NXP

White Paper

Addressing the Challenges of Functional Safety in the Automotive and Industrial Markets

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SAFE ASSURE™ by Freescale

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Contents

Overview

Real-time control of safety-critical applications has been a longtime challenge for engineers. Application functions are becoming more complex and industry standards require more sophisticated functional safety concepts in both the automotive and industrial markets. Freescale has introduced its **SafeAssure** program to help system manufacturers more easily achieve compliance with International Standards Organization (ISO) 26262 and International Electrotechnical Commission (IEC) 61508 standards. System designers can count on the solutions included in the Freescale **SafeAssure** program to stand up to rugged conditions and be supported by the necessary documentation and safety expertise, reducing the time required to develop safety systems.

This white paper covers how functional safety requirements are changing the design game, the details behind the Freescale **SafeAssure** program and the hardware solutions targeting safety applications.

Functional Safety for Automotive and Industrial Applications

The focus on safety-critical applications in both the automotive and industrial markets is significantly growing, bringing new and added pressures to systems engineers as they work to solve safety challenges.

The automotive industry is under pressure to provide new and improved vehicle safety systems, ranging from basic airbag deployment systems to extremely complex advanced driver assistance systems (ADAS) with accident prediction and avoidance capabilities. These safety functions are increasingly carried out by electronics, and ISO 26262 is intended to enable the design of electronic systems that can prevent dangerous failures and control them if they occur.

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 is also 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.

The Increasing Complexity of Safety Applications

Electronic safety systems, with their direct impact on human well-being, are experiencing increasingly stringent requirements. Designing safety systems while meeting state-of-the-art functional safety requirements can be a challenging job for system designers—especially when they are also managing increased application complexity combined with time to market urgency.

The challenge for system engineers is to architect their system in a way that prevents dangerous failures or at least sufficiently controls them when they occur. Dangerous failures may arise from:

- Random hardware failures
- Systematic hardware failures
- Systematic software failures

The functional safety standard IEC 61508 and its automotive adaptation ISO 26262 are applied to ensure that electronic systems in general industry and automotive applications are acceptably safe. The IEC 61508 document defines four general Safety Integrity Levels (SILs) with SIL 4 denoting the most stringent safety level. The ISO document defines four Automotive Safety Integrity Levels (ASILs) with ASIL D denoting the most stringent safety level. Each level corresponds to a range of target likelihood of failures of a safety function.

There is no direct correlation between the SIL and ASIL levels, but the ISO 26262 takes the safety process and requirements to a deeper level. From the beginning of the design process, evidence must be collected to show that the product has been developed according to regulation standards. Any potential deviations that have been identified must be documented to ensure that adequate mitigation is in place. New tools have been developed to support this additional element to automotive quality assurance.

Figure 1: Functional Safety Standards Details

Standards Defined

IEC 61508	Generic industry standard, applicable to electrical/electronic/programmable electronic safety-related systems	
	Integrity levels	SIL 1, SIL 2, SIL 3, SIL 4
	Publication date	More than 10 years ago
ISO 26262	Automotive industry standard, adaptation of IEC 61508 for electronic systems in road vehicles	
	Integrity levels	ASILA, ASILB, ASILC, ASILD
	Publication date	November 2011

Level Comparison

No direct correlation for SIL and ASIL levels

SIL (IEC)	ASIL (ISO)
4	D
3	C
2	B
1	A

Failure Measures

IEC 61508

SIL	Random HWFR target
4	$\geq 10^{-9}$ to $< 10^{-8}$
3	$\geq 10^{-8}$ to $< 10^{-7}$
2	$\geq 10^{-7}$ to $< 10^{-6}$
1	$\geq 10^{-6}$ to $< 10^{-4}$

ISO 26262

ASIL	Random HWFR target
D	$< 10^{-8} h^{-1}$
C	$< 10^{-7} h^{-1}$
B	$< 10^{-7} h^{-1}$

New Policy

- **Information** is more structured in IS0 26262
- **Concept of safety culture** exists in IS0 26262
- **Terminology** is well defined in ISO 26262 (safety plan, safety case, work products, confirmation measure, etc.)
- **Roles and responsibilities** are better defined in IS0 26262, (PM, safety manager)

Freescale Safety Foundation

Freescale is a leading supplier of safety solutions with a history of design experience in dual-core controller technology for safety-critical applications. Freescale has expertise in developing custom MCUs and analog companion devices for functional safety systems used in the automotive safety and chassis market and has shipped more than 60 million units of MCUs and 30 million analog companion devices for applications such as electronic stability control and anti-lock braking.

In 2008, we began developing our latest family of 32-bit devices, Qorivva 56xx automotive MCUs based on Power Architecture® technology. The devices are designed specifically to address the requirements of the ISO 26262 safety standards that are being applied to the growing number of safety-critical systems in road vehicles.

The Freescale safety portfolio also includes market-leading sensing solutions that have been operating in safety applications for more than a decade. The first MEMS-based inertial sensors for automotive airbags were introduced by Freescale in 1996.

At the heart of Freescale safety solutions is a focus on quality. From design to manufacturing, Freescale employs the ISO TS 16949 Certified Quality Management System as well as a zero defects methodology to help ensure our products meet the stringent demands of safety applications and standards in the automotive and industrial markets. We also focus on continuous improvement with process evaluation, assessments/audits and gap analyses to ensure processes are continually optimized.

Figure 2: Program Pillars

SafeAssure Functional Safety Program from Freescale

Building on our safety heritage and expertise, the **SafeAssure** functional safety program enables system designers to develop with confidence and more efficiently achieve their system-level design goals and compliance with the IEC 61508 and ISO 26262 requirements. The Freescale functional safety approach covers four key areas: Safety Process, Safety Hardware, Safety Software and Safety Support.

Functional safety requirements begin with the way a company designs and implements a functional safety solution—the **Safety Process**. We have made functional safety an integral part of our product development process to align to the rigorous requirements of IEC 61508 and ISO 26262. In addition, select Freescale products are defined and designed from the ground up to comply with the standards, with safety analysis done at each step of the development process and additional confirmation measures taken to help ensure safety requirements are fully met.

The Freescale **Safety Hardware** concept focuses on detecting and mitigating random hardware failures. This is achieved through built-in safety features, including self-testing, monitoring and hardware-based redundancy in Freescale MCUs, analog and power management integrated circuits (ICs) and sensors. Freescale analog automotive solutions provide additional functionality (such as checking MCU timing, voltages and error management) that helps improve system robustness and simplify electronic control unit designs. Our Qorivva 56xx and 57xx automotive MCUs and PXS family of industrial MCUs based on Power Architecture technology are designed specifically to address the requirements of the IEC 61508 and ISO 26262 safety standards. A number of devices in these families are already sampling, with some in full production. (See Figure 6 for more information on these MCU families)

To achieve system-level functional safety goals, hardware and software must seamlessly integrate to provide complete coverage of the safety requirements. To that end, the third key area of our functional safety approach is **Safety Software**. Freescale is developing a comprehensive set of automotive functional safety software deliverables, including AUTOSAR MCU abstraction layer (MCAL) drivers, as well as core self-test capabilities. To enhance our safety software portfolio for automotive and industrial markets, Freescale partners with leading third-party software providers to offer additional safety software solutions.

The fourth area of our functional safety approach is robust **Safety Support**, with the goal of easing system-level integration and functional safety standard compliance. Our capabilities extend from customer-specific training and system design reviews regarding functional safety architecture to extensive safety documentation and technical support.

To guide you to the right product for your design needs, look for the Freescale **SafeAssure** solutions mark. It designates hardware and software that can be used in functional safety applications and in system engineers' IEC/ISO-compliant systems. The mark indicates products whose implementation of functional safety technologies is truly optimal and are fully enabled to facilitate system-level design and functional safety standard compliance, including support for failure analysis, hardware and software integration.

SAFE ASSURE™ by Freescale

Freescale Functional Safety Hardware Solutions—Micros and More

Functional safety systems rely not only on MCUs or MPUs, but also companion power management devices and sensors. Freescale is one of the few companies able to offer the full spectrum of system solutions—and all three product classes are available within the **SafeAssure** program, simplifying system design and standards compliance.

Our safety hardware concept focuses on detecting and mitigating single-point faults, latent faults and dependent faults. This is achieved through built-in safety features, including self-testing, monitoring and hardware-based redundancy in Freescale MCUs, power management ICs and sensors.

Figure 3: Built-in Safety Features

MCUs	Analog and Power Management	Sensors
Lockstep cores	Voltage monitors	Timing checker
ECC on memories	External error monitor	Digital scan of signal chains
Redundant functions	Advanced watchdog	DSI3 and PSI5 Safety data links
Monitors	Built-in self-test	ECC on memories
Built-in self-test		Triggered self-test
Fault collection and control		

Microcontroller Assurance

Freescale has developed many innovations in its MCUs for functional safety applications that have seen wider adoption in the marketplace, such as the fault control and collection unit, the coherent safe core mechanism (patented) and the self-checking analog-to-digital converter (ADC).

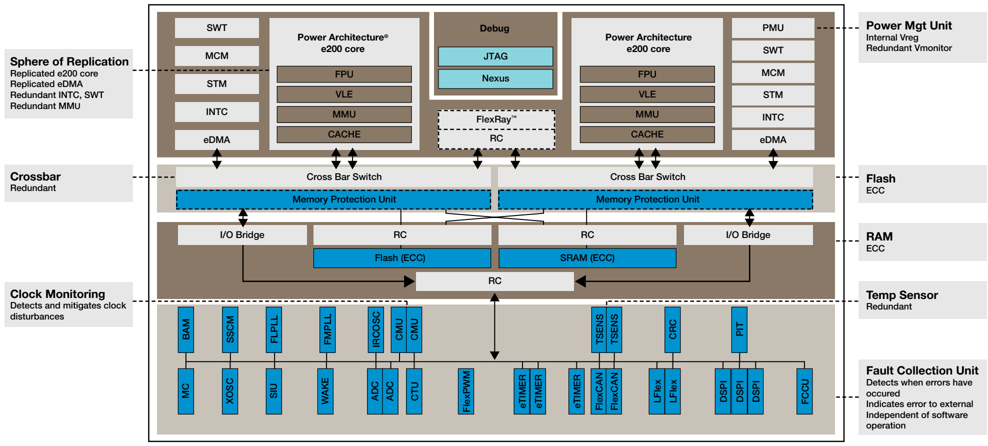
A number of Qorivva product families have been introduced that target specific applications ranging from the single-core MPC560xP family used for airbag and ultrasonic park assist to true multicore high-performing advanced driver assistance systems (ADAS) and powertrain systems with the MPC567xK family and MPC574xM family respectively.

Freescale continues to develop lockstep (computational shell) based architecture products in next-generation technology nodes (55 nm and beyond), leveraging one of the strongest functional safety supplier legacies in the market today with an acute focus on airbag, steering, braking applications and the growing market of ADAS, powertrain applications, body controller applications and various industrial applications.

Our extensive design experience in dual-core controller technology for safety-critical applications led to the latest development of two new 32-bit MCUs for safety-critical applications. They are the Qorivva dual-core MPC5744P, which targets chassis and safety applications, and the multicore MPC574xM for powertrain applications. Both MCUs have been developed in accordance with the ISO 26262 for ASIL-D safety integrity. In order to minimize additional software- and module-level features to reach this target, on-chip redundancy is offered for the critical components of the MCU (multiple CPU computational cores with delayed lockstep, I/O processor core, DMA controller, interrupt controller, dual crossbar bus system, memory protection unit, fault collection unit, flash memory and RAM controllers, peripheral bus bridge, system and watchdog timers, and end-to-end ECC).

Other featured MCU products include the Qorivva MPC5643L, which specifically targets ISO 26262-compliant automotive applications, and the PXS20 for IEC 61508-compliant industrial applications. The dual-core Qorivva MPC564xL and PXS20 contain two “channels,” each consisting of a core, bus, interrupt controller, memory controller and other core-related modules. Instead of using two MCUs for safety-critical applications, the dual-core MPC564xL and PXS20 offer simplified system-level design, reducing complexity and development time, as well as ISO 26262-compliant automotive safety or IEC 61508-compliant industrial safety.

Figure 4: Qorriva MPC5643L Key Safety Features



Qorivva Automotive MCU: First to Receive ISO 26262 Functional Safety Standard Certification

The 32-bit MCU was recently certified by exida, an independent accredited assessor, making it the industry's first semiconductor product to achieve the certification. The ISO 26262 standard targets complete automotive systems and consists of 10 parts, including clauses for hardware, software, their integration and the development and production processes. As the MPC5643L MCU will be only one component in such systems, exida carefully tailored the assessment scope to all clauses of the ISO 26262 that were identified as applicable to an MCU. The MPC5643L was successfully assessed and certified against the MCU-specific portions of the ISO 26262 standard.

The Qorivva MPC5643L 32-bit MCU, built on Power Architecture technology, is designed for use in a wide range of automotive applications and is suitable for use for all ASILs, up to and including the most stringent level, ASIL D.

Figure 5: ISO 26262 Functional Safety Standard Certificate

The manufacturer may use the mark

CERTIFIED • ISO 26262 • ASIL D • exida

Reports:
Freescale 11/08-067-C R009 V1 R0
Results of the ISO 26262 Functional Safety Assessment

Validity:
This assessment is valid for Microcontroller MPC5643L

This assessment is valid until August 31, 2015.

V1 R1 September, 2012

exida® CERTIFICATION

Certificate / Certificat

Zertifikat / 合格証

FREESCALE 1108067 P0026 C001

exida Certification S.A. hereby confirms that the:

MICROCONTROLLER MPC5643L

**FREESCALE Halbleiter Deutschland GmbH
Munich, Germany**

Has been assessed per the relevant requirements regarding µC development and verification & validation of:

**ISO 26262 : 2011 Parts 2, 4, 5, 7, 8, 9 and 10
(to the extent applicable)**

and meets requirements providing:

Systematic Integrity: ASIL D

Safety related function:
The µC supports the execution of safety-related software by a dual-core lock-step architecture with memory protection and centralized fault collection and control unit.

Application restrictions:
The microcontroller shall be used per the Safety Application Guide requirements.

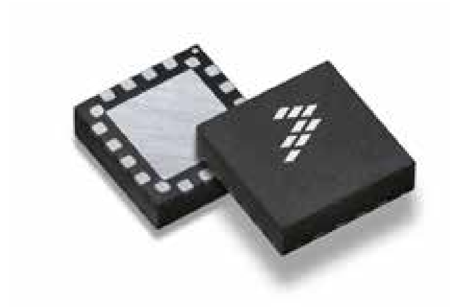
Evaluating Assessor

Certifying Assessor

The ISO 26262 functional safety assessment certificate issued by exida, "FREESCALE 1108067 P0026 C001," can be found in the Safety Automation Element List on the exida website.

Sensors for Safety

When a crash occurs, a vehicle rapidly decelerates while its structure absorbs the majority of the crash forces. Airbags supplement safety belts by reducing the chance that the occupant's head and upper body will strike some part of the vehicle's interior. They also help reduce the risk of serious injury by distributing crash forces more evenly across the occupant's body. From the onset of the crash, the entire deployment and inflation process takes only about 50 milliseconds, faster than the blink of an eye.



Because a vehicle changes speed so fast in a crash, MEMS sensors must detect the impact in a few milliseconds and airbags must inflate rapidly if they are to help reduce the risk of the occupant hitting the vehicle's interior. Freescale has several advanced Xtrinsic products that address the stringent requirements for airbag solutions, including the MEMS-based and MMA5xxxW and MMA17/27xx satellite crash accelerometers and the MEMS-based MMA68xxQ dual-axis crash sensors for the airbag ECU.

Our Xtrinsic MMA5xxxW is the industry's first PSI5 X- or Z-axis satellite inertial sensor in a quad flat no-lead (QFN) package designed for a small footprint. The MMA5xxxW family enables small, robust front and side airbag satellite solutions and improved system reliability against parasitic vibrations due to our advanced overdamped transducer. Compatible with the PSI5 rev 1.3 standard protocol, these inertial sensors can easily be integrated as part of an overall PSI5 airbag system and include a bus switch drive that simplifies daisy chain configurations.

The Xtrinsic MMA17/27xx is the industry's first DSI3 X- or Z-axis satellite inertial sensor. Similar to the present families of airbag satellites, the sensors include overdamped transducers and high robustness against overload and noise. The DSI3 protocol offers improved serial data link robustness with CRC, rolling frame and cumulative error counters, and runtime background diagnostics reporting.

The Xtrinsic MMA68xxQ digital inertial sensor family is designed as a main crash sensor or a safing sensor in airbag applications. The overdamped transducer coupled with a high resonant frequency package provides increased immunity to overload conditions induced by high-magnitude and high-frequency shocks encountered in crash detection applications. These features enable robust airbag designs.

The Xtrinsic MMA69xxQ low-g digital inertial sensor family is designed as a plausibility check for vehicle yaw gyroscopes, as well as inclination detection. The overdamped transducer includes very low offset properties, enabling secondary functions such as tamper detection, electronic parking brake and automatic hill hold.

Safety Companion: Analog and Power Management

To support a total system solution for functional safety applications, a class of companion power system basis chips (SBCs) with integrated safety measures matching the Freescale MCUs families and combining both safety monitor role for the MCU and power supply generation has been developed and is available on the market.

The MC33907 and MC33908 SBC devices are multi-output power supply ICs with HSCAN and optional LIN transceivers optimized for the automotive market. These SBC devices provide power to MCUs and other system loads and optimize energy consumption through low-power saving modes. These new SBCs devices also contain CAN and LIN physical layers compliant with the ISO 11898-2-5 and LIN 2.1/J2602-2 standards, safety measures and a serial peripheral interface to allow control and diagnostic with the MCU. The combination of the MCU and analog system basis chip, designed as a Safety Element out of Context (SEooC), facilitates the assessment of the safety of a system. These devices are developed to support the ISO 26262 standard requirements and provide a scalable approach to simplify development of systems that need to comply with functional safety standards. The optimal interaction between each element makes the system simpler and stronger. Moreover, this architecture enables the number of components at the system level to be reduced, addresses the functional safety requirements and increases reliability. Applications that can benefit include electric power steering, electronic stability control, vehicle dynamic and chassis control, safety domain control, adaptive cruise control and blind spot detection. MC33907 and MC33908 devices are the first Freescale analog solutions developed to satisfy ASIL D requirements. They include a range of integrated safety measures that simplify system designs and reduce software complexity when combined with dual-core lockstep MCUs.

To illustrate, inside the MC33907 device, the power management unit and the fail-safe machine combine to interact with the MCU. Four safety measures are implemented to secure the interaction between the MCU and SBC: uninterrupted supply, fail-safe inputs to monitor critical signals, fail-safe outputs to drive fail-safe state, and watchdog for advanced clock monitoring. When combined with the MCU, each safety measure is optimized for the highest level of safety performance. At the system level, safety check mechanisms proposed by the MCU can be monitored by the MC33907 through the bi-stable protocol of the fault collection control unit (FCCU). This IC cross-checking, like the challenger for monitoring timing, provides external measurement of the system and offers a redundancy to further secure fault detection. In line with safety architecture of the system basis chip family, a redundant path for safety state activation occurs through dedicated fail-safe outputs. These outputs complement the MCU fail-safe outputs by setting the application into a deterministic state when a failure condition occurs. These hardware implementations help software engineers simplify the software architecture and implement a software development strategy that focuses on safety using a single MCU approach.

Energy Efficient Solutions by Freescale™

The pin-compatible MC33907/8 family is the latest generation of Freescale SBC solutions including DC/DC switching regulators to optimize energy efficiency. An optional boost mode keeps the system available during engine cranking pulses. In addition, ultra-low-power modes are designed to drastically reduce current consumption and optimize wake-up times. These SBCs are part of the Freescale Energy-Efficient Solutions program, which means they are designed to offer customers assurance that Freescale has employed the right combination of technologies and techniques to achieve optimal energy savings as relevant to a particular application space.

The Freescale MC33789 SBC is a mixed-signal analog IC for airbag safety applications. The MC33789 SBC provides a flexible system IC solution partitioning across the range of airbag partitions used in cars and trucks. In order to protect vehicle occupants, the MC33789 includes a safing state machine to prevent unexpected events and enhance system functional safety. The safing concept involves the utilization of logic, independent of the MCU, to monitor both on-board and remote satellite sensors and determine if a sufficient inertial activity is present to warrant deployment arming of the system. An on-board analog sensor self-test is often used to verify functionality and the connection between the sensor and the MCU. To facilitate the test without activation of the arming airbag outputs due to the possiblity of fault, the MC33789 SBC monitors the analog sensor self-test control signal from the MCU. It can be used to detect seat belt switch input states and communicate with remote crash sensors via new PSI5 master interfaces to meet industry standards. Allowing scalability across a wide range of firing loops while providing enhanced safety and system reliability, the MC33789 SBC is well suited for low- to high-end airbag safety systems.

Build Your Safety System Today

Designing safety-critical systems brings new challenges to the system designer: ensuring compliance with the IEC 61508 and ISO 26262 functional safety standards. Our answer is the **SafeAssure** program, which covers how Freescale designs and implements a functional safety solution to our broad solution set, including MCUs, sensors and analog ICs along with our support of functional safety application design that extends to training, safety documentation and technical support. The **SafeAssure** program highlights selected solutions—including hardware and software—that are targeted for use in functional safety applications, enabling system designers to design with confidence and achieve their system-level design goals and standards compliance more efficiently.

To view the latest SafeAssure product table, visit **freescale.com/SafeAssure**

Figure 6: Freescale SafeAssure Hardware Solutions

Target Market	Product Type	Product	Target Applications	Safety Process	Safety Hardware	Safety Support
Automotive	MCU	Qorivva MPC5746M	• Diesel engine management • Direct injection engines • Electronically controlled transmissions • Gasoline engine management	ISO 26262 ASIL D	Integrated safety architecture e.g.; • Multicore • Delayed lockstep • e2eECC • Replicated peripherals • LBIST • MBIST • FCCU	• FMEDA • Safety manual
		Qorivva MPC5744P	• Electric power steering • Braking and stability control • 77 GHz RADAR system • Safety domain control	ISO 26262 ASIL D	Integrated safety architecture e.g.; • Dual core • Delayed lockstep • e2eECC • Replicated peripherals • LBIST • MBIST • FCCU	• FMEDA • Safety manual
		Qorivva MPC567xK	• 77 GHz RADAR system • Front-view camera	FSL QM	Integrated safety architecture e.g.; • Dual core • Lockstep or dual parallel processing • Replicated peripherals • FCCU	• FMEDA • Safety manual
		Qorivva MPC564xL	• 77 GHz RADAR system • Electric power steering • Braking and stability control	ISO 26262 ASIL D	Integrated safety architecture e.g.; • Dual core • Lockstep or dual parallel processing • Replicated peripherals • FCCU	• FMEDA • Safety manual • System level application note
		Qorivva MPC560xP	• Airbags • Electric power steering	FSL QM	Single core • SEC/DED ECC • Clock monitoring unit • Low-voltage detector • FCU	• FMEDA • System level application note
	Analog and Power	MC33907	• Electrical power steering • Safety critical motor control • Vehicle dynamic and chassis control	ISO 26262 ASIL D	Integrated safety architecture e.g.; • Voltage monitoring and fail-safe state machine (ABIST, LBIST) • FCCU • Monitoring for dual-core lockstep mode • Several HW diagnostic to cover SPF • LT	• FMEDA • Safety manual • System level application note
		MC33908	• Integrated chassis domain • Safety critical motor control	ISO 26262 ASIL D		• FMEDA • Safety manual • System level application note
		MC33789	• PSI5 airbag system	FSL QM	• 4x PSI5 host • Safing block	Safety FMEA
		MC33926	• Valve control in powertrain applications	FSL QM	Output state flag • Thermal shutdown	Safety FMEA
	Sensors	Xtrinsic MMA16/26xx	• Airbags • DSI2.5 satellites	FSL QM	• DSI2.5 safety bus • Triggered self test • Over-damped MEMS	FTA
		Xtrinsic MMA17/27xx	• Airbags • DSI3 satellites	FSL QM	• DSI3 safety bus • Triggered self test • Over-damped MEMS	FTA
		Xtrinsic MMA51/52xx	• Airbags • PSI5 satellites	FSL QM	• PSI5 safety bus • Triggered self test • Over-damped MEMS	FTA
		Xtrinsic MMA65/68xx	• Airbags • Main ECU	FSL QM	• SPI w/ CRC • Triggered self test • Over-damped MEMS	FTA
		Xtrinsic MMA69xx	• Braking and stability control	FSL QM	• SPI w/ CRC • Triggered self test • Over-damped MEMS	FTA
Industrial	MCU	PXS20	• Aerospace • Anesthesia unit monitor • Input-output control (I/O control) • Process control • Temperature control • Programmable logic control • Motor drivers • Robotics • Safety shutdown systems • Ventilators and respirators	ISO 26262 ASIL D	Integrated safety architecture e.g.; • Dual core • Lockstep or dual parallel processing • Replicated peripherals • FCCU	FMEDA
		PXS30		FSL QM		Safety application note

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