Hardware Implementation of Constant Current Dual Channel Human Centric LED Driver

Bharath B R[1], Rudranna Nandihalli[2]

[1]PG Student, Dept. of Electrical and Electronics Engineering, RV College of Engineering, Bengaluru, India
[2]Dept. of Electrical and Electronics Engineering, RV College of Engineering, Bengaluru, India

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Abstract – *In this paper, development of a constant current dual channel dimmable human centric LED driver is presented. Driver is designed by adopting ac-dc bridgeless flyback topology. Also, two PWM controlled channels are implemented to obtain warm white and cool white colour temperature (CCT) of 1500k and 6500k respectively. Hardware prototype was implemented and tested for different mode of operation at 30V, 925mA load condition. The feasibility of the proposed LED driver is validated by experimental results.*

Key Words: **Human Centric Lighting (HCL), LED Driver, ac-dc Converter, LED Luminaire, Correlated Colour Temperature (CCT)**

1. INTRODUCTION

Now a days most of the people spend their time in the artificial lighting environment. Hence, the characteristics of light like intensity and colour temperature were more significant. The light emitting diodes (LED) are most widely used lighting solution in indoor and outdoor applications, because of its application in energy saving, long life, high efficiency [1].

LED lighting has provided huge energy savings, flexibility, and reliability, and are now entering nearly every application in the built environment. Also, the aadvancement in LED light technology produced Human Centric LED (HCL) lighting. HCL brigs natural changes in environment light intensity and colour temperature. The demerits of existing conventional LED drivers such as inability to change the colour spectrum of light according to the time of the day is overcome by humancentric drivers [2][3].

1.1 Objective & Scope

The system needs a flyback and PFC controller aimed at LED lighting applications with functions to:

- Shift the colour spectrum (CCT) and intensity of light throughout the day.
- Perform PWM dimming from 100% to 0%.
- Achieve power factor greater than 0.95 with THD < 10%

This requires proper designing of the converters to be used, the transformer for the set voltage range, selection of ICs based on the requirement, and implementation to achieve the desired performance. Thus, prototypes developed and tested by considering two channel PWM control technique.

1.2 AC-DC Rectifier

Flyback is one of the widely used dc-dc isolated converter topology. It is used for systems with low output power ratings. In this projected flyback topology based ac-dc bridged rectifier is adopted. The ac-dc flyback converter topology is as shown in Fig -1.

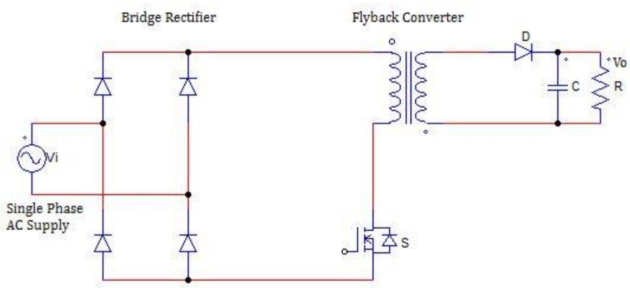

Fig -1: AC-DC Converter Topology

Primary winding of flyback converter is connected to the output of diode bridge rectifier. During ON state of switch S, the primary winding is energized. Due to the induced voltage in the secondary winding, diode D gets reverse biased. The output capacitor C discharges through the load. Throughout the switch-on time, the primary winding carries current. Secondary winding carries no current due to the reverse biased diode D in the secondary.

The current flow in the primary winding is prevented during OFF state of switch S. The voltage polarity across the secondary winding reverses. As a result, diode D conducts and offers a path for the load current flow in the secondary side. Stored energy in the primary winding transferred to the secondary or load.

Some of the major applications of flyback converters are DC-DC power supplies, telecom, LED lighting, power over ethernet (PoE), capacitor charging, battery charging, solar microinverters and AC-DC power supplies.

1.2 PWM Dimming

LED's that use constant current drivers generally adopt PWM dimming techniques. In this method the duty cycle of the current is adjusted. Hence, the average value of current changes. PWM technique handles high dimming ratios at high frequency so that the human eye cannot detect the flickering effect and it does not affect the LED colour temperature (CCT).

This type of dimming is ideal for lighting systems. In this method dimming below 10 percent also achievable. This method is incorporated for colour-mixing requirements in Human centric LED drivers because of its precise dimming properties.

2. BLOCK DIAGRAM

The block diagram of human centric LED driver is shown in Fig -2. The main blocks used in the block diagrams are explained in this section.

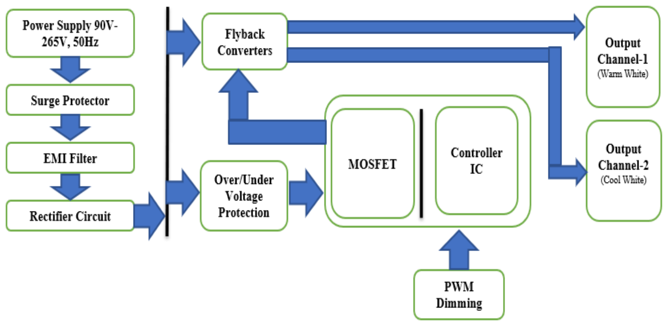

Fig -2: Block Diagram of the Proposed Human Centric LED Driver

Power Supply

Normal operating voltage is 230V, 50Hz. However, driver is designed to operate from 90VAC to 265VAC at 50Hz.

Surge Protection

The power supplied to the driver is pass through the surge protection circuit. Metal Oxide Varistor (MOV) is used protect the driver from surges.

EMI Filter

The high frequency noise produced by electronic and electrical equipment such as power supplies, inverters, microprocessors, clock circuits, appliances, etc. impact on power quality. Common mode choke and drum core inductors used to filter the noise.

Control Circuit

Traditional LED drivers are designed as single-stage or two-stage drivers. DC/DC converter with a constant output current having a power factor correction (PFC) circuit are the single-stage drivers while two-stage system has PFC circuit and a DC/DC converter separately. To obtain high power factor and low THD proper design is needed to meet the power requirement of the system. By integration technology, PFC and DC/DC converters are simplified into a single circuit through sharing of active power switches and control circuit.

Over and Under Voltage Protection Circuit

For proper functioning of electrical and electronic devices, voltage has to be maintained within recommended limits. Voltage fluctuations in power supply affect the driver as well as connected load. Such fluctuations are either of over or under voltage that are an outcome of factors such as surges, overload, sparking, etc.

Over voltage are one of the sources of insulation damage leading to short circuits. Under-voltage lead to overload of the equipment causing lamp flickers and unreliable, inefficient, and improper performance of the equipment. In this project, the minimum input voltage supplied to the converter is limited 90V. The maximum input voltage allowed for the stable operation is limited 265V.

Specifications of the proposed driver are mentioned as follows.

Minimum Input voltage (V_{inmin})	90VAC
Nominal input voltage	230VAC
Maximum input voltage (V_{inmax})	265VAC
Frequency	50Hz
Power Factor (PF)	>0.95
ATHD	<10%
Output voltage (V_{out})	24-55VDC
Maximum Output Current (I_{out})	1500mA

3. DESIGN OF FLYBACK CONVERTER

In this project, discontinuous mode of flyback converter operation is considered. Driver is designed for a load of 30W.

Design equations considered for flyback converter [6]:

$$\text{Turns Ratio (n)} = \frac{N_P}{N_s} = \frac{V_{OR}}{V_0} = \frac{V_{OR}}{V_0 + V_F} \quad (1)$$

$$\text{Duty Cycle (D)} = \frac{V_{OR}}{V_{in} + V_{OR}} \quad (2)$$

$$\text{Secondary side peak current } (I_{spk}) = \frac{2 * I_{omax}}{(1 - D \ldots)} \quad (3)$$

$$\text{Secondary Winding Inductance (Ls)} < \frac{(V_0 + V_F)(1 - D)^2}{2 * Iomax * f_{swmax}} \quad (4)$$

$$\text{Primary Winding Turns } (N_p) > \frac{V_{in} * ton}{A_e * Bsat} = \frac{L_p * Ippk}{A_e * Bsat} \quad (5)$$

4. HARDWARE IMPLEMENTATION

Proposed human centric LED driver was developed based on ac-dc flyback topology. Four layered printed circuit board of HCL was designed using EAGLE PCB design software. Continuity and ground points of PCB were tested and verified. Selected components are assembled in the verified PCB according to the component designation. The top view of the PCB is as shown in Fig -3.

Fig -3: Top View of Human Centric LED Driver

Testing driver is connected single phase 230V,50Hz power supply through autotransformer. A Power analyzer is connected at the input terminal for measurement of input voltage, input current, frequency, power factor, current and voltage THD. A multimeter is connected in parallel across the driver output terminals for the voltage measurement. Similarly, a multimeter connected in series with the output for measurement of output current. A digital oscilloscope of storage is employed to collect the waveforms of the various components.

During test, different input voltage (from 90V to 265V) provided through autotransformer. Required load connected at the output terminal of driver. The corresponding values recorded from the input side power analyzer and output side multi-meters. Performance test for different voltages were performed. At the instant, the input voltage exceeds the specified overvoltage value, the overvoltage protection circuit is activated. Similarly, during voltage falls below the specified voltage value, the under voltage protection circuit activated. The PWM pulse generation from the controller is terminated and the output side multi-meter reads zero value.

5. RESULTS

The human centric LED driver is tested for 30V, 925mA load condition. In driver Channel-1 is considered for warm white (1600k) and Channel-2 is considered for cool white (6500k). Performance test and dimming tests were performed. The efficiency is calculated for different mode of operating conditions. During dimming performance parameters were noted for every 10% PWM variation.

Performance Test

Performance test conducted for three different operating modes of driver i.e., warm white (1600k), daylight (3500k) and cool white (6500k). Efficiency is calculated based on input power and output power measured from power analyzer. Efficiency is expressed as the fraction of output power to input power. The specified efficiency is greater than 80% and the specified current THD is less than10%.

$$\text{Efficiency} = \frac{\text{Output Power}}{\text{Input Power}} = \frac{Vo\ X\ Io}{Po}\ X\ 100 \quad (6)$$

The test results are tabulated in Table -1, Table -2 and Table -3 for warm white, daylight and cool white colour temperature respectively.

Table -1: Performance Test Parameters for Warm white Load Condition (1600k)

Input Measurements	**V_{in} (V)**	230	
	I_{in} (mA)	155.2	
	PF	0.981	
	% ATHD	6.3	
	P_{in} (W)	35.22	
Output Measurements	**Channel No.**	**Ch. 1**	**Ch. 2**
	V_{out} (V)	31.68	24.07
	I_{out}(mA)	923	0
	P_{out} (W)	29.24	0.00
Calculation	**Efficiency %**	83.02%	

It is observed that, during warm white mode of operation the channel-2 output current is 0A. The efficiency is 83.02%. The current THD is less than 10%.

Table -2: Performance Test Parameters for Daylight Load Condition (3500k)

Input Measurements	**V_{in} (V)**	230	
	I_{in} (mA)	158.6	
	PF	0.989	
	% ATHD	6	
	P_{in} (W)	36.1	
Output Measurements	**Channel No.**	**Ch. 1**	**Ch. 2**
	V_{out} (V)	29.14	29.3
	I_{out}(mA)	732	315
	P_{out} (W)	21.33	9.23
Calculations	**Efficiency %**	84.65%	

It is observed that, during daylight mode both channel-1 and channel-2 are in active state. The efficiency at nominal input voltage i.e., at 230V is 84.6%. The current THD is less than 10%.

Table -3: Performance Test Parameters for Cool White Load Condition (6500k)

Input Measurements	**V_{in} (V)**	230	
	I_{in} (mA)	158.5	
	PF	0.982	
	% ATHD	6	
	P_{in} (W)	35.6	
Output Measurements	**Channel No.**	**Ch. 1**	**Ch. 2**
	V_{out} (V)	29	31.07
	I_{out}(mA)	0	949
	P_{out} (W)	0.00	29.49
Calculations	**Efficiency %**	82.82%	

It is observed that, during warm cool mode only channel-1 output current is 0A. The efficiency at nominal input voltage i.e., at 230V is 82.8%. The current THD is less than 10%.

Dimming Test

Dimming test carried out for daylight mode of operation using Putty software. Required dimming percentage from 0% to 100% is passed through putty commands. For every 10% variation efficiency calculated as tabulated in Table -4.

Table -4: Dimming Test Results

Dimming %	Efficiency %
100	84.2%
90	83.8%
80	82.9%
70	82.1%
60	80.4%
50	79.4%
40	77.5%
30	75.5%
20	72.2%
10	64.0%
0	0.0%

Waveforms

Proposed driver waveforms are observed in DSO. Fig -4 shows the diode bridge rectifier output waveforms for nominal input voltage of Vin=230V at full load conditions Vout= 30V and Iout=925mA.

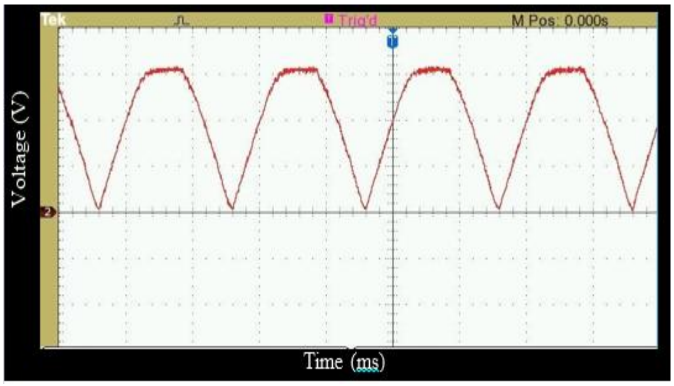

Fig -4: Rectifier output as observed in DSO for V_{in}=230V

The rectified output fed to the DC- DC flyback converter to get desired output voltage of 30V. Output voltage of flyback converter for full load condition is shown in Fig -5. The driver output is found to be as expected.

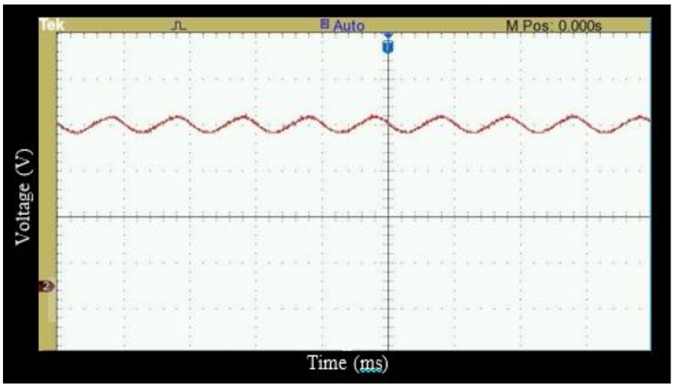

Fig -5: Output Voltage (30V) at full load condition

PWM signal observed in DSO for 10%, 25% and 50% dimming test condition is shown in Fig -6.

Fig -6: PWM Signals during Dimming Test

6. CONCLUSIONS

Constant current dual channel PWM controller based human centric LED driver was implemented. Bridged flyback ac-dc converter topology was adopted. Warm white and cool white are the two channels implemented to obtain the different colour spectrum varying from 1600k to 6500k. Hardware prototype was implemented and tested for different mode of operation at 30V, 925mAs load condition. The hardware test results showed that the driver was operating at an efficiency greater than 80% for all different colour spectrum modes. The current THD and power factors are found to be around 6% (less than 10%) and 0.98 (greater than 0.95) respectively. The experimental results obtained for dimming test under nominal operating voltage Vin= 230VAC were meeting the values of design specifications.

REFERENCES

[1] Petrinska, D. Pavlov and D. Ivanov, "Human Centric Lighting System - Change of Quality and Quantity Parameters with Dimming and Control", 11th Electrical Engineering Faculty Conference (BulEF), Varna, Bulgaria, 2019.

[2] Krames and Michael R, "Status and future of high-power light-emitting diodes for solid-state lighting", Journal of display technology, vol. 3.2: 160-175, 2017.

[3] Y. Wang, J. M. Alonso and X. Ruan, "A Review of LED Drivers and Related Technologies", IEEE Transactions on Industrial Electronics, vol. 64, no. 7, pp. 5754-5765, July 2017.

[4] B. Galabov and Z. Ivanov, "Adapted lighting control model for Human Centric Lighting", 11th Electrical Engineering Faculty Conference (BulEF), Varna, Bulgaria, pp. 1-6, 2019.

[5] Wang, T., Yang, F, Song, J and Han Z, “Dimming Techniques of Visible Light Communications for Human-Centric Illumination Networks”, State-of-the-Art, Challenges, and Trends. IEEE Wireless Communications, 27(4), 88–95, 2020.

[6] A. A. Mohammed and S. M. Nafie, "Flyback converter design for low power application", International Conference on Computing, Control, Networking, Electronics and Embedded Systems Engineering (ICCNEEE), pp. 447-450, 2015.

[7] H. Han, F. Zhang and M. Liu, "PWM Dimming Method for Capacitor-Clamped Current-Sharing Circuit in LED Backlight System", IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 6, no. 3, pp. 1190-1197, Sept. 2018.