LIGHTING GLOBAL
Catalyzing Markets for Modern Lighting
AN INNOVATION OF IFC International Finance Corporation World Bank Group
THE WORLD BANK

Technical Notes

Issue 2 March 2010

LED Lumen Depreciation and Lifetime

This Technical Note examines the light output (over time) of an LED light source, also known as LED Lumen Depreciation. Suggestions are made on ways to avoid rapid LED degradation, and the importance of good design is emphasized.

The Information contained in this article builds on previous Technical Notes. See also: http://www.lightingafrica.org/resources/briefing-notes.html

Introduction

The performance of LED Lighting Products has been seen to vary widely. Good design can yield LED lifetimes up to 50,000 hours or more, while poorly designed products can lose all or most of their light output within a few weeks or months.

Tests performed by Lighting Africa have indicated that some LED Lighting Products on the market will lose a large percentage of their light output in the first few days or months of operation. This poses a serious potential problem, and threatens to spoil the marketplace by giving consumers a negative impression of LED technology.

Product Lifetime

The lifetime of any product is typically a measure of how long the product lasts, or works, or simply is able to do the job for which it was intended. For products with multiple components, the failure of a single part may or may not render the product useless.

The term 'catastrophic failure' is used to describe a circumstance where the product is considered dead, unusable, or broken. With lighting products, this usually means that the light no longer works (produces zero light). This can be due to faulty batteries, a broken electrical connection, or any serious problem with one of many components in the system.

LED products can also fail is by losing light output over time in a non-reversible process called Lumen Depreciation. Lumen Depreciation is measured as a percentage of original light output. An LED that has lost half its light output is said to have 'depreciated' by 50%.

LED Lumen Depreciation

Unlike other light sources, LEDs usually don't "burn out;" instead, they get progressively dimmer over time. LED useful life is based on the number of operating hours until the LED is emitting 70% of its initial light output. This is called the L_{70} lifetime.

An LED product that has reached the L_{70} light level (produces 70% of its initial output) can be considered a failed unit even though it still produces light. The 30% loss of light output will be noticeable to most users, and for purposes of product comparison, a standard depreciation level must be adopted. The L_{70} level has become an accepted lifetime level for LED systems and will be used by Lighting Africa as the standard LED lifetime.

LED manufacturers should always provide lifetime data for their LEDs (Figure 1). These data should show LED light output over several thousand hours at a minimum. During these tests LEDs are kept at a constant temperature. Tests can occur in high temperature or high humidity environments, and they may also involve running the LEDs at several different drive currents.

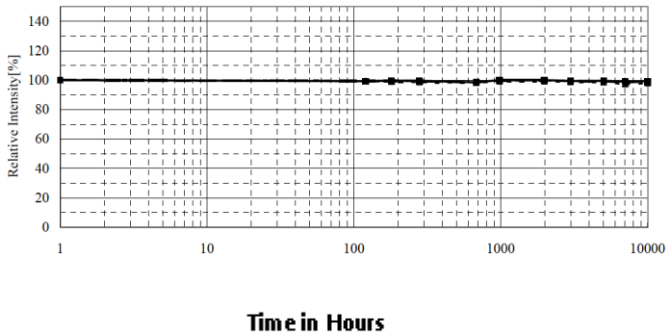

Figure 1. LED component lifetime data to 10000 hours for a light source with slow lumen depreciation

LED Lumen Depreciation and Lifetime

Issue 2 March 2010

LED Datasheets

LED datasheets usually do not list lumen depreciation information; this information must be obtained separately. LED manufacturers who cannot provide lumen depreciation data should be avoided and their LEDs should not be used in lighting products without first testing the product for at least 2000 hours.

In cases where lumen depreciation data are available from the LED manufacturer, the results should contain information about the LED temperatures during the test. These data can be used by an LED lighting product manufacturer to estimate the lumen depreciation of their product.

Causes of Lumen Depreciation

LED lumen depreciation can be caused by several different mechanisms. Some can be managed with good engineering design, and some are physical degradation mechanisms that occur at the LED chip level and will occur automatically and irreversibly. A high quality LED product starts with high quality LEDs and the proper thermal and electrical design elements to allow the LEDs to produce useful light for thousands of hours.

LED Chip quality

The quality of the semiconductor chip inside an LED is very important to light output. Poor quality chips can lead to very fast degradation; these LEDs may appear bright at first, but will lose light output after a few short hours due to defects inside the chip.

LED encapsulant

The epoxy or encapsulant lens that protects the LED chip can darken or yellow over time. This is particularly true of 3mm and 5mm LEDs. These LEDs in particular must have optical grade epoxy used for the package that resists yellowing from intense blue light and UV degradation.

LED bond wires and die attach

The small bond wires inside an LED can develop electric resistance and lead to power (and light) loss. The epoxy or metal used to bond the chip to the substrate can degrade, also leading to light loss.

Nothing will stop the irreversible light loss from the above mechanisms, and so high quality LEDs must be used at the beginning of the design.

Thermal Management

Another primary cause of LED lumen depreciation is excessive temperature at the LED chip level. This can be a result of driving the LEDs with too much power, or not designing the LED circuit board to effectively dissipate (remove) the heat that is always generated when running an LED. Any type of LED, no matter what package, will heat up when the LED is in use.

Electronic Controls

The electronics that control the drive current of the LEDs can drift over time – potentially leading to lumen depreciation from two different circumstances. The first is where the circuit delivers lower power to the LED, and the light output drops because the drive current drops. The second circumstance occurs when the power to the LED increases. In this instance, the LED chip temperature (junction temperature) may increase and accelerate the degradation of the chip or package components. The LED might become temporarily brighter due to the power increase, but could fade quickly because of the temperature increase. Either case will most likely lead to a decline in the light output of the LEDs over time.

Prevention of Rapid Lumen Depreciation

There is no way to completely prevent lumen depreciation, but with proper LED selection and product design, a manufacturer can significantly lower the LED degradation rate and help ensure that their product will produce useful light for a long time. This benefits the customer and also improves the reputation of the LED product and manufacturer.

The most important design element for an LED product is the electronic circuit that powers the LED. This circuit is responsible for delivering the correct amount of power to the LED array, and this in turn will determine the LED temperature. There are several ways to regulate LED power, and the manufacturer should use caution and good electronic design practices. Manufacturers should always run the LEDs below the recommended maximum current listed on the LED datasheet. Lower drive currents result in longer lifetimes and lower light output, and so a balance must be made between cost (more LEDs = higher cost) and lifetime.

Proper thermal management is also extremely important for long lifetime. The heat generated by the LED chip must be conducted and transferred to the ambient environment. A heat sink is typically used to do this, and proper heat sink design is essential for keeping the LED at an acceptable temperature. See Technical Brief "Thermal Management for LEDs" for ways to design LED circuit boards and heat sinks.

Light Africa Test Results

Lighting Africa performed lumen depreciation tests on a number of products currently being sold in African markets. Some of these tests indicate that lumen depreciation is a major problem, and many of the products have L70 lifetimes below 200 hours. A large portion of test samples had units that reached L70 in less than 50 hours, which means that after 50 hours of continuous operation, 30% of the light output was permanently lost from the product. This rapid degradation will hurt the emerging LED Lighting market if enough products perform this poorly. Based on preliminary test results, this appears to be a major concern.

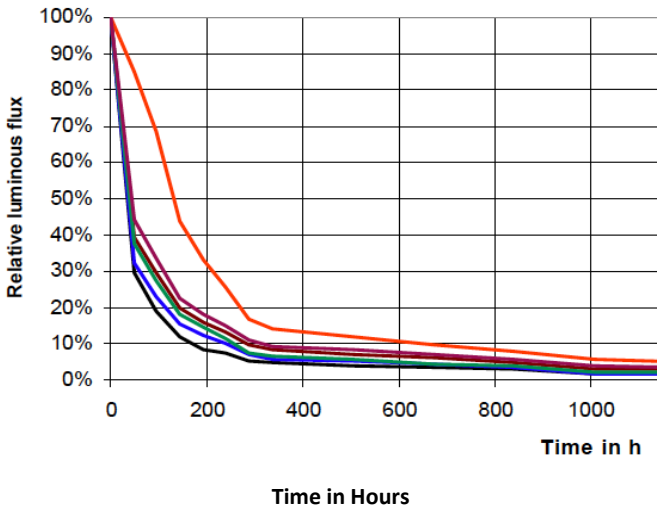

Figure 2. Example rapid Lumen Depreciation test result

A properly designed product will continue to produce useful life for thousands of hours, as illustrated in the test results in Figure 3.

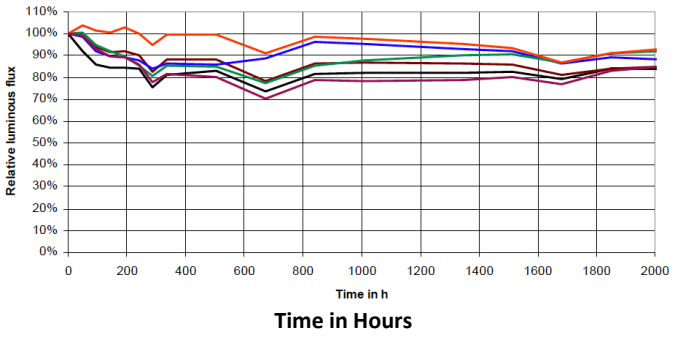

Figure 3. Acceptable Lumen Depreciation test result

Manufacturer Self Testing

Lighting Africa encourages manufacturers to test their products for 2000 hours prior to releasing them into the market. These tests can be performed with simple procedures and inexpensive equipment, but must be done properly to achieve a reliable result.

A standard light meter that measures illuminance can be used to measure relative lumen depreciation. One way to conduct measurements is to construct a test rig to securely hold the light meter and LED source, preferably inside a ventilated box or dedicated room. A power supply is used to power the LED array at the same voltage as the battery supplied with the product. The illuminance meter is used to periodically take measurements of the LED. It is VERY IMPORTANT that the LEDs and light meter are in EXACTLY THE SAME ORIENTATION for each measurement, and that any conditions surrounding the test, including external light or the position of people, walls, or other reflective surfaces, are the same each time the meter is used.

The temperature of the ambient environment must be consistent. It is especially important that the actual light output test be performed at the same temperature, preferably 25°C. The ambient temperature is always listed with any test results.

The test should last at least 2000 hours and be performed on 6 or more test samples. Multiple units must be tested to have a reliable average lifetime result.

A regular testing interval should be used to achieve accurate results. Products should be tested every 2 days for the first two weeks of the lumen depreciation test, then once a week until 12 weeks of test data (= 2000 hours) are collected. The results are then plotted on a graph. Inconsistent results are investigated to determine if the tests need to be repeated, and failure mechanisms should be identified when possible.

In addition to testing the light output, the power input from the power supply should also be monitored and listed with the results. The power to the LED array should not drift over the life of test.