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Authors:
Jessica Nian
Niall Jenkins

Functional Safety in Industrial Robots

Assessing the impact of new updates to the ISO 10218 standard on robotics software

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Executive Summary

Functional safety has not traditionally been a primary focus for software engineers building industrial robots. However, the introduction of a new standard (ISO 10218:2024) will be a game changer for the robotics market.

What is functional safety?

Functional safety refers to the capability to identify potentially hazardous conditions and activate protective or corrective mechanisms to prevent the event, provide mitigation measures or minimize the impact. It is an integral component of a comprehensive safety framework. Within the context of industrial robots, mechanical, electrical, and sensor technologies are employed to reduce interference with human activities and establish safer working environments.

How is functional safety evolving?

The progression of functional safety has seen a transition from rudimentary mechanical barriers to intricate, software-driven systems that permeate industries as diverse as industrial automation, robotics, autonomous vehicles, and smart infrastructure.

- **Basic Physical Protections:** Early safety measures relied on passive barriers and enclosures, physically separating operators from hazardous machinery components.
- **Electronic Safety Controls:** PLCs and safety relays ushered in an era of electronic safety management, capable of processing multiple safety signals.
- **Software-Driven Safety Logic:** Soft PLCs and specialized safety software enabled sophisticated safety algorithms, enhancing real-time response and monitoring capabilities.

Why is it important?

Industry 5.0 and the growth of smart factories are changing the types of robots used in industrial manufacturing. A core element of these trends is human-centric functionality using technology to complement human work. Governments and industry are both invested in these market trends and the associated technology evolution.

The impact of these trends is that robots with collaborative applications (formerly known as cobots) and robot manipulators with mobile platforms (AMRs) will gain market share in the industrial robot market. By 2027, these markets are forecast to be the third and fourth largest industrial robot markets (in terms of revenue), respectively.

Figure 1: Market growth rates (2022-27) for robots by type

19.1% Industrial robot manipulators with collaborative applications

23.2% Industrial robot manipulators with mobile platforms

New standard – ISO 10218:202X

A new standard update is under development to meet the future requirements of functional safety. It is called ISO 10218:202X. The new standard will accomplish several objectives.

First, it will enhance global harmonization to unify robotic regulations worldwide, fostering consistency and ease of compliance across international borders. Second, it aims to provide further clarity, rectify errors and correct inconsistencies in the previous version. Third, it will embrace technological advancements ensuring the standard remains relevant and supportive of cutting-edge robotic systems. Overarching these trends is a commitment to the safety development life cycle. This process includes rigorous testing for compliance and fault tolerance, controlled deployments, continuous monitoring, and regular updates.

Recommendations

Functional safety will become a priority activity for robot manufacturers and integrators. However, developing proprietary safety solutions or maintaining continuous cybersecurity updates is a huge challenge for these manufacturers. Partnering with software providers and dedicated safety certified RTOS platforms will provide the tools required to meet the functional safety requirements of the future while ensuring focus remains on the core role of building reliable robots.

Like in the automotive industry, this approach will ensure safety is embedded in the software platform, reduce the impact of system wide failures, speed up compliance with pre-certified solutions, and help mitigate current and future security risks. Ultimately, partnerships offer a constructive route to ensure compliance with ISO 10218:202X and build resilience and reliability into the functional safety aspects of robotic solutions.

Introduction to Functional Safety

Industrial Robots

The functionality required of industrial robots is changing. Industry 5.0 and smart manufacturing represent the next stage of industrial production. A core element of Industry 5.0 is human-centric functionality using technology to complement human work. It advocates for the reintroduction of workers into the manufacturing cycle while increasing their collaboration with intelligent machines to improve the resilience of the industrial supply chain. Industrial robot manipulators with collaborative applications, formerly known as collaborative robots (cobots), equipped with advanced vision systems and AI, will be important in supporting this market evolution.

Figure 2: Key trends affecting the global robot market

Industry 5.0	Smart factories	Labor shortages
• According to the EU, Industry 5.0 will support the manufacturing industry to meet its social and ecological goals. • Its core values include using technology to complement human work, balancing sustainable manufacturing with profit, risks, cost management, and an objective to improve supply chain resilience.	• Smart manufacturing is based on the smart factory concept which includes both intelligent production and intelligent logistics. • Smart supply chains integrate all components of manufacturing, including upstream material suppliers, third-party logistics, the intelligent factory, and sales departments.	• Skills shortages and a lack of available labor is a market challenge across industrial markets. • In response to this societal challenge, solution providers are moving to automate tasks and use technology to augment the human roles that are increasinlgy difficult to resource.

The smart factory concept includes intelligent production, intelligent logistics, and collaboration between the supplier side and the client side, to achieve the process of order delivery. Advanced technologies, including robotics, are being implemented to create smart and connected manufacturing environments.

This trend is driving demand for industrial robot manipulators with mobile platforms, also known as Type C Industrial Mobile Robots. These robots can independently understand their environment and move within it. They use a complex set of sensors, AI, machine learning, and path planning calculations to interpret and navigate, untethered to wired power sources.

The industry is also faced with challenges, such as workforce shortages, rising costs, and insufficient human effectiveness. In response, enterprises are using intelligent equipment, robots, and digital technology to break the boundary between people and machines, a trend that is called “human-machine coupling.” Each of these market trends makes functional safety more important.

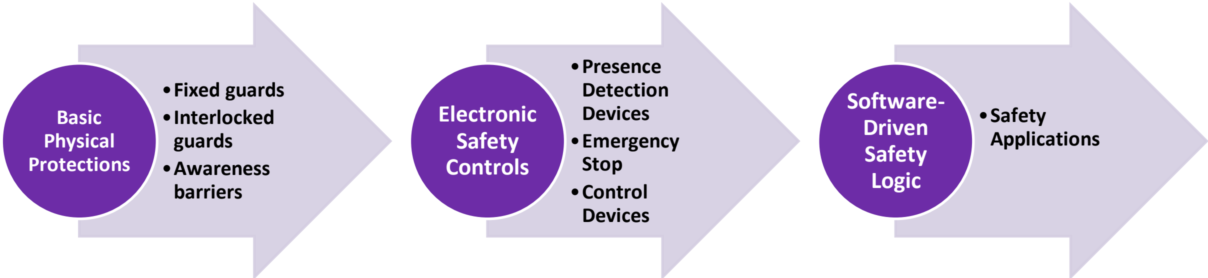
What is functional safety?

Functional safety is an integral component of a comprehensive safety framework. It relies on a system or equipment to function properly in response to its inputs. In essence, functional safety refers to the capability to identify potentially hazardous conditions and activate protective or corrective mechanisms to prevent the event, provide mitigation measures or minimize the impact.

Within the context of industrial robots, mechanical, electrical, and sensor technologies are employed to reduce interference with human activities and establish safer working environments.

The robotics industry is seeing a shift towards more collaborative applications where robots work alongside humans in shared workspaces. This trend has been driving advancements in robotics technology, particularly as it relates to human-robot interaction. The result is greater flexibility and agility in manufacturing. It enables robots to work alongside humans to perform tasks where additional strength is required, or where repetitive actions are completed. Most importantly, it increases productivity, efficiency, and quality in the production process, all while optimizing resources and improving workplace safety.

Figure 3: Evolution of functional safety



The progression of functional safety has seen a transition from rudimentary mechanical barriers to intricate, software-driven systems that permeate industries as diverse as industrial automation, robotics, autonomous vehicles, and smart infrastructure. This evolution can be traced through several pivotal milestones as shown in **Figure 3**.

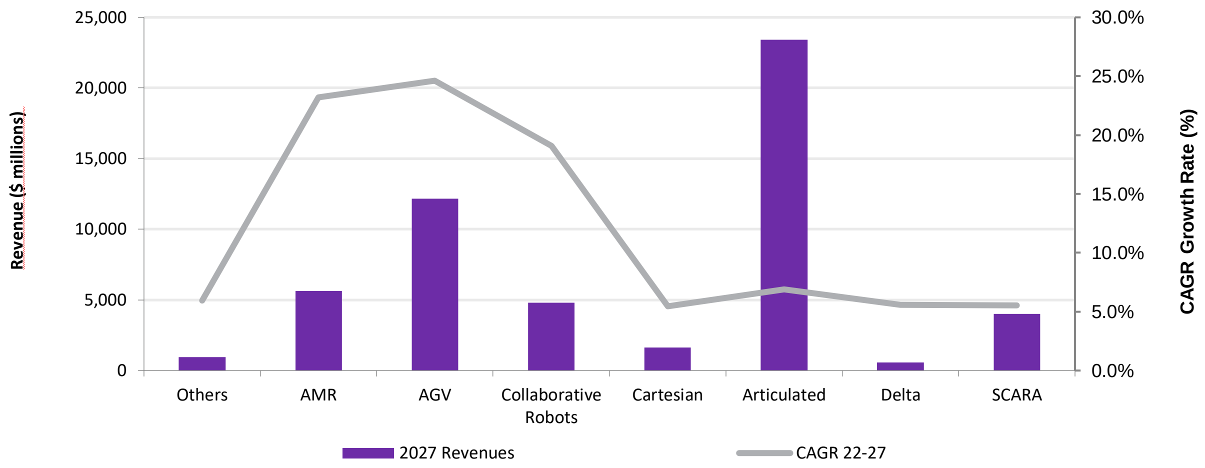
- **Basic Physical Protections:** Early safety measures relied on passive barriers and enclosures, physically separating operators from hazardous machinery components.
  - **Fixed Guards:** Fixed guards, such as enclosures and fences, serve a critical role in various industries and applications, providing safety, security, and protection.
  - **Interlocked Guards:** Interlocked guards, such as gates and doors, are a type of safety mechanism designed to ensure that machinery cannot operate when access to hazardous areas is possible.
  - **Awareness Barriers:** Awareness barriers, such as chains and railings, provide physical barriers to alert operators or restrict their access.
- **Electronic Safety Controls:** PLCs and safety relays ushered in an era of electronic safety management, capable of processing multiple safety signals.
  - **Presence Detection Devices:** Presence detection devices, such as light curtains and pressure-sensitive safety mats, are advanced safety technologies designed to enhance the protection of personnel around machinery and equipment.
  - **Emergency Stop:** Emergency stop devices, such as emergency stop buttons and pull cords, are critical safety components in machinery and industrial settings. They allow for immediate cessation of machine operation in response to an unsafe condition or imminent danger.
  - **Control Devices:** Control devices, such as teach pendants and human-machine interfaces (HMIs), provide operators with the means to safely and effectively control machinery and processes, offering a direct link between human operators and the automated systems they oversee.
- **Software-Driven Safety Logic:** Soft PLCs and specialized safety software enabled sophisticated safety algorithms, enhancing real-time response and monitoring capabilities.
  - **Safety Applications:** Safety applications in industrial automation play a vital role in ensuring the protection of workers and the safe operation of machinery. These applications are designed to prevent accidents, injuries, and damage to equipment by implementing various safety measures, such as speed and separation monitoring, power and force limiting, soft axis limiting, monitored standstill, and hand-guided controls. It is also important to note that security is implied in safety applications. Without protecting from cyber threats, there can be no functional safety.

Why is functional safety important?

Industry 5.0 and smart factories will change the types of robots used in industrial manufacturing. As shown in **Figure 4**, Omdia forecasts that robot manipulators with mobile platforms and robots with collaborative applications will be the third and fourth largest industrial robot markets by 2027 (in terms of revenue), respectively. These equipment markets will also have some of the highest annual growth rates of any robot type between 2022 and 2027.

Functional safety is more important in applications where robots interact with humans or can move around the factory floor, including in environments where robots and humans operate in separate workspaces. This, coupled with the revenue and growth potential of these markets, means functional safety will be a core component of many industrial robot vendor’s growth strategies, whether that is the software managing the safety requirements or the robot manufacturers incorporating this functionality in their products.

Figure 4: World market for robots by type (2027 revenue and market growth)



Source: Omdia

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Functional safety will also have an extended remit. The number of safety functions considered in the latest standard is increasing by an anticipated factor of fifteen. New technologies, such as AI, IIoT (connected industrial devices) and next generation sensing technologies, demand stringent functional safety measures due to their inherent complexity, the critical nature of data integrity, and the heightened security risks faced. Autonomous operations must be executed safely without human oversight, and regulatory compliance must be strictly adhered to, especially in high-stakes industries. These new technologies will support many of the software-based safety approaches required in the future. Knowing how to build with safety as a core component will be a skill that robot manufacturers need to embrace.

Improvements will occur in risk assessment procedures to mitigate potential hazards. Testing and validation will become core to the build process and new security approaches will ensure the system is protected from outside threats. Furthermore, considerations such as low latency and jitter and fault-tolerance will influence the robot design. Strict timing guarantees found in hard real-time operating systems will support timely responses to safety alerts.

In situations where robots are interacting with humans, this level of determinism and reliability is pivotal to the functional safety design. Robotic safety systems will represent the cutting edge of industrial reliability and efficiency, using real-time monitoring to prevent malfunctions and optimize performance.

These technologies will all be critical to meeting the challenges of the robot industry and functional safety software will be at the core of these solutions. As shown in **Figure 3**, functional safety has evolved from basic physical protections to software driven safety logic. Software will be at the core of both the industrial robot market growth and the evolution of functional safety solutions, including meeting new standards such as ISO 10218:202X.

Functional Safety Standards

Background of ISO 10218

ISO10218:2011 was developed in 2011 and is comprised of two distinct sections, 10218-1 and 10218-2. ISO 10218-1, the initial segment, focuses on robots as unfinished machinery, primarily impacting the producers of industrial robot manipulators and industrial robot manipulators with collaborative applications. The latter part, 10218-2, addresses fully assembled machines and systems that incorporate robots.

This section is pertinent to all entities involved in integrating industrial robots into comprehensive solutions, including machinery manufacturers and system integration specialists. An update was published in 2016 through the introduction of ISO/TS 15066, which specifically addressed the guidelines for robots with collaborative applications.

In the intervening period, the deployment of industrial robots has nearly doubled, reaching approximately 3.5 million units in operation today. Contemporary security threats and associated challenges, such as the implementation of the EU Cybersecurity Act and the US government's focus on securing critical infrastructure sectors like mobile communications and energy distribution, are exerting influence on the requirements outlined in ISO 10218-1.

The risk of a security breach extends not only to large corporations but also to medium-sized and smaller manufacturers of machinery and robots. This is particularly important when considering the extended lifespan of robotic solutions currently in use. These new market demands, particularly concerning security and the advancing field of collaborative applications, have driven a need to update the standard.

What's Changing with ISO 10218:202X?

A new standard update is currently under development to meet the future requirements of functional safety. It is called ISO 10218:202X. The revision will accomplish several objectives:

- **Enhanced Global Harmonization:** The standard seeks to unify robotic regulations worldwide, fostering consistency and ease of compliance across international borders.
- **Rectification of Errors & Structural Clarification:** Efforts are being made to correct inconsistencies and enhance differentiation between Part 1 and Part 2, ensuring each section is more distinct and purpose driven.

- **Embrace Technological Advancements:** The update seeks to acknowledge and integrate the latest technological innovations, ensuring the standard remains relevant and supportive of cutting-edge robotic systems.
- **Improved Functional Safety Clarity:** The new version is said to deliver more succinct and detailed guidance on functional safety requisites, particularly in the context of collaborative applications, to facilitate safer integration and operation of robots in shared work environments.
- **Safety Development Lifecycle:** Incorporating safety activities throughout the safety development life cycle involves identifying and documenting safety requirements, integrating them into software design and architecture, and embedding safety into coding practices. This process includes rigorous testing for compliance and fault tolerance, controlled deployments, continuous monitoring, and regular updates. Periodic reviews and audits refine safety practices, while incident handling procedures ensure swift response and corrective measures. Training and compliance with regulations reinforce safety awareness. A systematic, documented approach with defined roles ensures safety is integral to safety development life cycle, which also helps maintain ongoing compliance with evolving safety standards

This comprehensive overhaul aims to fortify the foundation for safer, more efficient, and globally aligned robotics practices in the coming years. In addition to many minor refinements, several pivotal modifications stand out:

- **Incorporation of ISO/TS 15066:2016:** This is notably reflected in ISO 10218-2, emphasizing the harmonious collaboration between humans and robots in shared workspaces (highlighted by the keywords "collaborative operation").
- **Robot Classification:** Introduction of two distinct classes for robots based on their functional safety requirements, enhancing clarity and applicability across different operational contexts.
- **Enhanced Functional Safety Requirements:** A clearer articulation and elaboration of the standards for functional safety, ensuring that they are both comprehensive and easily understandable for all stakeholders.
- **New Focus on Cybersecurity:** Recognizing the emergent threat landscape, security provisions have been newly introduced to safeguard robotic systems against digital attacks and protect sensitive data.

Significant enhancements have also been made to clarify the management of speeds during manual operation mode with reduced velocity, often referred to as manual slow-speed mode, T1, or teach mode. Of note, the updated standard explicitly stipulates that the speed of Class II robots must be subject to rigorous safety monitoring while functioning in this mode. This clarification ensures a higher level of safety control during the teaching and setup processes.

Furthermore, Annex C outlines essential safety functions and provides stakeholders with a concise inventory and explanation detailing which safety standards are compulsory versus optional, along with their required configurations. This addition improves understanding and simplifies compliance.

The standard is also broadening the minimum criteria for functional safety allowing for more tailored approaches to meet diverse application needs. The existing standard for functional safety requires a Performance Level (PL) d, or Safety Integrity Level (SIL) 2 within a Category 3 system architecture, conforming to ISO 13849-1, ISO 62443, and IEC 61508. However, the impending update relaxes this, removing the strict mandate for a Category 3 structure if a sufficiently low Probability of Failure per Hour (PFHd) can be achieved. This shift prompts the query: "Might we anticipate the emergence of single-channel safety solutions within the robotics sector going forward?"

Where are the Opportunities?

Market drivers

The new standard will create opportunities for companies focused on meeting, and exceeding, safety requirements and working with the latest technologies to support the factories of the future. Understanding the market drivers is important to maximize any market opportunity.

- **Adapting to Technological Innovations**: With industrial robots becoming smarter through AI/ML integration, enhanced sensor capabilities, and increased connectivity, safety standards must evolve to encompass the unique risks posed by these technologies. This includes ensuring that robots can safely interact with their environment and make decisions autonomously without compromising worker safety.

- **Enhanced Risk Assessment Frameworks**: As robots take on more complex tasks and operate in diverse settings, standard updates are necessary to provide more nuanced and dynamic methods for risk assessment. This helps organizations proactively manage potential hazards and implement effective controls in anticipation of new applications and operational scenarios.

- **Market Changes and Expansion**: Robot applications and use cases are evolving and operating environments are changing. This creates complexity as they must navigate in more dynamic environments. As applications scale to become more common on the factory floor, functional safety features also become more important. Furthermore, as robotics penetrate new industries and geographies, the standard must adapt to accommodate these unique robot types, applications, and usage contexts.

Market challenges

As with most market opportunities, there will also be challenges, pain points and potential traps that vendors and robot manufacturers can fall into.

- **Not Keeping Pace with Technology**: Vendors and software providers are used to doing what they currently do and changing course can be difficult. It requires time and resources to meet new requirements and implement new solutions. Meeting these requirements, while continuing to run the day-to-day business, is challenging.

- **Maintaining Safety and Security Across the Development Lifecycle:** Safety isn't just about the operational phase; it spans from the design and manufacturing stages to the end-of-life disposal. Updates need to encompass all these stages, ensuring that robots are designed with safety in mind, are maintained properly to prevent degradation that could compromise safety, and are decommissioned safely to prevent environmental or health hazards. For software developers, they need to ensure accurate testing and validation of the code to ensure solutions meet functional safety requirements.

- **Complexities in Certifying Open Source Software for Safety:** In addition to validating the software code, developers also need to consider the security of the operating system they build on. While off-the-shelf solutions are permissible, it is required to have a strategy to detect and protect the system from any software failures. Furthermore, platforms like Linux are often unsuitable for the task of functional safety with limited partitioning of subsystems, code maintenance challenges, old architecture, and incomplete testing. Pre-certified software can reduce the risk, cost and time required to meet safety requirements.

Recommendations

Functional safety has not traditionally been a primary focus for software engineers building industrial robots. However, this new standard will be a game changer. Safety requirements will expand from limited existing solutions, such as emergency stop buttons, to include new systems such as geofencing, hand guided control, and speed and separation monitoring. Manufacturers will need to ensure that their software is designed and documented with safety and security in mind. After all, security is a necessary component of safety. They will also need to ensure safety is part of their organizational culture and product development lifecycle.

The significance of adhering to rigorous standards for both functional safety and security cannot be overstated. It is not uncommon for the process, inclusive of obtaining accreditation from a certified body, to span multiple years. Hence, it is advisable that robot manufacturers and system integrators proactively engage with these new requirements.

Partnering to build a safety culture

It is also advisable that they work with software partners to help meet functional safety requirements. For most robot manufacturers, developing proprietary safety solutions or maintaining continuous security updates is a huge challenge. Consequently, many of these companies will find it necessary, as well as beneficial, to seek assistance from specialized software platform suppliers.

Outsourcing elements of the software design will enable manufacturers to access functional safety expertise without diverting their core business operations, namely building reliable robots. This is important for several reasons. First, safety is embedded in the initial design of these software platforms providing a higher level of confidence in the solutions reliability. In some cases, the partner’s real time operating system (RTOS) (e.g. BlackBerry QNX) can be run on isolated system components, reducing the impact of system-wide failure on the functional safety system.

Second, this approach speeds up the design process as compliance is already pre-certified to SIL 2 by external auditing partners. Third, security is baked into the solution design at the source code and is designed, developed, and produced to limit attack surfaces. This is a key consideration when mitigating security threats. Many of the biggest security risks are, in part, due to compliance being considered after the initial design.

In summary, functional safety will increasingly be a priority activity for robot manufacturers and integrators. Similar to the automotive industry, partnering with software providers and safety-certified RTOS platforms will provide the tools required to meet the functional safety requirements of the future. This approach will ensure compliance with ISO 10218:202X and build resilience and reliability in the safety aspects of robotic solutions.

Appendix

Authors

Jessica Nian,
Senior Analyst, Omdia

Niall Jenkins
Consultant, Omdia

Get in touch

www.omdia.com
customesuccess@omdia.com

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