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A Single Stage Driver Circuit for LED with Flyback converter

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ABSTRACT:The utilization of Light Emitting Diodes (LEDs) became more popular in recent years, because of their high efficiency, long life and small in size. Various types of LED driver circuits are available, but a single stage LED driver circuit is designed with full wave bridge rectifier (AC-DC), and a flyback converter (dc-dc) which is most commonly used for low power applications. The proposed converter is operated in complete energy transfer mode with constant peak current control mode for constant power. The designed LED driver circuit is more economical with single switch. The implementation of the LED driver circuit with a flyback converter circuit is explained in detail. The driver circuit is simulated using LTSPICE software packages for 40W (40v, 1A)

KEYWORDS: Light Emitting Diode, flyback converter, peak current mode control, complete energy transfer.

I.INTRODUCTION

About 25% of total electrical power generated is consumed for residential, commercial and industrial lighting applications throughout the world. The total electricity consumption in India, about 25% had been contributed to residential sector in 2011. The Application of the electric power in residential sector used mainly for lighting and other appliances like celling fans, refrigerators etc.

The usage of an incandescent and fluorescent bulb in residential, industrial is about 70%, which gives less efficiency. There are several developments taken place in recent years to find high efficiency lighting sources. Finally, the researchers discovered the light emitting diodes (LED) which give high efficiency than the other existing lighting sources. The major advantages of the light emitting diodes are long life time, small in size, energy efficient, and they available in different colours. But the LED's requires a constant DC power supply to emit light. So, there is a need to design the efficient driver circuit to drive the LED's. For that we have to design a power conversion circuit (AC-DC) by using a rectifier. But the DC power obtained after rectification consists of large ACripple. Thus, a DC-DC flyback converter is used to obtain desired power to drive the LEDs.

The Fig 1.Shows the block diagram of proposed LED driver circuit with flyback converter. The switched mode DC-DC flyback converter in the proposed LED driver circuit operates in Dis-continuous mode (DCM) with peak current mode control, to achieve complete power transfer in every switching cycle. Especially if the flyback converter is made to operate in DCM, there are several advantages. They are mainly (a) it requires small transformer. (b) It is not subject to sub harmonic oscillations in current mode. (c) Low cost secondary diode is needed (d) less turn on losses of MOSFET. (e) Good stability.

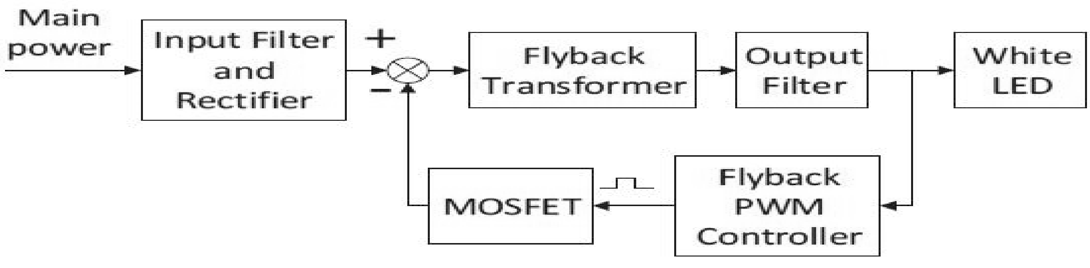

Fig.1 Block diagram of the proposed single stage LED driver.

II. PROPOSED LED DRIVER CIRCUIT

Fig 2. Shows the proposed single stage LED driver circuit. The proposed circuit consists of a bridge rectifier to convert the AC supply into DC supply. Then a storage capacitor is used in between the rectifier bridge and flyback converter to reduce the ripples in the DC voltage. The flyback transformer (T1) consists of two windings. The primary windings (N_p) and secondary winding (N_s). The magnetizing inductance of flyback convert is symbolised as L_m. A switch (SW) is used in series with the primary of the transformer for ON and OFF with high frequency of 65 KHz, because it offers a good compromise among switching losses, magnetic size and EMI signature.The secondary side of the converter is loaded with high brightness LEDs. A storage capacitor is connected just before the LEDs to provide constant voltage.

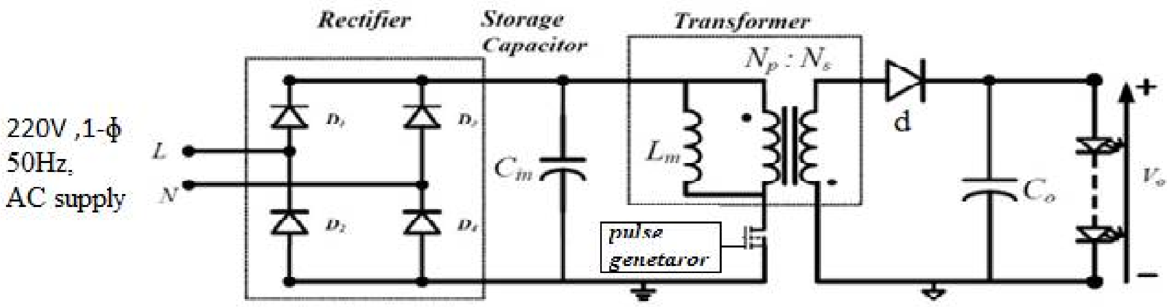

Fig. 2 Proposed single stage LED driver circuit.

The circuit operation of the proposed LED driver circuit can be explained in three modes, those are asfollows:

MODE I: (0 to DT$_s$)

The equivalent circuit diagram of mode I is shown in Fig 3.During this mode the switch (SW) is turned ON at t=0 and this causes the diodes in the bridge rectifier to conduct and a DC voltage is stored in the capacitor (C_{in}) , This voltage(V_{CIN}) acts as input to the flyback converter. The primary inductance draws the current to store energy in it. The current increases linearly in the L_m and reaches its maximum value. The diode (d) on secondary side of the transformer acts as open circuit .The output capacitor C_o discharges the energy stored in it to the load. This mode ends when the current in L_m reaches a set point, switch turns OFF.

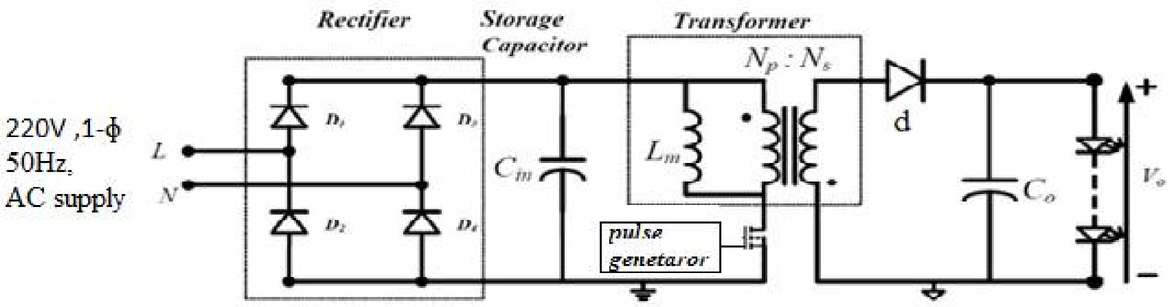

Fig 3: The flow of current during the mode I

The rectifier output voltage is given as $V_{CIN} = \frac{2V_M}{\Pi}$; where, V_M=maximum voltage of applied AC voltage. During this mode the mathematical expression for current and voltages in the primary sideis given as $(i_{L_{MAX}})_{closed} = \frac{V_{Cin}DT}{L_p}$.

and $V_{PRI} = V_{CIN}$ = voltage across the input capacitor.

Where, D= duty ratio of the switch.

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On secondary side of transformer, $I_{sec}=0$; $I_{Ds}=0$;

$$V_{sec} = V_{CIN}\left(\frac{N_2}{N_1}\right); \quad V_D = -V_O - V_{CIN}\left(\frac{N_2}{N_1}\right) < 0$$

MODE II :(DTsto D_1)

During this mode, the switch is OFF making the current in the L_m reaches to zero before the start of next cycle to achieve complete energy transfer. This equivalent circuit diagram of this mode is shown in Fig 4. Energy stored in the primary is transferred to secondary. The diode on secondary side conducts and the energy is transferred to output capacitor and to load.

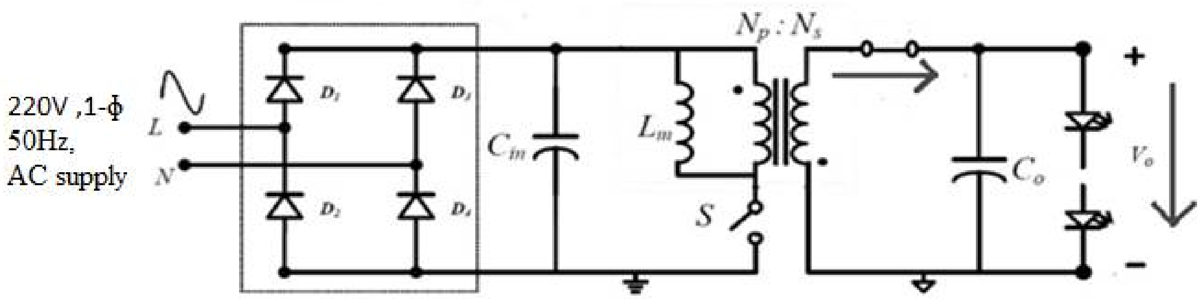

Fig. 4 Current flow during mode II

The equations of the current and voltages on primary side given as

$$(\Delta i_{L_m})_{open} = \frac{-V_o D_1 T}{L_m}\left(\frac{N_1}{N_2}\right);$$

$$V_{pri} = -V_O\left(\frac{N_1}{N_2}\right);$$

$$V_{SW} = V_s + V_o\left(\frac{N_1}{N_2}\right)$$

On secondary side,

$$V_{sec} = -V_o; \ I_{Sec}=I_{Ds};$$

MODE III: (D_1 to T_S):

This mode is continuation of mode II. Both the switch and diode are turned OFF. The current flow during this mode is shown in Fig 5. The output capacitor supplies the power to load till the switch is turned ON. The wave forms of the proposed converter over a switching cycle are shown in Fig 6.

The average primary inductor current for one switching cycle is given as $I_s = \frac{V_S D^2 T_S}{2L_M}$. The output power is given as $P_o = \frac{V_O^2}{R}$, on equating the power on both primary and secondary sides gives output voltage as $V_o = V_s D\sqrt{\frac{TR}{2L_M}}$.

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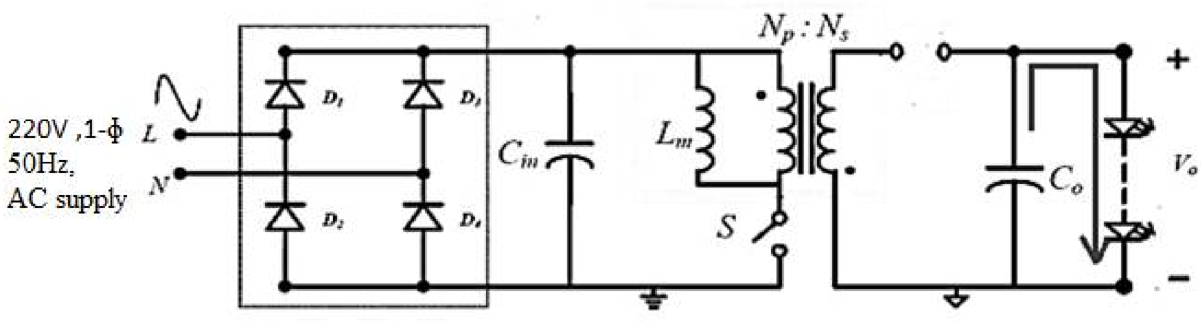

Fig.5 Circuit diagram for mode III

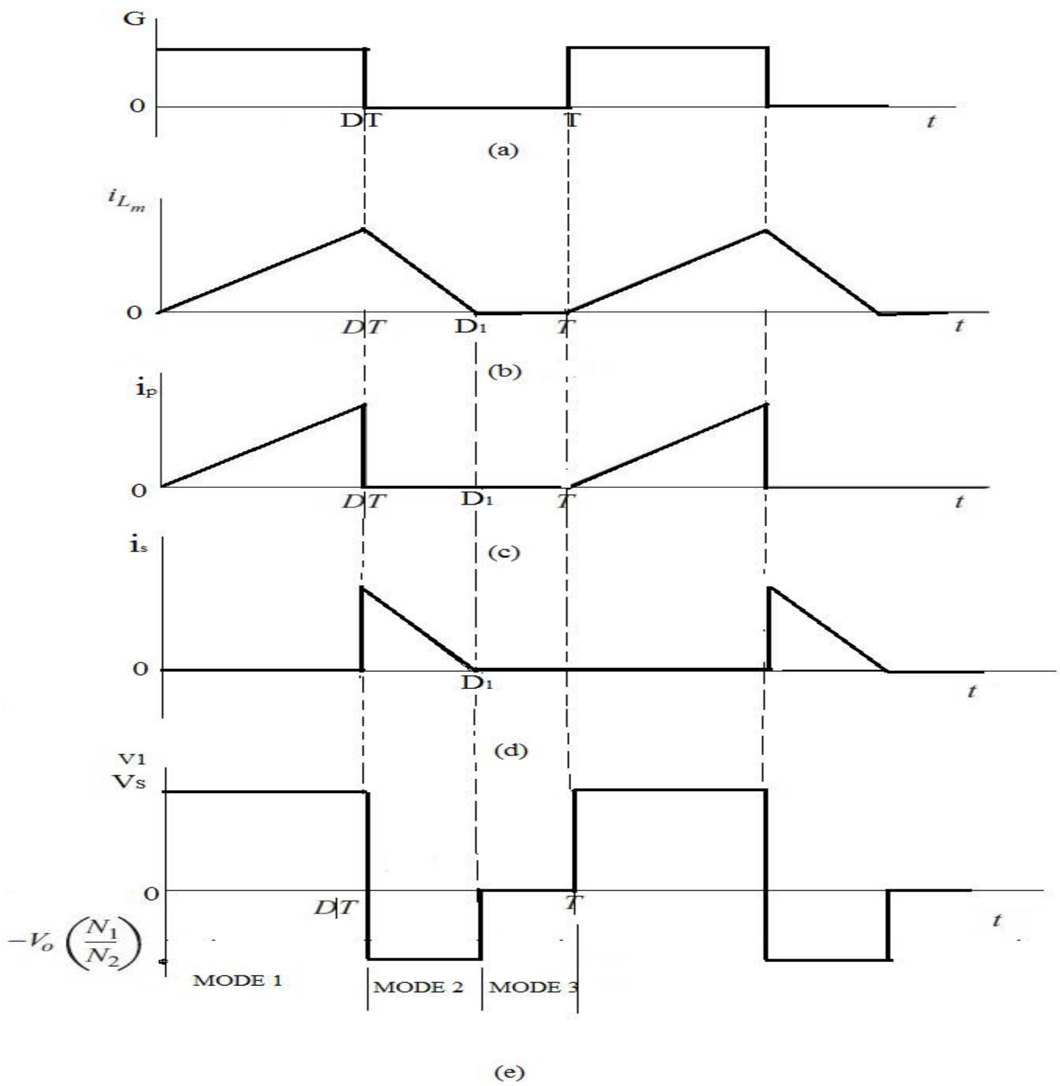

Fig.6 Wave forms of the proposed converter (a) gate pulses (b) current in the magnetizing inductance (c) current in primary inductance of the transformer (d) current in secondary side of transformer (e) voltage across the primary winding of transformer.

III.DESIGN SPECIFICATIONS AND SIMULATION CIRCUIT

The proposed LED driver is designed with the parameters as shown in Table 1.The driver circuit is designed for low power applications.

Table 1: Single stage LED driver circuit simulation parameters

Parameter	Specification
Input supply voltage V_{IN}	180-250 Vrms
Supply frequency	50Hz
Desired output voltage	40V
Designed output current	1A
Switching frequency	65KHz
Transformer turns ratio (N_p:N_s)	124:29
Primary inductance(L_p)	1mH

A closed loop simulation is designed by using the computer software LTSPICE IV. The closed loop simulation circuit of the single stage LED driver circuit is shown in Fig 7.

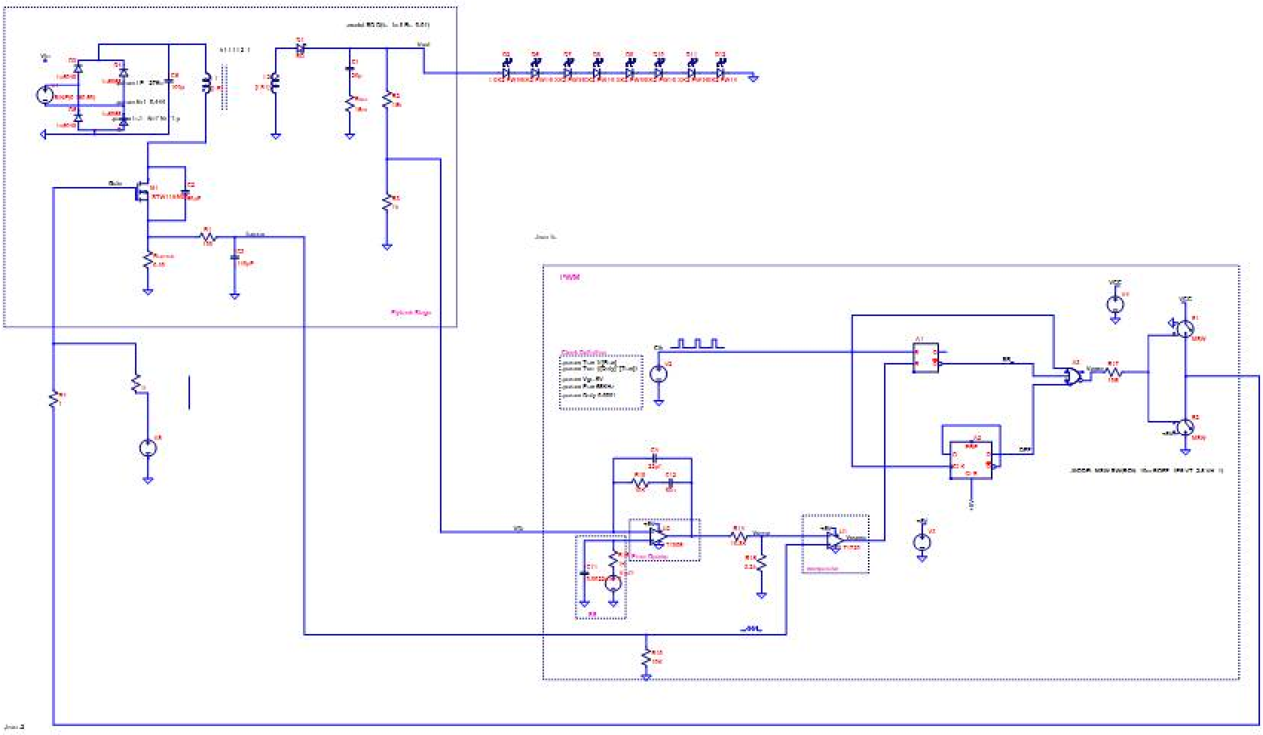

Fig.7 Closed loop simulation circuit diagram of the proposed single stage LED driver.

The main advantage of this software is we can choose the practical component from the library. This helps the user can implement the hardware circuit easily. The output voltage is sensed with a voltage divider circuit and compared with a

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reference value. The input current to the flyback transformer is sensed with a current sensing resistor and compared with a comparator.

A clock pulse sets the latch which closes the power switch. The current ramps in the primary of the transformer linearly, when the current reaches a given set point value a comparator detects it and resets the latch. Switch now opens and waits for next clock cycle to close again.

V. RESULT AND DISCUSSION

The output voltage and current wave forms of the LEDs are shown in the fig 8. The output voltage is obtained as 40V and the current is 1A as designed. The output voltage and currents are reaching the steady state value with very less number of oscillations.

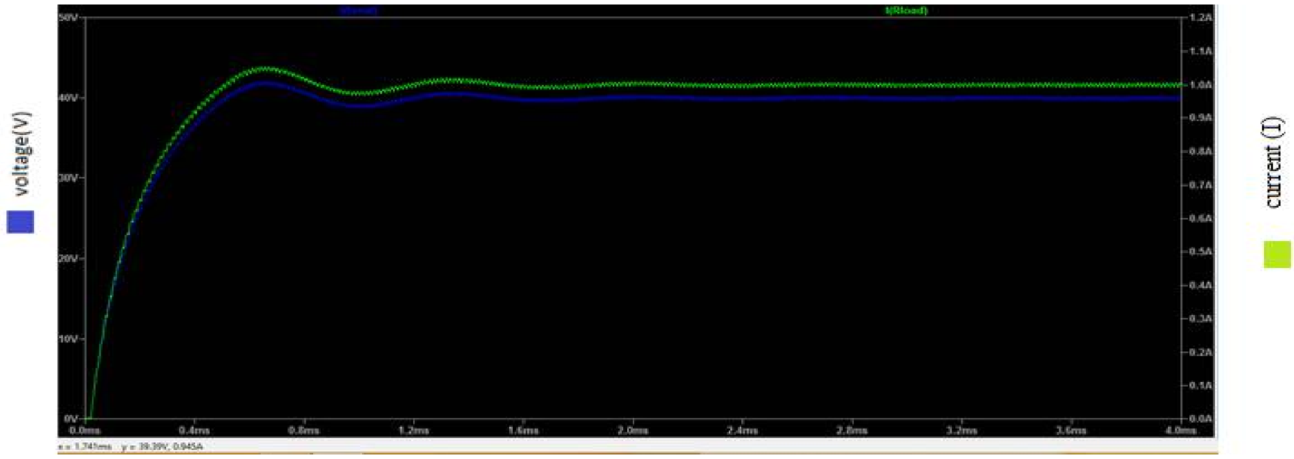

Fig.8 Waveforms of output voltage and current obtained from LEDs

Fig 9, shows the currents in the primary and secondary winding of the flyback transformer and gate pulses. It is clear that the switch is turned OFF when the primary current reaches a set peak value. As soon as the switch is turned OFF, the secondary winding current starts reaching zero before the switch is turn ON for next cycle. Thus it is clear that the transformer is operated to transfer complete energy from primary to secondary side.

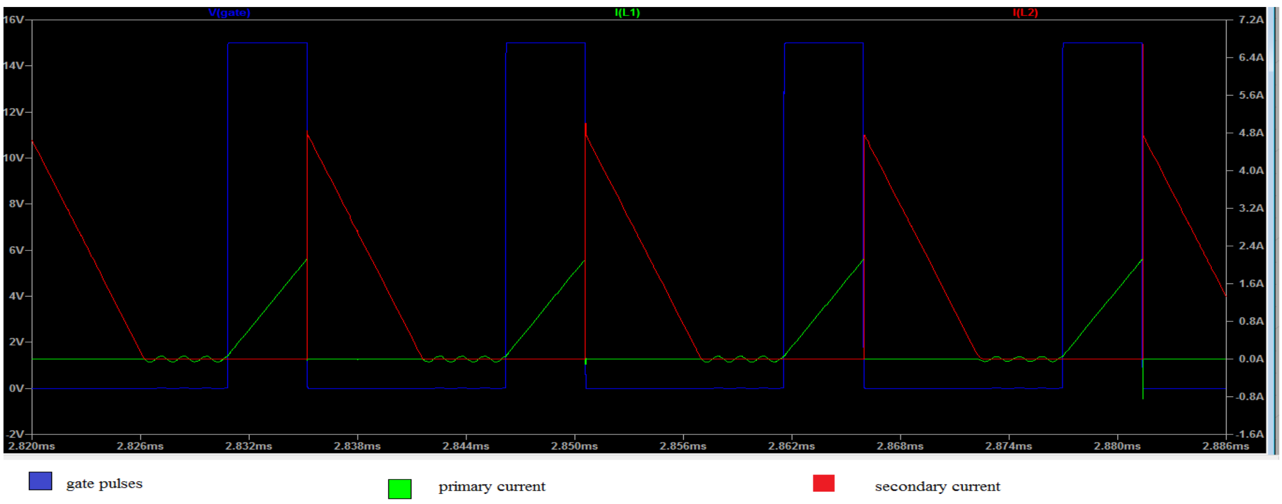

Fig.9 Wave forms of the primary, secondary winding currents and gate pulses to switch

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VI.CONCLUSION

The proposed design shows an efficient, less number of components and low cost LED driver design. The proposed driver circuit improves the efficiency. The proposed design emphasizes simple flyback topology, makes it very attractive for low cost application especially for lighting solution. The driver circuit is simulated for 40W with LTSPICE.The proposed circuit is small in size to implement and best suitable to low power applications with low cost.

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