

Automotive Optocouplers – Beyond Meeting the Electrical Performance at High Temperature



White Paper

Leong Yik Loong, Roy Tan, Andy Poh

Introduction

The trend of electric or hybrid electric vehicles has accelerated the introduction of electronic components into 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, they cannot be conveniently assumed to be suitable for automotive applications. Here, we take a look at what goes into an automotive grade optocoupler beyond meeting high temperature electrical specifications. As part of the R²Coupler™ 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.

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 their 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 R²Couplers.

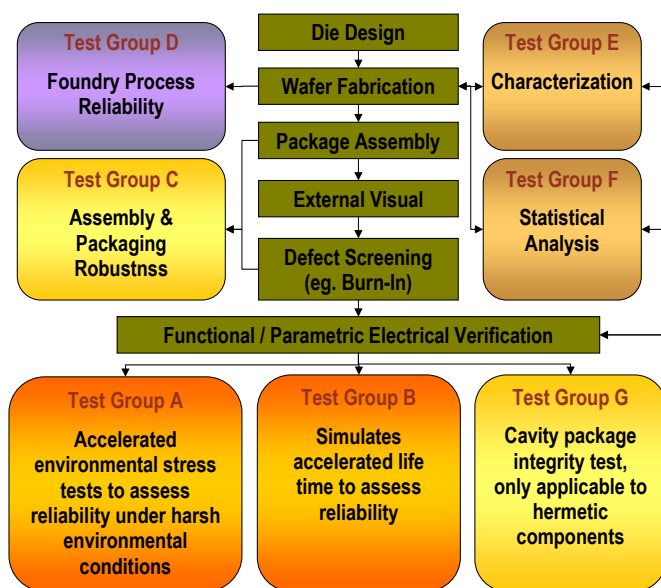


Figure 1. AEC-Q100 Qualification Groups

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, careful considerations on biasing conditions are taken to ensure both LED and silicon IC's 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. Packaging design to cope with heat dissipation from the chip set was taken into consideration as well.

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 order to survive the tests 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.

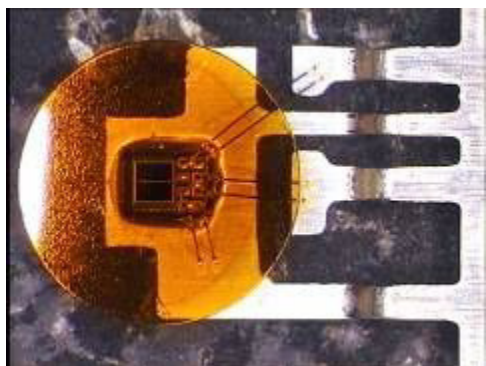


Figure 2. Reinforcing Critical Functional Pads with Double Wire Bonds

R²Couplers are focused on reinforced insulation and reliability to deliver safe signal isolation which is critical in automotive and high temperature industrial applications. Assessment on 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 on 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 will be prepared by the supplier for submission to the customer.

In addition to having qualification flow for new parts, AEC-Q100 also has guidelines for any changes to released automotive parts. This ensures that potential quality and reliability concerns shall be addressed during qualification of the change prior to actual implementation and notification to customers.

ISO/TS 16949

AEC-Q100 provides the necessary confidence on the robustness of the product, but not the quality management system of ensuring consistent production of quality parts for automotive applications. ISO/TS 16949 quality specification helps to address this gap specifically for the automotive industry.

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 into the quality management system. Certification of the automotive optocoupler line to ISO/TS 16949 specification ensures a quality management system is in place that provides for continual improvement, emphasizing defect prevention and reduction of variation and waste in the supply chain, as well as being customer-centric, taking into account additional customer requirements.

There are 5 technical reference handbooks from ISO/TS 16949. These include 3 core tools; Potential Failure Mode Effects Analysis (FMEA^[4]), Fundamental Statistical Process Control (SPC) and 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 modification or correction of discrepancy on previous submitted parts. Once completed, the PPAP documentation may be submitted to the customer for review to validate if their requirements are 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 on how Avago's automotive grade optocouplers support such administrative demands.

1. Longer record retention period

Automotive customers are typically requesting a minimum 10 years of record retention. A comprehensive and organized database was set up for automotive optocouplers to cater for the longer retention period as well as fast retrieval of any related information as needed.

2. Enhanced lot traceability

In the event of any quality or reliability problems, the unique date code extensions marked on individual automotive optocouplers will facilitate quick traceability of detailed lot histories of 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 key differences of Avago's industrial and automotive grade optocouplers is summarized in Table 1 below, reflecting the need for suppliers of automotive parts to comply with more comprehensive qualification guidelines (AEC-Q100) and quality management systems (ISO/TS 16949). Optocouplers, being insulation components, will need to be stressed beyond what is stipulated in the AEC-Q100, and having more piece parts and complex processes, will require emphasis on the quality system to ensure consistent quality parts.

References

- [1] ISO/TS 16949:2002 Technical Specification (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

	Industrial Grade Optocouplers	R ² Coupler	
		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

For product information and a complete list of distributors, please go to our web site: www.avagotech.com