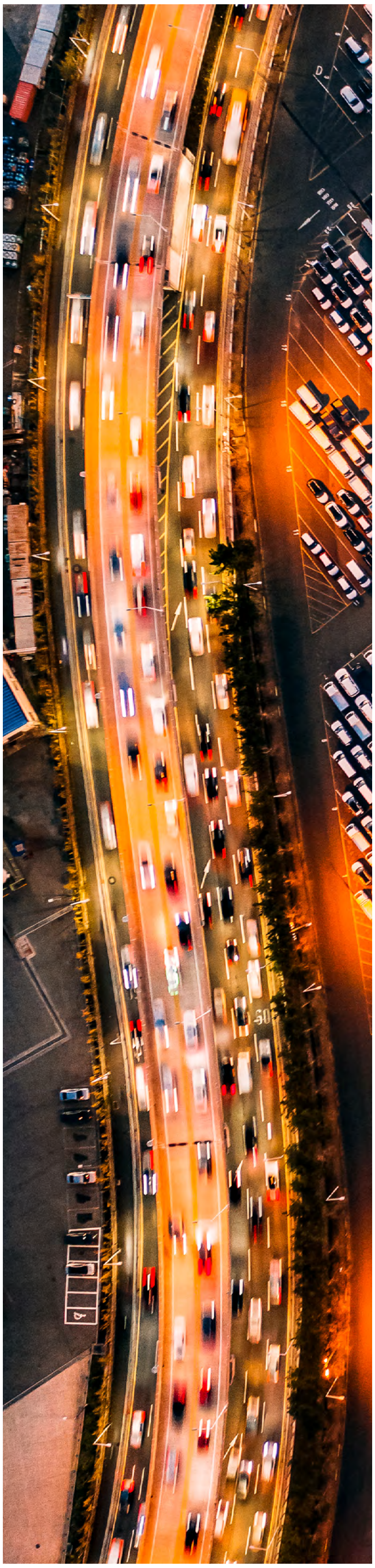
Functional Safety

Building Trust in the Safety of Complex Products

Empowering Trust®

As more products incorporate complex microelectronics and software into their design, engineers are increasingly challenged to assess and implement functional safety at the system level.



Functional safety: A comprehensive approach to safety

In the digital age, products are increasingly complex, containing software, microcontrollers and smart power sources. It's astounding to think that the pocket-sized smartphones we carry today are more powerful than the technology that sent humans to the moon in 1969.[1]

These small devices are packed with complex software, multiple microprocessors, cameras and rechargeable lithium-ion batteries, all working together to deliver complex functionality that consumers have come to depend on every moment of every day. The synthesis of these components functioning as a whole is a great deal more complex than the switch hook, dialer and ringer that comprise a landline phone. The examples of increasingly complex products are endless. Automobiles are powered with complex software and artificial intelligence (AI) capabilities as we move toward autonomous vehicles. Automotive sensors like light detection and ranging (LiDAR) may contain edge computing and other complex software. Many automotive electronics also have over-the-air connectivity capabilities. Even the devices that control temperature, lighting and locks in homes are connected to software for remote operation via a smartphone.

Along with the more sophisticated functionality of systems comes additional safety and performance risks. Verifying the safety of complex systems is not as simple as single-component evaluations that were used for basic mechanical systems. Functional safety offers a more comprehensive approach that evaluates all the parts of the system that must function correctly together to maintain safe operation of the overall system. This evaluation involves understanding the design (what), the intended use (why), the product life cycle (when) and the process (how). UL supports this evaluation through training, assessment, auditing, inspection and testing.

Example applications of functional safety include the safety-related functionality of a battery management system (BMS) that monitors voltage, current and temperature inside a lithium-ion battery, solar photovoltaic (PV) rapid shutdown devices used to ensure a PV/solar installation is off when placed into a rapid shutdown mode, and electronic throttle control in a passenger vehicle.

Stakeholders across the value chain, from manufacturers to suppliers, buyers, end users and government institutions, all have an interest in the safety and performance of products. By understanding the principles and benefits of functional safety, manufacturers and suppliers can tap into a methodology that offers a more effective and comprehensive approach to safety, meeting the needs of a digital era of products.

While developing a practice and culture of functional safety requires some deliberate action and education, it is an effective way to advance safety and protect brand equity. Here we'll explore the importance of functional safety, the benefits to businesses, strategies for creating a functional safety culture and resources for taking next steps.

Functional safety meets complexity of modern devices

Functional safety assessments are designed to:

- Understand the ways in which products can fail and the potential safety implications
- Evaluate systems engineering techniques and safety mitigation mechanisms for components and systems
- Ensure safeguards are in place to reduce risk of harm to users
- Meet evolving international safety standards

The growing complexity of systems and how functional safety works

To understand the value of functional safety evaluations, consider the many ways that products are changing.

Reliance on software — Software is embedded in most electronic systems today, posing new functionality and cybersecurity risks. Software bugs may cause software to execute erratically, triggering performance and safety failures. Failure of equipment running the software may cause the system to malfunction, or cybersecurity breaches may disable software altogether. While evaluating every possible point of software failure is impossible, systems should be tested and evaluated to help ensure that if and when software does fail, the product can continue to operate safely or be able to shut down safely.

Interconnected components — Components in devices today are inextricably linked. For example, the processor must operate properly to allow software to run, both of which rely on the power system. With this level of interconnectivity, when one component becomes compromised due to wear and fatigue, external conditions or misuse, it can cause the entire system to fail. In the product design process, consider how one safety-related component failure impacts the entire system.

Energy storage — Energy storage is inherent in most electronic products. These systems can be varied and complex, depending on the device. An energy storage system may refer to a combination of a BMS and the battery cells to create a battery pack. Or, it may include a battery, inverter from a solar panel and a connection system. Lithium-ion batteries are more volatile than lead-acid batteries and can overheat and explode if not appropriately monitored. In all of these cases, power sources are more complex than ever. Safety monitoring and mitigation mechanisms help ensure these chemistries do not become hazardous.

These characteristics of electronic devices today demonstrate why safety methodologies must evaluate how each part impacts the system as a whole. Functional safety addresses those issues by reducing the risks of simple and complex systems so that they function safely in the event of an electrical or electronic malfunction.

Functional safety in specific products

Automotive and Mobility – Functional safety examples include steering systems, braking systems and autonomous vehicles.

Oil and Gas – Functional safety examples include gas detectors, safety PLCs and other safety instrumented systems.

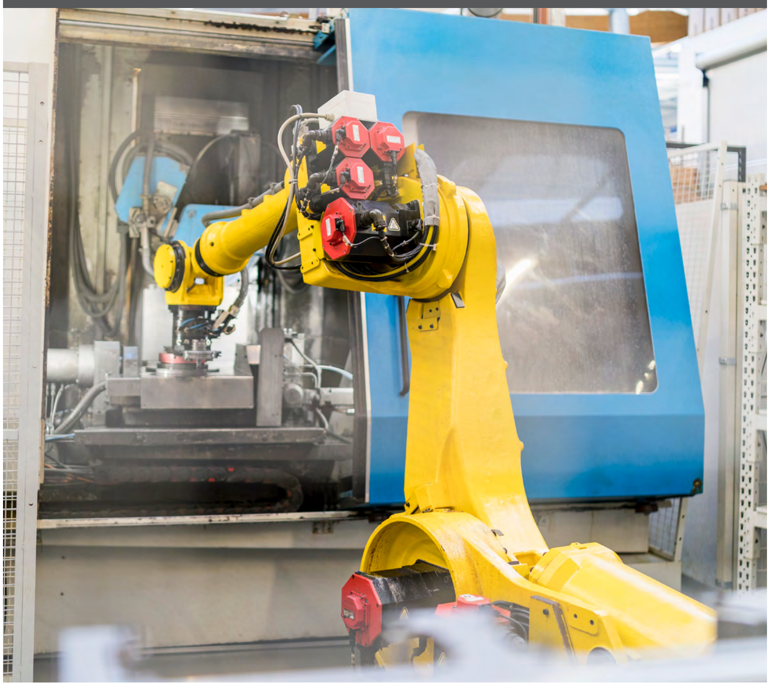
Energy Systems and Renewables – Functional safety examples include battery management systems, inverters, PV rapid shutdown, energy storage systems and their related subsystems.

Robotics – Functional safety examples include automated guided vehicles, automated mobile platforms, fixed robot arms and other industrial robots and their related equipment.

Fundamental step to functional safety: building a culture of safety

Navigating the complexities of functional safety can be a challenge. The creation of a culture of functional safety is a fundamental step. A culture of functional safety is built on three pillars: education, risk management and development process.

Education — Education includes training employees on the importance of functional safety and how different employees can play a role. Education may include financial incentives and rewards for meeting functional safety goals as well as recognition throughout all levels of the organization. Making tools available to



THE CREATION OF A CULTURE OF *functional safety is* **a fundamental step**

quality control and compliance managers can facilitate the pursuit of functional safety. The research and development (R&D) role should be heavily engaged in functional safety. By incorporating a safety mindset into the early phases of product development, R&D engineers can ensure that safety is a design criteria from the outset, reducing the likelihood of costly changes later in the product development process.

Risk management — Risk management involves assessing products for potential risks throughout their life cycle. Teams dedicated to functional safety should consider risks across the sourcing, manufacturing, packaging, shipment, storage, use, misuse and disposal of a product. A thorough approach to risk assessments includes questioning aspects of the product beyond those factors within the organization’s immediate control. For example, what if the BMS supplier does not have a robust software development methodology in place and has a bug in their product? What if the product is subject to high temperatures during shipment? What if the consumer improperly uses the product? Risk assessment becomes an exercise in identifying the weakest potential link in the chain and then building in evaluations and contingencies for that problem.

Development process — The time to integrate safety is in the early phases of product development. Design documentation is critical to functional safety, as it outlines the objectives of each component in a system and allows for thorough, directed testing and evaluation of these components. Testing is also important and can take many forms, from evaluation of low-level software and hardware components to evaluation of integrated hardware and software working together. Products also need to be evaluated as a whole, ensuring performance. Test findings should inform adjustments in design and other risk mitigation measures.

A

Figure A

A three-pronged foundation helps companies create a culture of functional safety.

The three main ways an independent third party can support the development of a safety culture. This leads to an efficient and cost-effective approach to supplement traditional safety testing and evaluation.

Functional safety resources and solutions from UL

Committed to safety for more than 125 years, UL is a pioneer in functional safety. With a long history performing testing on thousands of different types of products, UL is now on the forefront of thought leadership for functional safety and autonomy safety standards in pursuit of a safer world. As a member of the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC), UL participates in standards development, working to advance safety standards and promote harmonized international standard development. We partner with our customers to help them build in-house competencies in functional safety. To that end, we offer a full range of solutions to support our customers.

Functional safety training — UL can provide training on functional safety to organizations about what it is, its importance and the requirements for making functional safety a part of your product development process. Our UL - Certified Functional Safety Professional (UL-CFSP) training program concludes with certification for participants that individuals can use to demonstrate that they understand functional safety. This training supports the creation of a culture of functional safety.

Functional safety product and process assessments — Backed by more than a century of technical expertise, UL is distinguished by the breadth and depth of services and capabilities we offer. UL assessments are a symbol of safety unparalleled in the industry. UL offers functional safety product certification services – denoted by UL Functional Safety Certificates – that can be added for qualifying products in the process of obtaining a traditional safety certification from UL and other regulatory approvals. The Functional Safety Mark is available for compliance to U.S., Canada and European requirements.

Advisory services — Whether seeking to build functional safety competency in your organization, investing in tools to facilitate functional safety or providing expert insight on functional safety standards applicable to your products, UL advisory services let you expand your knowledge just where you need to.

UL's Functional Safety Certification Program delivers knowledge and skills in functional safety in the automotive, semiconductor, autonomous vehicles, machinery, industrial automation, cybersecurity and consumer electronics sectors. We evaluate dozens of common products to a variety of standards, including those listed in the table below.

Automotive	Battery storage and energy storage systems	Oil and gas, machinery and industrial automation	UL functional safety and autonomy safety
ISO26262:2018 - Road vehicles - Functional safety	**UL 1973**, the Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications	**IEC 61508** - Functional safety of electrical/ electronic/programmable electronic safety-related systems	**UL 991**, the Standard for Tests for Safety-Related Controls Employing Solid-State Devices
ISO 21448 - Road vehicles - Safety of the intended functionality (SOTIF)	**UL 9540**, the Standard for Energy Storage Systems and Equipment	**IEC 61511** - Functional safety - Safety instrumented systems for the process industry sector	**UL 1998**, the Standard for Software in Programmable Components
ISO 21434 - Road vehicles - Cybersecurity engineering	**UL 2271**, the Standard for Batteries for Use In Light Electric Vehicle (LEV) Applications	**IEC 62061** - Safety of machinery - Functional safety of safety-related control systems	**UL 4600**, the Standard for the Evaluation of Autonomous Products
ISO 15504 - Information Technology - Process Assessment (ASPICE)	**UL 2580**, the Standard for Batteries for Use In Electric Vehicles	**ISO 13849** - Safety of machinery - Safety-related parts of control systems	**IEC/UL 60730** - Standard for Automatic Electrical Controls for Household and Similar Use Annex H
	UL 2849, the Standard for Electrical Systems for eBikes	**ISO 25119** - Tractors and machinery for agriculture and forestry - Safety -related parts of control systems	**UL 3100**, the Standard for Automated Mobile Platforms (AMPs)
	UL 2272, the Standard for Electrical Systems for Personal E-Mobility Device	**ISO 19014** - Earth-moving machinery - Functional safety	**UL 3300**, the Outline of Investigation for Service, Communication, Information, Education and Entertainment Robots
	UL 1741, the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources		**UL 2900**, the Standard for Software Cybersecurity for Network-Connectable Products
			UL 5500, the Standard for Safety for Remote Software Updates

Summary and conclusion

Digital products of all kinds require attention to their safety and effectiveness when performing in a range of regular usage and unanticipated conditions. Savvy companies are taking a more comprehensive approach to safety engineering and testing by building competencies in functional safety.

Using this approach, organizations can save money by identifying and addressing potential safety issues early in the product development process. They can also position themselves to meet evolving functional safety standards across local, federal and international regulatory landscapes. Assessments can help them increase visibility into potential issues in the supply chain and earn market acceptability. Most importantly, this type of comprehensive safety thinking will protect people from potential harm associated with use of products.

Let UL help you build trust in your products with our functional safety solutions.
To get started, visit the website.

Endnotes

1. "Your smartphone is millions of times more powerful than the Apollo 11 guidance computers," blog posting on ZME Science, hosted by Tibi Puiu. May 13, 2021. Web. 1 November 2021. https://www.zmescience.com/science/news-science/smartphone-power-compared-to-apollo-432/