LED Driving Technology for Long Term Flexibility

Application Note

Abstract

In order to guarantee constant brightness for LED illumination systems with long product cycle times, the availability of LEDs with constant brightness within the product cycle is often still required or expected.

This application note is intended to show that in spite of the continuous further development of LED technology, the issue can be avoided or completely eliminated with a simple solution.

Introduction

In the last decade, LED light sources have undergone an unexpected development and are being deployed more frequently as a replacement for the incandescent lamp. The main reason for their penetration into all segments of lighting is the constant increase in semiconductor efficiency and brightness over time. This is also a key factor in the LED's ability to address the issues of general lighting.

At first glance, this constant increase in light output appears to be problematic for systems with long product cycles, in which consistent, uniform characteristics and behavior are required over the product life cycle.

If this advancement or change is already taken into consideration in the design phase, however, the effects can be easily compensated for in the circuitry with the aid of a PWM driver.

In this way, illumination systems can be manufactured with a constant brightness over their entire product cycle and their characteristics can be guaranteed without having to resort to LEDs with the same brightness values.

Root Cause

Increasing LED brightness

The desired goal of LED manufacturers of replacing lighting products with LEDs has lead to intense competition with respect to the development and mass production of increasingly brighter LEDs, particularly white LEDs.

Ultimately, this has also added considerable pressure on the development steps of LED technology during the last few years. For LEDs, the general opinion is that the end of this development still has not been reached.

Looking back, it can be determined that between 1960 and 2000, the radiated light output of LEDs has nearly doubled every two years.

The expected increase in the future can be exemplified if one draws upon the efficiency estimates of the US Department of Energy from 2010, for example (Figure 1).

Based on commercial and laboratory data from 2005 until today it shows the efficacy trend of white LEDs for the next years with a maximum upper limit of about 250lm/W.
For the warm white devices for example it predicts a doubling in efficiency to 160lm/W by 2013.

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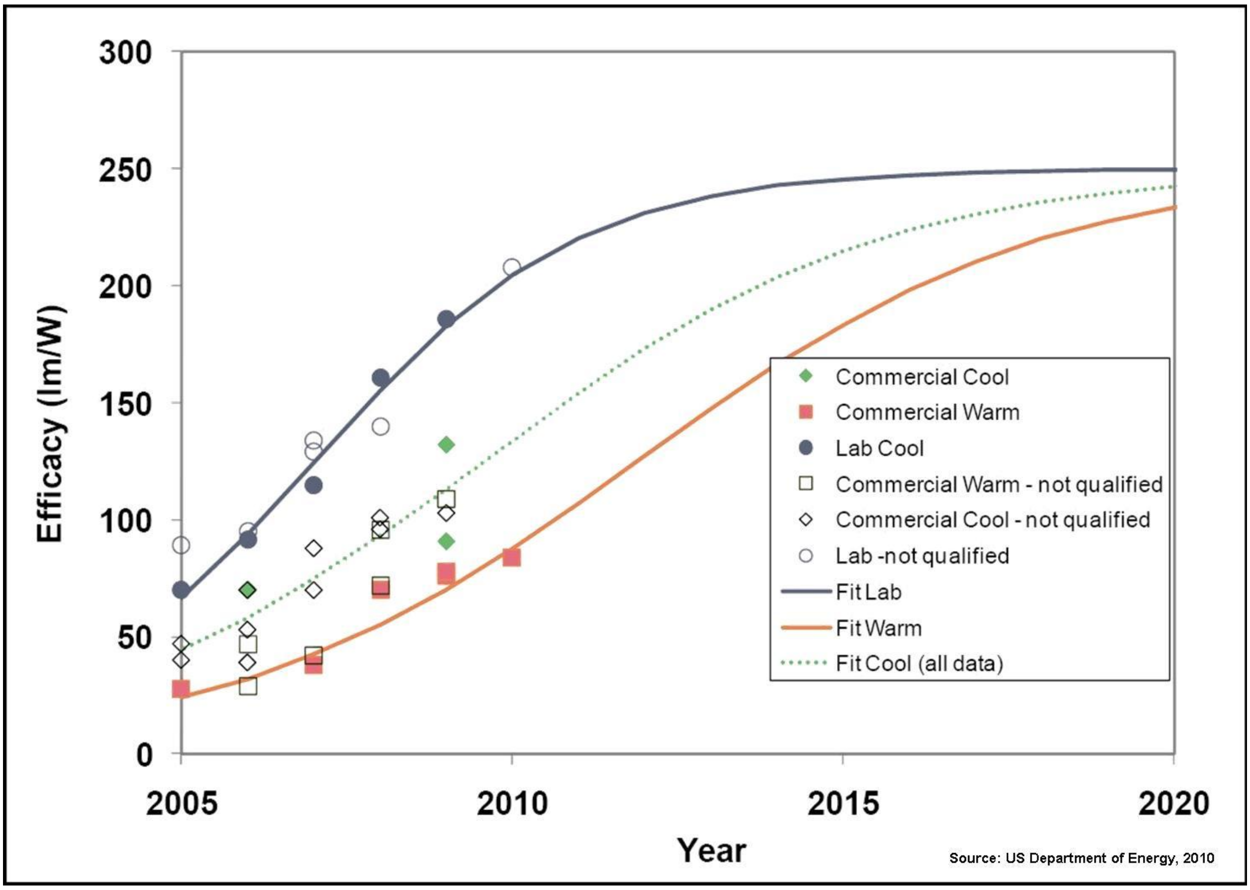

Figure 1: White-Light LED efficacy targets over the years

Impact on production distribution and the availability of LED bins

From the base substrate to mounting of the semiconductor chip in the housing, LED manufacturing involves numerous process steps and complex procedures (Figure 2).

Since the individual processes are subject to fluctuations, the LEDs also do not possess the same characteristics; rather, the parameters fall with certain limits or exhibit a distribution (Figure 3).

As a result of this, each LED is characterized and placed in a so-called bin, with tight specifications regarding color, brightness and forward voltage.
In this way, the production distribution is separated into several different bins, sometimes resulting in more than a hundred bin combinations.
For the production distribution, this means that in the end, the individual measures for increasing brightness result in a shift to higher brightness values.

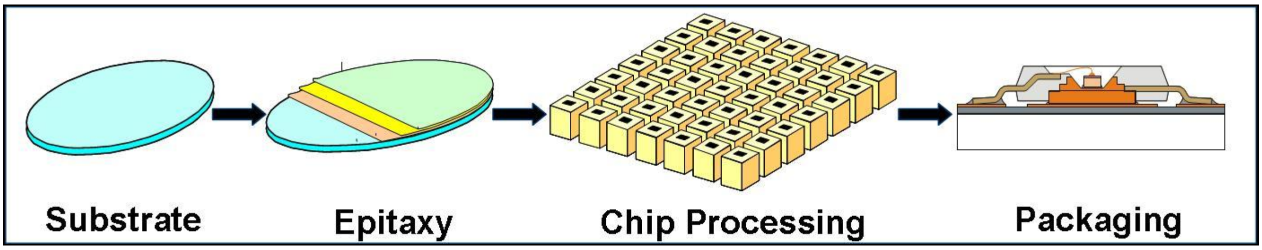

Figure 2: Principle of LED manufacturing

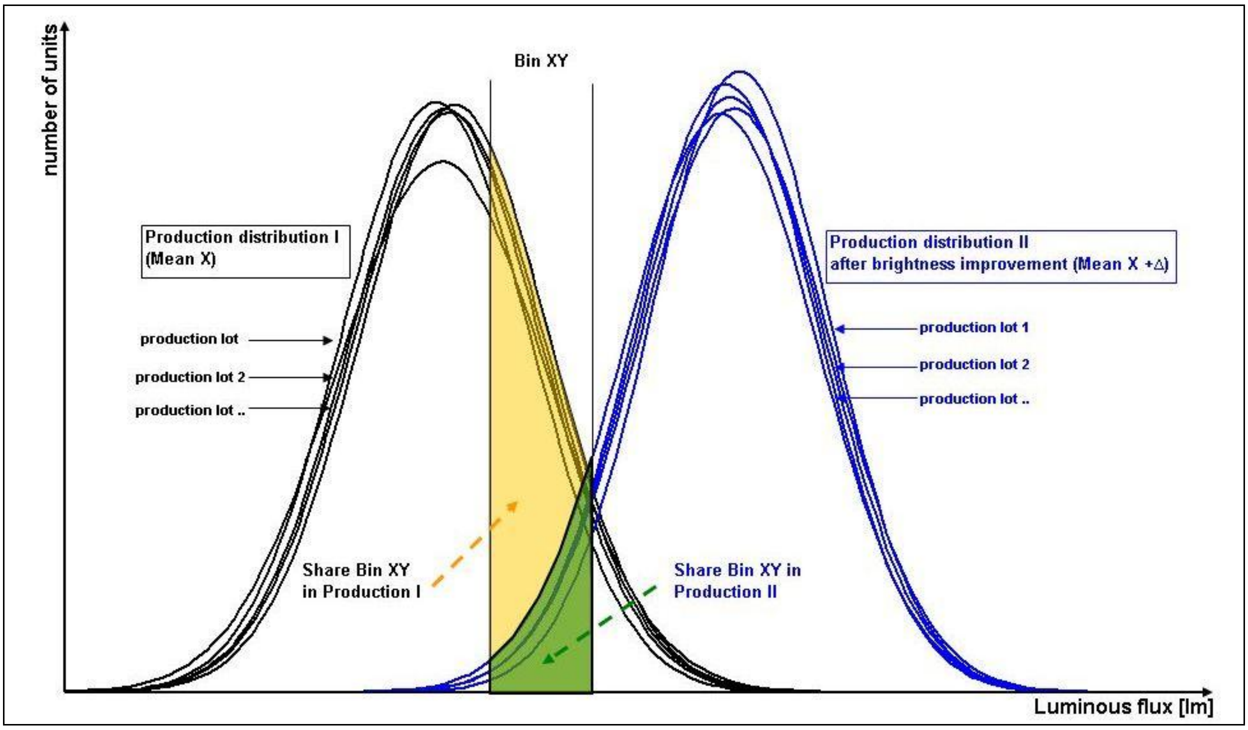

Figure 3: Production distribution of brightness over the years

This development-driven focus is always associated with a change in the quantity-related distribution of the LEDs within a bin, however.

For the availability of an individual bin, this means that depending on the rate of brightness increase, LEDs with a particular brightness value will only appear in reduced quantities or possibly not at all in the production time. Bins that were previously represented in high quantities in the middle of production will then be shifted to the edge of the new distribution with significantly lower LED percentages, or will no longer be present.

This continuously progressing optimization and improvement of LED technology has an influence on the LED applications of the customer, however.

Applications are typically developed as a system, consisting of mechanical, electrical, thermal and optical designs to meet the required specifications. Any modification of the components or their properties normally leads to a shift of system characteristics if they are not taken into consideration.

This is especially critical for applications with long product cycles, as is typical in the automotive market, for example. Here, the applications run for a long time without changes and must also be available during a corresponding period. The product cycle with its different phases can last over a decade in this case.

This mismatch of the timelines between LED evolution and the product lifetime of an application can lead to a compatibility problem.

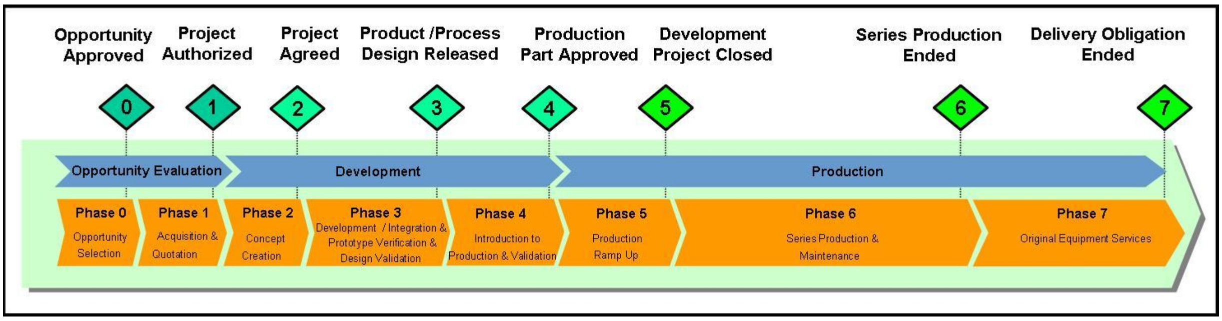

Figure 4: Product lifetime phases in the automotive industry as an example

LED Driving Technology

To solve this problem, a more sophisticated driving method is required for the LED.

Basically, the LED has to be driven with constant current at the grouping current (also known as the nominal current) in order to achieve the parameters according to the data sheet.

Any deviations to this rule will lead to a change in the parameters, which must be tolerated by the application.

One common method of driving the LED is the well known resistive ballasting with a current limiting resistor. This cost advantage of this solution is accompanied by several disadvantages such as power inefficiency and low flexibility.

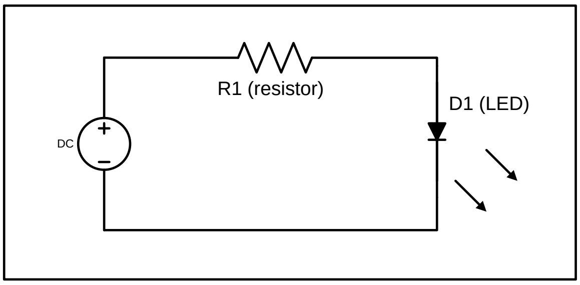

Figure 5: Driving an LED with a current limiting resistor

If the brightness of the LED increases over time but the brightness of the application must remain constant in order to meet the stated requirements, the current through the LED has to be reduced by a higher resistor value. This is acceptable as long as the current does not fall below the lower current limit of the LED and the color shift is acceptable for LEDs manufactured with InGaN technology.
In any case, the more the current differs from the grouping current, the more the characteristics of the LED will vary.

Pulse Width Modulation (PWM)

The driving method which solves this problem is known as pulse width modulation - PWM - which currently is considered to be the state of the art in electrical power applications.
Instead of being driven with a constant current, the LED is driven by current pulses which vary with the required power in order to obtain the specified light output. (see also application note "Dimming InGaN").

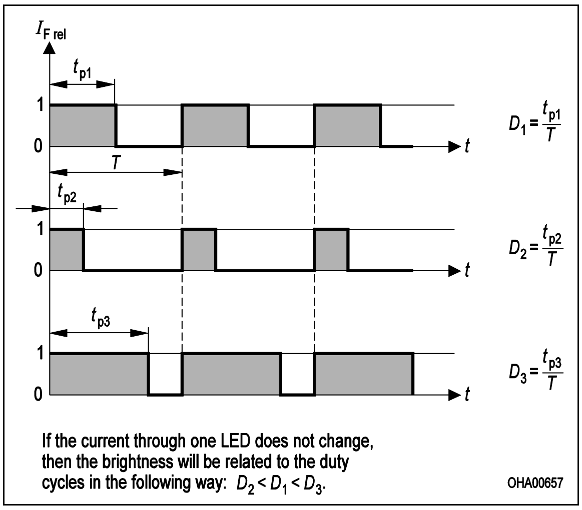

Figure 6: PWM and the relation between brightness and duty cycle

This method is highly recommended because the value of the current can be set to the nominal value of the LED and the brightness can be adjusted by varying the duty cycle D of the signal.

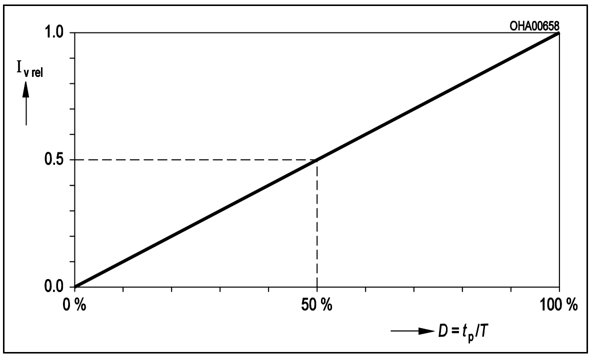

Figure 7: Linearity of brightness versus duty cycle (I_f = const., f > 200 Hz, T_A = 25°C)

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If the PWM frequency is greater than 500 Hz, it is not possible for the human eye to recognize the short OFF time of the LED (see also application note “Dimming LEDs with respect to grouping current”).

The LED data sheet also contains information about permissible pulse values at different temperatures (Figure 8).

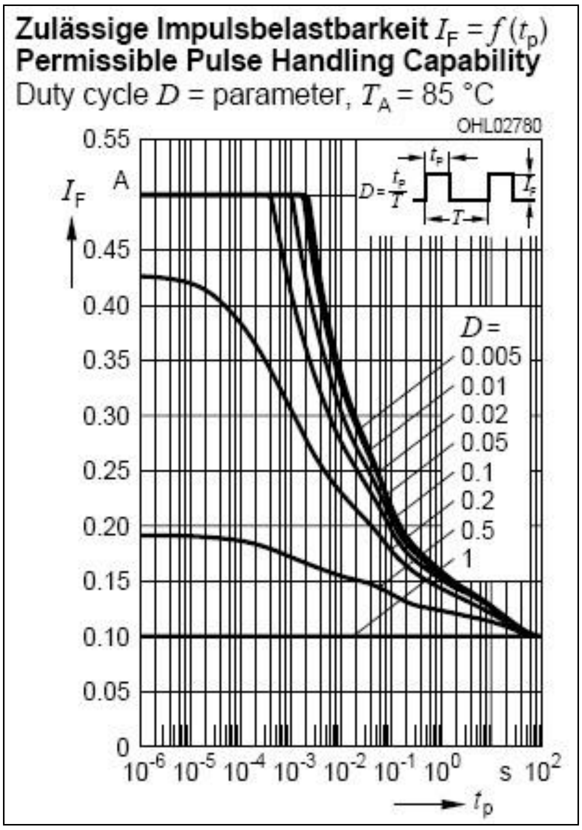

Figure 8: Example of pulse current specifications for PWM driving at T_A=85°C

By calculating a reserve into the duty cycle, a broad range of brightness variations can be covered over the product lifetime.

Further advantages of driving an LED with PWM are:

- The color of the LED complies with the data sheet
- The lifetime is only influenced by the ON time of the LED
- The LED is can be dimmed by reducing the ON time
- The application can use several brightness bins
- Over-temperature protection can be easily realized
- No influence of U_f variations over temperature

PWM controllers range from discrete implementations to highly sophisticated integrated circuits (ICs) from various manufacturers.

Summary

In order to be able to compensate for the continuous increase in brightness of LED technology for applications which require a constant brightness profile over the entire product lifetime, driving the LED by means of PWM is the most effective approach.

In addition to other advantages, only this driving method provides the required flexibility to compensate for advancements in LED technology with very little effort and in principle, is independent of particular brightness classes and their availability.

For further information or application support, please contact OSRAM Opto Semiconductors or your sales representative.

Appendix

Don't forget: LED Light for you is your place to be whenever you are looking for information or worldwide partners for your LED Lighting project.

www.ledlightforyou.com

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