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Light Net with Brightness and Color Temperature Control using Android Phone

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Abstract:
In the real world, every sector such as commercial or industrial LEDs are configured efficiently in terms of lighting outcome and energy consumption. In residential areas, modern techniques and controlling of LEDs lighting are on higher demand. The basic objective is to provide PWM dimming in range 1-10v for two LEDs stripe, warm white (WW) and cool white (CW) along with RGB LEDs. Dimming control of bi-color LEDs is operated on android mobile. Along with controlling process, it is necessary to preserve the desired light level which includes intensity and temperature of it at that point. The most vital thing to be considered for controlling the light level at a minimum level, along with conserving the carved light intensity. Here, by providing the PWM dimming, brightness and CCT is obtained by proper regulation of light. Compared to various continuous current dimming methods, PWM signal gives lesser levels of light intensity and also behaves highly linear in control. To get the required outcome, closed loop system with non-linear feedback method is used for dimming control. In surplus, RGB LEDs stripe is used for measuring intensity and CCT of light by providing 1-10v range dimming.

Keywords: *Bi-color LEDs stripes; RGB LEDs; PWM dimming; brightness; Color correlated temperature (CCT); luminance; 1-10v range; non-linear feedback control; feedback method.*

I. Introduction

The lifetime of lighting lamps after a specific time get exhausted due to heat up effect at junction or maintaining color point, etc. As compared to the traditional lamps such as fluorescent lamps or tubes, LED providing higher power possesses more advantages such as higher lighting efficiency, lower use of consuming electricity, In [2] used various lighting applications are on greater demands considering environmental friendly with higher lifespan. The factors which may affect the color temperature causing inconsistent variations such as component operating terms changes and their aging [7]. At the end, the result may leads to different color appearance due to the continuous changes in temperature during operable provisions [8].

With the new technology in market, various advanced techniques have been used in LEDs to provide greater amount of CCT (Color Correlated Temperature) variations along with the dimming schemes which help to provide the accurate and precise outcome. As now, with the use of Bi-color LED stripes such as combination of warm white (WW) and cool white (CW) or using them separately in various applications are at the verge. Here, for extra factor RGB LEDs are also in practice [9] to [12].

In most of the high level lighting applications such as lightings at ceiling in museums, theater lighting, malls lighting, and hotel and resort applications and so on, this Bi-color LEDs provides higher result using the dimming characteristic by adjusting CCT. The dimming functions and CCT are greatly inexact and non-independent for linear control systems.
The propounded system uses non-linear approach providing the feedback control instead of the linear approach for LED controlling in order to obtain the

higher precision in terms of microcontroller, color sensor and CCT. In addition to it android phone is used in order to display the range bar, Bluetooth module for data transmission to provide the communication between microcontroller, android phone, and a bi-color LED strip. Obtaining highly uniform and accurate lighting control may give rise to the various new Generating uniform and precise light outcomes by the bi-color LED course may provide the chances in adopting the color mixing between two bi-color LEDs or RGB LEDs, increasing dimming quality, and various lighting control applications.

II. Literature Survey

Ching-Cherng Sun proposes a efficient lighting system for street roads, [1] provides the avoidance of energy waste and and adaptive mechanism in lighting that would be beneficial for other lighting applications. Matthew F. Leong in [2] discusses the safety issues of lighting in industrial applications in addition to it he assist the end users during operations, design and maintenance. Albert Lee propounds the non linear control along with closed loop feedback mechanism, [3] motto is to adopt precise and accurate dimming for the LEDs stripes such as cool-white and warm-white LEDs.Huan-Ting Chen proposes the new techniques of modeling in [6] with the help of color mixing techniques which possesses various LED devices of different color temperatures'. C. Wang adds new features in his thesis for RGB lighting system which is used to ply the luminous intensity output along with LED color. In [8] this operation, various different control operations are used.Xiaohui Qu uses feedback techniques in [13], with the help of light sensor to obtain the highly outcome of color mixture, junction temperature and light intensity. Mark Dyble considered a output as white pure LED, for this he used PWM scheme along with transformed phosphor. Various methods are used for dimming control in terms of color and dimming intensities of LED in [14] terms of current control methods. M. M. Sisto intended maximization in CRI (Color Rendering Index) to achieve accurate colors by the LED over the surface. Challenges faced in [11] were resolved in [10].

III. Methodology

A. *A simple light theory*

Light is a form of energy radiant that moves in waves having specific wavelength made up of vibrating magnetic and electric field. The wavelength plays vital role in visibility of light. There are three light properties such as:

- Frequency,
- Intensity (Brightness), and
- Polarisation.

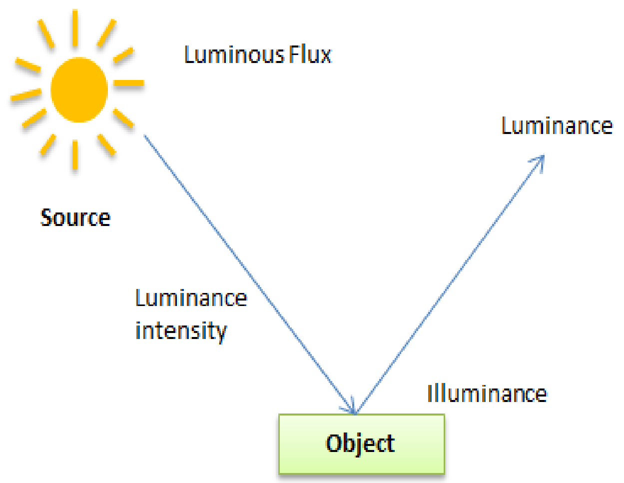

Fig. 1 Theory of incident light on object

Light energy when incident and reflected back from the source on any surface or object yields the different parameters. Out of that the propounded theory deals with three vital notions.

Illuminance: Illuminance is the entire luminous flux which incidents on the surface per unit area. It is represented as (lm/m^2), where lm is for lumens. Illuminance manifests at particular point of time in form of light, exhibits as brightness.

Luminous flux: It's a light energy induced by light source which emits light intensity of one candela over solid angle of one steradian (sr).
1lm (lumen) = 1cd * 1sr

CCT (Color correlated temperature): CCT represents the temperature of blackbody radiator (BBR) of which the chromaticity point of a non-planckian source of light is nearly closest to the chromaticity point of blackbody radiator light source.CCT usually represents the color light such as neutral (no color), reddish-white or bluish-white.

B. Color-Blending Technique

In general color mixing technique leads to mixing of different individual LEDs along their varying lighting level in order to obtain the white light. To generate a white light various color LEDs are mixed such as blue mixed in proper proposition with yellow. With the help of this technique more than two color LEDs can be used for generating the various colors or white color. The LEDs colors such as red, green and blue provides the mixing a gives the new color and also mixing of red(R), Yellow(Y), Blue (B) and Green (G). In the propounded method, the color blending is done by using two LED stripes of warm white and cool white LEDs. In addition to it the color combinations of RGB LEDs is proposed to obtain the white light as in table 4. As compared to the wavelength conversion, color mixing provides the higher efficient output.

C. Computation of CCT

CCT is calculated using the color sensor from a particular source point to the chromaticity point of closest to the Planckian locus. This can be done by collecting the data of RGB response and transfer it into the chromaticity diagram which helps to find the location on Planckian locus nearest to the source's chromaticity point. The color sensor provides the red, blue and green color response i.e. RGB response.

The tristimulus values are XYZ having the coordinates of chromaticity as (x,y). In order to obtain the CCT values, the color sensor values RGB response is mapped along with the tristimulus value XYZ. The coordinates (x,y) can be achieved and assessed. Hence, CCT can be determined by the McCamy's rule. Fig 2 portraits the procedural for CCT [16].

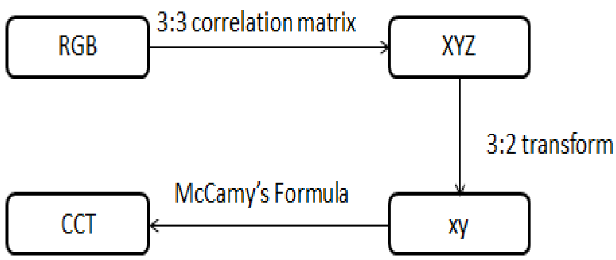

Fig. 2 CCT Computation flow

Using Mc-Camy's rule [16], the CCT value in case of the (x, y) gives,

$$CCT = 449n^3 + 3525n^2 + 6823.3n + 5520.33 \quad (1)$$

$$n = (x-0.332) / (0.185-y) \quad (2)$$

The computation of luminous flux, tristimulus values (XYZ) provides Y conducts illuminance in [18]. The luminous flux stands as φ. Hence, Y multiplied by *k* and given as (3),

$$\varphi = Y * k \quad (3)$$

The value of *k* is proportionality constant obtained through calibration using color sensor. Based on the measurement in [21], the value of *Y* can be calculated by using (4) as follows.

$$Y = a_{21}*R + a_{22}*G + a_{23}*B \quad (4)$$

Here, the values of φ and Y are already present, constant *k* provided in (3). Here, the value of *k* is 0.137 white higher deviation of around 0.003.

IV. PROPOSED SYSTEM

In most of the industrial sectors, LEDs dimming is carried out in order to keep the mind fresh and happy for the workers. Dimming LEDs with different level

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can be done manually or automatically. In the proposed system individual LED stripes WW and CW are used. Also with of addition RGB LEDs stripes are also used. The Bi-color LEDs behaves in an ideal state when the CCT remains constant. In this, luminous flux and CCT are not dependent of each other. The variation in different parameters such as non-linear light levels, CCT, junction temperature, aging of components, driving currents, luminous flux, etc may affect the system and leads to inaccurate dimming and color control in linear control systems.

A. Problem statement

i. The scaling range is 1-10V for LED driver which must attend the linearity from microcontroller 3.3V.
ii. Acquiring the proper dimming using color sensor with feedback technique.
iii. RGB LEDs behavior must change in proportion with CCT values by using the color sensor in linearity.

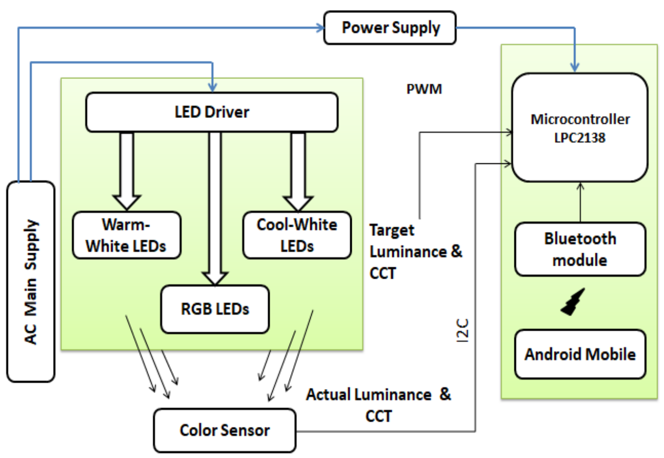

Fig. 3 Basic Schema of System

Fig. 3 projects a basic functional schema of regimen meant in [3]. In system gives the basic block diagram of overall dimming control. The heart of the system, non-linear closed loop method is used to problem the proper dimming of Bi-Color LEDs. By using the LCD display, the color sensor values are monitored and feedback is provided to the microcontroller via I2C serial bus along with it the dimming of LEDs having separate sensing values of red, blue and green color is displayed [16]. Here, CCT values are also being sensed by color sensor. Dimming of LED can be done in two ways as PWM or analog dimming. Here, PWM dimming is done in range 1-10v. The level of duty cycle ratio is obtained by adjusting the voltage level of 12v driver output. These levels in set in range of 1 to 10 in the mobile app using Bluetooth SPP. Bluetooth SSP gives reliable outcome as per the levels are fixed using keypad display. Independently current flows through both the bi-color LEDs that produces different PWM output signals, the result is obtained by regulating the set of duty cycle ratio through microcontroller. RGB LEDs also provides the dimming in range of 1-10v controlled by MCU through driver. A color sensor monitored values is given fed back to the microcontroller (MCU) in a way that comparison is done for CCT of both actual values and target values. By implementing an allotted software method, a new set with duty cycle is resolved with microcontroller in managing a bi-color LEDs such that the actual values alley with target values. Below methodology in fig.5 provides the flow of non-linear closed loop control system.

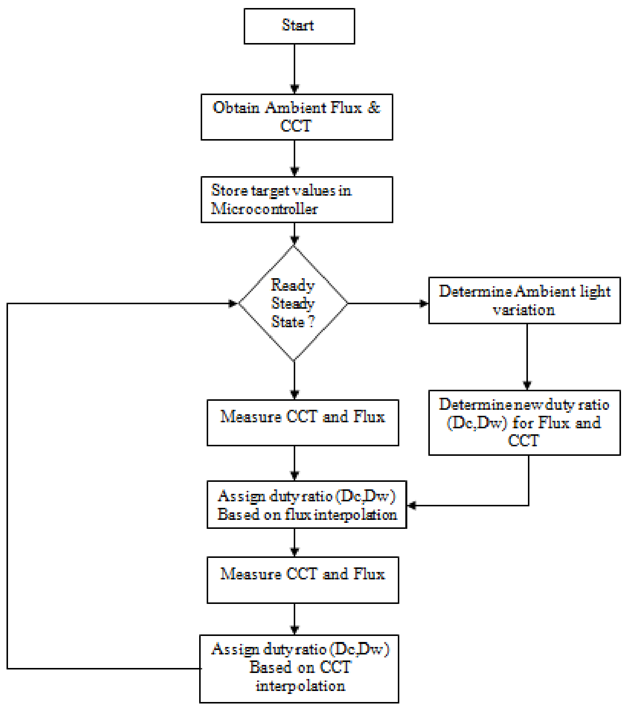

Fig.4 Flowchart for Non-Linear Closed Loop Control

It is impractical to obtained all the set of duty cycle values for CCT calculation as it s hard to obtain the real time CCT values all the time due to lack of storage and higher manipulation complexity.

V. Result and Discussion

In order to obtained efficient control, results are calculated individual at room temperature. Moving forward in Table no. 1 for warm white, the driver voltage 12v is divided into multiple ratios of 4 levels.

Warm White DC %	**CCT in K**	**Red in K**	**Green in K**	**Blue in K**	**Error**	**Error in %**
4	285	132	82	63	0.0280	2.8070
16	595	258	190	127	0.0336	3.3617
28	898	380	295	190	0.0367	3.6748
40	1190	496	398	250	0.0386	3.8655
52	1487	615	500	311	0.0410	4.1022
64	1777	731	603	372	0.0399	3.9954
76	2066	847	706	432	0.0392	3.9206
88	2363	964	807	493	0.0418	4.1895
100	2657	1081	910	554	0.0421	4.2152

Table no. 2 for Cool white, the CCT is on higher side as compared to warm white depending on it the color sensor gives RGB values of each color.

Cool White DC %	**CCT in K**	**Red in K**	**Green in K**	**Blue in K**	**Error**	**Error in %**
4	340	135	99	96	0.0294	2.9411
16	688	233	234	198	0.0334	3.3430
28	1071	351	374	315	0.0239	2.8944
40	1447	465	512	431	0.0269	2.6952
52	1863	591	666	555	0.0273	2.7375
64	2222	701	798	666	0.0256	2.5652
76	2590	816	932	778	0.0247	2.4710
88	2946	923	1062	888	0.0247	2.4779
100	3290	1028	1187	992	0.0252	2.5227

Table no. 3 is for combination of both WW and CW, here CCT observed is much higher than cool white.

WW,CW DC %	**CCT in K**	**Red in K**	**Green in K**	**Blue in K**	**Error**	**Error in %**
2	205	89	63	46	0.0341	3.4146
14	734	281	252	192	0.0122	1.2261
26	1232	467	451	292	0.0178	1.7857
38	1711	627	624	424	0.0210	2.1040
50	2187	795	784	548	0.0274	2.7434
62	2654	971	953	653	0.0290	2.9012
74	3119	1146	1142	764	0.0214	2.1481
86	3583	1312	1298	884	0.0248	2.4839

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98	4211	1562	1528	1015	0.0251	2.5172
100	4167	1553	1509	992	0.0271	2.7117

Table no. 4 is for RGB LEDs, obtained result for white light as it is combination of red, green and blue color.

White Color DC %	**CCT in K**	**Red in K**	**Green in K**	**Blue in K**	**Error**	**Error in %**
2	515	185	171	154	0.0097	0.9708
25	627	192	230	201	0.0063	0.6379
50	752	198	292	256	0.0079	0.7978
75	866	206	353	300	0.0080	0.8083
100	972	211	408	341	0.0123	1.2345

Table no. 5 is for dimming individual color, green color dominates more as compared to other two colors.

Green Color DC %	**CCT in K**	**Red in K**	**Green in K**	**Blue in K**	**Error**	**Error in %**
2	323	55	217	44	0.0216	2.1678
25	386	60	261	56	0.0233	2.3316
50	446	65	309	63	0.0201	2.0179
75	521	77	357	71	0.0326	3.2629
100	575	76	395	83	0.0365	3.6521

In table no. 6, repeating the same process for blue color as well gives result as red is constant. The values for blue color are on higher side. The same procedure is repeated for red color.

Blue Color DC %	**CCT in K**	**Red in K**	**Green in K**	**Blue in K**	**Error**	**Error in %**
2	323	55	213	48	0.0371	3.7151
25	365	55	248	50	0.0328	3.2876
50	407	56	289	53	0.0221	2.2113
75	452	57	331	53	0.0243	2.4336
100	487	57	362	58	0.0205	2.0533

Fig. 5 shows the outcome for RGB dimming along with color sensor placed in between them.

Red Color   Green Color   Blue Color

Fig. 5 Individual LED dimming

In fig. 6 the experimental setup of warm white and color white is obtained having the duty cycle for warm white is 25% while for cool white is 0%

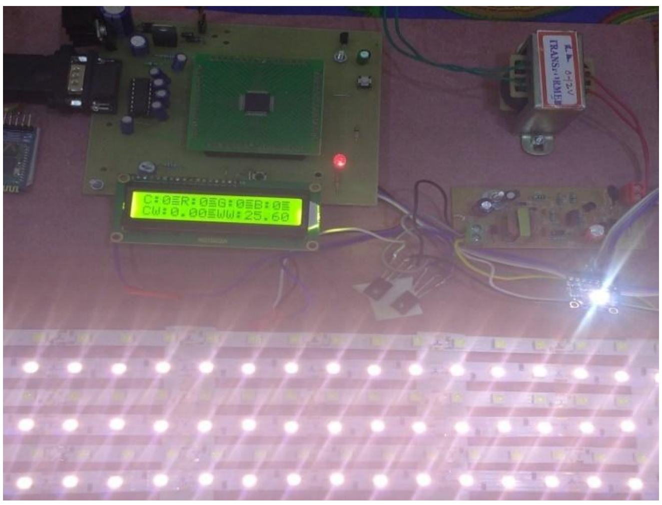

Fig. 6 Setup of overall system with warm white and cool white

VI. Conclusion

The propounded lightening system gives an adequate dimming of LEDs using feedback technique which can be implemented with various industrial or commercial sectors. The color sensor is used to obtained the values of red, blue, green along with CCT values separately which helps to provide precise value to the microcontroller. The accuracy is around 82% from overall system. In addition, the RGB LEDs are used to obtain the values for individual LEDs by proper dimming control through android phones.

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