ANALYSIS AND IMPLEMENTATION OF 200W LED DRIVER CIRCUIT

Boyapati Chandrasekhar*, Anjan Padmasali[1]

**E&E Dept., MIT, Manipal University, Manipal, INDIA, taj.chandu@gmail.com*
[1]E&E Dept., MIT, Manipal University, Manipal, INDIA,anjan.np@manipal.edu

Keywords: Continuous conduction mode (CCM), Power factor correction (PFC), Colour rendering index (CRI), Correlated colour temperature (CCT), Mean time between failures (MTBF).

Abstract

High power LED's are superseding all conventional light sources and since it is current controlled, precise driver design is indispensable. The LED driver should have the capability of providing constant current regardless of the LED forward voltage variations. In this paper the DC to DC converter is designed and controlled to operate in constant current mode. A 200W LED driver is designed and calculated to verify the proposed circuit. The proposed hardware model consists of a full bridge rectifier to convert AC to DC and increases the rectified output voltage utilizing boost converter which is operated in continuous conduction mode and a quasi-half bridge LLC resonant converter to drive the LED load with coupling LLC transformer. The DC to DC converter is designed such that solid state switches of boost converter and quasi half bridge LLC converter are working under low thermal stress to reduce switching losses. The analysis, design and modelling of 200 W LED driver is carried out by hardware analysis for Universal AC mains.

1 Introduction

The latest LED technology opens up wide areas for incipient applications like street and industrial lighting, incipient technical possibilities to reduce the size of the circuit and preserves the electrical energy, reduced cost because of fewer components in driver circuit and longevity of LEDs over long time, not deleterious for human beings as they do not emit UV rays. In order to amend the performance of LEDs, now days the design of electronic drivers has gained paramountcy. Due to the variations in the voltage versus current characteristics of the LED, controlling only the voltage across them would lead to variations in the light output. Hence to achieve effulgence control, many LED drivers make use of current control technique [1]-[2].

Literatures have proposed many driver circuit topologies for the LED drivers, but for high power applications both power factor rectification and DC to DC converter is required. In this paper, after rectifying the supply voltage AC to pulsating DC the DC to DC conversion part will commence. In DC to DC part it undergoes two stages. In first stage the rectifying voltage will boost up to 400V by utilizing CCM boost converter and victualed to half bridge LLC section. This LLC section will directly give to LED load [3]-[12].

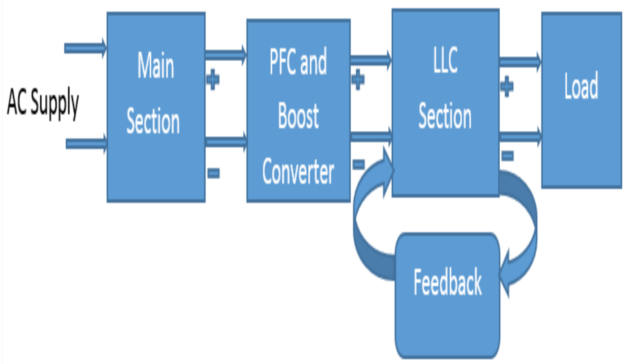

Figure 1. Overall proposed schematic

Fig.1, represents schematic of the proposed converter. It consists of main section, PFC and boost converter section, LLC section with feedback and load section. In main section it consists of MOVs for surge bulwark and Pie filter to smoothen the supply and to abstract the harmonics of supply to give pristine supply to the rectifier section [3]-[5].

In PFC and boost converter section it consists immensely colossal capacitor to amend the puissance factor of the circuit and of boost converter parameters like inductor, capacitor, diode and MOSFET to increment the voltage up to 400V for LLC section [4]-[8]. In LLC section it consists of two MOSFETs to reduce the encumbrance of switches and resonant parameters to operate in soft switching mode and LLC transformer to victual to the load [9]-[13]. In load section 96 LED's are connected in an arrangement of 48 in series and 2 in parallel. The LLC resonant converter stands out among those types of resonant topologies and is widely utilized as power supply for high power applications.

2 Designing of dc to dc conversion stage

2.1 BOOST CONVERTER DESIGN

Fig.2, represents the basic boost converter operating in CCM. In Boost converter when the switch is closed, the inductor stores the energy and when the switch is open inductor will release the energy to the capacitor. The boost converter is designed at 60 KHz switching frequency and the value of inductor, capacitor and duty ratio are calculated for 400V output voltage.

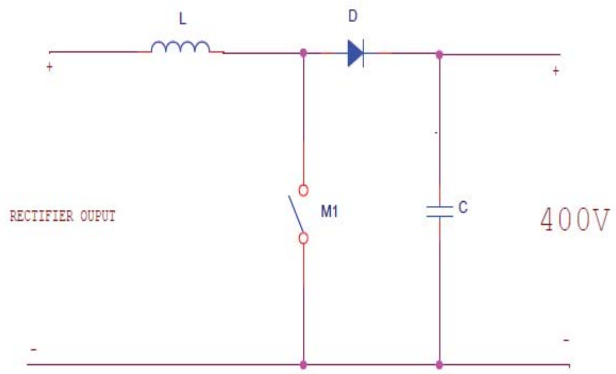

Figure 2. Boost converter design

Table 1: Designed parameters of Boost converter

Boost converter parameters	*Value*
Inductor (L)	280uH
Capacitor (C)	110uF
Duty ratio (D)	0.495
N-Channel Mosfet (M1)	16A,650V
Diode (D)	3A,600V

Table 1, represents the designed parameters of Boost converter to get 400V output voltage to feed LLC section. LLC Converter Design.

2.2 LLC CONVERTER DESIGN

In Fig.3, represents the basic LLC resonant topology.

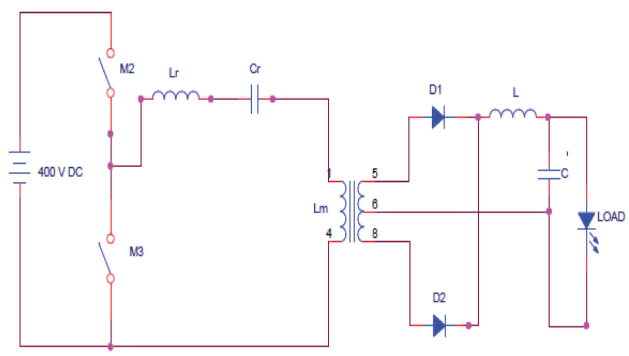

Figure 3. LLC converter design

In this the Quasi-half bridge LLC resonant topology is designed based on LLC MOSFET's switching frequency. The LLC resonant converter parameters like resonant inductor, resonant capacitor and mutual inductor are calculated for 100 KHz switching frequency.

Table 2: Designed parameters of LLC converter

LLC converter parameters	*Value*
Resonant Inductor (L_r)	100uH
Resonant Capacitor (C_r)	220pF
Mutual Inductor (L_m)	620uH
N-channel Mosfet (M2,M3)	11A,650V
Diode (D1,D2)	4A,200V
Output Inductor (L)	10uH
Output Capacitor (C)	470uF

Table 2, represents the designed parameters of LLC converter to feed the LLC transformer and to the load.

2.3 Transformer Design

The transformer is designed to give the required output voltage for the load and to isolate the LLC section from the output section for safety purpose.

Table 3: Designed parameters of Boost converter

Transformer parameters	*Winding Value*
Primary winding (N_1)	48
Secondary winding (N_2)	36
Auxiliary winding	6

Table 3, shows the designed parameters of transformer to provide required voltage level to the load.

3 Hard ware Results

In order to confirm accuracy and validity of the proposed hardware model, it is tested with CRO and electrical parameters tested are with Power analyser. The Fig.4, shows the input voltage and current of the whole circuit.

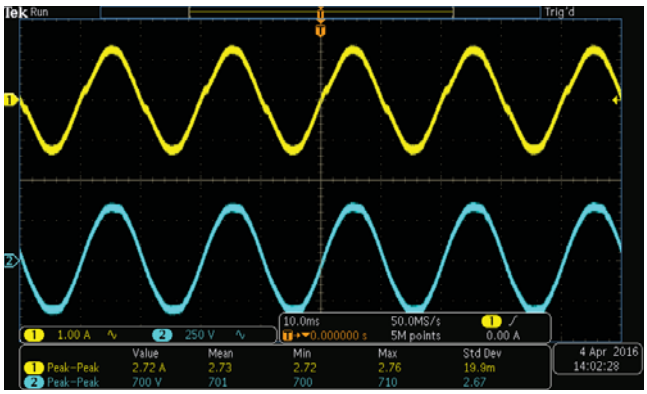

Figure 4. Input current and volatge waveforms

After rectifying the input volatge by using boost converter the output volatge of rectifier is increased up to 400V to feed LLC section. Fig.5, shows the boost converter output voltage.

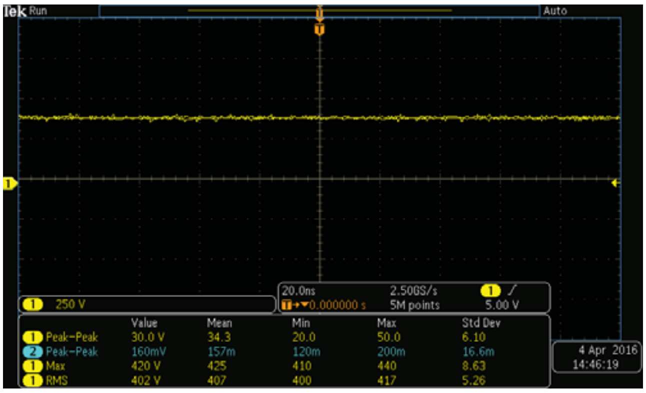

Figure 5. Boost converter output voltage

After LLC section it is fed to the load through LLC transfomer. The Fig.6, and Fig.7, show the output volatge and current of the entire circuit flowing through the load.

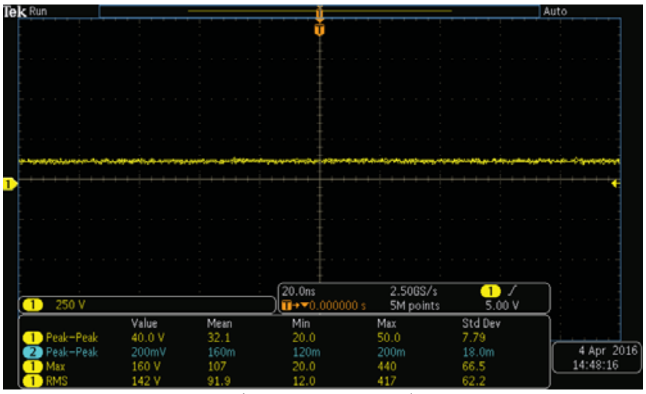

Fig.6. Output Voltage

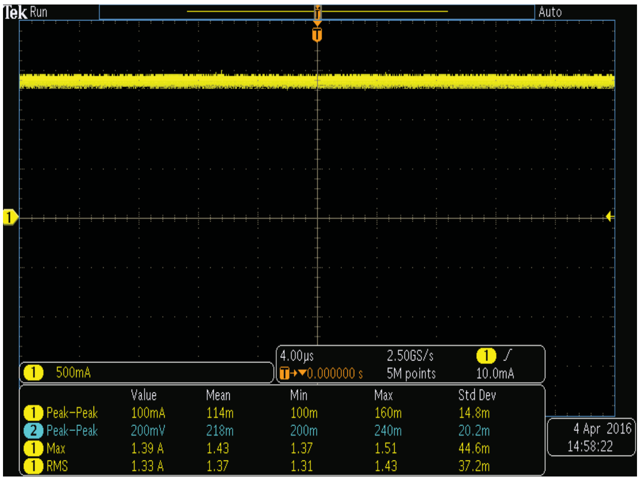

Figure 7. Output Current

Fig.8, shows the hardware model of 200W driver circuit. It consists of less parameters and is very small in size to fit into any fixture.

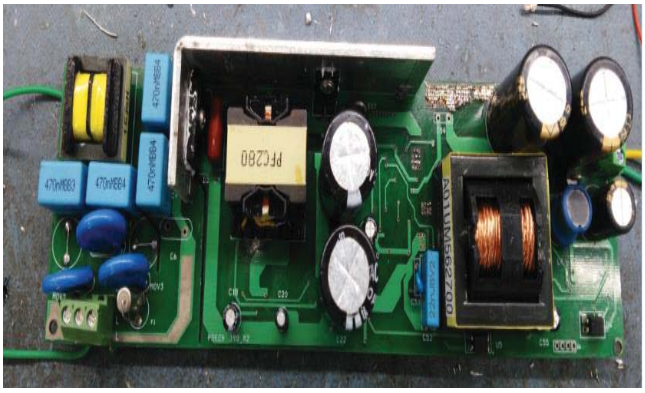

Figure 8. Hardware mode of driver circuit

Fig.9 shows the electrical test parameters of the power analyzer. The parameters shown in the Fig.6 are input voltage, input current, input power, power factor, output voltage, output current, output power and efficiency of driver circuit for 48 Series and 2 parallel LED load.

Figure 9. Electrical test parameters from power analyzer

Fig.10, shows the harmonic value from the power analyzer. The parameters shown in Fig.7 are V_{thd} ,I_{thd} and ouput parameters from the driver circuit at supply voltage.

Fig.10 Voltage and current Hormonics value

The Fig.11 shows the full testing setup with fixture and load.

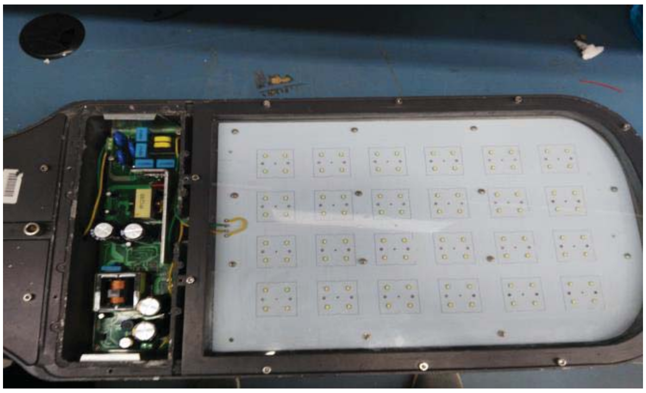

Figure 11. Testing setup with driver,load and fixture

The Fig.12, shows the testing setup of integrated sphere for photometric test of the full fixture.

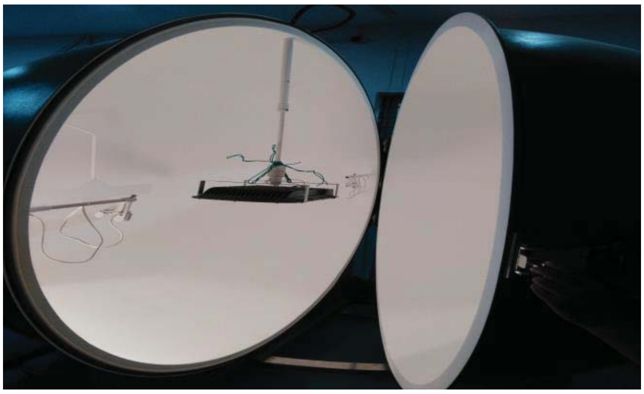

Figure 12. Integrated sphere testing setup

Table 4: Input Electrical parameters of the driver from the testing setup

Input Electrical Parameters(AC)	*Test Results*
Input voltage operating range	80-300V
Nominal input voltage	240V
Input current	870mA
Input power	204.2W
Power factor	0.995
I_{thd}	5.1%
V_{thd}	1.9%

From Table 4, the input parameters are tested with power analyzer and values are validated with input nominal supply of driver.

Table 5: Output electrical parameters of the driver from e testing setup

Output Electrical Parameters(AC)	*Test Results*
Output voltage	140V
Output current	1.4A
Output power	191.3W
Driver losses	12.9W
Driver Efficiency	93.6%

From Table 5, the output parameters are tested with power analyzer and values are validated with input nominal supply of driver. The driver losses are very less because of less switching losses in the circuit.

Table 6: Photometric values with testing setup of integrated sphere

Photometric Parameters	*Test Results*
Flux	20617lm
Efficacy	103.07lm/w
CRI	72.2
CCT	5940K
X,Y coordinates	(0.3228,0.3411)

From Table 6, the photometric parameters are tested with EVERFINE Integrated sphere and values are validated with input nominal supply of driver. The efficacy and CRI are proper with those results with less wastage of light.

4 Conclusion

The proposed 200W LED driver circuit is suitable for street lighting and industrial applications because of lesser driver losses, less light wastage, more efficacy and the wide input range operation. Based on MTBF, calculated lifetime of driver is more than 60,000 hrs. From this we can say it is economical, reliable and can be replaced with all other conventional light sources. From this analysis the LLC resonant converter has become more attractive for front end AC to DC converters. In this paper, the theoretical analysis is done on the circuit operation at steady state mode between the boost and LLC converters and the operation range has been observed in CRO. Moreover, by choosing Boost converter L, C and LLC converter L_r, L_m, C_r, the transformer design operation range of the DC to DC converter can be ensured. The proposed 200W LED driver has demonstrated cost effectiveness because of less losses, less components, high circuit efficiency (>90%), low THD level, constant output voltage (140V) and constant output current (1.4A) to improve the life of driver and LED's. The driver circuit is modelled using CRO for stability analysis and testing with Power analyser and integrated sphere to check electrical and photometric parameters of the proposed circuit design.

References

[1] E. F. Schubert, Light-emitting diodes, Cambridge University Press, 2006.

[2] ON Semiconductor, "LED lighting solutions," pp. 1-36, February 2010.

[3] F.Y. Shih, "A procedure for designing EMI Filters for AC Line Applications", IEEE Transaction on Power Electronics, vol. 11, no. 1, pp. 170-181, 1996

[4] "IEEE Standard 519", Recommended Practice and Requirements for Harmonic Control in Electric Power System, 1992

[5] Leopoldo Rossetto, Simone Buso, and Giorgio Spiazzi, "Conducted EMI Issues in a 600-W Single-Phase Boost PFC Design," Industry Applications, IEEE Transactions on Volume 36, Issue 2, March-April 2000.

[6] F. Zhang, J. Ni and Y. Yu, "High power factor AC–DC LED driver", IEEE Trans. Power Electron., vol. 28, no. 10, pp. 4831-4840, 2013

[7] C. M. Lai and K.K. Shyu, "A single-stage AC/DC converter based on zero voltage switching LLC resonant topology", IET Electr. Power Appl., vol. 1, no. 5, pp. 743-752, 2007

[8] "High power factor LED ballast using FSFR2100 Fairchild power switch (FPSTM) for resonant half-bridge converter and FAN7529 PFC controller", Design Note, 2008, Fairchild Semiconductor, Inc.

[9] S.-Y. Chen, Z. R. Li and C.-L. Chen, "Analysis and design of single-stage AC/DC LLC resonant converter", IEEE Trans. Ind. Electron., vol. 59, no. 3, pp. 1538-1544, 2012

[10] X. Ruan and Y. Yan, "A novel zero-voltage and zero-current-switching PWM full-bridge converter using two diodes in series with the lagging leg", IEEE Trans. Ind. Electron., vol. 48, no. 4, pp. 777-785, 2001

[11] X. Wu, C. Hu, J. Zhang and Z. Qian, "Analysis and design considerations of LLCC resonant multioutput dc/dc LED driver with charge balancing and exchanging of secondary series resonant capacitors", IEEE Trans. Power Electron., vol. 30, no. 2, pp. 780-789, 2015

[12] R. L. Steigerwald, "A comparison of half-bridge resonant converter topologies ", IEEE Trans. Power Electron., vol. 3, no. 2, pp. 174-182, 1988

[13] P. S. Almeida, D. Camponogara, M. Dalla Costa, H. Braga and J. M. Alonso, "Matching LED and driver life spans: a review of different techniques", IEEE Ind. Electron. Mag., vol. 9, no. 2, pp. 36-47, 2015.