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The use of an available Color Sensor for Burn-In of LED Products

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Abstract

In today's world it is important that a product has sufficient accreditation that it can be enter many different market places. While accreditation can be a costly process, it is prudent to know that your product is fit for purpose before going for accreditation. We propose a novel cost effective system for testing 100% of the LEDs (Light Emitting Diode) on a lighting product. This system will not only monitor the intensity and colour changes of a product while it is running but alert the engineer of early failures allowing the test to terminate, and faults to be examined. We propose this system as a rapid prototype tester. This system also allows unique LED changes to be monitored such as one LED to noticeably change while not changing the macro properties of the lighting unit. While a small change in individual LEDs or a small group of LEDs in a lighting product might not affect the accreditation process, it could have warrantee effects when the product is in the market place. We will introduce the system, and show the results of five different LED based products being tested simultaneously over the course of three months. Each product consists of twenty LEDs, so we will monitor 100 LEDs simultaneously. The results will show unexpected behaviour of the LEDs, over the period of three months as a case study. We will show how such a system could be adapted for Standards such as IESNA LM-80 [1] and TM-21 [2]. Lastly we will show the advantage of pre-aging LED products to allow for improved lifetime estimation. While not a replacement for standards such as IESNA LM-80 [1] and TM-21 [2], the technique outlined above would allow smaller companies increased confidence in their product when getting a product range accredited. The system allow shorter prototype development times and hence a cost saving to end-users.

Introduction

In the recent past, the Light Emitting Diode (LED) was hailed as the new energy efficient light source that would never have to be replaced. There were claims of 50,000+ hrs lifetime for the humble LED. That story has changed over the last few years as the number and diversity of the LED based products has increased. This is not to say that the original evidence was incorrect, but the initial enthusiastic estimates from the labs did not match the ultimate test, customers.

As a result of poor quality products affecting the overall opinion of LED based products, it is critical that manufacturers can be confident in the quality of their product. In current times we want to have products certified, checked and ensure that we have the best quality.

For the purposes of this paper we will look at one aspect of LED product, and this is the Lumen maintenance and estimated lifetime. The method described here does not seek to replace using high quality rating labs, but hopefully will allow the manufacturer to know with confidence that their prototype product, upon going to certification labs will be of a high enough quality that no expensive re-designs are required.

Estimate of LED based product Lifetime using the Luminous Output as a Metric

The guiding standard for estimating the projected lifetime of an LED or LED based product based on its luminous output is called TM-21 [2]. In this standard measurements are made at 1000 hour intervals (41.6 days), over a 6000 hour period, at three different temperatures 55 degree, 85 degrees, and a temperature chosen by the manufacturer. A requirement of the TM-21 [2] standard is to test 20 LEDs or 20 LED based products (luminaire) for lumen maintenance. This data is analysed statistically to determine the time it would take for the LED or luminaire to reach 70% of its initial value The Intensity over time is plotted on a logarithmic scale and the lifetime of the product is defined as the time the device intensity would reach 70% of its initial intensity (t = 1000hrs). This measurement process requires a significant amount of time and significant resources to receive accreditation. If the product under test should fail, the fault must be found, fixed and the product retested. It would be better if a simpler test could be applied to the prototype stages to weed out the earlier design flaws.

Methodology

For a simple LED PCB, detailed in Fig. 1, the board has 20 white LEDs connected in a parallel circuit. Each LED has a series resistor. The board is designed to be powered from a USB or 5 V power supply. The LEDs are PLCC-2 footprint, and the LEDs are 8mm centre to centre. They come from a single real of LEDs and are assumed to be from one colour bin and intensity bin.

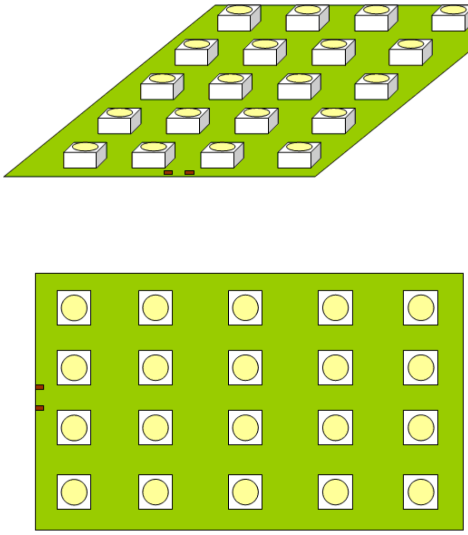


Figure 1: LED prototype board for used in experiments

The optical monitoring will be conducted in two parts; firstly, continuous monitoring by a 20 channel LED Analyser Fig 2(a) and secondly, reference measurements made by a Spectrometer Fig 2(b). These devices allow measurements of each individual LED. The LED Analyser can simultaneously sample the light emitted from 20 LEDs. Stable monitoring is achieved by using individual optical probes over each LED. These are shown in Fig 2(a).

Figure 2: LED Analyser module (a) used for constant monitoring of colour LED colour. The optical probes can be seen in the bottom of the picture, and the Spectrometer module (b) used for reference measurements. We can also see the mini-integrating sphere.

A small test fixture is built to apply power to the board and to hold the 20 optical probes that will collect the light Fig 3(a). The probes are held in a Perspex plate and are positioned such that each probe is only 2 mm from the emitting surface of each LED. For the purposes of this example, an experiment was carried out at standard room temperature 25 degrees Celsius, for the duration of the experiment. The optical probes are linked to the sensors of the LED Analyser by optical fibers.

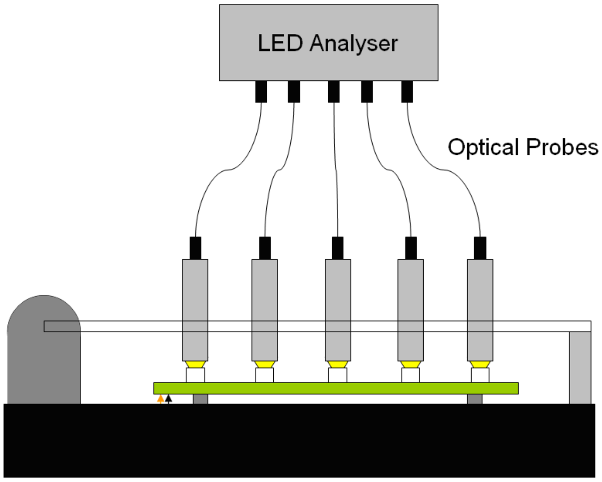


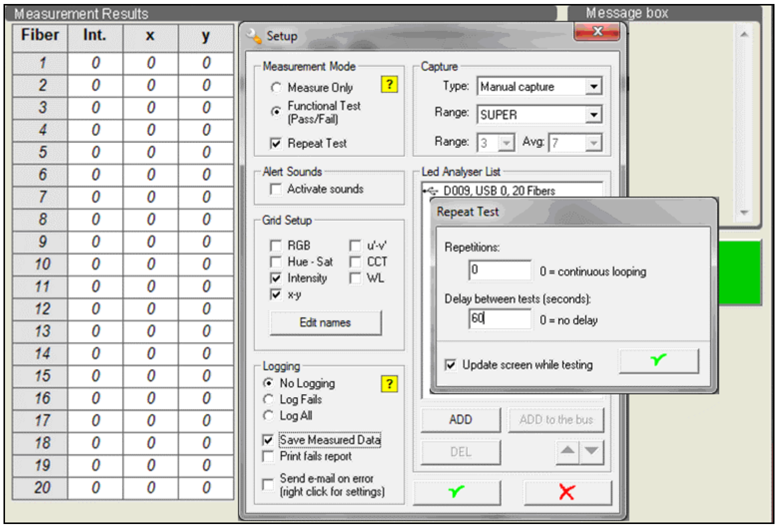
Figure 3: Schematic showing the features of the fixture used to continuously measure the colour and intensity of the LEDs on the prototype lighting product.

Continuous measurements are made when the lid of the test fixture is closed, and the optical probes are close to the LEDs. The numerical aperture of the optical probe and small distance between the LED and the optical probe prevents crosstalk from neighbouring LEDs. Reference measurements are made when the lid of the fixture is open, and the LEDs can be accessed by the mini-integrating sphere. Each individual LED can be measured without light crosstalk from neighbouring LEDs.

The LED Analyser comes with logging software; which is used to store data, which can then be manipulated in a spreadsheet software to obtain the intensity-time curves. In this example we will use normalised intensity, where the initial intensity at the start of the experiment is set to 100%. We choose this for our discussion of the lumen maintenance limit of 70%. We can also use the lumen value of the LED.

The evaluation was started with a PCB which was populated with the correct components. This board was not powered up (no voltage applied to it) as we did not want to modify the LED characteristics by passing a current through it, which would heat the LED. The LED Analyser is connected to the computer using the USB. The logging software, Fig. 4, is opened and configured to record data as fast as possible. This was done for the first hour. The intensity typically will drop as the LED junction temperature increases from room temperature in the first few seconds. As the LED junction temperature increases, we expect the intensity to decrease. Depending on the LED and the driving current, this heating process can occur quickly and so fast sampling frequency is chosen in the logging software to record this intensity variation.

The software recording was started, and after 10 seconds power was applied to the PCB. The data was recorded for 1 hour. This allowed the capture of all the transient intensity features of the individual LEDs as the LEDs reach thermal equilibrium. Thermal equilibrium is when the temperature of the LEDs reaches a stable value. This is accompanied by stable intensity-time response. When all 20 LEDs have been measured and the data saved, then the fixture lid is closed. The software is configured to record data every 10 minutes (600 s) for the next 24 hours. At the end of the 24 hrs, the LED values are recorded with the spectrometer again.



Measurement Results

Fiber	Int.	x	y
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	0	0	0
14	0	0	0
15	0	0	0
16	0	0	0
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0

Setup

Measurement Mode
○ Measure Only
● Functional Test (Pass/Fail)
☑ Repeat Test

Capture
Type: Manual capture
Range: SUPER
Range: 3 Avg: 7

Alert Sounds
☐ Activate sounds

Led Analyser List
D009, USB 0, 20 Fibers

Grid Setup
☐ RGB ☐ u'-v'
☐ Hue - Sat ☐ CCT
☑ Intensity ☐ WL
☑ x-y

Logging
● No Logging
○ Log Fails
○ Log All
☑ Save Measured Data
☐ Print fails report
☐ Send e-mail on error (right click for settings)

Repeat Test
Repetitions: 0 0 = continuous looping
Delay between tests (seconds): 60 0 = no delay
☑ Update screen while testing

Figure 4: A snapshot of the software used to continuously monitor the colour and intensity of the LED during the month long experiment. Parameters such optical probes to use, type of exposure, intensity and colour parameters to log, and sampling frequency can all be chosen a single software package.

Results and Discussion

Figure 5 shows the variation of normalised intensity with time from the moment the LEDs are powered up (t=0 s), for a period of 60 minutes. The data is adjusted such that the intensity at 0 s is set to 100%. We can see very different responses from the 20 LEDs. LED number 20 is seen to be very stable, with the intensity remaining stable at 98.8 %, while LED number 15 shows an intensity drop to 94.3 % after only 60 minutes.

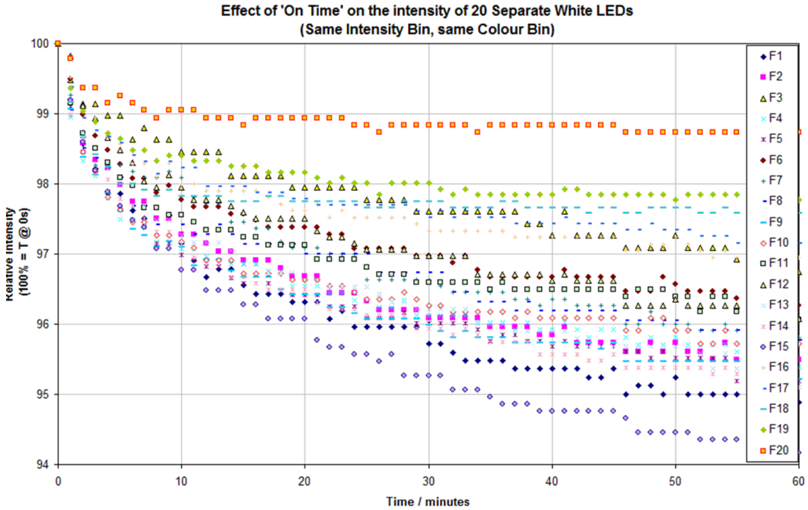


Figure 5: The variation of relative intensity for 20 LEDs over a 60 minute period. The intensity axis is scaled such that the normalised intensity of all optical probes at the start of the experiment, t = 0 minutes, is 100%.

As the intensity-time curves the 60 minute time marker, the LED intensity is seen to be very stable. The software logging is stopped, and the lid of the fixture is opened. The fixture continues to supply power to the board uninterrupted. The spectrometer is then used to record the intensity (Lumen) and colour (chromaticity) of the LEDs. The spectrum of each of the LEDs can also be saved. Each LED is individually measured as using the mini-integrating sphere as shown in Fig. 6. The sphere has been designed to enclose each LED, while having a small footprint.

There are now two sets of values, the lumen values of each LED as measured by the spectrometer and the matching data from the optical probes from the LED Analyser.

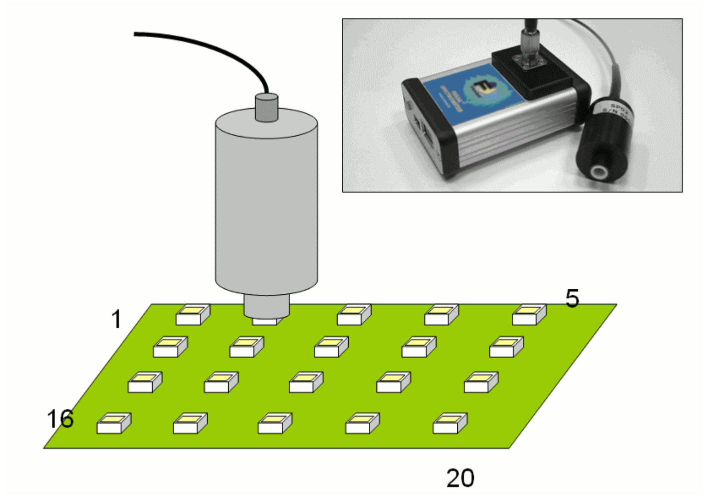


Figure 6: A schematic diagram showing how the mini-integrating sphere is placed over each LED. The design of the probe end prevents neighbouring LEDs affecting the LED measurement. The inset in the top left shows the actual spectrometer and mini-integrating sphere.

The LED Analyser output can now be scaled to match the Spectrometer values. The software accompanying the LED Analyser has a built in function to convert between the Spectrometer and LED Analyser. This method allows absolute intensity to be obtained from the test fixture data.

Fig. 7 shows the intensity data after an uninterrupted period of 24 hours. The 5V was continuously applied for the purposes of this experiment. The intensity has continued to drop. For the majority of the LEDs the intensity has dropped to an average value of 88%, with a minimum of 84% and maximum of 95%.

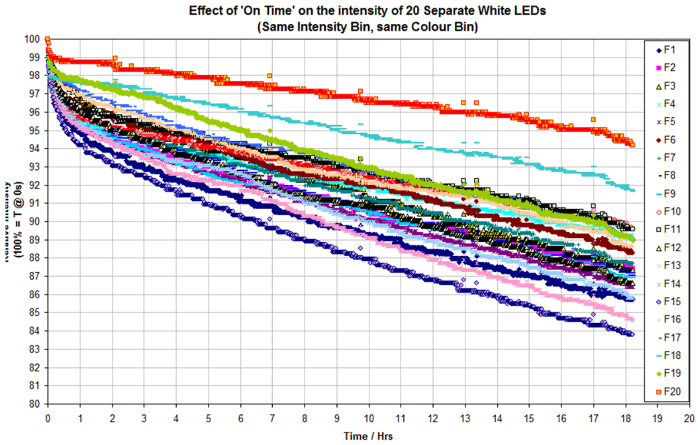


Figure 7: The variation of relative intensity for 20 LEDs over a 20 minute period. The intensity axis is scaled such that the intensity of all optical probes at t=0 mins is 100%. After the initial transient in the first hour, the subsequent decrease in intensity is approximately linear over the 23 hour period.

Fig. 8 shows the intensity data after a one month period. The power was uninterrupted. We observe more complex intensity versus time behaviour. For all 20 LEDs, the intensity is observed to decrease for the first 3 days. For the next 3 days the intensity remains relatively constant. Starting at day 7 there is some unexpected behaviour, with some of the LEDs showing an increase in intensity, while others show an expected continuous decrease in intensity. We observe more unusual behaviour towards Day 21, where some of the LEDs, in particular, LED number 3 show unusual behaviour.

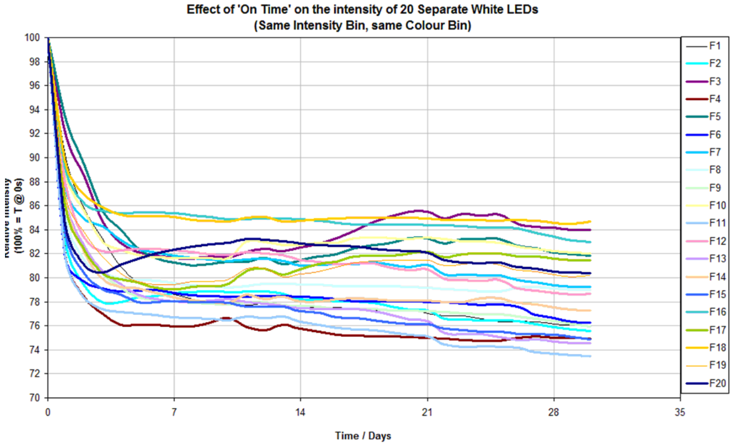


Figure 8: The variation of relative intensity for 20 LEDs over a 20 minute period. The intensity axis is scaled such that the intensity of all optical probes at t=0 mins is 100%. The linear intensity decrease observed in Figure 7 is replaced by a variety of intensity-time behaviours. Some LEDs show increasing intensity, some decreasing intensity and some semi-constant behaviour.

Examining the final normalised intensity LED number 18 has a value of 84.8 % and LED number 11 a value of 73.4 %. The percentage difference between the brightest and dimmest is 15 %, while the average percentage drop from initial power on is 21 %, which means that generally no-one will determine an intensity difference across the lighting device.

The resulting data shown in Fig. 8 shows the effect of “burn-in” time on the resultant quality of the lighting product. In this particular product the performance of the device upon power-up is very different to that after 2 days and especially after 30 days. This is especially important when retro-fitting products or replacing defective parts.

For the example of an LED car headlamp that gets damaged after 2 years of use, if one of the LED modules is replaced with a newer “un-aged” module, it is likely that an intensity difference is observed between the replaced module and the remaining module. If repairs are carried out under guarantee, it may be necessary to replace both modules at a potentially large cost. Pre-aging a product before shipment would possibly reduce variations. At least this technique would highlight intensity drift at an early stage and corrective action such as board redesign could be implemented.

Conclusions:

A technique that uses a spectrometer and sensor combination has been developed to achieve continuous absolute intensity monitoring of each individual LED of an LED based product.

This continuous monitoring has highlighted unusual behaviour, which would be undetected if using only an individual spectrometer.

In this case, the LEDs required a certain burn-in time before they approximately stabilised.

At the end of the first month, in the case of this LED based board, the variation between the brightest LED and dimmest LED was 15%. This met the requirements of the TM-21 [2] standard. The LEDs variation would need to be much less than 30% at the end of the 6 month measurement period.

The technique is adaptable for the TM-21 approach, as these measurement products are designed to operate up to 100 degrees Celsius, and so can meet the 55 degree Celsius and 85 degree Celsius conditions.

References

[1] IESNA Testing Procedures Committee, Approved Method for Measuring Lumen Maintenance of LED Light Sources, LM-80-08.
[2] IESNA Testing Procedures Committee, Lumen Method Extrapolation, TM-21.