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A highly efficient SMPS led driver for lighting applications

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ABSTRACT

This paper proposes an efficient LED Driver for lighting applications. This LED Driver uses TOP256YN Controller which is having an inbuilt controller along with the switch. The Driver is having least number of components so as the losses and compact in size helps to cut its cost and improves the efficiency. The simulation is carried out using PSIM software.

Keywords: *Light Emitting Diode (LED) Driver, Flyback converter, PSIM, Switch Mode Power Supply (SMPS).*

1. INTRODUCTION

Solid state lighting technology is more common today [1]. Solid state lighting (SSL) is widely accepted as the energy efficient technology for general lighting [3]. Light emitting diode (LED) becomes more popular for lighting applications due to efficiency, low power utilization, pollution free, low manufacturing cost, long life time, very small in size and require very less cut-in voltage [4-6].

An LED driver is an electrical device which regulates the power to an LED or a string (or strings) of LEDs. An LED driver responds to the changing needs of the LED, or LED circuit, by providing a constant quantity of power to the LED as its electrical properties change with temperature. An LED driver is a self-contained power supply which has outputs that are matched to the electrical characteristics of the LED or LEDs. LED drivers may offer dimming by means of pulse width modulation circuits and may have more than one channel for separate control of different LEDs or LED arrays. The power level of the LED is maintained constant by the LED driver as the electrical properties change throughout the temperature increases and decrease seen by the LED or LEDs. Without the proper driver, the LED may become too hot and unstable, therefore causing poor performance or failure.
Compared to inefficient incandescent lighting, LED is an innovative technology. In order to effectively drive LED, the LED driver must be properly designed to support the LED advantages. Improper driver circuit will cause high power dissipation on the LED which will heat up the LED, thus reducing lifespan. The flyback LED driver is an attractive LED driving solution for low component costs and high efficiency [7]. Flyback SMPS is proven to deliver high power efficiency at low-cost Flyback topology as shown in Fig.1 has a simple design suitable for low power applications [9]. The flyback transformer serves as an energy storage medium, as well as providing isolation in practical application, simplifying design [10].
This paper is configured as follows. Section II includes basic flyback topology. Section III working and design consideration. Section IV discusses the obtained simulation results.
The final section concludes this research.

2. BASIC FLYBACK TOPOLOGY

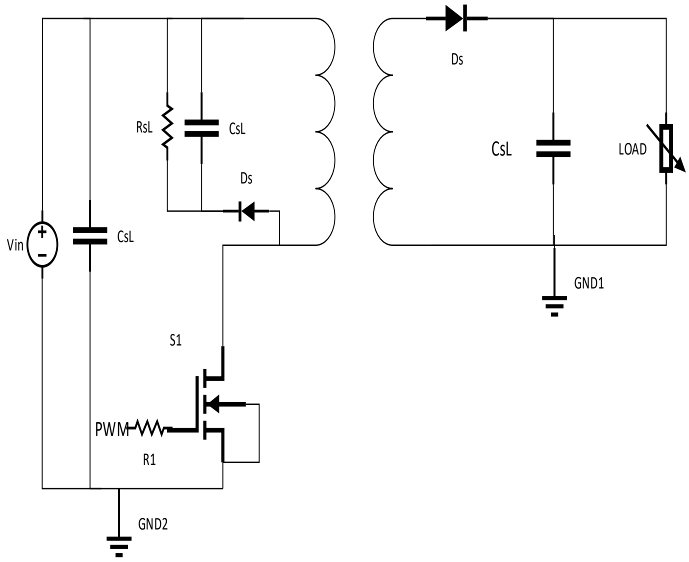


Fig.1 Basic Flyback Circuit

Flyback topology operates in a fundamentally different way. During their power transistor on time, they store energy in their power transformer while load current is supplied from an output filter capacitor. When the power transistor turns off, the energy stored in the power transformer is transferred to the output as load current and to the filter capacitor to replenish the charge it lost when it alone was delivering load current. The major advantage of this topology is that the output filter inductors required for all forward topologies are not required for flybacks. Especially for multi-output power supplies, this is a significant saving in cost and space. Flyback converter topology is shown in Fig.1. It is very widely used for output powers from about 150 down to under 5 W. Its great initial attraction-although it is not strictly so, as will soon be seen-is that it has no secondary output inductors as have all topologies. The consequent savings in cost and volume of the output inductors is a significant advantage.

3. WORKING AND DESIGN CONSIDERATION

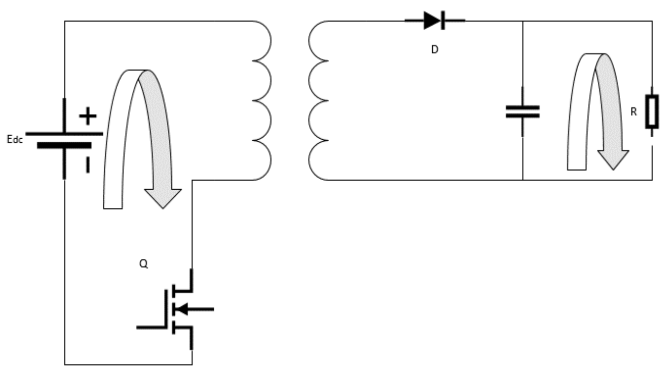
The schematic of a flyback converter can be seen in Fig. 1. It is equivalent to that of a buck-boost converter, with the inductor split to form a transformer. Therefore, the operating principle of both converters is very similar:

- When the switch is closed the primary of the transformer is directly connected to the input voltage source. The primary current and magnetic flux in the transformer increases, storing energy in the transformer. The voltage induced in the secondary winding is negative, so the diode is reverse-biased (i.e., blocked). The output capacitor supplies energy to the output load.
- When the switch is opened, the primary current and magnetic flux drop. The secondary voltage is positive, forward-biasing the diode, allowing current to flow from the transformer. The energy from the transformer core recharges the capacitor and supplies the load.

The operation of storing energy in the transformer before transferring to the output of the converter allows the topology to easily generate multiple outputs with little additional circuitry, although the output voltages have to be able to match each other through the turns ratio. Also, there is a need for a controlling rail which has to be loaded before the load is applied to the uncontrolled rails, this is to allow the PWM to open up and supply enough energy to the transformer.

Modes of Operation

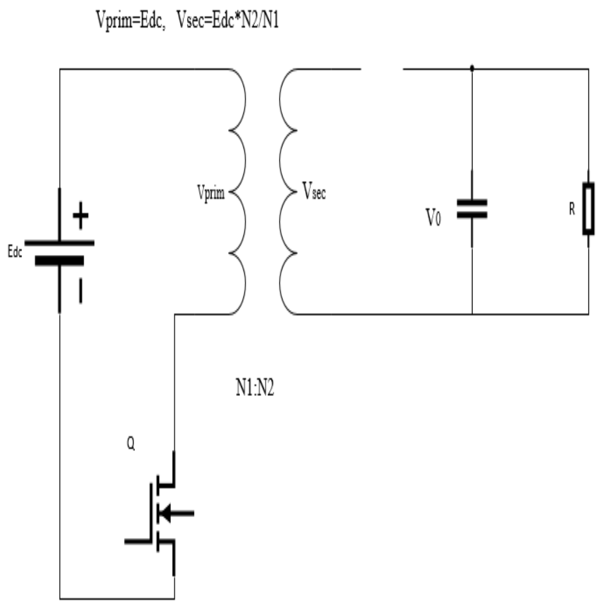
The principle of Operation Mode-1



When switch 'Q' is on, the primary winding of the transformer gets connected to the input supply with its dotted end connected to the positive side.

At this time the diode 'D' connected in series with the secondary winding gets reverse biased due to the induced voltage in the secondary (dotted end potential being higher).

Mode-1 Equivalent Circuit



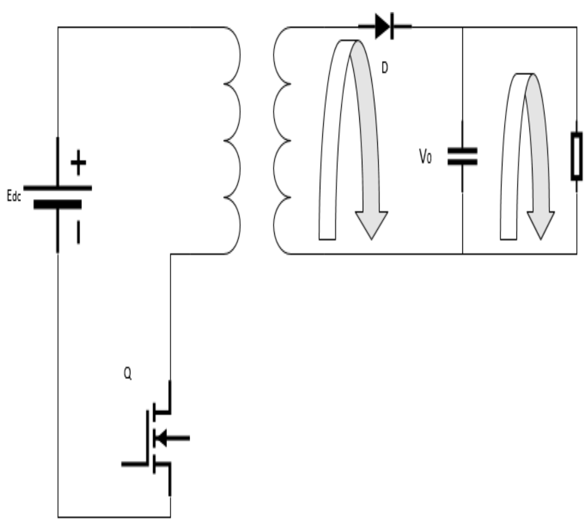
Mode 1: Switch is ON; Diode is OFF

$$E_{DC} = L_{pri} \times \frac{d}{dt} i_{pri}$$

At the end of Mode-1, the energy stored in the primary winding is

$$\frac{L_{PRI} \times L_P{}^2}{2}$$

The principle of Operation Mode-2

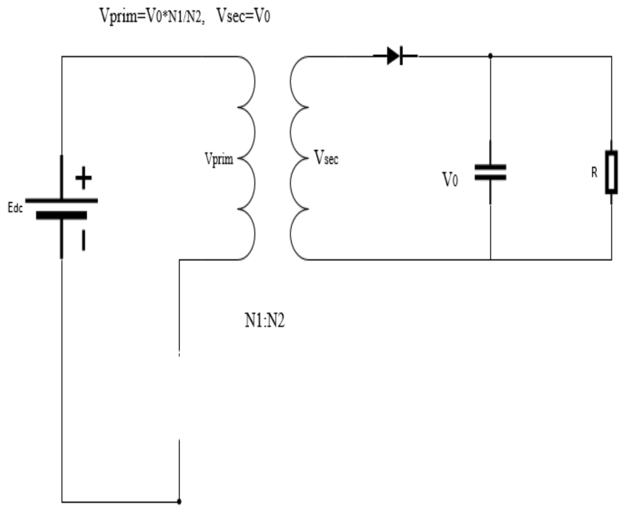


Mode 2: Switch is OFF, Diode is ON

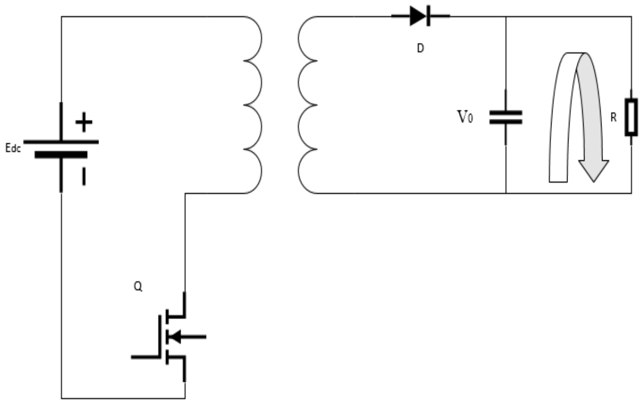
When Switch turns off, the current in the primary winding drops suddenly, the voltage across the primary winding reverses. The diode becomes forward biased. The secondary winding, while charging the output capacitor (and feeding the load), starts transferring energy from the magnetic field of the fly back transformer to the output in electrical form. If the off period of the switch is kept large, the secondary current gets sufficient time to decay to zero and magnetic field energy is completely transferred to the output capacitor and load. Flux linked by the windings remain zero until the next turn-on of the switch, and the circuit is under discontinuous flux mode of operation. Alternately, if the off period of the switch is small, the next turn on takes place before the secondary current decays to zero. The circuit is then under continuous flux mode of operation.

Mode-2 Equivalent Circuit

The primary and secondary windings of the flyback transformer don't carry current simultaneously. The fly-back transformer works differently from a normal transformer.

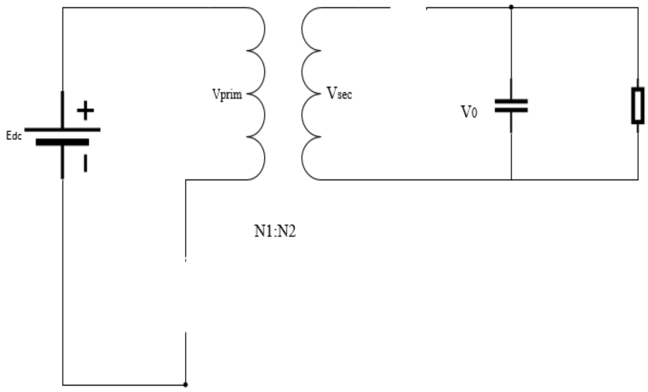


The principle of Operation Mode-3



After complete transfer of the magnetic field energy to the output, the secondary winding emf, as well as current fall to zero and the diode in series with the winding, stops conducting.

The output capacitor, however, continues to supply uninterrupted voltage to the load. This part of the circuit operation has been referred to as Mode-3 of the circuit operation.



During discontinuous mode, MOSFET is OFF; Diode is OFF. The output capacitor continues to supply uninterrupted voltage to the load.

Design Steps:

- Selection of converter Rating
- Selection of ferrite core
- Transformer calculation
- Output inductor design
- Output Capacitor design

a. Transformer calculations:

$$T_{on} = \frac{(V_o + 1)(\frac{N_p}{N_{sm}})(0.8T)}{\left(V_{dc(min)} - 1\right) + (V_o + 1)(\frac{N_p}{N_{sm}})}$$

$$V_{ms} = V_{dc} + \frac{N_p}{N_{sm}}(V_o + 1)$$

Where:

$V_{ms} - {''off''} transistor\ voltage\ stress$

$V_{dc} - maximum\ input\ dc\ voltage$

$\frac{N_p}{N_{sm}} \to \frac{Primary}{secondary} turn\ ratio$

$V_o - Output\ voltage$

- Primary Turns:

$$N_p = \frac{V_{dc(min)} \times T_{on}}{B \times A_e}$$

- Primary Inductance:

$$L_p = \frac{(V_{dc} * T_{on})^2}{2.5\ T\ P_o}$$

Output Capacitor Design:

$$V = I(T - t_{off})/C_o$$

4. SIMULATION AND RESULTS

CLOSE LOOP SIMULATION

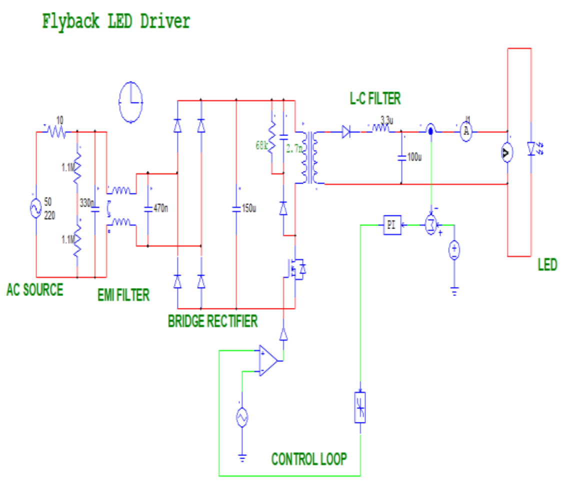


Fig.2 Close Loop Simulation of Proposed Topology

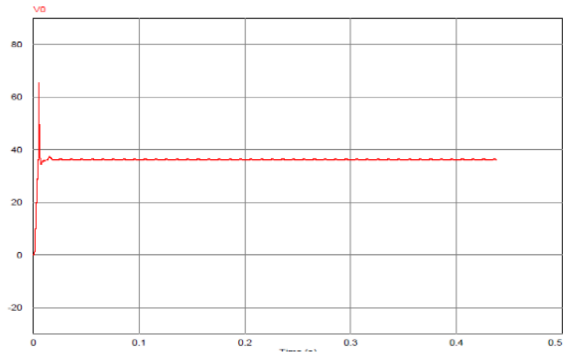


Fig.3 Output Voltage Waveform of Proposed Topology

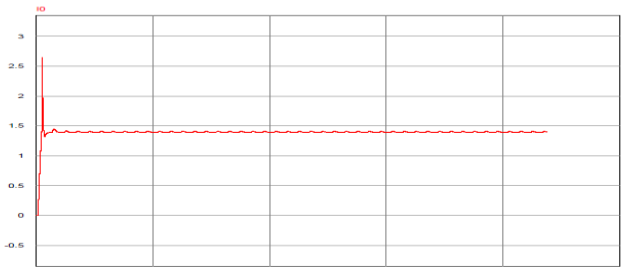


Fig.4 Output Current Waveform of Proposed Topology

5. CONCLUSION

The design shows an efficient, low cost LED driver design. The proposed design significantly improves the efficiency of the LED driver. However, in when implemented into hardware this might not be the case due to more disturbances.
The proposed design emphasizes simple topology, makes it very attractive for low-cost application, especially for lighting solution.

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