Cree® XLamp® MX-6 LED Reliability

September 2009

This application note describes the types of failures common to high-power LEDs, details Cree's pre-release qualification testing for XLamp MX-6 LEDs, and includes results of white-point-stability testing.

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LED Failure Types

Catastrophic failures are failures that result in the LED emitting no light or very little light at normal current levels (e.g. 350 mA for XLamp MX-6 LEDs). Catastrophic failures are not expected for XLamp MX-6 LEDs that are handled and operated within the limits specified in XLamp documentation. Please refer to the product's datasheet and the application note XLamp MX-6 LED Soldering & Handling for more information on design limits.

Parametric failures are failures that cause key characteristics to shift outside of acceptable bounds. The most common parametric failure, for a high-power LED, is permanent light output degradation over operating life. Most other light sources experience catastrophic failure at the end of their useful life, providing a clear indication that the light source must be replaced. For instance, the filament of an incandescent light bulb breaks and the bulb ceases to create light. In contrast, high-power LEDs generally do not experience catastrophic failure but simply become too dim to be useful in the intended application.

Pre-Release Qualification Testing

Before releasing the XLamp MX-6 LEDs to production, Cree puts a representative product sample set through an entire suite of pre-release qualification tests. There is no unified standard for qualification testing in the high-power LED industry. Each LED company must decide what tests and conditions to use to qualify new products.

Cree's pre-release qualification test suite, shown below, is based on standard semiconductor pre-release qualification test conditions and methods defined by JEDEC (Joint Electron Device Engineering Council).

Pre-Release Qualification Test List (Operating Life Tests)

Test	Applicable Standards	Test Conditions & Failure Criteria
Room Temperature Operating Life Test (RTOL)	JESD22 Method A108-C	**Test Conditions:** • Ambient Temperature : 55°C • Forward Current : Maximum in data sheet • Test Period : 1008 hours **Failure Criteria [1]:** • Forward Voltage shift [2] : > 200 mV • Luminous Flux degradation [2] : > 15% • Catastrophic failure [3]
High Temperature Operating Life Test (HTOL)	JESD22 Method A108-C	**Test Conditions:** • Ambient Temperature : 85°C • Forward Current : Maximum in data sheet • Test Period : 1008 hours **Failure Criteria [1]:** • Forward Voltage shift [2] : > 200 mV • Luminous Flux degradation [2] : > 15% • Catastrophic failure [3]
Wet High Temperature Operating Life Test (WHTOL)		**Test Conditions:** • Forward Current : Maximum in data sheet • Ambient Temperature : 60°C • Humidity : 90% RH • Test Period : 1008 hours (cycled) **Failure Criteria [1]:** • Forward Voltage shift [2] : > 200 mV • Luminous Flux degradation [2] : > 15% • Catastrophic failure [3]

Notes:
1. The entire test has failed if one LED (or more) from the sample set satisfy the listed failure criteria. If no LED satisfies the listed failure criteria, the test is successful.
2. Comparison is made between [value at time 0] and [value at the end of the test period].
3. A catastrophic failure is a failure that causes the LED to become non-functional (i.e., open or short).

Cree, Inc.
4600 Silicon Drive
Durham, NC 27703
USA Tel: +1.919.313.5300
www.cree.com/xlamp

Procedures for Operating Life Tests

The following procedures are followed for RTOL, HTOL and WHTOLtests:

- XLamp LEDs are reflow soldered onto metal-core printed circuit boards
- PC boards are mounted onto heat sinks within reliability test chambers.
- While the LEDs are powered off, internal conditions within the test chambers are brought to those specified for the individual tests.
- Heat-sink temperature is maintained at the test-chamber temperature during the test.
- Power is applied to the lamps. In the case of WHTOL, power is applied in one-hour intervals that are followed by one-hour intervals without power in order to let the moisture penetrate the package as much as possible. This procedure results in a test that is more rigorous than one that calls for applying continuous power.
- At regular intervals power is turned off and the sample boards are removed from the tester according to JEDEC testing protocol.
  - The lamps are characterized according to reliability test criteria.
  - The boards are placed back into the test chambers and the procedure is repeated until the test has concluded.

Pre-Release Qualification Test List (Non-Operating Life Tests)

Test	Applicable Standards	Test Conditions & Failure Criteria
Thermal Shock	MIL-STD-202G Method 107G	**Test Conditions:** • Temperature Range : -40°C to 125°C • Dwell Time : 15 minutes • Transfer Time : < 20 seconds • Cycles : 200 cycles **Failure Criteria [1]:** • LED no longer lights up after test
Mechanical Shock	JESD22 Method B104-C Condition B	**Test Conditions:** • Shock : 1500 G • Pulse Width : 0.5 ms • Direction : 5 each, 6 axis (30 total) **Failure Criteria [1]:** • LED no longer lights up after test
Salt Atmosphere (Corrosion Test)	JESD22 Method A107-B Condition B	**Test Conditions:** • Ambient Temperature : 35°C • Salt Deposit : 30 g/m^2/day • Test Period : 48 hours **Failure Criteria [1]:** • LED no longer lights up after test

Note:
1. The entire test has failed if one LED (or more) from the sample set satisfy the listed failure criteria. If no LED satisfies the listed failure criteria, the test is successful.

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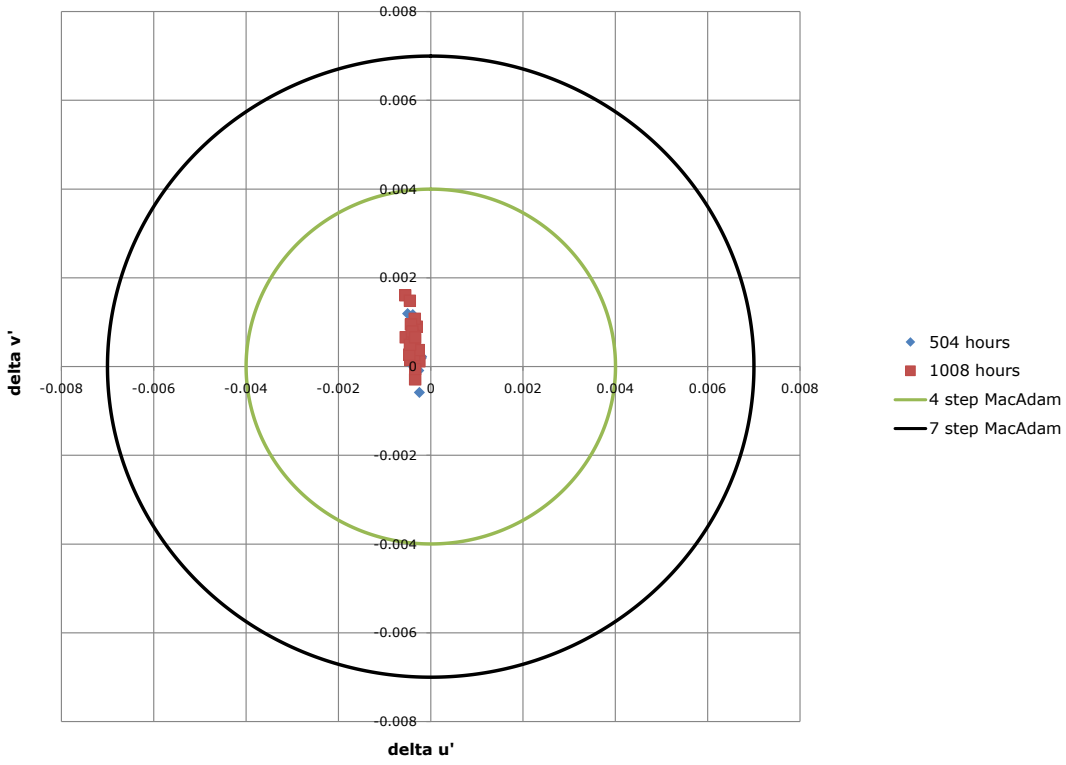
White Point Stability

The lighting industry demands both high lumen maintenance and very stable color output from the incumbent lighting technologies. White high-power LEDs will experience shifts in white light output over operational life. High-temperature conditions will accelerate these white point shifts. Therefore, Cree monitors the white light output of the XLamp MX-6 LED over time under high-temperature conditions.

Specifically, the exact color of the white light output, expressed in terms of the CIE 1976 color space, is measured periodically while the XLamp LEDs are operating in high-temperature conditions. The following graphs show the change in color after the specified time in the specified conditions, in terms of change in u' and v' in the CIE 1976 color space. Included in the graphs for reference are 4-Step and 7-Step MacAdam ellipses for 6500 K and 3500 K CCT. MacAdam ellipses are derived from subjective testing and are a measure of how sensitive the human eye is to slight changes in color.

XLamp MX-6 Cool White LED - White Point Stability: I_F = 350 mA @ 85°C (6500 K)



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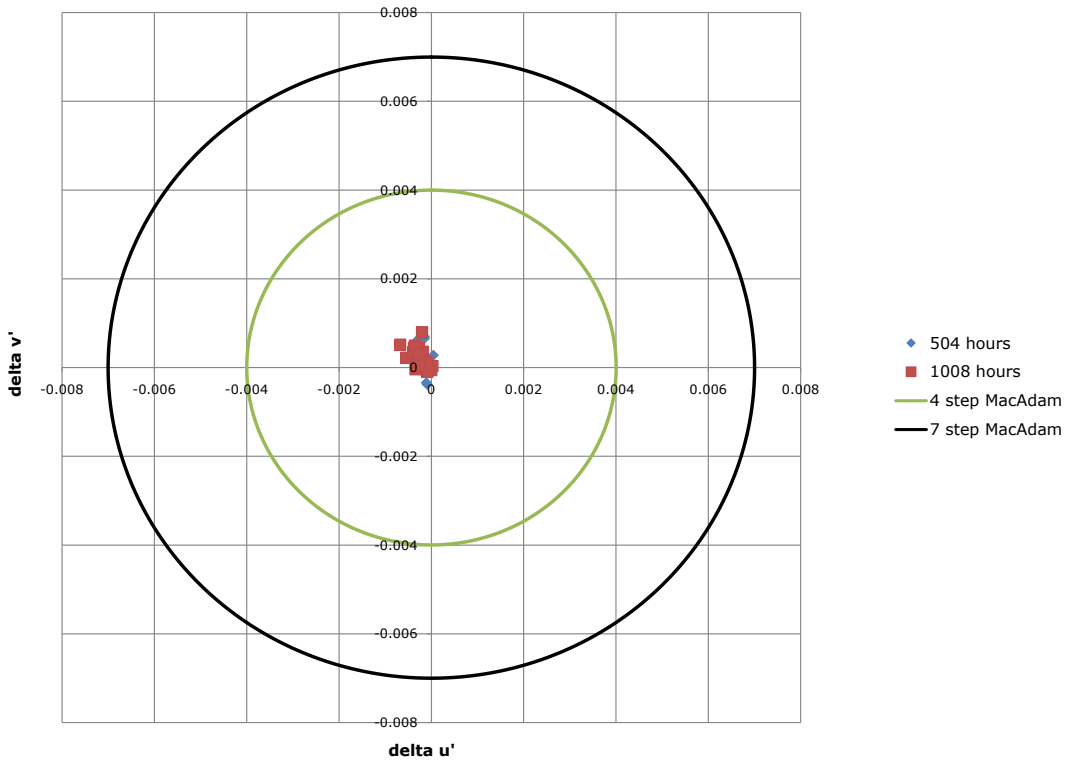
White Point Stability (continued)

XLamp MX-6 Warm White LED - White Point Stability: I_F = 350 mA @ 85°C (3500 K)



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