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Digital Regulation Scheme for Multimode Primary-Side Controlled Fly-Back Converter

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ABSRACT:

The fly back converters are used in both ac to dc and dc to dc conversion with galvanic isolation between the input and output and hence controlling techniques of fly back converter has become most popular method in recent years .In conventional fly back converter control is using an opto-coupler. These opto-couplers are highly temperature dependent. The output of the converter is feedback and controlled. Which is not providing better results as it depends on temperature. In proposed fly-back converter, eliminating the opto-coupler and adding the active clamp circuit. To avoid device voltage stress, switching loss, to achieve higher efficiency using two switch topology. In this proposed method of active clamp fly-back converter are used to solve these problems by using , Mat lab/Simulink model to be examine the system performance of PI based digital controller which will reduce the complexity (duty cycle control) . by this we achieved high efficiency ,stress free , soft switching operation and absorbed leakage inductance.

Index Terms: Active clamp, Fly back, High efficiency, Z-source, mosfet, digital regulation, multimode primary control, PI controller.

INTRODUCTION:

The commonly used fly-back converter requires a single controllable switch like, MOSFET and the usual switching frequency is in the range of 100 kHz. A two-switch topology exists that offers better energy efficiency and less voltage stress across the switches but costs more and the circuit complexity also increases slightly.

The present lesson is limited to the study of fly-back circuit of singles witch topology. With more and more emphasis on the environment protection and energy saving, the efficiency and standby power loss of the power supply are much concerned. For external power supplies, such as adaptors, the average efficiency instead of the full-load efficiency is more important to save the energy. Therefore, both the light-load efficiency and full-load efficiency need to be carefully considered, which creates new challenge for the power supply design. Fly-back converters are widely adopted for low-power offline application due to its simplicity and low cost. Usually, an RCD clamp circuit is necessary to dissipate the leakage energy during the switch is OFF.

And a well-coupled transformer with minimized leakage inductance is critical to achieve the high efficiency and to minimize the voltage spikes across the switch. However, a labor-intensive manufacturing process is required to produce these well-coupled transformers as well as passing the safety regulation. How to further improve the efficiency of a flyback converter still challenges the power supply designers. The first way to improve the efficiency is reducing the leakage inductance energy loss. The conventional RCD clamp circuit absorbed the leakage energy and dissipated it in the snubber resistor. If the leakage inductance is large, the dissipated energy is much larger than the energy stored in the leakage inductance due to part of the magnetizing energy fed to the snubber circuit during the commutation time, which deteriorate the efficiency.

The lossless snubber for single-end converter was proposed to recycle the leakage energy, but the snubber parameters makes the circulating energy relative large during normal operation, which limited the efficiency improvement. The active clamp flyback converter can recycle the energy in the leakage inductor and achieve soft switching for both primary and auxiliary switch. Although it has good performance in efficiency at full-load condition, it is sensitive to parameters variations. The variation of leakage inductance and snubber capacitor affects the conduction angle of the secondary-side rectifier, which lowers the efficiency. And the two active switches also increase the cost. Furthermore, the conventional complementary gate signal and constant frequency (CF) control method result in poor efficiency at light-load condition, which also leads to lower average efficiency. DC to DC converters are important in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries primarily.

Such electronic devices often contain several sub-circuits with its own voltage level requirement different than that supplied by the battery or an external supply (sometimes higher or lower than the supply voltage, and possibly even negative voltage). Additionally, the battery voltage declines as its stored power is drained. Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing. And digital controller methods used in new papers are frequency control methods where the frequency increases the stress on the switches. So here simple PI based digital control method is used for controlling.

PROBLEM STATEMENT:

In recent frequency based digital control ,if the frequencies are increasing ,switch voltage stress is also increases. so these type of control methods fails to increase the life span of the MOSFET'S.

Using active clamp technique, the voltage stress are reduced so in this digital control technique output is maintained cost without using frequency control we are using duty cycle control so the stress of the switch is maintained and control is also happen and in this new technique there is no need of new IC's normal controller can control the voltage There is no need of digital controller which is based on frequency.

LITERATURE SURVEYACTIVE CLAMP TECHNIQUE

With more and more emphasis on the environment protection and energy saving, the efficiency and standby power loss of the power supply are much concerned. For external power supplies, such as adaptors, the average efficiency instead of the full-load efficiency is more important to save the energy. Therefore, both the light-load efficiency and full-load efficiency need to be carefully considered, which creates new challenge for the power supply design. Fly back converters are widely adopted for low-power offline application due to its simplicity and low cost. Usually, an RCD clamp circuit is necessary to dissipate the leakage energy during the switch is OFF.

And a well-coupled transformer with minimized leakage inductance is critical to achieve the high efficiency and to minimize the voltage spikes across the switch. However, a labor-intensive manufacturing process is required to produce these well-coupled transformers as well as passing the safety regulation. How to further improve the efficiency of a fly back converter still challenges the power supply designers. The first way to improve the efficiency is reducing the leakage inductance energy loss. The conventional RCD clamp circuit absorbed the leakage energy and dissipated it in the snubber resistor. If the leakage inductance is large, the dissipated energy is much larger than the energy stored in the leakage inductance. Due to part of the magnetizing energy fed to the snubber circuit during the commutation time, which deteriorate the efficiency.

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The lossless snubber for single-end converter was proposed to recycle the leakage energy, but the snubber parameters makes the circulating energy relative large during normal operation, which limited the efficiency improvement [10]. The active clamp flyback converter can recycle the energy in the leakage inductor and achieve soft switching for both primary and auxiliary switch Although it has good performance in efficiency at full-load condition, it is sensitive to parameters variations. The variation of leakage inductance and snubber capacitor affects the conduction angle of the secondary-side rectifier, which lowers the efficiency. And the two active switches also increase the cost. Furthermore, the conventional complementary gate signal and constant frequency (CF) control method result in poor efficiency at light-load condition, which also leads to lower average efficiency. Other topologies with two active switches in half-bridge structure can absorb the leakage energy with pulsewidth modulation control or resonant control, such as asymmetrical half-bridge (AHB), asymmetrical flyback, or LLC converter [19] they can achieve soft switching for main switches and high efficiency, but most of them are not suitable for wide input range application as usually required for universal input condition without front-end power factor corrected (PFC)converter.

DIGITAL CONTROL TECHNIQUE:

In recent years, the primary-side control technique of flyback converter increasingly draws people's attention. In conventional flyback converters the output voltage or output current is regulated by utilising an opto-coupler and error amplifier feedback loop so as to achieve isolation between input and output. Opto-couplers' transfer function is highly non-linear and dependent on both time and ambient temperature. This drawback imposes an upper constraint on the converter operating temperature, efficiency and size In contrast, the primary-side control scheme achieves output regulation without the feedback loop from secondary side.

Owing to its elimination of opto-coupler, this type of converter results in lower cost, higher power density, lower standby power and simpler control circuit [5By replacing the analog control to Digital control the is proposed in paper has a new digital IC is introduced to reduce the complexity. But frequency control is complex to control so in this thesis we have used a PI based digital control which will reduce the complexity. And about active clamp technique for reducing the switch stress is also discussed.

PROPOSED SYSTEM:

Fly-back converter is the most commonly used SMPS circuit for low output power applications where the output voltage needs to be isolated from the input main supply. The output power of fly-back type SMPS circuits may vary from few watts to less than 100 watts. The overall circuit topology of this converter is considerably simpler than other SMPS circuits. Input to the circuit is generally unregulated dc voltage obtained by rectifying the utility ac voltage followed by a simple capacitor filter. The circuit can offer single or multiple isolated output voltages and can operate over wide range of input voltage variation. In respect of energy-efficiency, fly-back power supplies are inferior to many other SMPS circuits but its simple topology and low cost makes it popular in low output power range. This project proposes a flyback converter with a new non complementary active clamp control method. With the proposed control method, the energy in the leakage inductance can be fully recycled. The soft switching can be achieved for the main switch and the absorbed leakage energy is transferred to the output and input side. Compared to the conventional active clamp technique, the proposed methods can achieve high efficiency both for heavy-load and light-load condition, and the efficiency is almost not affected by the leakage inductance. As well as digital control introduced in this is based on PI controller. The detailed operation principle and design considerations are presented. And this can be carried out in a Simulink/matlab.

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FLYBACK CONVERTER:

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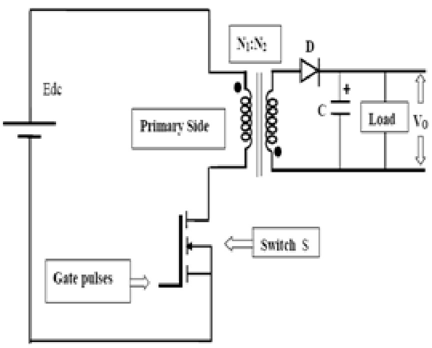
BASIC TOPOLOGY OF FLY-BACK CONVERTER



Flyback converter

PRINCIPLE OF OPERATION:

During its operation fly-back converter assumes different circuit-configurations. Each of these circuit configurations have been referred here as modes of circuit operation.

The complete operation of the power supply circuit is explained with the help of functionally equivalent circuits in these different modes.There are 8 modes of operation for the circuit:

Mode 1 (to-t1): At to, the primary switch Sw is ON, and the auxillary switch Sa is OFF. In this mode, the primary side current Ip increases linearly, and the energy is stored in the magnetizing inductor.

Mode 2 (t1-t2): At t1, Swis turned OFF, and Cossis charged up by the magnetizing current. The drain-source voltage Vds_Sw of main switch Sw increases linearly, due to relative large magnetizing inductance. The end of this mode happens when the drain-source voltage Vds_Swreaches the input voltage Vin plus the clamp voltage Vc, ie, Vin + Vc . In this mode, the turn-on of output diode rectifier DR depends on the clamp voltage Vc and the ratio of leakage inductance and magnetizing inductance, ie, Lk/Lm. The secondary – side rectifier DR turns ON once the Vc reaches (1+m)NVo. Then,onceVds_Sw reaches Vin + Vc, and the secondary – siderectifier DR also turns ON.

Mode 3 (t2-t3): At t2, when the voltage Vds_Sw reaches Vin+Vc, the antiparallel diode of Sa turns ON and the output dioderectifier DR also turns ON. The energy stored in the magnetizing inductor is delivered to the output, and the energy in the leakage inductor is absorbed by the clamp capacitor.The leakage inductor current Ip decreases linearly when the clamp capacitor is large and the circuit is lossless, ie, during this mode, the difference between the primary and magnetizing current is delivered to secondary side. This mode ends as soon as the current in the leakage inductor reaches zero. Then all the magnetizing current is transferred to secondary side.

Mode 4 (t3-t4): At t3, as the current through leakage inductance reaches zero, the antiparallel diode of Sa is OFF.Now the magnetizing current delivered to the load decreases linearly.

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Mode 5 (t4-t5): At t4, as the magnetizing current reaches zero,DR turns OFF. Then a parasitic resonance occurs between ,Lm and Coss.

Mode 6 (t5-t6): At t5, auxillary switch Sa turns ON. The voltage across leakage inductor Lk and magnetizing inductorLm is clamped to Vc and DR turns ON. Then current through Lk increases reversely and the magnetizing current ILmalso increases reversely, but the magnitude will be smaller than leakage current. These negative current will achieve ZVS of main switch Sw. The absorbed leakage energy in Mode 3 willbe transferred to output side and leakage inductor again. The auxillary switch ON time determines the clamp voltage.

Mode 7 (t6-t7): At t6, the auxillary switch Sa is turned OFFand the negative current Ip discharges parasitic capacitor loss.If the leakage energy is larger than the parasitic capacitor energy the secondary DR keeps ON, and the difference between Ip and ILm is fed to secondary side. Once the leakage energy becomes smaller than that of parasitic capacitor, the magnetizing inductance also helps to achieve soft switching.As soon as the leakage inductor current Ipreaches magnetizing inductor current ILm, the DR is OFF and then both the magnetizing inductance and leakage inductancedischargeCoss.

Mode 8(t7-t8): At t7, the output capacitor Cossvoltage is decreased to zero and then the antiparalleled diode of main switch Sw turns ON. Here, the primary-side switch Swshould be turned ON before the primary current Ipchanges the polarity. If the leakage energy ELk is larger than parasiticcapacitor energy ECoss, then leakage energy alone will help to achieve ZVS operation of the main switch.ELk = ½ Lk≥ ECoss = ½ Coss .If the leakage energy is smaller than parasitic capacitor energy, then themagnetizing energy ELmis also used to realize ZVS operation. ½ Lk + ½ Lm ≥ECoss = 1/2Coss For CCM condition, Mode 5 does not exist and only the leakage energy can be used to achieve ZVS.

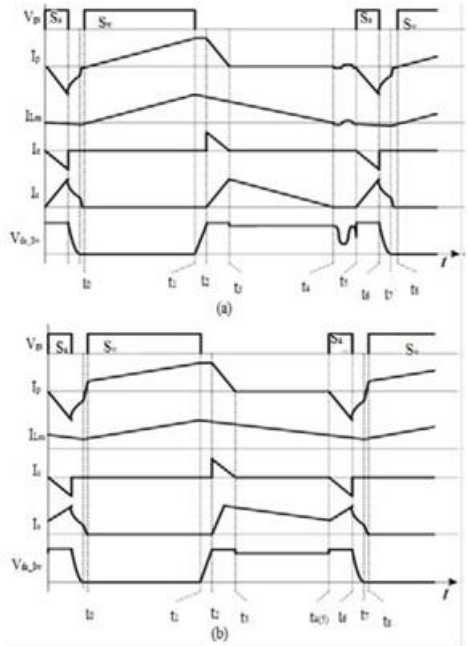

Figure 2: Steady-state operation waveforms with proposed non complementary control method. (a) DCM operation. (b)CCM operation

PRINCIPAL OF OPERATION:

This paper presents a Z-source converter based flybackconverter with a new active clamp technique, to minimie the leakage energy and achieve soft switching for the main switch. The power stage is same as conventional active clamp circuit, but the control methodology and principle of operation will be different.Flyback derived topologies are widely adopted for low power application due to its relative simplicity compared to other topologies. Active clamp based flyback topology is usedto recycle transformer leakage energy while attaining minimum switch voltage stress. The incorporation of active clampflyback circuit also serves to attain zero voltage switching for both primary and auxillary switches. ZVS also reduces turn-off di/dtof the output rectifier, thus minimizing rectifier switching losses. The Zsourceconverter, which is aunque impedance network, is incorporated betweeen the converter main circuit and power source to achieve high efficiency. The Z-source converter is actually a buck-boost converter that has wide obtainable voltage.

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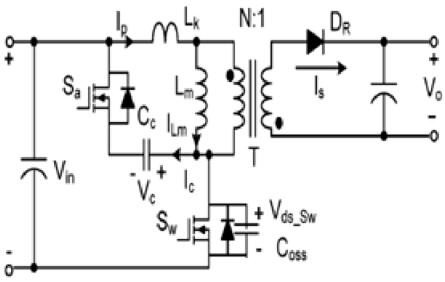
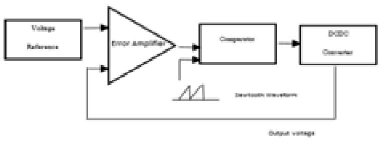
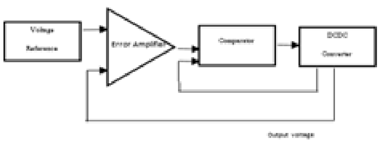
In this proposed method, the auxillary switch is turned ON for a short time before the primary switch is turned ON. And recycled leakage energy will achieve soft switching of the main switch. This reduces the circulating energy and thus the circuit can achieve high efficiency at any condition. Figure 1 shows the circuit diagram of the proposed z-source converter based active clamp flyback converter. In the figure, Lm is the transformer magnetizing inductance,Lkis the transformer leakage inductance. Let DR be the output diode rectifier and Sw, Sa be the primary and auxillary switches. Sacan be NMOS or PMOS. The equivalent parasitic capacitance of Sw, Saand the parasitic winding capacitance of the transformer is represented by Coss. N is the transformerturns ratio, and Vois the output voltage. **Figure**Topology of the active clamp flyback Converter For simplifying analysis in steady state circuit operation, the clamp voltage is assumed to be constant. The waveforms of DCM and CCM operation are shown in Figure



Topology of the active clamp fly-back converter

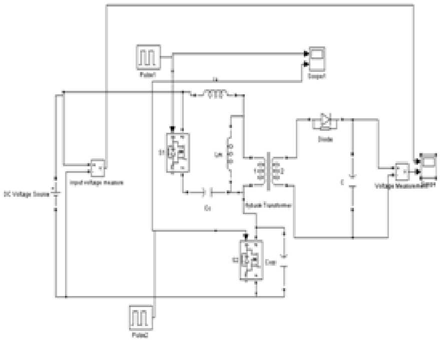
Closed Loop Control Circuit



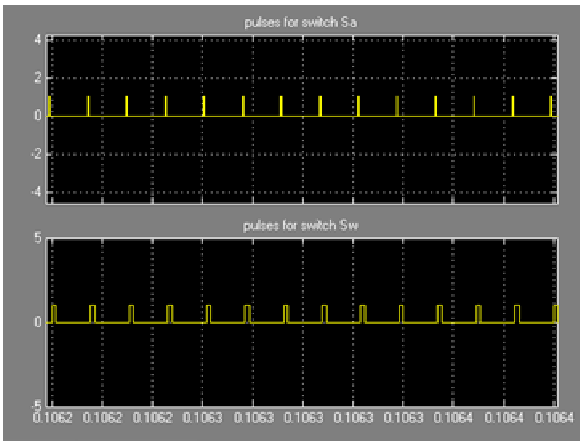


SIMULATION CIRCUIT:

Simulation result of proposed circuit

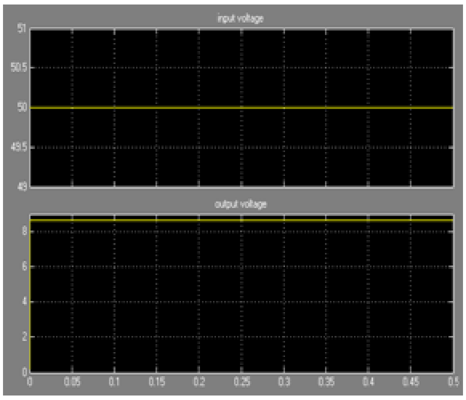


PULSE WAVEFORMS:



INPUT AND OUTPUT VOLTAGE:

CLOSED LOOP WITHOUT ACTIVE CLAMP:



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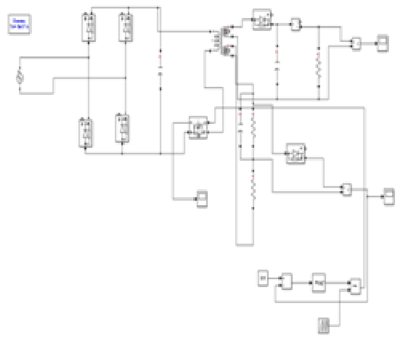
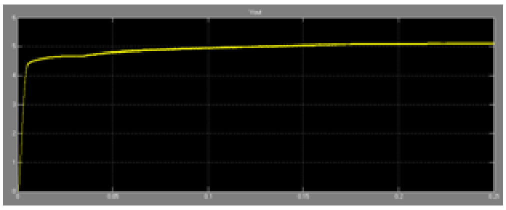
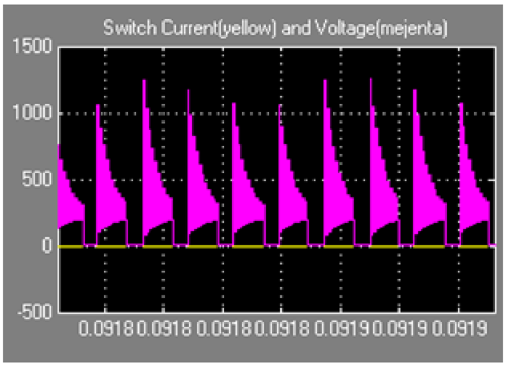
Proposed circuit without clamp-results



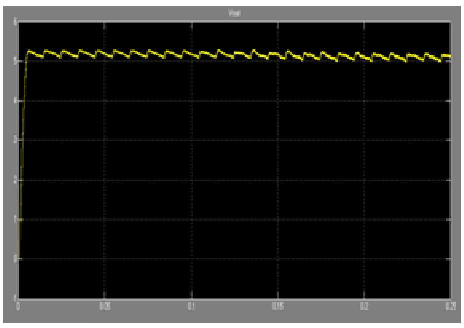


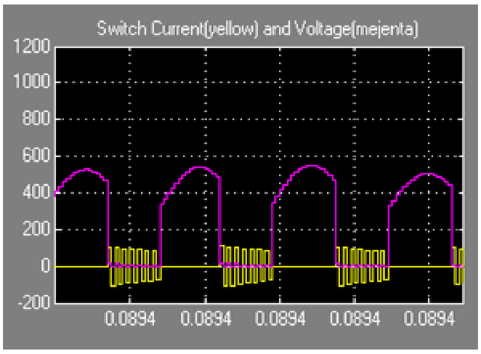
Switch current and voltage waveforms



It can be seen from above figure switch voltage is reaching more than 1000V as the switching frequency is high. So the converter losses are more due to this. The output voltage is stable at 5V as the digital control is applied.

CLOSED LOOP WITH ACTIV CLAMP:





It can be seen from above figure switch voltage is 550V as the active clamp technique is used. So the converter losses are less due to this active clamp. The output voltage is stable at 5V as the digital control is applied. This is known as softswitching.

Design specifications:

Requirements	Configurations
Input voltage	230v
Output voltage	5v
frequency	65khz
controller	Digital controller
base	Pi controller
concept	Voltage regulation active clamp technique

Advantages:

- Voltage stress is reduced nearly 40% so efficiency is improved.
- Controlled complexity**.**
- Achieved regulated voltage.
- Soft switching operation is achieved.
- Recycled leakage energy is achieved.

Applications:

- Used for mobile charging
- Used for battery charging in electrical vehicles
- Laptop based battery charger.

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Future enhancement:

- Hardware can be implemented as a prototype and it can be tested with above said applications.
- Arduino based digital control can be applied in the hardware.

CONCLUSION:

This paper proposes a high efficiency flyback converter with new active clamp control method. The proposed circuit has very attractive features, such as low device stress, soft switching operation. All the advantages make it suitable for low-power offline application with strict efficiency and standby power requirement. A detailed theoretical analysis for the parameters design is presented in the paper. And the simulation is done which shows the effectiveness of digital control and active clamp technique.

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