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Research Article

LED Power Driving Circuit for Street Light Application

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Abstract

This Paper deals with the practical implementation of 100W streetlight LED power driving circuit in which the flyback converter topology is used. An LNK420EG controller IC is used to provide constant output current to the LED string which may serves additional functions such as power factor improvement, over current protection, high efficiency. This paper consists of basic functional block diagram of the system, flyback converter topology for continuous conduction mode. This paper also consists of test report which is carried out over the actual hardware of 100W LED power driving circuit. Finally experimental results shows that proposed LED power driving circuit is best suited for the lighting applications.

Keywords: *Flyback converter, LNK420EG Link switch, continuous conduction mode, Test report and related graphs*

1. Introduction

Now a day's development of green technology is highly demanded as energy crises and the environmental problems are considered as serious issue. Energy consumption by lighting equipment is significantly high so there is a need to implement cost effective and energy saving solution over conventional lighting sources. After doing worldwide survey it is found that about one-fifth of the electric power is used for commercial, industrial and residential lighting applications. Incandescent bulbs and fluorescent lamps are commonly employed lighting sources. However the luminous efficiency of incandescent bulbs is very low because only about 10% of the electricity flowing through incandescent bulbs is converted to light. Mercury content of the fluorescent lamp is harmful to both the environment and the human being. Again for starting the fluorescent lamps require high striking voltage. Unlike the fluorescent lamp, LED does not contain mercury. It has many merits over conventional lighting sources i.e. light in weight, energy saving, small in size, high luminous efficiency, environmental friendliness and longer lifetime (Ying-Chun Chuang *et al*, 2010). The implementation of LED lighting is based on constant current at the output side so it is prime important to develop driving circuit for LED string.

Basically the power supply unit has to meet certain terminal specifications such as the permissible limits of output voltage regulation and less ripple voltage component with the use of switch mode power supply. Switch mode power supplies are most widely used in electronic equipment. These are also called switching power supplies or switching regulators. LED power driving circuits consist of such switch mode power supply linear regulator is an alternative to an SMPS. These are good for low power applications but are inefficient and uneconomical for high power applications (Joseph Vithayathil).

There is a lot of research and development work carried out over LED power driving circuit. Some LED driving circuits use flyback topology and it runs on discontinuous conduction mode (Ying-Chun Chuang *et al*, 2010, Yu Hung *et al*, 2013). For better control over output voltage, discontinuous conduction mode or discontinuous flux mode of operation is preferred. However for the given ratings of transformer and auxiliary device like switch, more output power can be transferred during continuous conduction mode or continuous flux mode. Some LED power driving circuits use transistorized linear regulator coupled to buck converter (Zito P. da Fonseca *et al*, 2011). In this case efficiency of linear regulator based LED power driving circuit is low as compared to switch mode power supply based LED power driving circuit. Some LED driving circuit uses resonant converter based topologies and these are best suited for higher output power (Yong-Nong Chang *et al*, 2013, Christian Brañas *et al*, 2011). Some other LED driving circuit uses two-stage topology. In the first stage boost converter is to be used for power factor improvement and second stage DC/DC converter is to be used to realize output regulation with isolation and fast response (Yu Hung *et al*, 2013).

There are basically 14 basic topologies which are commonly used to implement a switching power supply. Some topologies are best suited for low output power (< 200W) and some are best suited for higher output power (>200W) (Abraham I. Pressman).

The proposed project work consists of Single stage flyback converter based 100W dual channel LED power

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driving circuit. The proposed project is based on continuous conduction mode (CCM). According to driving method circuit model is fabricated and tested to verify its current stability.

This paper is divided into six different sections. In section I, basic introduction about LED power driving circuit is discussed. In II section, necessity of LED power driving circuit and objective of proposed project work are presented. In section III, description about basic block diagram of proposed LED power driving circuit is explained. In section IV, flyback converter topology is explained. In section V, test report of 100W LED power driving circuit is given and in section VI, experimental results have been shown and their related graphs are also being plotted.

2. Necessity of LED power driving circuit

There is a tremendous scope for LED lighting as a lighting source because of their high luminous efficiency, energy saving and longer lifetime. Therefore to implement LED lighting world-wide there is a need of LED power drive to provide constant current to the output LED string which makes the stability in the brightness of all LEDs which are connected in the string.

LEDs are nonlinear devices (forward current versus forward voltage) having forward voltage that is a function of temperature. Therefore this forward voltage is needed to be controlled by regulating the current and this can be achieved by using LED power drive. LEDs are not a purely resistive load like an incandescent bulbs, therefore drivers are required to provide a power factor close to unity. (excelsys).

3. Proposed LED power drive block diagram description

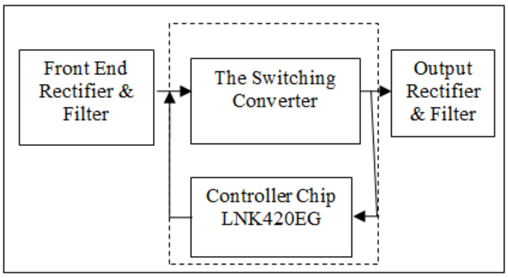


Figure 1: Block Diagram of LED Power Driving Circuit

The front end rectifier and filter

The main purpose of this block is to provide the raw DC voltage from the input AC voltage. It consists of rectifier circuit and filter. Usually the rectifier is a diode bridge which is available as a single four-terminal module. The filter consists of bank of electrolytic capacitors which is used to bring down the ripple content in the rectified voltage to an acceptable level.

The switching converter and controller chip

The purpose of this block is to convert the unregulated DC into high frequency pulse width modulated AC of the required voltage level with the help of repetitive switching. In this the switching frequencies may be obtained as high as several hundred kilohertz with the help of power semiconductor switches for example power MOSFET (because power MOSFET is having very high switching frequency capability).

The high frequency transformer is also used to provide the required voltage level on the output side. It also serves to provide electrical isolation of the regulated output from the input AC bus. The core material used for the transformer is made up of ferrite material because it is suitable for the use in high frequency operation.

It also consists of controller chip LNK420EG. The controller block works as a comparator which is used to sense the output current then compare with an accurate reference quantity. If any error occurs then error gets amplified and accurate pulse width modulation technique is implemented to obtain desired output.

The basic function of controller chip is to provide better output regulation with having additional useful features such as over voltage protection and power factor improvement.

The output rectifier and filter

The high frequency pulse width modulated AC of the secondary of the ferrite core transformer is impressed across output rectifier to obtain the desired output voltage. In proposed scheme Schottky diode is used at the output rectifier circuit due to its higher frequency capability. The output filter generally consists of electrolytic capacitor (Joseph Vithayathil).

4. Flyback converter topology

Flyback converter is the most commonly used SMPS circuit which is used for low output power applications. This topology is basically used where the output voltage needs to be isolated from the input main supply. Generally input to the circuit is unregulated DC voltage which is obtained from the utility AC voltage after rectification and filtering. To maintain the desired output voltage a fast switching device like a MOSFET is used. Basically transformer is used for voltage isolation purpose as well as for better matching between input and output voltage and current requirement. Unlike an ideal or normal transformer current does not flow simultaneously in both the windings of the flyback transformer. In the output section of the flyback transformer voltage rectification and filtering stages are provided which are considerably simpler than other switch mode power supply circuits (NPTEL).

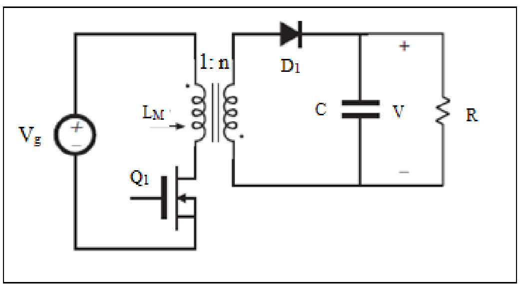


Figure 2 (a): Flyback convertor

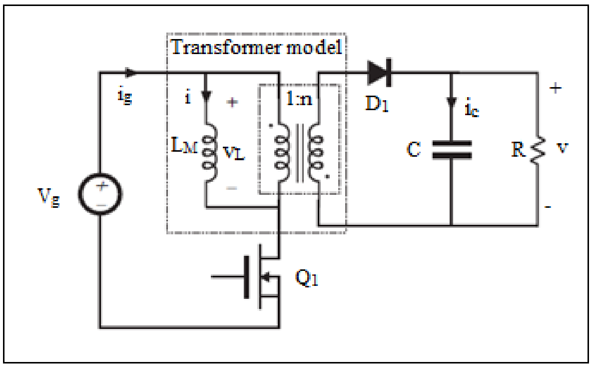


Figure 2 (b): Flyback converter circuit with transformer equivalent circuit model

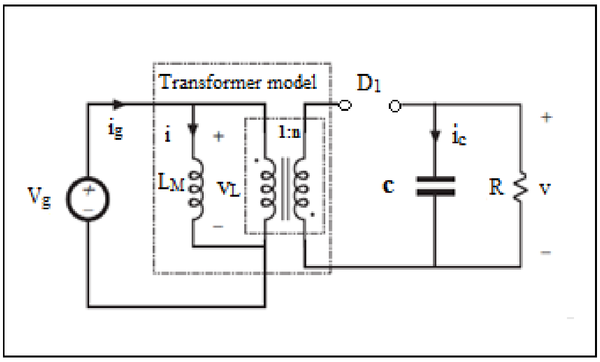


Figure 2 (c): Equivalent circuit during subinterval 1

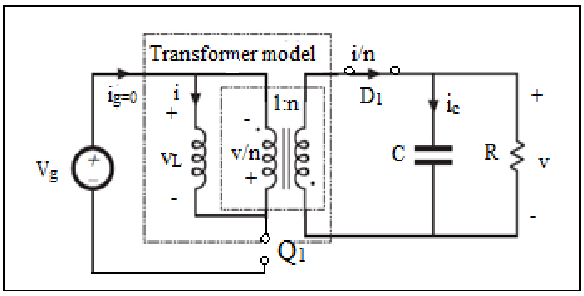


Figure 2 (d): Equivalent circuit during subinterval 2

Figure 2 (a) shows the basic configuration of the flyback converter.

The behavior of most transformer-isolated converters can be adequately understood by modeling the physical transformer with a simple equivalent circuit consisting of an ideal transformer in parallel with the magnetizing inductance L_M as shown in figure 2(b).

In figure 2 (b), when switch Q1 conducts energy from the dc source V_g is stored in L_M and when diode D1 conducts this stored energy is transferred to the load. Figure 2 (c) shows equivalent circuit for subinterval 1. During the subinterval 1, switch Q1 conducts and diode D_1 does not conduct as it becomes reverse biased. The inductor voltage v_L, capacitor current i_c and dc source current i_g are given by,

$v_L = V_g$
$i_c = -v/R$
$i_g =$ (1)

Assuming that converter operates with small inductor current ripple and small capacitor voltage ripple, so the magnetizing current i and output capacitor voltage v can be approximated by their dc components, I and V respectively. Therefore equation (1) becomes,

$v_L = V_g$
$i_c = -V/R$
$i_g = I$ (2)

Figure 2 (d) shows the equivalent circuit for subinterval 2. During the second subinterval, the switch Q1 is in the off state and the diode D1 conducts. So in this subinterval following equations are obtained.

$v_L = -v/n$
$i_c = i/n-v/R$
$i_g = 0$ (3)

Similarly considering the same approximation equation (3) becomes,

$v_L= -V/n$
$i_c = I/n-V/R$
$i_g = 0$

The resultant waveforms of $v_L(t)$, $i_c(t)$ and $i_g(t)$ are sketched in figure 3.

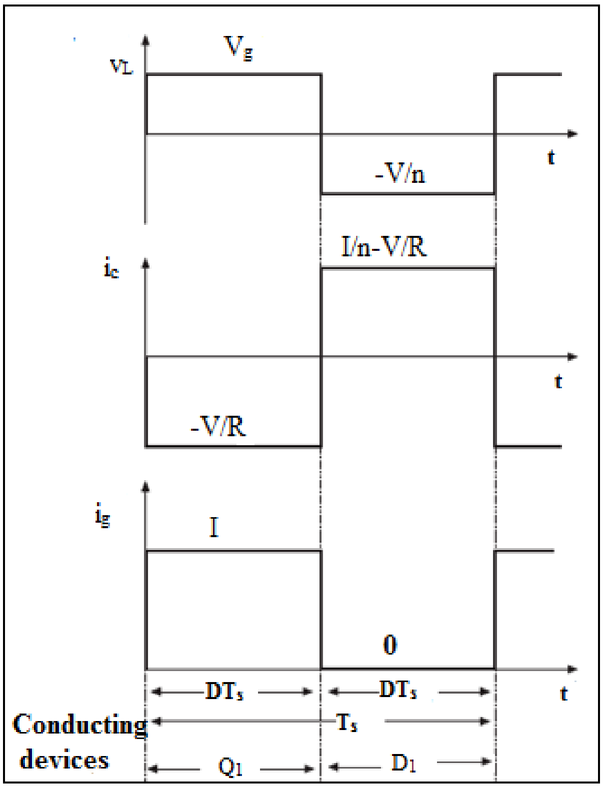


Figure 3: Flyback converter waveforms, continuous conduction mode.

5. 100W LED Driver test report

The test report of proposed scheme is presented in table 1.

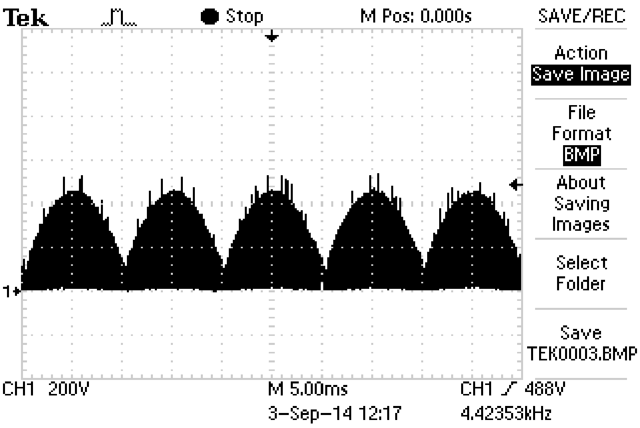
Table 1: Test report of proposed scheme

V_{in} (Volts)	170	230	270
I_{in} (Ampere)	0.563	0.428	0.369
P_{in} (Watts)	96.2	97.4	95
V_{out} (Volts)	38.57	38.71	38.52
I_o (Ampere)	2.2	2.23	2.17
P_{out} (Watts)	84.85	86.32	83.58
Efficiency (%)	88.2	88.6	87.98
Power Factor	0.98	0.97	0.96
Athd (%)	15.60	18.70	20

6. Experimental Results

Following are the graphs obtained on the oscilloscope which shows the behavior of the MOSFET and output rectifier.

X-Axis: Voltage (200V/Div.)
Y-Axis: Time (5ms/Div.)



X-Axis: Voltage (200V/Div.)
Y-Axis: Time (10us/Div.)

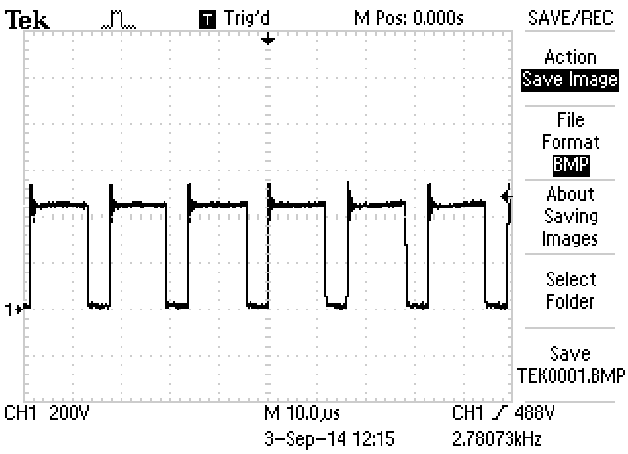
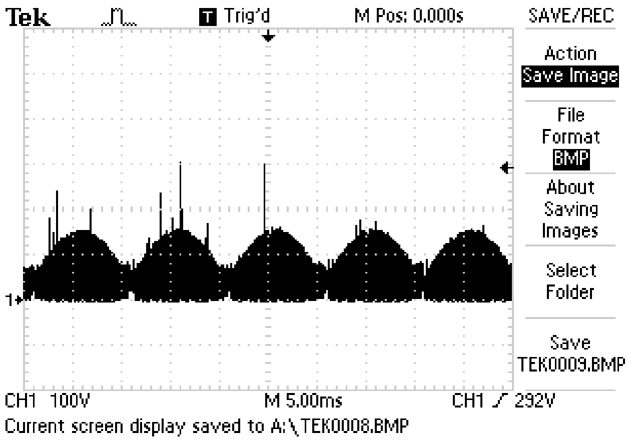


Figure 4: Drain to source voltage

X-Axis: Voltage (100V/Div)
Y-Axis: Time (5ms/Div)



X-Axis: Voltage (100V/Div)
Y-Axis: Time (10us/Div)

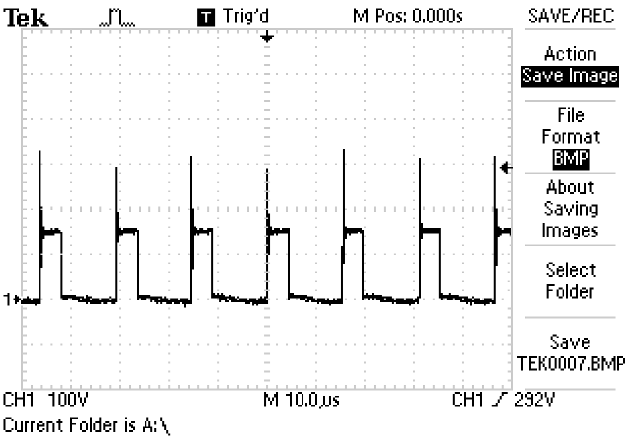


Figure 5: Output rectifier peak inverse voltage

Figure 4 shows drain to source voltage of MOSFET and figure 5 Shows output rectifier peak inverse voltage. These graphs shows that the spikes generated in this are within the acceptable limits.

Following are the graphs which are obtained from the test report.

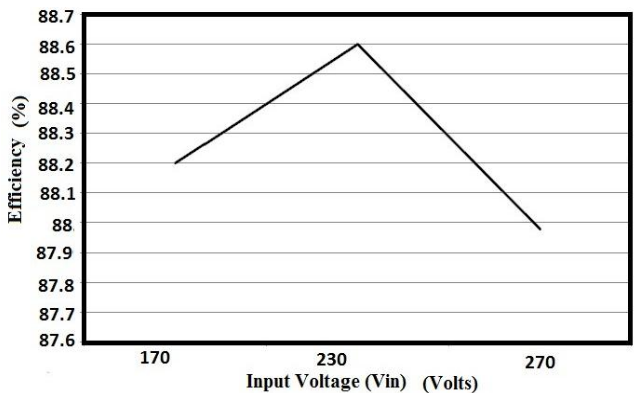


Figure 6: Efficiency Vs Input voltage (Vin) curve

Figure 6 shows efficiency Vs Input voltage (Vin) curve. This curve shows that efficiency of proposed LED power driving circuit is above 87% for a input voltage range of 170V to 270 V AC. Figure 7 gives the relation of power factor Vs input voltage (Vin) curve. This curve shows that power factor above 0.95 is obtained in the proposed LED power driving circuit for a input voltage range of 170V to 270V AC. Figure 8 shows load regulation curve it shows that acceptable load regulation (<3%) is obtained. Figure 9 shows total harmonic distortion (THD) Vs input voltage curve. This curve shows that low THD (less than 21%) is obtained. The above results are within the acceptable limits indicates the proposed scheme is best suited for lighting applications (Power Integrations)

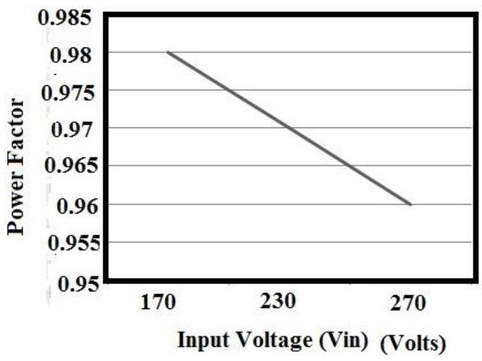


Figure 7: Power factor Vs Input voltage (Vin) curve

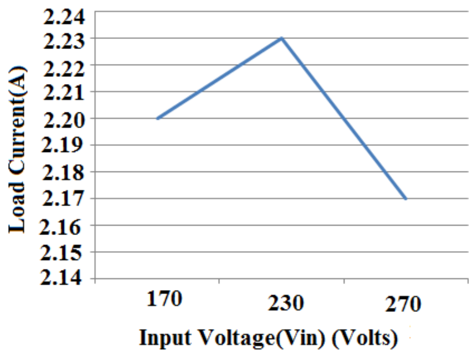


Figure 8: Regulation curve Line and load

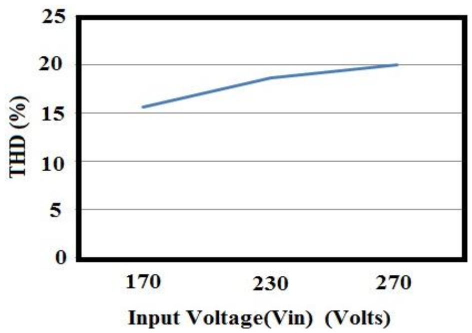


Figure 9: Total harmonic distortion Vs input voltage (Vin) curve

Conclusion

An LED power driving circuit with having improved power factor for lighting applications has been presented in this paper. The flyback converter based topology is used to satisfy present standard requirements. The controller IC LNK420EG is used in this driving circuit which improves the power factor of the proposed circuit. The proposed scheme has been implemented successfully, obtained experimental results and test report provides better load regulation (<3%), low total harmonic distortion (< 21%), high efficiency (>87%) and almost unity power factor. The proposed topology works as a good solution to implement low cost, high power factor LED driving circuit for lighting applications.

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NPTEL Notes

Application Note, Design Example Report, *Power Integrations.*