LED Light Color - Binning System

Characterizing Chromaticity and Luminous Flux

Differences in LEDs light color

LED lighting systems offer a wide range of white color LEDs. Watch the light color or brightness constancy. Samples of LED projects that emit light in slightly different light colors or different luminances are reasons for bad reputations. What is the reason for that problem?

The manufacturing process is accompanied by variations in material and action itself. The results are white light LEDs with different characteristics.

No one intends to have different white color LEDs in one light source if the light product is not intended to be a color mixing luminaire. To support the performance of LEDs and LED products, binning systems have been introduced. Binning is focusing on LEDs chromaticity (light color) and luminous flux (brightness). Binning can be described as the grouping of the LEDs into samples with the same or closest light color and according to their brightness.

MacAdam Ellipses

David MacAdam, a color scientist, introduced his research on human color perception mid of the 20th century. He examined color differences in visual observations and mapped them into a color space. The most commonly used one is the CIE color space from 1931 (see picture 1). The graph shows the color space as X-Y-Graph, the values for x and y define the chromaticity of a light source.

MacAdam’s observers tended to cluster similar
colors as “nearly same ones”. When MacAdam measured the chromaticity of the cluster, they formed ellipses in the color diagram. The MacAdam ellipses are representing the area that is just noticeable to be different from the original light source, indicated as black point in picture 2.

**Binning LEDs is based on MacAdam ellipses that are placed around the center of a reference chromaticity point.**

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### Color Temperature and Correlated Color Temperature

The color temperature of a light source is defined in comparison to an idealized black body radiator. The black body is emitting visible light when heated up. The more heated up, the cooler the color temperature. The lower the temperature, the warmer the light color of the radiator. The temperature range of a black body radiator is called black body line. The ideal white color chromaticity values are located on that line.

Due to production processes and material, the color temperature of a light source does not lie on the black body curve. The light color is then defined as correlated color temperature and is an approximation of the color temperature that is not located at the black body curve but corresponds to lines crossing the black body curve (see picture 3).
Application

Binning systems manage variations in LED performance like chromaticity and luminous flux during mass production. Manufacturers tend to develop their own binning system that fits the production results. Therefore the NEMA published the SSL 3-2010 “High Power White LED Binning for General Illumination”. The paper is standardizing the minimum binning areas and ranges, see picture 4.

Choosing a small binning is not the overall solution. The manufacturing process is connected to variations. The decision for a small binning will lead to incredible costs as all the other LEDs of the same manufacturing sample are hard to sell to other customers. Right and wrong is not given. Which color variations are acceptable for your special product or project? Talk to the lighting experts at MyLEDlightingguide.com for further advice and information.

Future Prospects

The human eye can distinguish, in worst case, color temperature differences of 50K. The minimum temperature range within one binning of the ANSI standard is about 250K (between 2700K and 3000K, see picture 4). The MacAdam ellipses need to be viewed critical. The test of David Mac Adam included the adaptation to a single chromaticity (daylight) only. His study
involved few observers and focused on noticeable differences in perception. Closer steps have not been examined.

Under the headline “New Binning Strategy for White LEDs” the Technical University Darmstadt in Germany approaches newly to this topic. The researchers want to connect LED binning to visually acceptable chromaticity differences. The study is completely new (January 2015) and needs to enforce within the future.