# Automotive Optocouplers—Beyond Meeting the Electrical Performance at High Temperature

## White Paper

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### Introduction

The trend toward electric or hybrid electric vehicles has accelerated the introduction of electronic components in cars. The components residing under the hood will experience high ambient temperatures in excess of +105°C. While some products are able to meet electrical specifications up to +125°C, it cannot be assumed that they are suitable for automotive applications. Here, we take a look at the stringent requirements for an automotive grade optocoupler besides meeting high temperature electrical specifications. As part of the R$^2$Coupler™ family, Avago Technologies' automotive grade optocouplers were designed and qualified to meet these stringent standards.

Automotive components, like any other devices, need to comply with certain specifications or standards. The most well-known technical specification for automotive suppliers is the ISO/TS 16949[1] quality management system, prepared by the International Automotive Task Force (IATF), in conjunction with the International Organization for Standardization (ISO). The Automotive Electronics Council's AEC-Q100 standard[2] provides a guideline for failure mechanism-based stress tests for qualification of automotive integrated circuits.

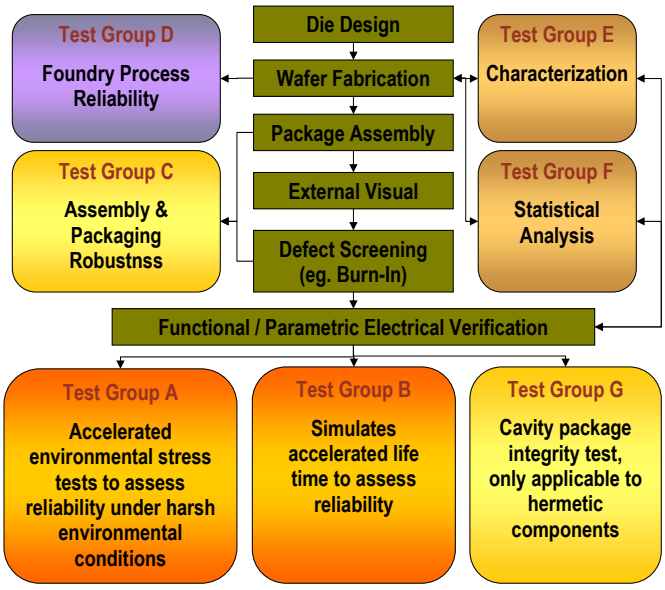


**Figure 1. AEC-Q100 Qualification Groups**

### AEC-Q100

In the AEC-Q100 document, a comprehensive set of qualification tests is recommended for different grades (segregated according to different operating temperature) and/or different packaging (plastic or hermetic). It stipulates the quantity, coupled with variability, of samples required per stress test. The qualification groups, as summarized in Figure 1, involve accessing the assembly and packaging parameters before performing electrical testing. Parts are then subsequently subjected to various electrical, environmental, as well as mechanical stresses, to ascertain the reliability of the parts for automotive applications.

Starting at the foundry level, Test Group D evaluates the reliability of the foundry process and its design rules. These tests are typically performed by the foundry and reliability is checked through the monitoring of critical data, such as electro-migration and hot carrier injection. For assembly packaging, in-process tests under Test Group C include wire pull tests, physical dimensions validation, and solderability verification to ensure package assembly robustness.

Test Groups E and F assess the performance of the parts in terms of statistical distributions and electrical characteristics. Test Group G is classified as cavity package integrity tests, which recommends specialized tests applicable only to hermetic components, and is not applicable to plastic encapsulated R$^2$Couplers.

Test Group B simulates accelerated lifetime to assess reliability. A common test in Test Group B is the High Temperature Operating Life, where parts are biased under high temperature over time to screen for potential failure modes during actual operation. For R²Couplers, biasing conditions are carefully considered to ensure both LED and silicon ICs are well-assessed. The LED used in R²Couplers is designed to cope with the high junction temperature to ensure long life operation with minimal drop in light output power when subjected to temperature and current stress. The packaging was also designed to cope with heat dissipation from the chip set.

Test Group A utilizes various accelerated environmental stress tests, such as Temperature Cycling and Autoclave, to evaluate reliability under harsh environments with temperature and/or humidity extremes. Optocouplers, having more components and involving more complex assembly processes than monolithic ICs, tend to face many technical challenges in this group. R²Couplers implement the concept of redundancy by reinforcing critical functional pads with double wire bonds (see Figure 2), improving package robustness and reliability under such harsh conditions.

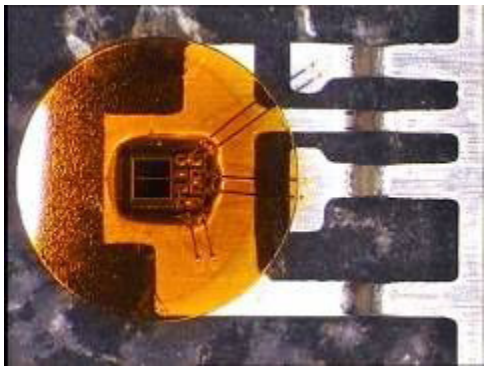

**Figure 2. Reinforcing Critical Functional Pads with Double Wire Bonds**

R²Couplers offer reinforced insulation and reliability to deliver safe signal isolation which is critical in automotive and high temperature industrial applications. Assessment of the reliability of the insulation barrier is not specifically defined under the AEC-Q100 guidelines. Optocouplers have been in use for high voltage insulation for many years and experienced manufacturers have developed appropriate tests to check the integrity and reliability of insulation layers and construction. R²Couplers are certified to safety standards specifically for optocouplers, such as UL1577, CSA Component Acceptance Notice #5, and IEC60747-5-2 or IEC60747-5-5, with well-defined high voltage safety criteria in terms of withstand voltage, transient overvoltage, working voltage, creepage, and clearance.

At the end of the qualification, a Certificate of Design, Construction, and Qualification is prepared by the supplier for submission to the customer.

In addition to specifying the qualification flow for new parts, AEC-Q100 also defines guidelines for any revisions made to released automotive parts. This ensures that any potential quality and reliability concerns are addressed prior to implementation and customer notification.

## ISO/TS 16949

As AEC-Q100 addresses the robustness of the product, ISO/TS 16949 ensures consistent production of quality parts for automotive applications.

While ISO 9000[3] quality management principles are widely accepted in the industry, ISO/TS 16949 technical specification includes additional clauses pertaining to the automotive industry and incorporates any applicable automotive customer-specific requirements. Certification of the automotive optocoupler line to ISO/TS 16949 specification ensures a quality management system is in place providing continual improvement, emphasizing defect prevention, reduction of variation and waste in the supply chain, while being customer-centric—taking into account additional customer requirements.

There are five ISO/TS 16949 technical reference handbooks. These include 3 core tools: Potential Failure Mode Effects Analysis (FMEA),[4] Fundamental Statistical Process Control (SPC), Measurement System Analysis (MSA), and 2 technical handbooks: Advanced Product Quality and Control Plan (APQP)[5] and Production Part Approval Process (PPAP).[6]

Depending on the level of submission requested by the automotive customers, PPAP documentation may be required for any new parts, product modifications, or discrepancy corrections to previously submitted parts. Once completed, the PPAP documentation may be submitted to the customer for review to validate that requirements have been met.

In addition to the extensive and detailed documentary support highlighted above, automotive customers often have more stringent requirements than other industries. A few examples are cited below, illustrating how Avago Technologies' automotive grade optocouplers support such administrative demands.

### 1. Longer record retention period

Automotive customers are typically requesting records be retained for a minimum of 10 years. Avago Technologies set up a comprehensive and organized database to accommodate this retention period, as well as to allow for fast retrieval of any related information.

### 2. Enhanced lot traceability

In the event of any quality or reliability problems, the unique date code extensions marked on Avago Technologies' individual automotive optocouplers facilitate quick traceability of detailed lot histories of any affected parts for containment action. Critical information, such as LED and IC wafers or a batch of raw materials used, can be retrieved based on the unit marking.

## Conclusion

A comparison of the key differences among Avago Technologies' industrial and automotive grade optocouplers is summarized in Table 1 below. It can be seen that suppliers of automotive parts need to comply with more comprehensive qualification guidelines (AEC-Q100) and quality management systems (ISO/TS 16949). Optocouplers, being insulation components, need to be stressed beyond what is stipulated in AEC-Q100. Due to the higher number of piece parts and complex processes, optocouplers require adherence to a quality system.

## References


[1] ISO/TS 16949:2002 Technical Speciation (2nd Ed)

[2] AEC-Q100 Rev G

[3] ISO 9001:2000 (3rd Edition)

[4] FMEA Reference Manual (4th Edition)

[5] APQP Reference Manual (2nd Edition)

[6] PPAP Reference Manual (4th Edition)


**Table 1. Key Differences between Industrial and Automotive Grade Optocouplers**

| | | R²Coupler | |
|---|---|---|---|
| | **Industrial Grade Optocouplers** | **Extended Temp ACPL-xxxU** | **Automotive Grade ACPL-xxxV/xxxT** |
| Maximum Temperature Range | -40°C ≤ $T_A$ ≤ +105°C | -40°C ≤ $T_A$ ≤ +125°C | -40°C ≤ $T_A$ ≤ +125°C |
| Piece Part | Industrial Grade | Industrial Grade | Automotive Grade |
| Critical Wire Bonds | Single Wire | Double Wire | Double Wire |
| Qualification Plan | JEDEC47 | JEDEC47 | AEC-Q100 |
| Qualification Sample | 3 x 25 units typically (Per JEDEC) | 3 x 25 units typically (Per JEDEC) | 3 x 77 units typically (Per AEC-Q100) |
| Qualification Groups | Per JEDEC47 | Per JEDEC47 | Per AEC-Q100 |
| Quality Management | ISO 9001 | ISO 9001 | ISO/TS 16949 |
| Assembly Line | ISO certified | ISO certified | TS certified |
| PPAP | Not provided | Not provided | Per customer requirement |
| Record Retention | ≤10 years typically | ≤10 years typically | ≥10 years typically |
| Lot Tracking | Normal datecode marking | Normal datecode marking | Extended datecode marking |

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