HIGH POWER FACTOR AND EFFICIENT LED DRIVE CIRCUITS: THE TRANSFORMED SINGLE-STAGE FLYBACK CONVERTER

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ABSTRACT:

A dynamic model for forward-flyback toggling DC-DC converters is presented in this study. Using a single power switch, a single input inductor, a fully capacitive output filter, isolation, minimum current variation across the output capacitor, and consistent frequency operating inside a standard pulse-width-modulation scheme are just a few of the many advantages of the suggested architecture. The proposed converter is one-of-a-kind and works reliably over a broad input voltage range; potential applications include power factor correction and multiple-output power supply. In traditional AC/DC flyback converters, the transformer's core loses significant amounts of energy due to an imbalance in current across the magnetizing inductor. The power factor is reduced at zero cross AC input voltage in conventional forward converters, despite the fact that they are capable of a high level of power conversion efficiency due to their low core loss. However, the proposed converter may be able to transfer power during the entire switching period and obtain a high power factor through the flyback operation since it can work as both forward and flyback converters throughout the on and off phases. In addition, regardless of the AC input voltage, the offset current passing through the transformer's magnetizing inductor can be effectively reduced by employing a current-balanced capacitor. This allows for a smaller overall transformer footprint and lower core loss. So, the proposed converter has excellent power factor and efficiency. A simulation model is developed in MATLAB/Simulink and then tested by running it on a simulation platform and comparing the results.

Keywords: Forward-Flyback converters; DC-DC converters;SingleSwitch design;
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1. INTRODUCTION

In recent years, LEDs' popularity for use in display and illumination applications has grown due to their high efficiency, long lifespan, and low environmental impact. Light-emitting diodes (LEDs) are gradually replacing incandescent bulbs and fluorescent fixtures. Due to its high efficiency and power density, switch-mode drivers are frequently used in LED applications. A power factor corrector and an isolated DC/DC converter are two of the power conversion stages found in LED lighting drivers. High power factor, robust output regulation, and low ripple voltage are all benefits of a two-stage arrangement, but it comes at the expense of a large system size, high production costs, and inefficient energy conversion. Therefore, low-power LED drivers often use single-stage drivers, while high-power applications typically use two-stage drivers.

As high-intensity LED bulbs become more widely available, they are gradually displacing traditional light sources like incandescent and fluorescent lamps. LEDs' brightness and hue can be adjusted by changing the current through them. Therefore, LED drivers need to provide precise control over the current they deliver. At the same time, low Voltage stresses and high Power Factor (PF) are becoming critical design requirements for LED driver systems. Applications that require precise regulation of output current typically employ a control method that relies on secondary-side current sensing, which might result in additional sensing-related losses (transformer).

Superior quality, compact size, light weight, reliability, and remarkable efficiency are all necessary for today's electronic systems. High-quality output voltage can be produced with linear regulators. The principal application for low-power levels is as low-dropout voltage regulators. Linear regulators use electronic components that operate in an active (linear) mode. In order to boost power, switching regulators are used. Power electronic semiconductor switches are used in switching regulators, which cycle between on and off states. When there is no power loss, switching regulators can transfer energy efficiently. Modern power electrical devices may function at very high frequencies. As transformers, filter inductors, and capacitors get smaller and lighter, operating frequencies go up. Furthermore, converters' dynamic properties improve as their working frequencies rise.

One form of dc-dc converter uses hard switching with pulse width modulation (PWM), while the other uses resonant and soft switching. In spite of its low cost, fast transient response, and accurate current control, the linear driver generates a lot of heat and isn't very energy efficient. Due to its high efficiency and high power density, the switch-mode driver is frequently used in LED applications. To achieve the highest possible efficiency and power factor, a number of different converter topologies are proposed, such as the forward and flyback converters.

2. LITERATURE SURVEY

Multiple recent articles were read in order to fully grasp DC-DC converters and LED propulsion technologies.

Isolated flyback converters are the focus of this paper, which introduces a novel approach to their design and simulation. Parasitic component models and non-parasitic component models are both taken into account. Continuous conduction mode (CCM) flyback converters are the focus of this paper's analysis, modeling, and collection of control solutions. This research highlights the value of transformer modeling when one or more outputs are required by an application.

In this article, Ting Qian and Brad Lehman offer an integrated magnetic dc-dc converter that is ideal for use in situations where a high input voltage is required. The input and output are connected serially and parallelly, respectively, in a design known as dual interleaved Fly back. The transformers have been combined into a single magnetic core with loose coupling, and the central and peripheral legs have been fully decoupled from one another. The void reduces voltage spikes caused by windings operating at different voltages. An proper coupling design minimizes current disturbance while the two transformers are coupled in a backwards arrangement.

A unique ZVZCS active clamped dual switch flyback converter was presented in the research. This converter has both primary and secondary switches that activate at zero volts. On the secondary side, a rectifier diode is utilized to switch at zero current. Slope correction enables a duty cycle greater than 50%, and also alleviates the problem of high voltage pressure on the primary switch in conventional flyback converters. Therefore, it's useful in situations when maximum efficiency, input voltage, and range are all required. The converter makes effective use of the energy from the defective inductor, hence an additional snubber is unnecessary.

Milanovi et al. investigate the issue of voltage surge-induced leakage inductance in transformers. They suggest using either dissipative RCD clamp circuits or non-dissipative LCD clamp circuits to lessen the impact of this problem. In each of the clamp circuits, a diode is used. The diode's reverse recovery charge causes a rise in the dissipation of the clamp circuits, which in turn causes the oscillation. In addition, it addresses the issue of ringing and suggests using an RC-RCD clamp circuit to reduce oscillation in the clamp diode. This clamp circuit can be used to increase the fly back converter's power-to-weight ratio.

The forward-flyback zero-voltage-switching (ZVS) DC-DC converter has been described in detail by Frank Chen and his team. This converter can effectively regulate and distribute electricity over a wide range of input voltages. The converter operates in a mode halfway between its continuous and discontinuous modes to achieve Zero Voltage Switching (ZVS). To lessen losses in the transformer core and boost overall efficiency, variable frequency with a consistent off-time is used. In the meantime, the proposed converter's viability and performance are evaluated by analyzing the power distribution between the forward and flyback approaches.

SINGLE-STAGE BALANCED FORWARD-FLYBACK CONVERTER

The forward and flyback converter topologies are combined in this article to create a single-stage balanced forward-flyback converter with excellent efficiency and power factor. There is a large offset current in the flyback converter's magnetizing inductor, which results in significant core losses and lower power conversion efficiency. In addition, conventional forward converters can achieve a high level of power conversion efficiency because of their low core loss, but the power factor is reduced because of a dead zone in the input current at zero cross AC input voltage. However, the proposed converter may be able to transfer power during the entire switching period and obtain a high power factor through the flyback operation since it can work as both forward and flyback converters throughout the on and off phases. Furthermore, the offset current flowing through the transformer's magnetizing inductor can be successfully mitigated by employing a current-balanced capacitor, regardless of the AC input voltage. This allows for a smaller overall transformer footprint and lower core loss. So, the proposed converter has excellent power factor and efficiency. The suggested forward-flyback converter's block diagram is shown in Figure 1.

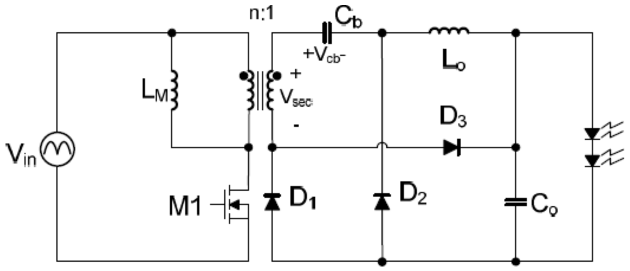

Figure1:Blockdiagram of forward-flyback converter

3.OPERATION PRINICIPLE

The proposed forward-flyback converter (shown in Figure 2) operates in two modes, illustrated by the waveforms shown there, depending on the conduction state of each switch.

The following assumptions are made to facilitate the analysis of the steady state mode:

With the exception of the diode it contains, M1 is a fantastic switch. The only problem with the transformer is the relatively high magnetizing inductance LM. Capacitor Co at the output and capacitor Cb at the DC block are both large enough to be treated as uninterruptible sources of DC voltage, Vo and Vcb.

10.

The considered circuit operates in the BCM, or boundary conduction mode.

Assuming M1 is blocked before t0, LM's stored energy is transferred to the load side via D3 and D1. Right now, ILM is charging Cb a charge as ILo wanders aimlessly about D2.

When the instantaneous luminous intensity (iLM) drops to zero, time t0, mode 1[t0t1] begins. When Mode 1 is engaged, Vin is multiplied by LM, increasing ILM in a linear fashion with a slope equal to Vin/LM. Although Vo is greater than the voltage across the secondary side of the transformer (Vsec), the voltage applied to the input side of the output LC filter (Vsec plus Vcb) is greater than Vo. D1's high conductivity facilitates the efficient forward transfer of input energy to the load side. Additionally, D1 can effectively limit the voltage across D2 to Vo, and this value can be represented as Vin/n+Vcb.

At time t1, Mode 2[t1t2] begins, and M1 is turned off. Mode 1 involves transferring energy from LM to the load side via D2 and D3. Transformer secondary current matches the energy discharged to charge the balancing capacitor Cb. At the same time, there is no resistance to the flow of electricity through Lo because of D2. ILM decreases linearly with a slope equal to n(Vo+Vcb)/LM when applied to LM. When the ILM value drops to zero, M1 is activated, and the process of cycling between Modes 1 and 2 begins again.

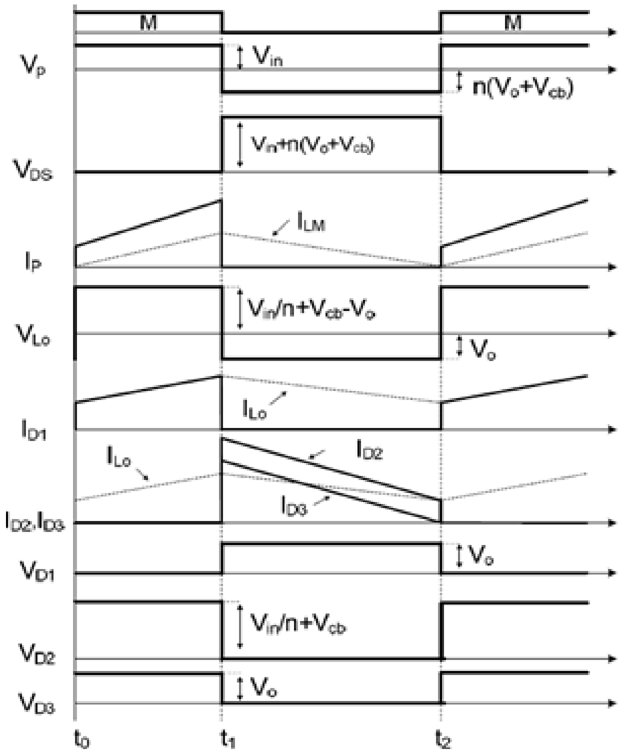

Figure2:Waveform of forward-flybackconverter

COMPLETE SIMULATION MODEL OF FORWARD-FLYBACK CONVERTER

The suggested converter using Cb can, with the help of Vcb, function as both a forward and flyback converter across the full input voltage range. The converter without Cb can transfer energy from the input to the output when the input voltage divided by the turns ratio (Vin/n) is greater than the output voltage (Vo). Not so when Vin/n is less than or equal to Vo, though. Because of this, the suggested converter, which includes a compensating capacitor Cb, displays a lower magnetizing offset current, which in turn results in less core loss and a more compact transformer.

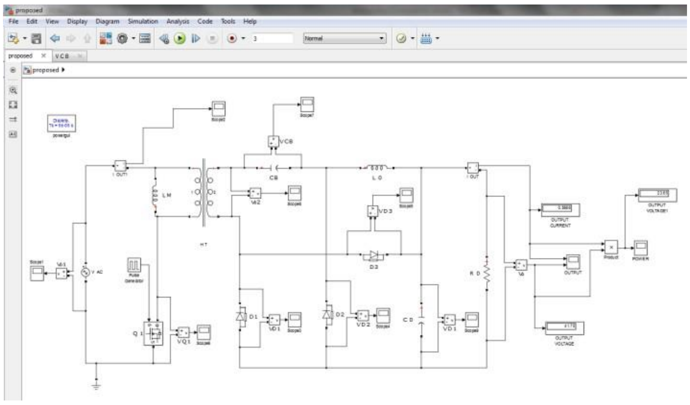

Fig 3: Simulation Model of a Proposed Forward-FlybackConverter

The electrical design parameters are

Table1:Design Parameters of Forward Flyback Converter

Parameters	Value
Input Voltage [Vin]	90V
Magnetizing Inductance [Lm]	1.8mH
Frequency	100KHz
Primary Voltage [V1]	100V
Secondary Voltage [V2]	180V
Balancing Capacitance [Cb]	100 µF
Output Capacitance [Co]	10mF
Output Resistance [Ro]	73.68Ω
Output Current [Io]	0.56A
Output Voltage [Vo]	42V
Output Power [Po]	24W

As shown in figure –the waveforms are as below:

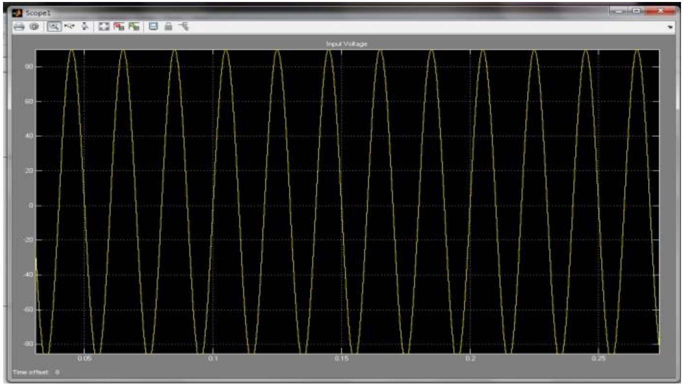

Fig4:Inputvoltagewaveform

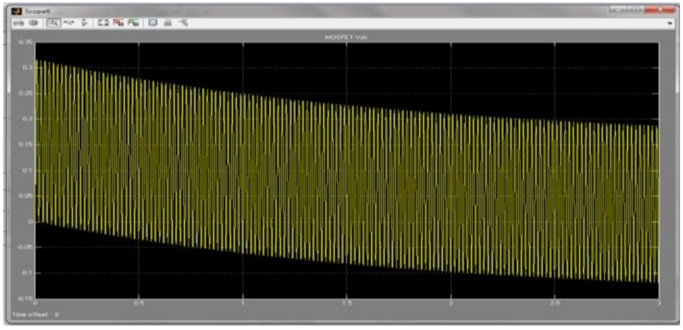

Fig5:MosfetVds waveform of PWM Switch for the Proposed Forward FlybackConverter

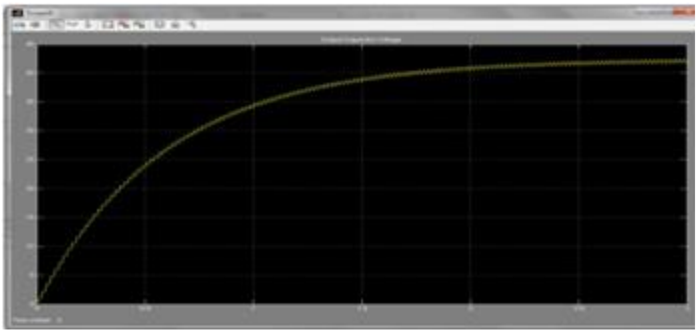

Fig 6: Output Capacitor Voltage waveform for the Proposed Forward Flyback Converter

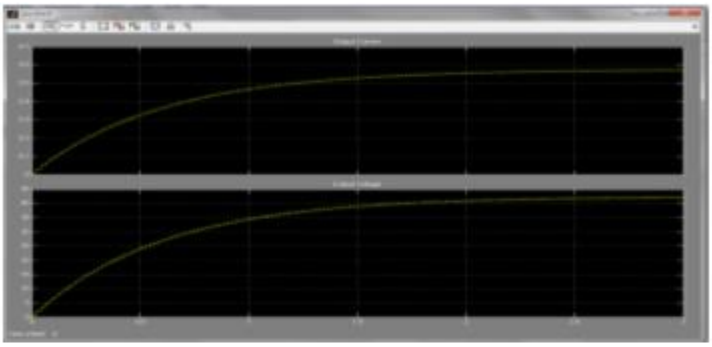

Fig 7: Output Current & Voltage waveform for the Proposed Forward Flyback Converter

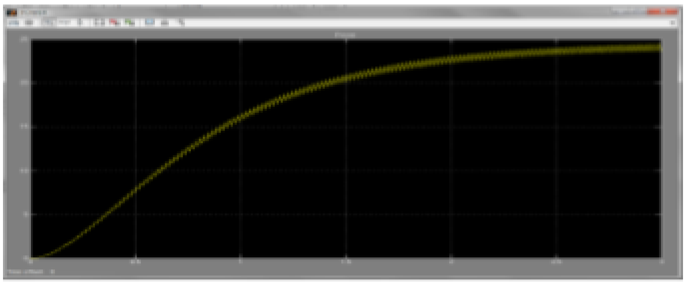

Fig8:Output Power waveform for the Proposed Forward Flyback Converter

5. CONCLUSION

This article delves into the science behind an LED-tailored balanced forward-fly-back converter with a single stage of power-factor adjustment. With its balancing capacitor in place, the proposed forward-fly back converter can switch between forward and fly back modes automatically, regardless of the input voltage. This results in a smaller transformer core and less core loss by reducing the magnetizing offset current. The proposed converter, therefore, can only reach its full efficiency and capacitance with the main power switch turned off. The forward converter is typically used in applications that require a power output of 100 to 200 watts and is more efficient in terms of energy use than the fly-back circuit. Simulation circuits tailored to LED applications are developed to test the effectiveness of the proposed designs. The capacity to accurately evaluate power factor and efficiency is a highlight of these circuits. Furthermore, the proposed circuit is able to transmit power efficiently throughout the entire time of the transition. Because of these merits, the proposed circuit is generally agreed upon as being excellent for numerous LED driver uses.

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