burst pipe or broken supply line under sinks using Differential Pressure Sensors
  - Transmit anomaly detection to Home Hub
  - Devices are located on all major plumbing systems
  - Sensor and main controller are located on the same module.

- ## Critical Requirements
  - The main sensor data transmission necessary for this application is 1 axis acceleration, transmitted as acceleration in g
  - The acceleration is provided by 10-bit or 16-bits precision
  - Operating temperature requirement is -40°C to +125°C

- ## Enabled By
  - NPS300x differential pressure sensor
  - MPVZ4006 media resistant differential flow sensor
  - FXLS8471 for vibration monitoring

Boilers

Hot Water Tank

Pumps

Heat Exchanger

Domestic Water Supply

Chiller
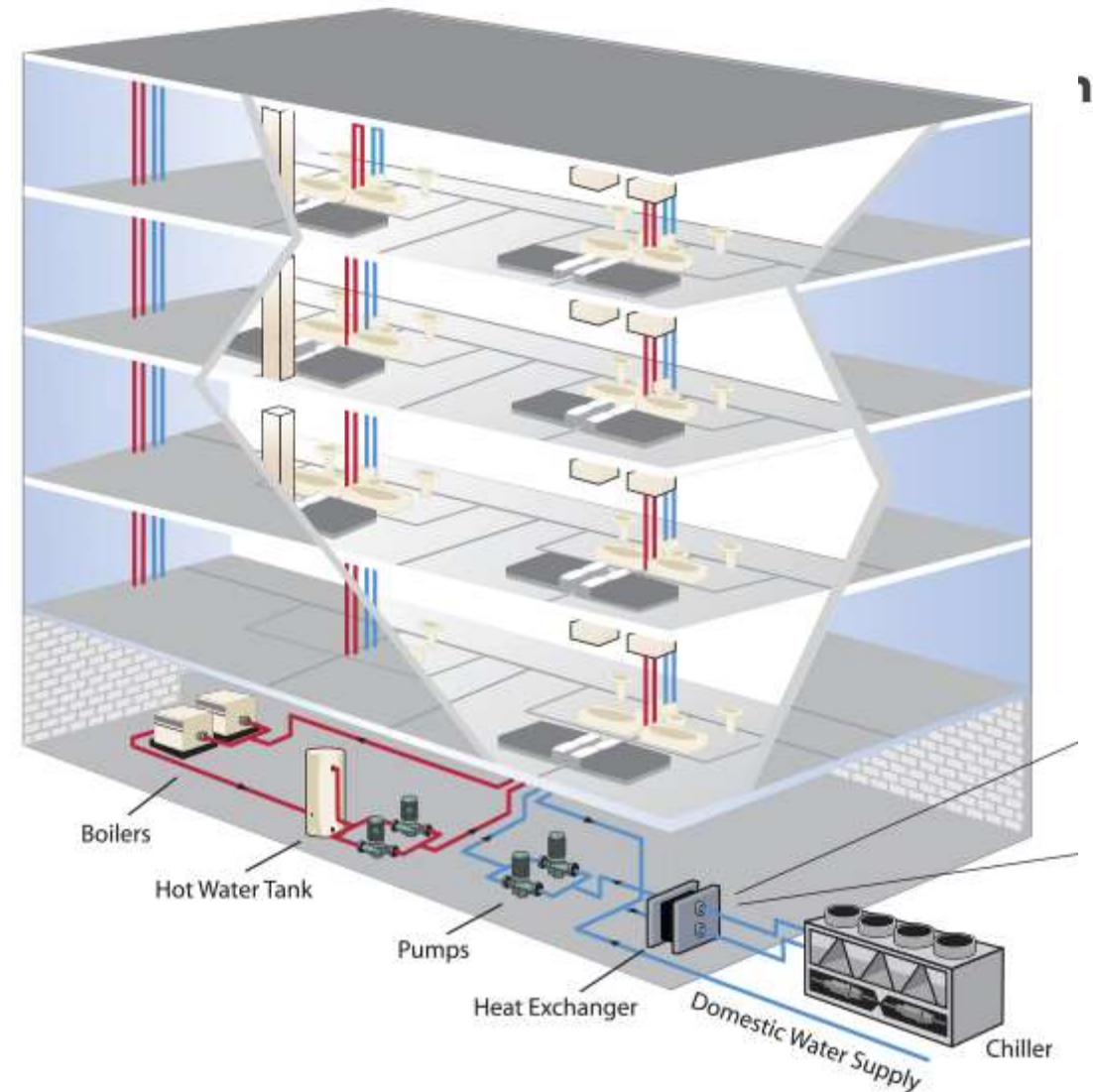
Home Appliances

Household Appliance Market

Market Segmentation:

- Water heater (boiler/geyser)

- Dishwasher

- Refrigerator

- Cooktop, cooking range, microwave & oven

- Vacuum cleaner

> Largest revenue share: 27.8% in 2016 modest 3.3% CAGR to 2025

- Mixer, grinder, & food processor

- Washing machine

- Air conditioner & heater

> Highest growth segment: CAGR 5% to 2025.

Market Trends
- increasing connectivity, the Internet of Things (IoT) makes it possible to access the appliances in real time even without the physical presence of the user.
- This has resulted in easy and efficient use of these products.

U.S. household appliances market size, by product type, 2014 - 2025 (USD Billion)

Legend: Water heater (boiler/geyser) | Dishwasher | Refrigerator | Cooktop, cooking range, microwave, & oven | Vacuum cleaner | Mixer, grinder, & food processor | Washing machine | Air conditioner & heater

NXP
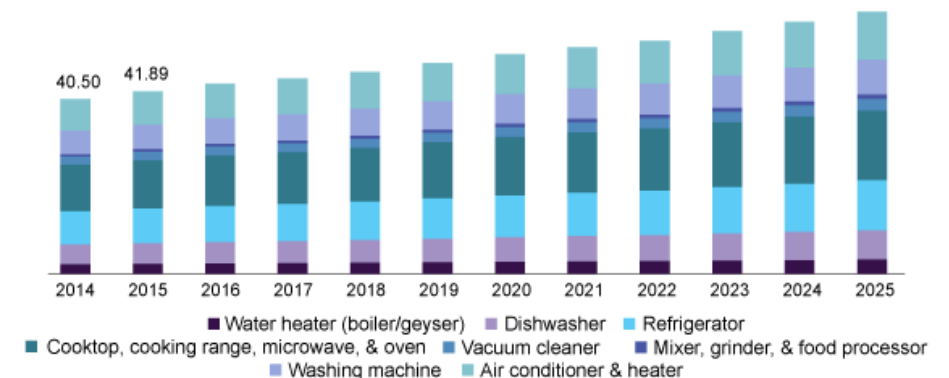
Appliance Condition Monitoring

Sensors Use Case

- Smart Pool Pump, Washing Machine and Smart Stove.

- Accelerometer detects vibration signatures to measure the fundamental frequency of a motor along with its harmonics

- Detecting changes as a result of shaft misalignment, bearing failures, load imbalance, gearbox faults, drive belt failures

- Extracted Features include Variance, Standard Deviation, Kurtosis, FFT and Mean Crossing Rate.

- Pressure sensors detect water/air flow in appliances.

- Accelerometer and magnetometer can also be used to monitor the door position of appliances.
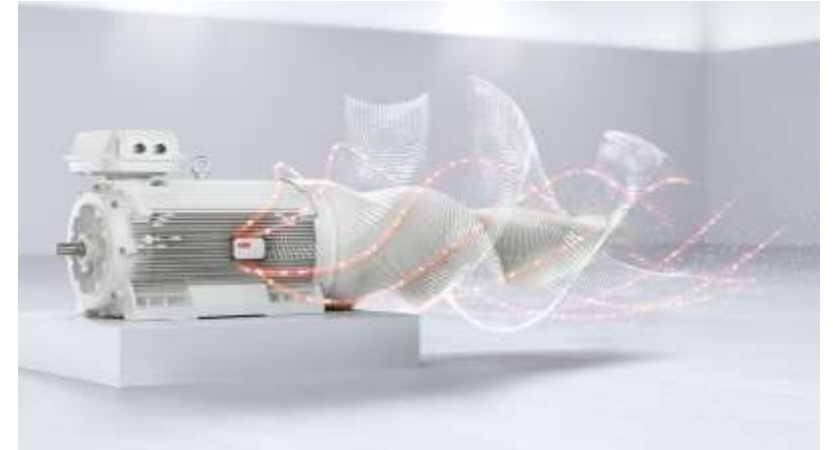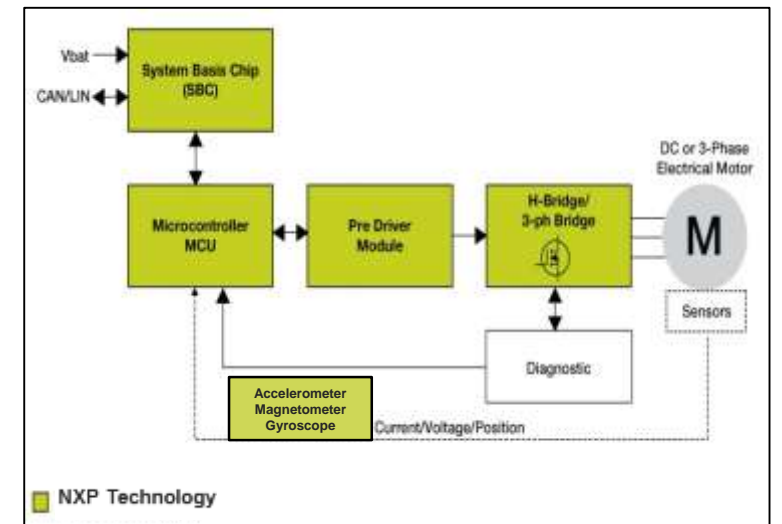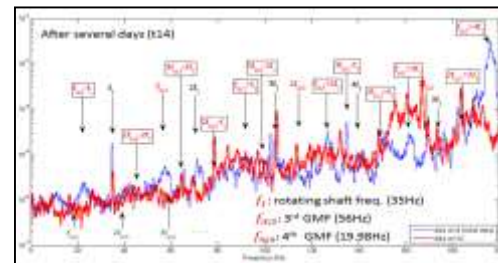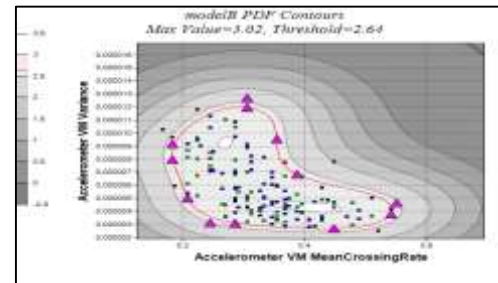
Critical Parameters

- High bandwidth
- Low Non-linearity
- Low noise
- Active power (battery powered to avoid loose wires)

## Enabled By

- FXOS8700: 14-Bit Resolution, Low noise
- FXLN83xxQ: Analog Accelerometers
- FXLS8471Q: ±2g/±4g/±8g, Low g, 14-Bit Digital Accelerometer

Washing Machine/Dishwashers

- Accelerometer vibration and machine learning to identify the different operating states of the machine

- Accelerometer and magnetometer to monitor the Open/close position of the lid (marks the start of the washing cycle)

- Pressure sensor monitors water level. Number of Wash cycles depend on the water level in the drum.
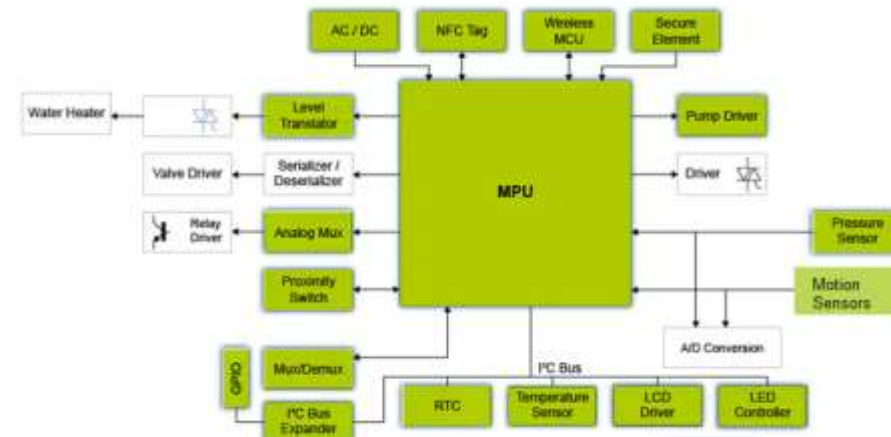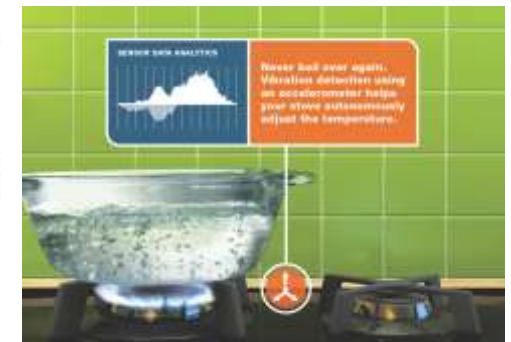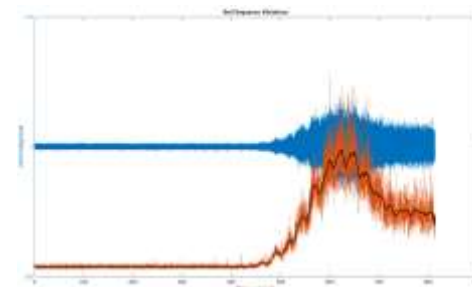
Smart Cooktop, Cooking Range, Microwave & Oven

Use Case

- Accelerometer to detect open/close position of refrigerator and oven to avoid over heating
- Accelerometer to understand door knock and show list of items in the fridge
- Pressure sensor to detect the weight of food on the tray for periodic updates
- Detect fluid pressure on a membrane controlling the availability of fluid
- As the water boils, the cooktop experiences unique vibrations continuously
- Vibration signatures can be captured by an accelerometer and analyzed to understand the different states of water boiling
- Can Identify output states: Simmer, high heat and Not boiling
- Supervised Machine Learning can then help classify the real time boiling data to these 3 states

Market Trends

- Personalization, automation driving kitchen development
- different platforms to personalize and streamline the meal preparation process.

The periodic heating cycle of the stove top was captured in the standard deviation feature

Refrigerators

Use Case

- Accelerometer to detect open/close position of refrigerator and oven to avoid over heating
- Accelerometer to understand door knock and show list of items in the fridge
- Pressure sensor to detect the weight of food on the tray for periodic updates
- Detect fluid pressure on a membrane controlling the availability of fluid. It can provide the availability of drinks

Critical Parameters

- Always 'ON' Accelerometer
- Low Active power for battery powered products
- Transient Detection, Motion Detection
- Auto wake Sleep for power savings
- Magnetometer Sensitivity
- Efficient Magnetic calibration
- Parameter change with temperature (TCO, TCS)

Enabled by Accelerometers and Magnetic Sensors

- **FXOS8700CQ 6-axis sensor** high resolution (14/16 bit), low noise and low power hybrid mode
- **MMA8451** high performance 3-axis accelerometer with low noise, 14-bit resolution, and TCO performance.
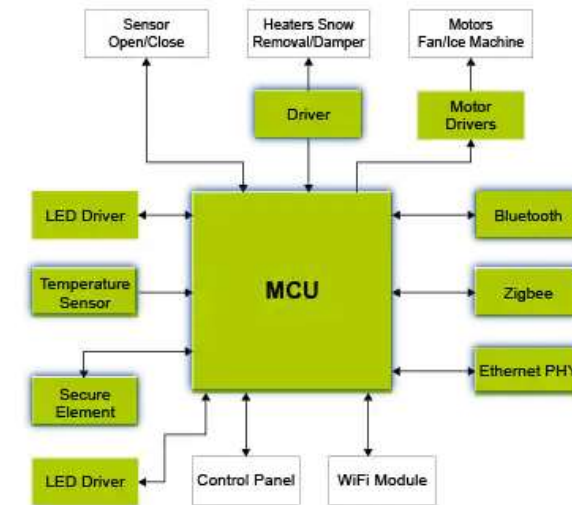
Home Comfort and Convenience

Smart House Lighting
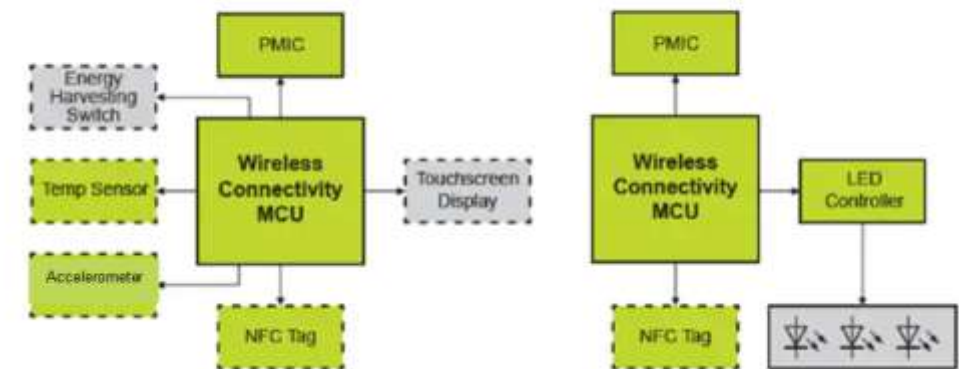
- ## Sensor Use Cases

  - Tamper Detection for Security lighting using Accelerometers
  - Gyroscopes can be used on wireless lanterns to change light colors and shades based on angle of rotation

- ## Critical Parameters

  - High Sampling rate
  - High ODR
  - Motion interrupts based on FIFO

- ## Enabled By

  - MMA8451 High performance 3-axis accelerometer with low noise, 14-bit resolution, and TCO performance
  - FXAS21002 angular acceleration detection with the ability to determine yaw, pitch and roll that complements NXP's broader sensor portfolio
  - FXOS8700 for orientation, motion, vibration, shock, fall, g-force, altitude changes

Comfort Smart Beds at Home

- **Sensor Use Cases**
  - The pressure sensor enables mattress to make automatic adjustments via a air-controlled system to adapt to sleep patterns, creating the optimal comfort and firmness
  - Accelerometers can be installed in the bed to track sleep condition of the person
  - Accelerometers for low power system to wake to guide a woken up person in the night

- **Critical Parameters**
  - Pressure Range
  - Resolution
  - Sensitivity
  - Higher sampling rate
  - Full scale range
  - Low power wake up on motion

- **Enabled By**
  - MMA8451 High performance 3-axis accelerometer with low noise, 14-bit resolution, and TCO performance
  - FXAS21002 angular acceleration detection with the ability to determine yaw, pitch and roll that complements NXP's broader sensor portfolio
  - FXOS8700 for orientation, motion, vibration, shock, fall, g-force, altitude changes

Smart Home Portable Appliances

Use Case

- Smart Iron: Sleep on No-Motion/Tilt, Wake up on Motion, Steam Press on forward movement
- Smart Torch: Automated torch switch ON in dark places on a Shake Motion
- Smart Styling tools: The movement and orientation of the dryer/brush can be monitored to ensure healthy brush practice
- Portable vacuum Cleaner: Wake up the system on motion

Critical Parameters

- Low Power Wake up
- Transient Detection, Motion Detection, Vector Magnitude
- Auto wake Sleep for power savings
- Low TCO
- High Tilt Accuracy (Good sensitivity)
- Orientation Detection: Sensor Fusion Algorithm

Enabled By

- MMA8652: small 2x2 mm 3-axis accelerometer with low power, good dynamic performance and fast turn on time
- MMA8451 high performance 3-axis accelerometer with low noise, 14-bit resolution and TCO performance.
- RD-KL25-AGMP01 9-axis small factor data logger board useful for data analytic applications
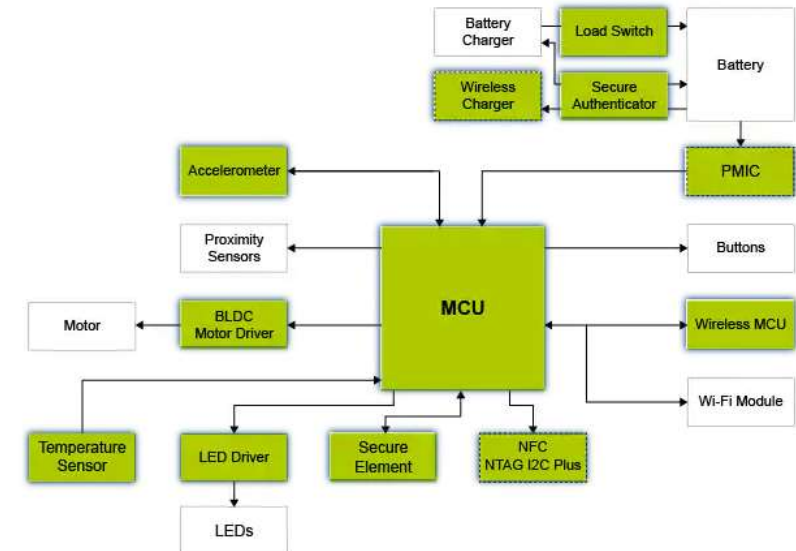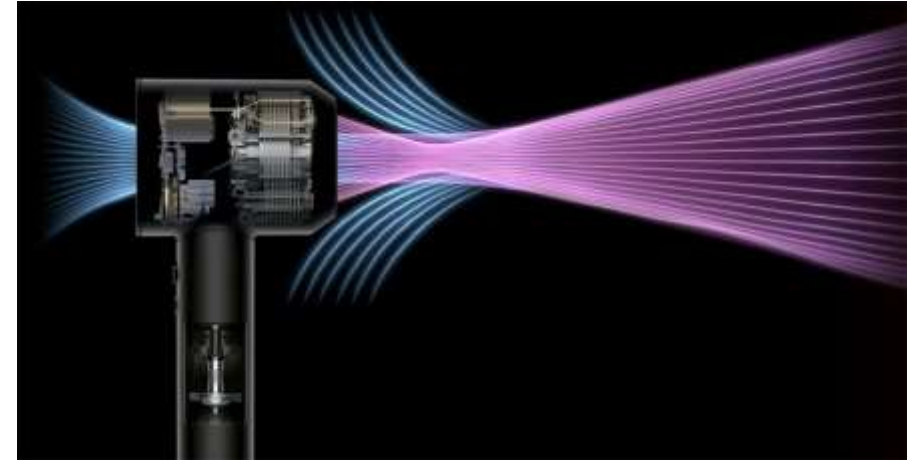
Device Monitoring for Home Safety

Sensor Use Cases

- Low Power wake up detection for remotely monitoring precious goods in the house to avoid Theft.
- Low Power Wake up to avoid children from indulging with dangerous goods such as knives, blades or medicine boxes.
- Cabinet monitoring to avoid harsh chemicals

Critical Parameters

- Low standby power
- active power for always
- Low power wake up
- Motion detection (Relative mode)

Enabled By

- FXL8972 low power wake up accelerometer

Home Automation

Home Automation Global Market

Market segment by Application

- Security
- Lighting
- Entertainment
- HVAC & Energy Management
- Smart Kitchen

Market Trends

- Increase in usage of internet of things (IoT) mainly in the developed countries.
- Preference for advanced standards of living with access to smart
- Globally, the increase in electricity prices has increased house owners' operating budgets

Market Size and Growth

$85 billion by 2023   Garner Insights

USD ~85 Billion

CAGR ~ ~11%

USD Billion

2017 2018 2019 2020 2021 2022 2023

History Year: 2014-2018
Base Year: 2018
Estimated Year: 2019
Forecast Year 2019 to 2025

Vacuum Cleaners

- **Sensor Use Cases**
  - Pool Pump Cleaner, Vacuum Cleaner for the house, Robots for kitchen aid
  - Angle of robot arm
  - Orientation Detection, collision Avoidance, Tracking turns
  - Safety switch

- **Critical Parameters**
  - Angle random walk and bias stability
  - 3-axis angular rate detection
  - High Sensitivity and low noise
  - Sensor Fusion algorithm
  - Temperature variation of offset (Z axis)
  - Temperature variation of sensitivity

- **Enabled By**
  - MMA8451 High performance 3-axis accelerometer with low noise, 14-bit resolution, and TCO performance.
  - FXAS21002 angular acceleration detection with the ability to determine yaw, pitch and roll that complements NXP's broader sensor portfolio.
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NXP
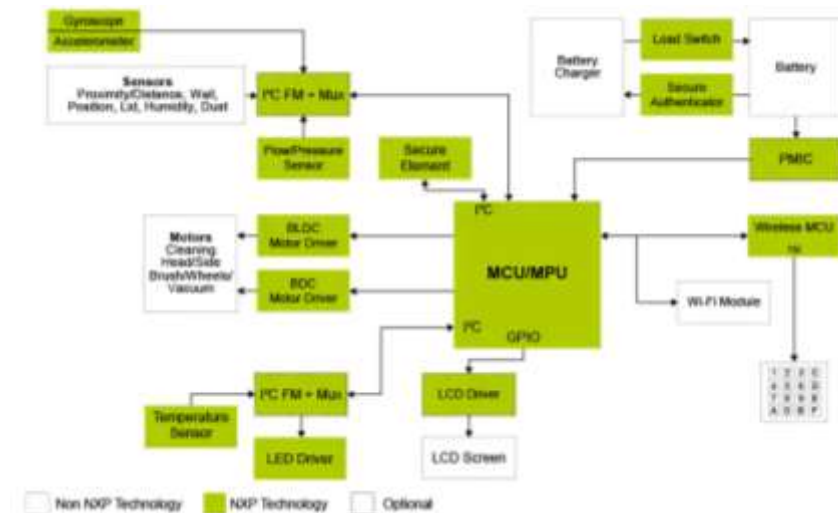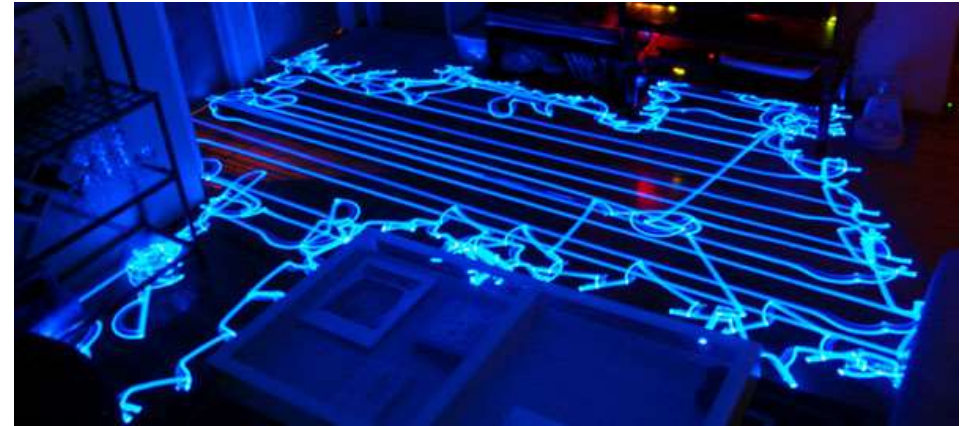
Smart Lock Market

Market Size

- Estimated at $559.4 million in 2016
- CAGR of just over 60.0%
- Projected to exceed 135 million units by 2024.

Market Trends

- Rising adoption of connected home solutions and soaring need to establish connectivity across all electronic devices in users' houses as a consequence of growing penetration of smart homes are among the key trends escalating market growth.

Market Enablement

- Cloud connectivity
- Enabled by BLE, WiFi and NFC for more adaptive and robust solutions

U.S. smart lock market size, by application, 2013-2024 (USD Million)

Residential ■ Hospitality ■ Enterprise ■ Critical Infra ■ Others
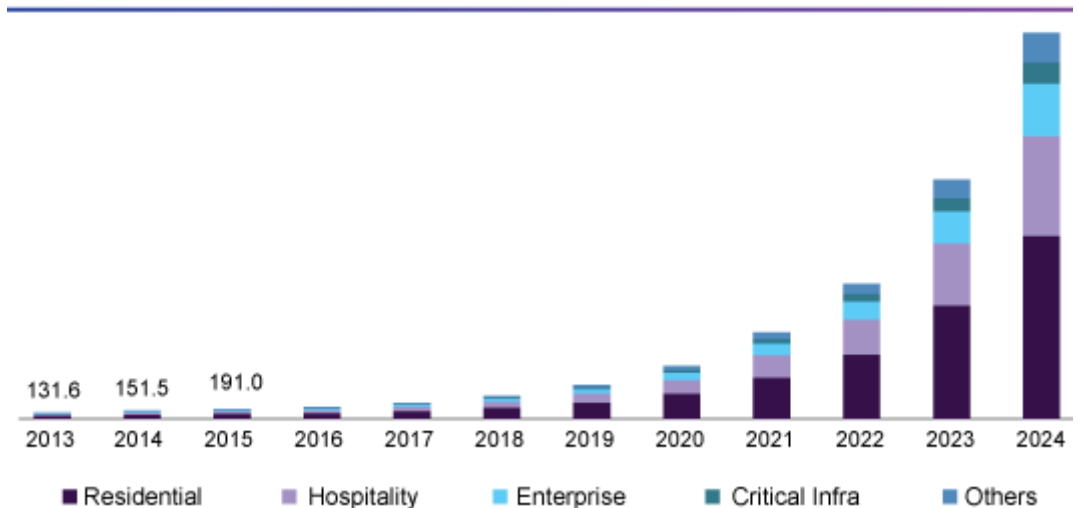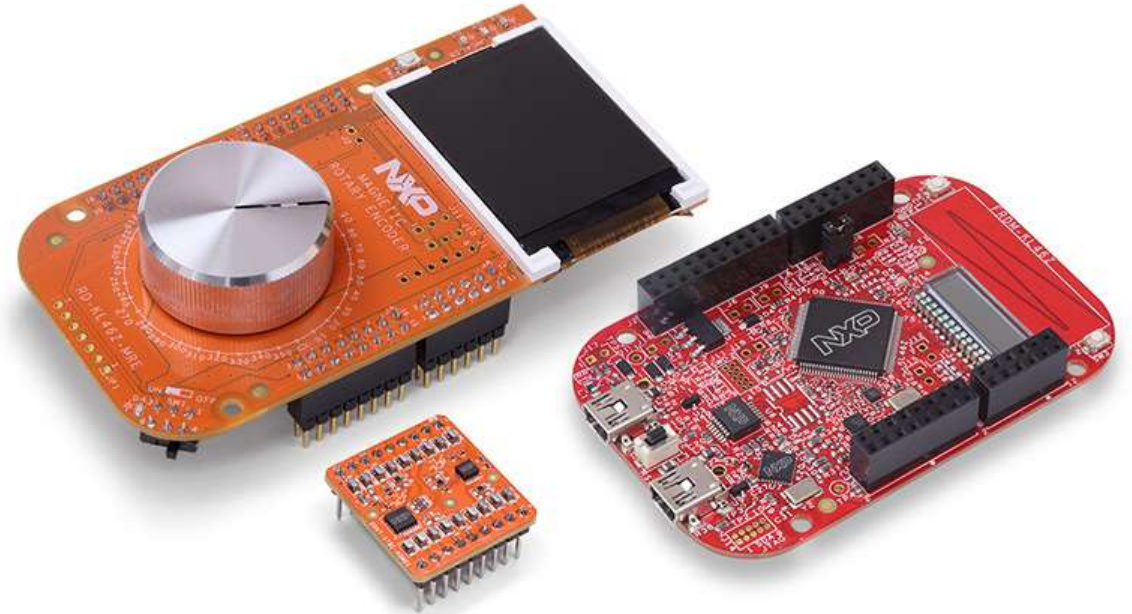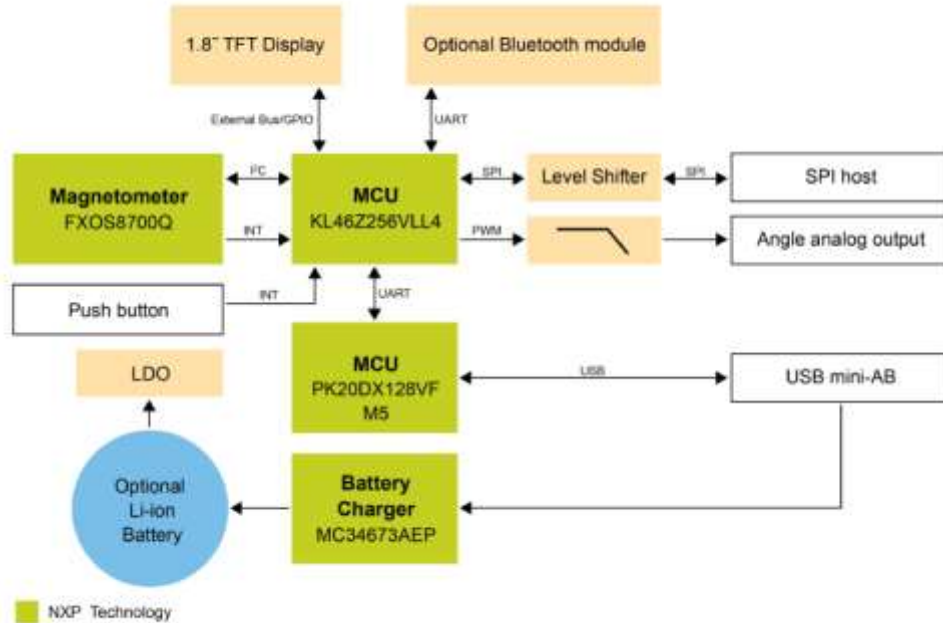
Reference Designs
for Smart Home

10-axis Sensor Data Logging Tool

The **RD-KL25-AGMP01** provides a total system solution for sensor data collection and processing . This size of the board is an efficient 1.2 x 1.5 square inches for portability and ease of use.

✓ This board supports the FXOS8700CQ 6-axis e-compass sensor, the FXAS21002C 3-axis gyroscope, and the MPL3115 pressure sensor driven by a Kinetis KL25Z MCU.

✓ A microSD card slot is provided should the user decide to collect the sensor or application data in cases where a host computer might not be available.

✓ Includes NXP's smart Li-ion battery charger and power management

✓ The board is semi-enclosed, generating a flat surface on one side of the design, to allow easy mounting to different surfaces.

• *Search for "10-Axis" on NXP.com* – Includes: Demo Code, schematics, reference for vibration and other materials
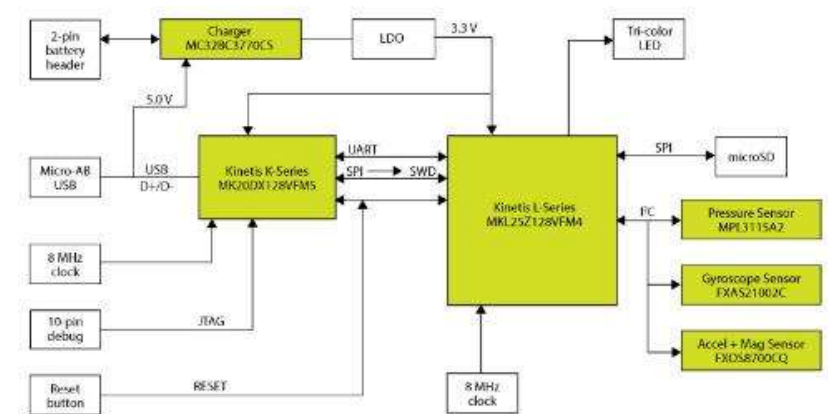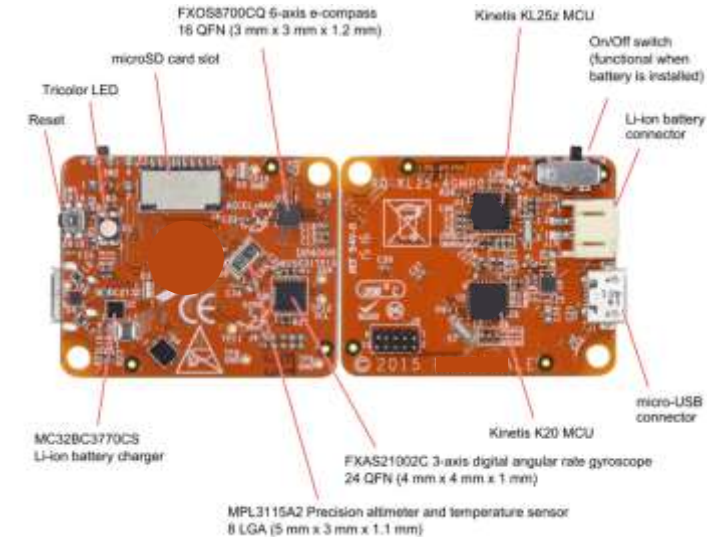
Magnetic Rotary Encoder (Reference Design)

A reference design showing a contactless knob for angle measurement. Demonstrator for many other Smart home and IoT solutions with magnetometer. See the tool first hand and learn how to demonstrate it to your customers.

Find more information here:

http://www.nxp.com/products/reference-designs/magnetic-rotary-encoder-reference-design:RD-KL46Z-MRE

NXP Smart Door Lock Demo

The smart low cost sensor solution to ensure home security

Detect door state (Open or Close)

- Magnetometer is used to detect magnetic field change for door position measurements

- Accelerometer helps in detecting motion, avoiding magnetic jamming and saving overall system power consumption.

Detect door knock

- Transient Block used to detect the high pulse events

- Low current consumption ~18uA

- Auto-Wake Sleep feature makes the operation autonomous

- MCU only wakes up when a knock is detected.

Demonstration based on

RD-KL25Z-AGMP01

Door

Non-closed door position

Closed door area

Closed door position
(location reference)

Find more information about the board here:
www.nxp.com/products/sensors/gyroscopes/10-axis-sensor-data-logger-reference-design:RD-KL25-AGMP01
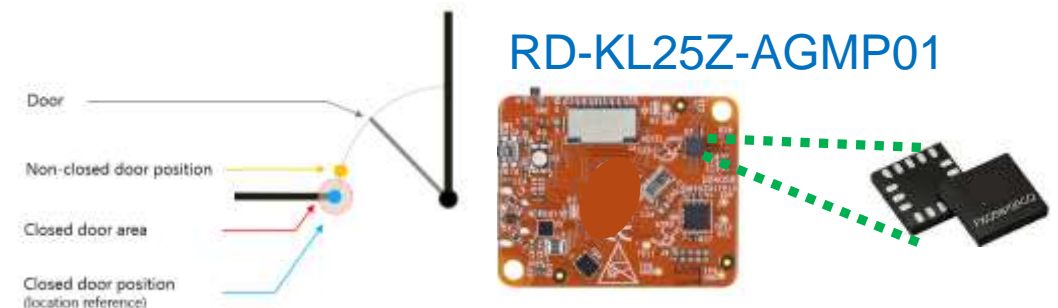
Smart Autonomous Home Electronics

- Accelerometer powers up in an extreme low power motion detection mode

- Average sensor current – 1 uA (always on)

- Detects the slightest motion (>125mg) and turns on the LED

- No embedded software/algorithm required

- Efficient solution for any low power wake up application
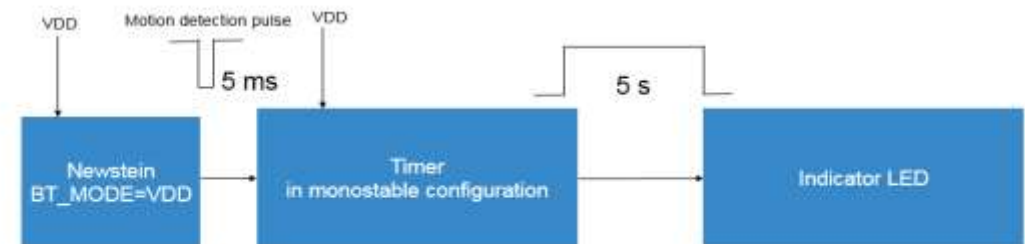
HVAC Smart Filter Monitoring

- Differential pressure sensor uses change in pressure to sense when the air filter/damper needs to be replaced

- Provides the MCU with filter replacement notifications

- Up to three pressure events can be reported for specific user thresholds

- Continuous filter degradation monitoring giving more flexibility with filter replacement

- Critical filter alerts can automatically shut off the system to avoid further damage

- Improves HVAC performance and air quality

- Enabled by NPS30xxx (Available in Q4 2019)
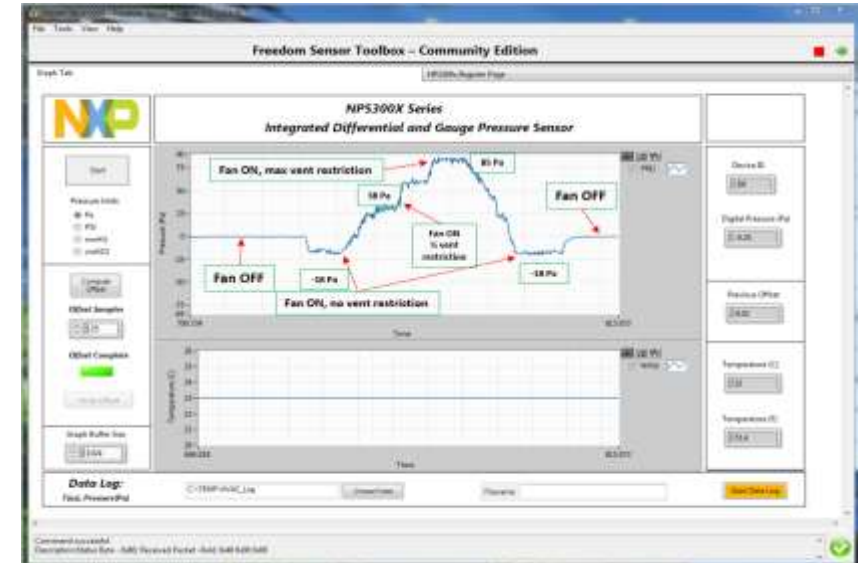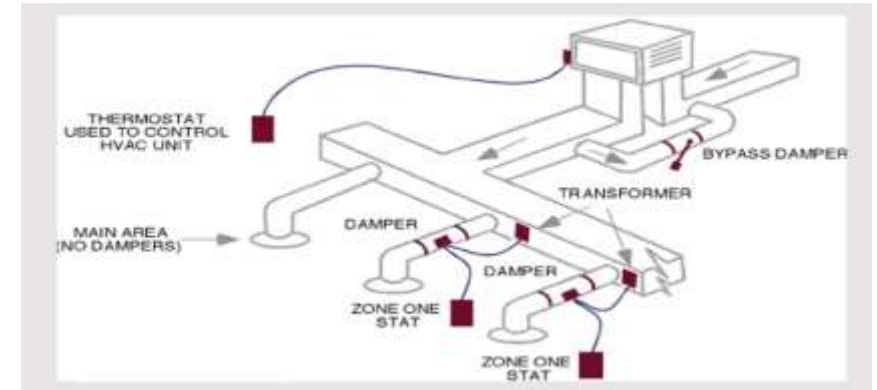
Pedestal: #301

NTAG Smart Condition Monitoring

- Ultra-low power smart logistics solution using NTAG (NHS3100), RAIN RFID and Motion sensors

- NFC or UHF reader scans the package and reports critical Shock, Tilt, Shake, Vibration, Temperature and Humidity events in the journey

- Ultra-low power 12 bit accelerometer FXLS896x with SDCD block for vibration, shock, shake and tilt detection, 1 µA IDD for output data rates (ODRs) up to 6.25 Hz

- Individually calibrated temperature sensor with absolute accuracy of 0.3° C - 0.5 ° C in the range of -40 to 85° C

- NFC phone compatibility: Android 5 or newer, iOS11 or newer for iPhone 7/7plus or newer models

- Enabled by: NHS3100, FXLS896x

NFC

UHF RFID

NHS3100
NTAG
SmartSensor

SL354011FHK
RAIN RFID transponder

I2C bus

FXLS8967X
MEMS
Accelerometer

Third party
Humidity
Sensor
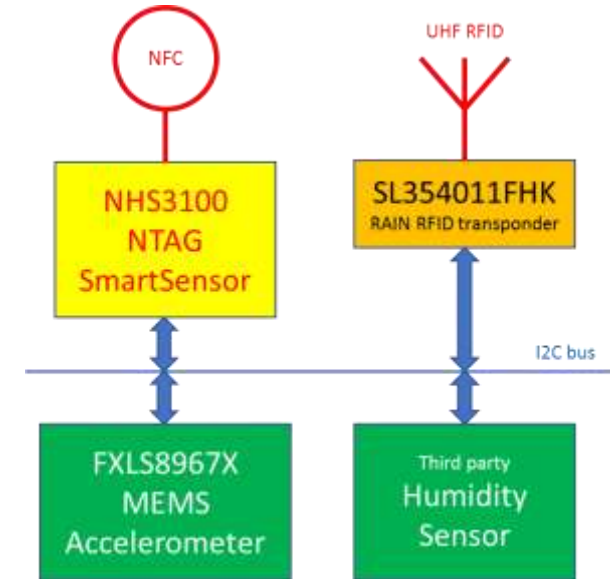
Sensor Board

Sensor Button

Pedestal: #302

LYNQ Low Power Long Range Tracker

- Real Time Long Range Distance (~3 mi) and Direction Tracking

- Extreme Low Power: Up to 3 days of battery life on a single charge

- Durable: Weatherproof, waterproof and military-tested durability

- Decentralization: No Phones, Wi-Fi, Cell Networks, Map or Apps Required. No Monthly Fees

- Accurate Compass Heading: Using FXOS8700 E-Compass solution to obtain the relative heading of the person accurately

- Tilt Sensing: Using FXOS8700 accelerometer for auto sleep power savings from the MCU

- Applications: Tracking children, pets, drones, groups on outdoor activities in remote locations. Also, has 'Safe Zone alert' feature

Pedestal: #302

Air Flow Demo

Condition Monitoring Demo

Reference Designs/Demos/Evaluation Platforms

Name	Type	Availability
Asset Tracking Demo using Motion Sensors	Demo	Demo Available for showcase. Contact factory for more information
Condition Monitoring using NTAG and Motion Sensors	Reference Design/Demo	Reference Design and Starter Kit will be available in Q3, 2019. Demo available for showcase. Contact factory for more information
Sigfox Low power Asset Tracking Demo	Evaluation Platform	Will be available on nxp.com in Q4, 2019
Sensor Anomaly Detection	Demo	Demo Available for showcase. Contact factory for more information
Smart Home Demo (3 demos in one) 1)Door Open/Close Detect 2) Door Knock 3)Safe Box "	Demo	Demo Available for showcase. Contact factory for more information
9-axis activity monitoring with BLE	Demo	Demo available for showcase. Contact factory for more information
Smart Torch with FXLS8962	Demo	Demo available for showcase. Contact factory for more information
Key fob design with FXLS8962 demo	Reference Design	Demo available for showcase. Contact factory for more information
"subMicro-Ampermeter" sensor shield	Evaluation Platform	Will be available on nxp.com in Q4, 2019
LYNQ low power long range tracker	Demo	Product can be ordered on lynqme.com
Alexa based Sensor Alert Demo based on LPC55xx family	Demo	Will be available in Q4, 2019
Smart Pool Pump	Reference Design	Will be available in Q3, 2019
Inclinometer	Evaluation Platform	Will be available in Q3, 2019
HVAC Demo	Demo	Demo Available for showcase. Contact factory for more information
Smart Sensing Inhaler	Demo	Demo Available for showcase. Contact factory for more information
Smart IoT Ball	Demo	Demo Available for showcase. Contact factory for more information
Magnetic Rotary Encoder	Reference Design	Available on nxp.com
10 axis Data logger	Reference Design	Available on nxp.com

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FOR A SMARTER WORLD