Unveiling the Mystery of LiDAR Qualification for Automotive Applications:

The four pillars you should know

by

Dr. Marc Schillgalies
First Sensor AG

Paul Sharman
First Sensor, Inc.

White paper

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Introduction

LiDAR systems have become a hot topic for autonomous vehicle applications. The opportunity to provide solutions for large fleets of self-driving vehicles has spurred a wave of competing LiDAR companies and technologies. As these solutions mature and seek to enter the commercial market, their focus will shift from performance to manufacturability and quality that meet automotive OEM standards.

Automotive industry quality and safety requirements are rigorous and must be applied from the system down to the component level. Automotive OEMs put their systems through a battery of functional tests that can take up to 1 to 2 years. They also demand that all their systems' components are qualified to automotive standards. The LiDAR system is a key element of an autonomous vehicle. Knowledge of qualification and certification standards and procedures is essential for their designers and manufacturers.

Established LiDAR suppliers to the automotive market most likely are familiar with these complex requirements. But industrial suppliers and start-up companies new to the market may underestimate the extent of component and system qualification efforts.

I. Development and production process certification – according to automotive standards
II. Qualification testing – for specific groups of automotive products
II. Robustness validation – testing under accelerated conditions that extrapolate failure rates to parts-per-million levels
IV. Functional safety – Incorporating product features that reduce the risk of failure or, when failure does occur, ensures no harm will come to people within the vehicle.

In this paper, we will review the four pillars and explain how LiDAR system suppliers must apply them in the automotive qualification process.

Pillar 1: Development and Production Process Certification

IATF 16949:2016 is a technical specification for automotive quality management systems and has become one of the most widely used international standards in the industry. It harmonizes the different assessment and certification systems in the global automotive supply chain. In 2016, the International Automotive Task Force (IATF), ruled that this specification superseded and replaced ISO/TS 16949 as the new global industry standard.

The IATF 16949:2016 quality management standard is applied by suppliers and audited by accredited organizations and consultants throughout product development, manufacturing, and the supply chain. According to Paul Blattner, global automotive program manager at Intertek, "It's upgraded with enhancements, particularly addressing risk management and safety, to keep up with changes in electronics and software that are now being introduced into vehicles that weren't there before. There's also language concerning embedded software and even a total productive maintenance system is required. Risk management language is everywhere in the new standard."

IATF 16949:2016 is not a stand-alone quality management standard, but is implemented as a supplement to, and in conjunction with, ISO 9001:2015. For LiDAR sensors and receivers, wafer fabrication, packaging, assembly, and testing must be certified to these standards.

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Pillar 2: Qualification Testing

In the 1990s, the Automotive Electronics Council (AEC) released sets of failure mechanism-based stress test qualification for the supply of electronic components in the automotive industry. They were created by the major automotive manufacturers to establish common part qualification and quality-system standards. The standards are as follows:

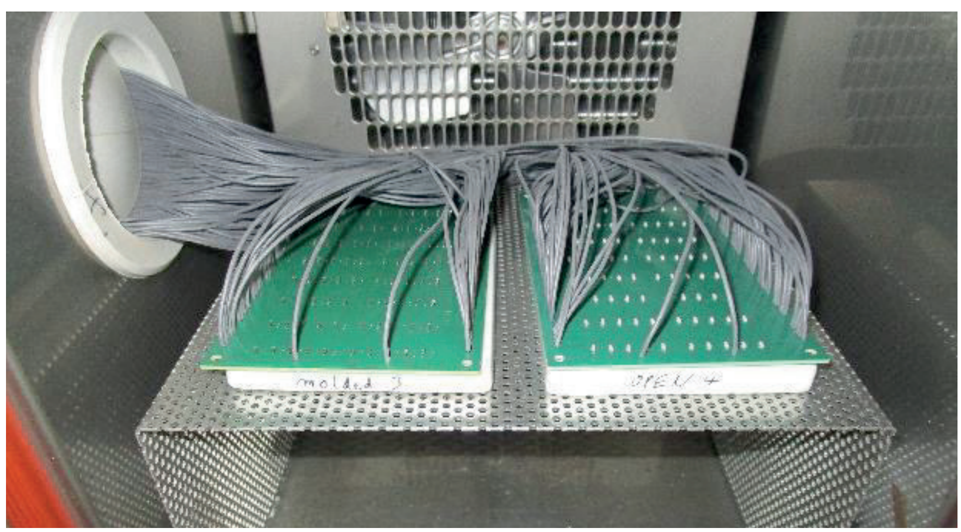
- AEC - Q100: for packaged integrated circuits
- AEC - Q101: for discrete semiconductors
- AEC - Q102: for discrete optoelectronic semiconductors
- AEC - Q104: for multi-chip modules (MCM)
- AEC - Q200: for passive components

Testing usually is performed on a limited sample quantity in several lots. A 100% passing rate on all tests along the production part approval process (PPAP) generally means the product is qualified. The tests include simulation of extreme environmental conditions on packaged parts. The assembly technologies protecting the dies as well as the semiconductors are stressed. Qualification of the die only is not enough. Therefore, the choice of assembly technology is key to passing the AEC-Q tests.

AEC-Q100 includes testing to different temperature grades, with Grade 0 for the most extreme operation temperatures of -40° C to 150° C. LiDAR applications are commonly tested to Grade 1 (-40° C to 125° C).

Semiconductor chips must be qualified in their working environments — usually the package. However, if the chip is used without package, it is difficult for suppliers to know all the criteria that exist in the application environment. Suppliers must work closely with LiDAR sensor makers or OEMs to ensure the unpackaged chip can be qualified in the customer's application. If the customer decides to only buy the chip, then the LiDAR sensor supplier must provide information such as reference data about the silicon and lifetime testing results on the packaging. However, the supplier cannot claim the sensor is qualified.

Many LiDAR companies new to the autonomous vehicle market use new, yet unproven, technologies in their systems. At present, it's not known which of these technologies will be embraced by the automotive OEMs. The automotive companies expect that prototypes of these systems will be ready to install in cars for testing. Suppliers that rely on proven automotive-grade sensor technology platforms will be much more successful in providing higher-quality, lower-risk systems to OEMs and can expect faster AEC-Q qualification.



Qualification: Testing under extreme conditions to ensure reliability in all applications

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Pillar 3: Robustness Validation

The days of accepting 0.1% to 0.5% failure rates in the automotive industry have long passed. OEMs expect failure levels in parts-per-million, not parts-per-hundred. The AEC-Q methodology allowing the use of testing samples as statistical lot acceptance criteria is no longer adequate for automotive OEMs. Since it is impractical to test one million parts, a new test methodology is required. That methodology is called robustness validation.

Robustness validation incorporates risk assessment to overcome the shortcomings of AEC-Q testing. The methodology determines the safety margin between the capability of a semiconductor device and the cumulated stress in the actual application (the mission profile). This approach involves knowing when the part or component actually breaks. For example, instead of testing 250 pieces at 125° C, the parts are tested at up to 200° C to determine when they fail. Then, statistical models can be used to calculate the actual failure rate at 125° C.

However, to assess the safety margin, the system's or part's individual application must be defined. This data typically is presented in the form of a mission profile that summarizes the stress conditions (strong acceleration, high temperature, etc.) expected in the application. It enables the supplier to fully understand how its component will be used and what it will experience in the vehicle.

For example, there is not a single AEC-Q test that puts a LiDAR system's photo diode under stress for extreme ambient sunlight conditions. Sunlight intensity makes a big difference in photo diode performance in an autonomous vehicle application. The photo diode converts large amounts of light into large amounts of current. High current can accelerate semiconductor failures. If the mission profile includes strong light levels for an extended period, then AEC-Q qualification doesn't ensure the component will survive in the application. You must perform robustness validation to ensure performance in strong sunlight.

The AEC-Q qualification of LiDAR systems for autonomous vehicles must be complemented with robustness validation. Only by obtaining the knowledge of failure mechanisms, the acceleration models that trigger them, the limits of the device, and the application's mission profile, can the actual failure rates for LiDAR sensors in autonomous vehicle systems be achieved.

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Pillar 4: Functional Safety

With the growing complexity of safety-related electronic systems in automotive applications, the possibility of malfunctions is increasing. To reduce the occurrence and/or impact of these events, an international standard for the functional safety of electrical and/or electronic systems in production automobiles was defined by the International Organization for Standardization in 2011.

ISO 26262 is usually required to be an integral part of all product development phases and production release for safety-related commercial automotive products. During LiDAR system development, the risk of hazards is assessed, and critical components of functional safety are classified by ISO 26262's Automotive Safety Integrity Levels (ASIL) A to D (with A being the lowest integrity level and D the highest). These classifications help define the safety requirements necessary to be in line with the ISO 26262 standard.

Functional safety can be improved through redundancy and early malfunction detection. For example, if a vehicle's headlights fail, it would become a safety concern and might cause an accident. So, the headlights are connected to a dashboard display that indicates if they are not working. This is a typical of many electronic alerts and warnings in the vehicle that inform if a critical system is broken.

LiDAR sensors without integrated electronics do not possess self-diagnostic capabilities that would indicate failure. And it would not be cost-effective to install two redundant devices. Yet, to reduce the risk of failure, redundancies can be incorporated by including for example two bond pads and two bond wires with the LiDAR sensor. In the unlikely event that vibration breaks a bond wire connection, the duplicate set takes over.

Conclusion

As companies developed new LiDAR system technologies for autonomous vehicles, performance testing has been emphasized. However, this focus will change to qualification and certification testing as autonomous vehicles are commercialized. LiDAR system suppliers must qualify their products to be successful in the automotive market.

There are four steps in the qualification process. First, development and production processes certified to IATF 16949:2016 ensure that the supplier has complied with a globally recognized quality management standard. Second, electronic products for the automotive industry must be qualified to the AEC-Q failure mechanism-based stress tests. Third, robustness validation incorporates risk assessment to overcome the shortcomings of AEC-Q testing and determine the safety margin between the capability of a semiconductor device and the cumulated stress in the actual application. Finally, functional safety ensures there are redundancies built into the system that reduce the occurrence or impact of system malfunction.

LiDAR system design must include automotive quality and safety considerations. Even if systems are still in the development phase, reliance on automotive standard processes or designs for sub-modules and components will facilitate qualification down the road. Also, a LiDAR sensor provider with strong knowledge of the automotive market can help ensure high system quality and safety levels.

By incorporating the four pillars of automotive quality in their development programs, LiDAR system suppliers will have a step up on the competition when their products require qualification and certification.

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About First Sensor

First Sensor is one of the world's leading suppliers in the field of sensor systems. In this growth market, First Sensor develops and produces standard products and customer-specific solutions for the ever-increasing number of applications in the industrial, medical, and mobility markets. With the most innovative sensor solutions, our goal is to identify, meet, and solve the challenges of the future — today.

About the Authors

Dr. Marc Schillgalies is the Vice President of Development at First Sensor AG. He has over 13 years' experience in opto-semiconductors and has held various roles in development and product management at First Sensor AG. Prior to joining First Sensor, he was a Laser Development Engineer at Osram Optosemiconductors. Dr. Schillgalies holds a Ph.D. in semiconductor physics (lasers), an M.B.A. in general management, an M.Sc. in physics, and an M.Sc. in optical sciences.

Paul Sharman is the CEO, President, and Vice President of Sales & Marketing at First Sensor, Inc. He has 30 years' professional experience in opto-semiconductors, with past roles including Vice President of Manufacturing and Vice President of Quality and Reliability. Mr. Sharman holds a B.Sc. in engineering.

First Sensor, Inc.
5700 Corsa Avenue #105
Westlake Village, CA 91362
T +1 818 706-3400
F +1 818 889-7053
us@first-sensor.com

www.first-sensor.com