

Specification for Testing Automotive LED Modules

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SPECIFICATION FOR TESTING AUTOMOTIVE LED MODULES

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1. SCOPE

This specification is a general level subsystem light source specification that establishes test requirements of light emitting diode (LED) components and modules for use in automotive lighting systems.

The completed test data from this test specification is intended to be provided to the OEM by the Tier 1 lamp set maker as part of the lamp assembly PPAP. Re-testing shall be required if any portion of the approved LED module experiences a design, manufacturing, or component change.

This document shall be applied to systems that meet the requirements for design, performance, and validation established by government standards.

The LED module is defined as the LED devices and any electronics required to properly energize the LEDs using a vehicle electrical power system along with any associated electrical wiring, connectors, and thermal management system. Samples shall be tested as a subsystem and considered one test sample for the entire test sequence. A failure of any component in the test sample shall constitute a failure of the entire sample.

NOTE: If other manufacturers' components are intended to be approved for use in the LED modules, then those possible combinations of components shall be considered a new LED module and shall also be tested.

Additional testing may be required by individual OEMs to meet specific EMC, quality, reliability, and durability objectives.

The following tests are to be performed under the following conditions:

- New sample.
- Design or process change made to an existing module.
- Completion of one calendar year as noted in the annual tests table shown in Appendix E. *(Note: Production process control data, collected at a shorter interval per an approved control plan, may be substituted if approved by customer's responsible engineer and purchasing representative.)*

2. SAFETY PRECAUTIONS

Refer to IEC 62471.

3. REFERENCE STANDARDS

In the event of a conflict between the text of this specification and the documents cited herein, the text of this specification takes precedence. Nothing in this specification, however, supersedes applicable laws and regulations unless a specific exemption has been obtained. The latest issue of reference documents shall apply.

- AEC Q101, AEC Q102, AEC Q100, AEC Q200
- AIAG/APQP-2: Fiat Chrysler Automobiles (FCA), Ford, and General Motors Advanced Product Quality Planning and Control Plan Reference Manual
- AIAG/MSA-3: Measurement Systems Analysis Reference Manual
- AIAG/FMEA-3: Potential Failure Mode and Effects Analysis Reference Manual (SAE J1739)
- AIAG/PPAP-3: FCA, Ford, and General Motors Production Part Approval Process Manual
- ASTM B117: Standard Practice for Operating Salt Spray (Fog) Testing Apparatus
- FCA, Ford, and General Motors Quality System Requirements QS-9000 Manual

- AIAG Fundamental Statistical Process Control Reference Manual**
- ASTM E595-07: Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
- IEC 60068-2-1: Cold
- IEC 60068-2-2: Ba, Dry Heat
- IEC 60068-2-14: Na, Rapid Change of Temperature With Prescribed Time of Transition
- IEC 60068-2-14: Nb, Change of Temperature with Specified Rate of Change
- IEC 60068-2-27: Ea, Mechanical Shock
- IEC 60068-2-32: Ed, Free Fall
- IEC 60068-2-64: Vibration
- IPC-A-610D: Acceptability of Electronic Assemblies
- ISO 16750-1: Road vehicles - Environmental conditions and testing for electrical and electronic equipment — Part 1: General
- ISO 16750-2: Road vehicles - Environmental conditions and testing for electrical and electronic equipment — Part 2: Electrical loads
- ISO TC 22/SC 3/WG 13 N139: Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 1: General
- ISO TC 22/SC 3/WG 13 N140: Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 2: Electrical loads
- ISO TC 22/SC 3/WG 13 N142: Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 3: Mechanical loads
- ISO TC 22/SC 3/WG 13 N141: Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 4: Climatic loads
- ISO 2575 Index M: Electrical Functions in General and Electric Road Vehicles
- SAE/USCAR-2: Performance Standard for Automotive Electrical Connector Systems.
- SAE/USCAR-12: Wiring Component Design Guidelines
- SAE/USCAR-20: Field Correlated Life Test Supplement to SAE/USCAR-2
- SAE/USCAR-21: Performance Specification for Cable-to-Terminal Electrical Crimps
- SAE/USCAR-34: Specification for Testing Automotive Lamp Assemblies
- SAE J2602: LIN Network for Vehicle Applications
- SAE J575: Test Methods and Equipment for Lighting Devices for Use on Vehicles Less than 2032 mm in Overall Width

- SAE J578: Color Specification
- SAE J1128: Low Voltage Primary Cable
- SAE J1330: Photometry Laboratory Accuracy Guidelines
- SAE J1344: Marking of Plastic Parts
- SAE J1383: Performance Requirements for Motor Vehicle Headlamps
- SAE J1673: High Voltage Wiring Assembly Design
- SAE J1889: LED Signal and Marking Lighting Devices
- SAE J2357: Application Guidelines for Electronically Driven and/or Controlled Exterior Automotive Lighting Equipment
- SAE J2602: LIN Network for Vehicle Applications
- SAE J2650: Performance Requirements for Light Emitting Diode (LED) Road Illumination Device Systems
- SAE J2938: LED Light Source Tests and Requirements Standard
- VDA 260: Marking Standard - Federation of the Automobile Industry
- Q7-K: TS-16949 Supplier Quality Requirements
- ANSI-ESD-S20-20_2007: For the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices)

**Copies of the AIAG Manuals can be obtained from AIAG (Automotive Industry Action Group) by calling (248) 358-3570 or by writing to AIAG, Dept. 77839, Post Office Box 77000, Detroit MI 48277-0839, Attn: Customer Service.

4. DIAGRAMS AND DEFINITIONS

4.1 Appendices

Diagrams are provided at the end of this specification to clarify the details of the test procedures. A glossary of terms is also included in Appendix A.

5. GENERAL REQUIREMENTS

5.1 Record Retention

Supplier must maintain a file for the storage of laboratory reports and calibration records and establish a record retention policy concerning these records in accordance with TS-16949 and PPAP requirements. These records need not follow a standard format but must present the required data in an orderly, professional manner. The file must be made available to any and all customer personnel upon request, including, but not limited to, representatives from the following areas: product engineering, purchasing, quality, and reliability.

5.1.1 Objectives of Record Retention

The following are the main objectives for retention of test documents or records:

1. Retain records that will evidence compliance so that the supplier can appropriately respond when, or if, product compliance is challenged. Files must exist for the storage of all laboratory records, data, and calibration records. The files must be available at any time for audit or inspection.
2. Retain records as needed to assist in evidencing the exercise of "due care" in matters relating to product compliance, government requirements, or product liability.
3. Comply with statutory requirements for the maintenance and retention of specific records.

5.1.2 Retention Methods

Methods of retention may include retention of original documents, the use of film, or the use of electronic storage equipment. Records shall be stored so that they are accessible in a reasonable amount of time. Storage areas should provide adequate protection from unauthorized access, moisture, and fire.

5.2 Sample Documentation And Retention

Engineering test samples must be identified by Industry Accepted Trade Number and manufacturer's serial number unless otherwise noted. Documentation must identify the type of test performed and describe special tests that are not a part of this specification. (Refer to TS-16949 and PPAP requirements.)

5.2.1 Required Data Package

Supplier must submit the data package for the appropriate level of submission to the customer's responsible engineer and purchasing division for approval signatures.

5.2.1.1 Production Process Approval

The LED module design shall be capable of meeting the requirements of Automotive Industry Action Group (AIAG) document "Production Part Approval Process" (PPAP).

5.2.2 Sample Retention

Samples tested to obtain part approval must be retained by the manufacturer for a period of time specified in the PPAP Manual.

5.3 Power Sources

Supplier must use voltage regulated DC power sources for all tests to simulate an automotive battery and charging system. When pulse width modulation (PWM) can be used to energize or control a function, the PWM supply shall be duplicated in each test. When the vehicle electrical power system uses a pulse width modulation (PWM) power supply to energize an LED module, then the test must also use a PWM power supply of similar frequency and duty cycle.

5.3.1 Output Current

The power source must be capable of supplying a continuous output current, as required by the design loads, including inrush current. Where required to simulate automotive inrush current conditions, an automotive battery, or batteries, with sufficient cold cranking amps may be connected in parallel with the power supply.

5.3.2 Output Voltage

The power source must be capable of supplying an output voltage that must not deviate more than 0.1 V from the nominal setting over the entire load range (including surges). The power source must recover 63% of its maximum excursion within 5.0 ms. Ripple voltage must not exceed 25 mV peak to peak. Power supplies used for photometric measurements must conform to SAE J1330.

5.4 Equipment Tolerances

Supplier must use test setups and equipment capable of measuring test parameters (nominal) within the limits found in Table 1.

Table 1 - Equipment tolerance

Test Chamber Temperature/Humidity	Nominal $\pm 2^{\circ}\text{C}$ Relative Humidity $\pm 5\%$
Time	Nominal $\pm 0.5\%$
Forces	Nominal $\pm 0.1\text{ N}$
Distances	Nominal $\pm 0.1\text{ mm}$
Voltages	Nominal $\pm 0.1\text{ V}$
MSCD	Nominal $\pm 2.0\%$

NOTE: This table is not to be used for performance-dependent variable. See 5.5.

5.5 Measurement Accuracy

Meters and gauges used to assess the performance dependent variable, as defined by the basic function of the test sample, must have a smallest unit of measure one order of magnitude less than the least significant digit specified. For example, even though a 0.6 mm and 0.60 mm wire might be the same diameter, calipers capable of 0.01 mm resolution may be used to measure the first wire but a micrometer with 0.001 mm resolution is needed for the second wire.

5.6 Test Repeatability and Calibration

5.6.1 Equipment Repeatability

All measurement equipment used for product evaluation must be repeatable to within 10% of the part tolerance according to Fiat Chrysler Automobiles (FCA), Ford, and General Motors Measurement Systems Analysis Reference Manual.

5.6.2 Equipment Calibration

Equipment re-calibration/re-certification timing is to be calculated based on the capability of any individual instrument to retain its "manufacture stated accuracy" between recall periods. However, this time shall not exceed 1 year.

5.6.3 Laboratory Masters (Photometry Only)

Lamps that are traceable to known standards are laboratory masters. Each supplier must use laboratory masters for comparison measurements, calibration of test equipment, and for evaluating long-term drift in test equipment.

5.7 Test Default Conditions

Tests shall be conducted under conditions and methods specified herein. When specific test conditions are not given, the following basic conditions apply:

1. Voltage input to LED module, unless otherwise specified.
 - a. Nominal voltage V_{nom} shall be 13.5 VDC.
 - b. Low voltage V_{low} shall be 9.0 VDC.
 - c. High voltage V_{high} shall be 16.0 VDC.
 - d. Any inputs which are intended to incorporate pulse width modulation (PWM) shall be energized in that manner using the voltage parameters specified by the OEM.
2. Any signals utilized to control or communicate shall be included in the test setup.
3. Perform tests or measurements at the following ambient temperature of $23\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ unless otherwise specified.

5.8 Test Sharing Within Light Source Families

The results of tests performed on one light source type may, in some cases, be used to indicate the capability of another light source type within the same family.

5.9 Test Failure Procedure

Should a test failure occur, the customer (quality, purchasing, and design/release engineer) shall be notified immediately.

5.10 Control Plans

Supplier must maintain a control plan, consistent with the AIAG, for each LED component or module that contains appropriate controls to ensure that all the significant/critical characteristics covered by the tests in this document are met.

5.11 Reliability Programs and Methods

5.11.1 Reliability Growth and Ongoing Quality Improvements

Suppliers must establish and implement a plan to improve demonstrated product quality and reliability. They must establish procedures for analyzing and correcting end-of-line defects and predominant failure modes identified by the field return program. True reliability growth occurs when design changes to the design or manufacturing process are made to eliminate the failure modes.

5.11.2 Notification of Process Changes

PPAP resubmission and approval is required unless all customers agree that PPAP resubmission is not required.

5.11.3 Quality/Reliability Improvement Tools

Suppliers must use appropriate methods to improve the quality and reliability of their products in accordance with TS-16949. Examples of such methods are field return programs, design failure mode effects analysis (DFMEA), process failure mode effects analysis (PFMEA), and fault tree analysis (FTA), or fishbone diagrams. Further information on these methods is available from the Automotive Industry Action Group (AIAG).

5.12 Hazardous Material Restriction

Any regulated substance that is identified by any federal, state, provincial, or local government unit, or automotive manufacturer, shall not be used in the manufacturing process of any LED module components. Any LED module components manufacturer that is currently supplying hazardous material in a component will submit a timeline to General Motors, Ford, and FCA for the removal of said product.

Materials selected for use in the LED modules shall not produce corrosive or deleterious fumes under manufacturing, assembly, operating, or test conditions stated herein.

5.12.1 Recyclability

The LED module is considered a recyclable item, and the design shall utilize recyclable materials where practical.

5.12.1.1 Recycling Information

The LED modules shall be marked with recycling information with either specific instructions or molded marking in accordance with SAE J1344, VDA 260, or equivalent document, as appropriate.

5.12.2 Item Diagram

A block diagram for the LED modules and interfacing elements is required. Internal partitioning, content, design, and construction details to meet requirements of this specification are at the discretion of subsystem supplier except as otherwise specified herein.

5.13 Documentation

5.13.1 Component

The LED components used in a LED module shall be documented and provided in the PPAP. The documentation shall identify the LED supplier, LED supplier part number, LED package type, LED encapsulation method, output viewing angle, the color BINs used, forward voltage, and flux or brightness, any voltage and color matching requirements for the module, along with the required current draw for each flux or brightness BIN.

5.13.2 Module

The PPAP shall document the module input operating voltage, current, functional behavior, and power dissipation across the operation temperature and I/O voltage range which produce the required functions at a level required by the OEM.

Any fault detection functionality, including outage detection used to comply with regulatory requirements, shall be described in the design specification for the module. The fault detection design shall be approved by the customer prior to module design freeze. Test requirements shall be generated to validate these functionalities and included as part of the PPAP.

6. ANALYSIS

The analysis shall be used to aid in designing reliability into the component during the time when physical components are not yet available. analysis should be the earliest activity in the A/D/V process. All analytical activities shall be documented and provided to the customer, including results. Analytical activities shall be completed prior to the design freeze.

6.1.1 Reliability

Reliability of each system, including LEDs and any drive electronics, shall be demonstrated based on the lifetime requirements outlined in 10.1 of this document, using reliability assessment MIL-HDBK-217F. Assessments shall be made for the module at its intended drive conditions and expected temperature conditions. Any component database assumptions shall be reviewed and approved by the customer. The output should be a chart of the predicted yearly failure rate in ppm or in R/1000 over operating temperature and hours of operation per year.

6.1.2 Nominal and Worst-Case Analysis

A circuit analysis to determine voltage, current, power dissipation for each part across the operation temperature and supply, and I/O voltage range shall be performed and provided. The analysis shall include a plot of current through the LEDs versus module voltage across all temperature extremes. This analysis shall verify that the design of the circuit can produce the required functions under all conditions.

7. LED MODULE COMPONENTS

7.1 Module Components

All electronic components contained within LED modules shall comply with all LED specifications contained in IEC 60810 and applicable AEC-Q100. In addition, all passive components shall comply with all AEC Q200 tests referenced in Tables 2 through 14, and all integrated circuits shall comply with all AEC-Q100 Stress Qualification for Integrated Circuits.

If any tests are considered not applicable, these exceptions shall be agreed to by the customer. LED module assemblies shall adhere to the applicable requirements and recommendations contained in IPC-A-610D at a Class 3 level.

Electronic modules that have a portion of the device protected in service by the lamp assembly may have that portion of the electronic module similarly shielded during the test.

All LED packages with gold bond wires shall only use gold lead frames unless the LED package has protection against corrosion (example: silver protected from sulfur corrosion by epoxy encapsulation, etc.).

7.2 Lumen/Chromaticity Maintenance

LED lumen maintenance testing shall be conducted according to IES LM-80-15, with the following modifications:

- Section 7.4, DUT Case Temperatures: The first case temperature (T_s) specified shall be set at 85 °C. The second case temperature (T_s) shall be set at the maximum specified case temperature for the LED powered at the maximum current rating specified for the LED.
- If the maximum specified current rating and the maximum specified case temperature for the LED do not converge at a single point (Figure 1, point a), both the maximum current rating set at the maximum case temperature for that current rating (Figure 1, point b) and the maximum specified case temperature set at the maximum current rating for that temperature (Figure 1, point c) shall be tested. See Figure 1.

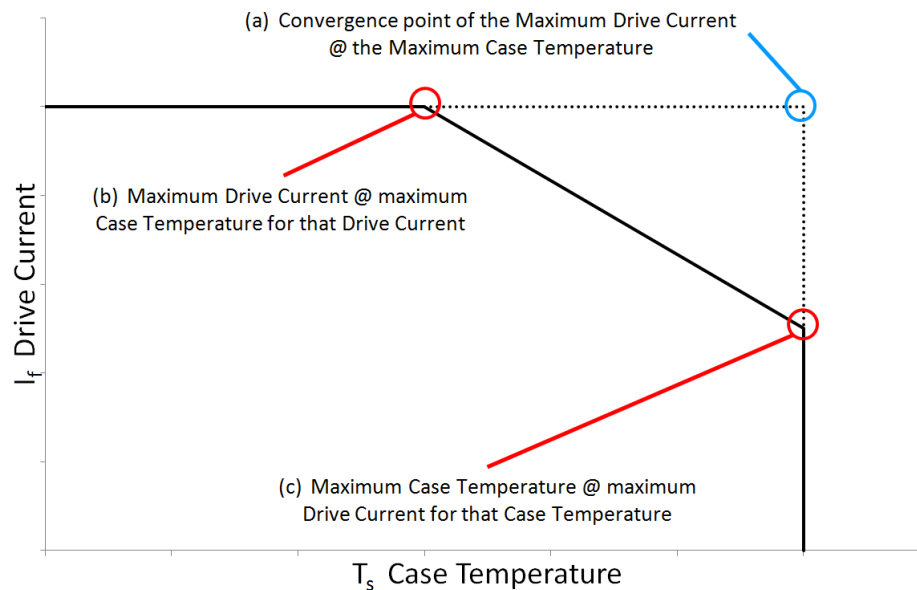


Figure 1 - LED forward drive current versus case temperature

- Section 5.3, Input Current Regulation: The current shall not be de-rated as a function of temperature when tested at the maximum case temperature specified above.
- Section 7.5, Maintenance Test Duration and Measurement Interval: The testing duration when tested at the maximum case temperature shall be no less than 6,000 hours, and the testing interval shall be no more than 500 hours. Lumen maintenance testing of the LED can be halted if the lumen maintenance drops below 50%. Catastrophic failures during testing shall be included in the lumen maintenance calculation.
- Section 6.1, DUT Photometric and Electrical Measurements: During the test, the color shall not shift more than one adjacent color bin, according to IEC 62707-1.

7.3 LED Binning

White LEDs shall be binned for color according to IEC 62707-1 and according to IEC 62707-2 and -3 for light output and forward voltage, when published.

Individual modules, regardless of LED color, shall be manufactured using a single-color bin, a single forward voltage bin, and single intensity LED bin (if not compensated in the module circuitry).

7.4 LED Overstress Testing

7.4.1 Purpose

To determine the performance of an LED subjected to overstress conditions.

7.4.2 Test Samples

Each LED type and LED color shall be tested through each stress test as indicated in Table 2. A minimum of 78 LEDs are required for each stress test. LEDs shall be taken from three different production batches of 26 each.

7.4.3 Procedure

Test details are given in Table 2. Monitor LED function at regular intervals with a minimum of once a week. LEDs shall be energized such that any LED failures shall not impact the function of other LEDs.

7.4.4 Required Data

Data shall be provided for each Stress Test for each LED type for all samples tested.

NOTE: There are no acceptance criteria for these tests.

Table 2 - LED Overstress Tests

Stress Test	Mid-Power (≤ 1 W) LED Stress Conditions	High Power (> 1 W) LED Stress Conditions	Stress Duration	Minimum Sample Size ⁽¹⁾	Data to Provide
High Temperature Operating Life (HTOL) ⁽²⁾	T_c set such that $T_j = T_{jmax} + 30\text{ }^\circ\text{C}$ $I_f = 150\% I_{f(max)} \text{ mA}^{(3)}$	T_c set such that $T_j = T_{jmax} + 15\text{ }^\circ\text{C}$ $I_f = 125\% I_{f(max)} \text{ mA}^{(3)}$	Minimum 50% of sample size failed, maximum 1500 hours	78	Measure and record LED parameters at beginning of test, and the surviving LEDs at the end of the test. Parameters to measure are light output, forward voltage, and color following ISO/IEC standards. Provide parameter measurement results on all samples tested. Use binning current for measurement above. Indicate test times for any parameter anomalies.
Low Temperature Operating Life (LTOL) ⁽²⁾	$T_c = -40\text{ }^\circ\text{C}$ $I_f = 150\% I_{f(max)} \text{ mA}^{(3)}$	$T_c = -40\text{ }^\circ\text{C}$ $I_f = 125\% I_{f(max)} \text{ mA}^{(3)}$	Minimum 50% of sample size failed, maximum 1500 hours	78	
Wet High Temperature Operating Life (WHTOL) ⁽²⁾	85 °C/85% RH ambient $I_f = 150\% I_{f(max)} \text{ mA}^{(3)}$	85 °C/85% RH ambient $I_f = 125\% I_{f(max)} \text{ mA}^{(3)}$	Minimum 50% of sample size failed, maximum 1500 hours	78	
Powered Temperature Cycle (PTMCL) ⁽²⁾	-40 to 125 °C ambient 10 minutes dwell 20 minutes transfer (1 hour cycle) 2 minutes on 2 minutes off $I_f = 150\% I_{f(max)} \text{ mA}$	-40 to 125 °C ambient 10 minutes dwell 20 minutes transfer (1 hour cycle) 2 minutes on 2 minutes off $I_f = 130\% I_{f(max)} \text{ mA}$	Minimum 50% of sample size failed, maximum 1500 cycles	78	
Thermal Shock (TMSK) ⁽²⁾	-55 °C/150 °C ambient 10 second transfer Dwell time 15 minutes	-55 °C/150 °C ambient 10 second transfer Dwell time 15 minutes	Minimum 50% of sample size failed, maximum 3000 cycles	78	

$T_{j,max}$ = Maximum manufacturer specified LED junction temperature (refer to SAE J2938).

T_j = LED junction temperature ($T_{junction} = T_{case} + \text{maximum power dissipation} * \text{thermal resistance}$)

$T_{s,max}/T_{c,max}$ = Maximum manufacturer specified case temperature as specified by the manufacturer of the package (refer to IES LM-80-08).

T_s/T_c = Case temperature measured as specified by the manufacturer of the package (refer to IES LM-80-08).

$I_{f(max)}$ = Maximum manufacturer specified current (mA).

I_f = Specified current.

Failure = Open or short/no light output.

Note: T_s can be used instead of T_j if the manufacturer specifies the LED package in this way.

(1) 78 LEDs taken from three different batches (production lot) of 26 each shall be used for each test.

(2) For all surface mount reflowable solder: Preconditioning per AEC Q101 at 85 °C and 85% RH for 168 hours (JEDEC Level 1 MSL) followed by three Pb-free reflow solder cycles. Reflow cycles shall be completed between 15 minutes and 4 hours after preconditioning is completed.

(3) Units soldered to a stress board using Pb-free reflow process. The temperature of the stress board is kept constant at the temperature noted.