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# Dual Switch Forward & Flyback Converter: A Comparison

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## Abstract

**This paper presents a comparison of dynamic models for dual switch flyback and forward switching DC-DC converters. The proposed models have significant advantages such as dual switch technique, single-input inductor, purely capacitive output filter, isolation, low current ripple through the output capacitor and operation at constant frequency in a conventional pulse-width-modulation scheme. The new practical converter operates over a wide input-voltage range and can be employed in power factor correction and multiple-output power supplies. Comparing with the current existing models in published literatures, several factors are taken into account, such as anomalous loss in magnetic cores, differential inductance and leakage inductance. In order to obtain accurate parameters, modeling is performed to calculate some key parameters of transformer, capacitor and operating frequency. A simulation model in MATLAB/Simulink is built & the developed model is validated by executing the model on a simulation platform and several performance metrics are obtained and verified.**

***Keywords:*** *Flyback, Forward, Dual Switch converters; AC-DC converters; Inductor design;*

## 1. Introduction

There is an increasing demand in modern power electronics for high density power converters. In most cases, the size of the magnetic components, including transformers and inductors, significantly influences the overall profiles of the converters. Integrated magnetic techniques seem to be suitable solutions for high density application. The attraction is that transformers and inductors are combined in a single core, and therefore, cost and size of the converters may be reduced. Generally, there are two dominant types of isolated topologies using integrated magnetics: buck mode topologies, such as forward, push–pull, half-bridge and full-bridge, and buck-boost mode topologies, such as dual Flyback and Forward converters. Electronic switch-mode DC to DC converters convert one DC voltage level to another, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components (capacitors)[1]. This conversion method is more power efficient (often 75% to 98%) than linear voltage regulation (which dissipates unwanted power as heat). In these DC-to-DC converters, energy is periodically stored into and released from a magnetic field in an inductor or a transformer, typically in the range from 300 kHz to 10 MHz. By adjusting the duty cycle of the charging voltage (that is, the ratio of on/off time), the amount of power transferred can be controlled. Usually, this is applied to control the output voltage, though it could be applied to control the input current, the output current, or maintain a constant power. Transformer-based converters may provide isolation between the input and the output. In general, the term "DC-to-DC converter" refers to one of these switching converters. These circuits are the heart of a switched-mode power supply.

At higher power levels switching regulators use power electronic semiconductor switches in on and off states. Since there is a small power loss in these states, switching regulators can achieve high energy conversion efficiencies. Modern power electronic switches can operate at high frequencies. The higher the operating frequencies, the smaller and lighter the transformers, filter inductors and capacitors. In addition, the dynamic characteristics of the converters improve with increasing operating frequencies. Pulse-width modulation (PWM) allows control and regulation of the total output voltage. This approach is also employed in applications involving alternating current, including high-efficiency dc-ac power converters (inverters and power amplifiers), ac-ac power converters, and some ac-dc power converters (low-harmonic rectifiers)[2]. The objectives of this paper are to present a detailed analysis of the two-switch flyback & forward DC–DC converter, including the switch output capacitance, and the transformer design.

## 2. Assumptions

The following simplifying assumptions are made before proceeding to the detailed analysis of the circuit[3]:

- ON state voltage drops of switches and diodes are neglected. Similarly, leakage currents through the off

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state devices is assumed zero. The switching-on and switching-off times of the switch and diodes are neglected.

- The transformer used in the circuit is assumed to be ideal requiring no magnetizing current, having no leakage inductance and no losses.
- The filter circuit elements like, inductors and capacitors are assumed loss-less.
- For the simplified steady-state analysis of the circuit the switch duty ratio ($\delta$), is assumed constant.
- The input and output dc voltages are assumed to be constant and ripple-free. Current through the filter inductor (L) is assumed to be continuous.

## 3. Dual switch flyback converter

Flyback 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 Flyback type SMPS circuit may vary from few watts to less than 100 vats. The overall circuit topology of the circuit 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 [4]. In respect of energy-efficiency, Flyback power supplies are inferior to many other SMPS circuits but its simple topology and low cost makes it popular in low out power range. The commonly used Flyback converter requires a single controllable switch like MOSFET and the usual switching frequency is in the range of 100 KHz.

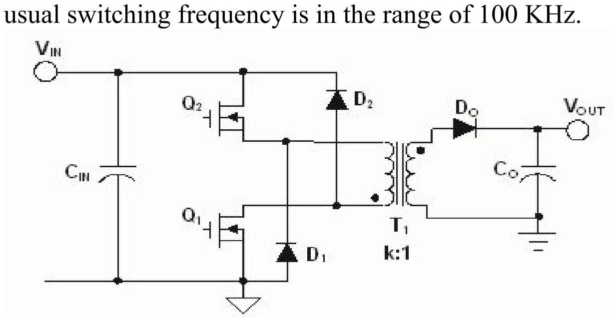


Fig 1: Dual Switch Flyback Converter

A two switch topology exits that offers better energy efficiency and less voltage stress across the switches. However, traditional single switch flyback DC-DC converter suffers from low utilization of transformer, high switch voltage stress and severe EMI. A variety of soft-switching techniques either passive-clamping or active-clamping methods have been presented in open literatures which have well solved the problem of voltage spike caused by leakage inductor, but the voltage stress is still so high that it is inapplicable to high voltage occasions. The traditional dual switch flyback converter conquered the demerit of high switch voltage stress, whose two main switches just bear input voltage when they are off.

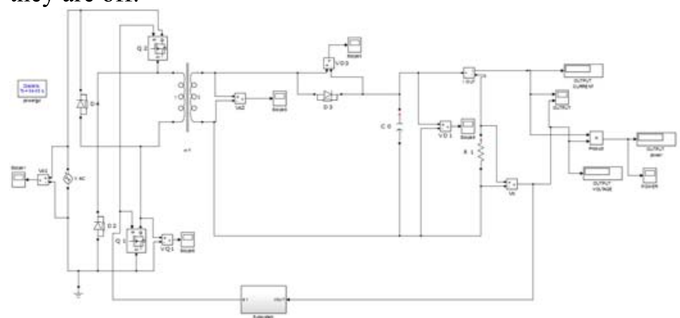

Fig: 2 Simulink diagram of Dual Switch Flyback Converter

Additionally, energy of leakage inductor feedbacks to input source, no snubber is needed. However, the duty cycle this kind of topology cannot exceed 50% and hard switching operation is commutated. Thus it cannot be utilized in wide input voltage application. Though some improved topologies, which have the advantage of wide duty cycle, are also proposed, meanwhile the demerits are obvious such as complicated control strategy or topology structure, one of the main switches inevitably subjecting to voltage spike.

The two-switch flyback DC–DC converter is an extended version of the conventional single-switch flyback converter. An additional switch and two clamping diodes serve as a simple, but an effective way to limit the switch overvoltages, which occur in the conventional single-switch flyback converter due to the ringing of the resonant circuit formed by the transformer leakage inductance and the transistor output capacitance. The clamping diodes in the two-switch flyback topology clamp the maximum voltage across each switch equal to the DC input voltage.

The flyback pulse-width modulated (PWM) DC–DC power converter is one of the most commonly used converters in the industry for low-power applications. The main drawback of the single-switch flyback converter is the high turn-off voltage stress suffered by the switch. The high-voltage transients are caused by the resonant behavior of the transformer leakage inductance and the transistor output capacitance, resulting in higher conduction and switching losses. A switch with higher voltage rating must be selected to withstand the turn-off transient voltage.

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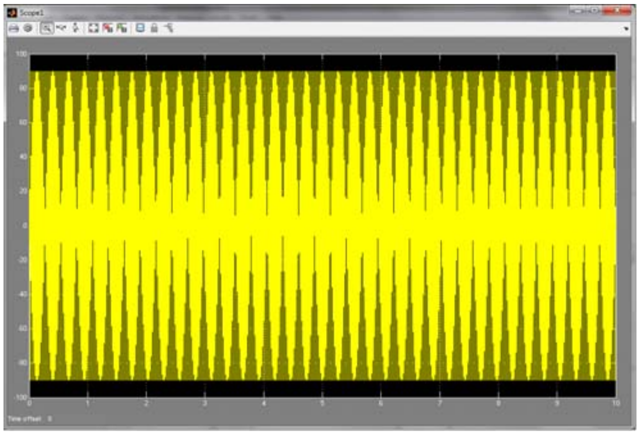

Fig 3: Dual Switch Flyback Converter Input Voltage

A switch with higher-voltage blocking capability is usually accompanied by a higher on-resistance $R_{DS}$, resulting in increased conduction losses. As a solution, several topologies of the single-switch flyback converter with active-clamp circuit have been proposed to reduce the switching losses by achieving soft switching. However, the switches in converters suffer from high voltage stress as the maximum voltage across the switch is the sum of the DC input and the reflected output voltages. In addition, the gate-drive circuit is complex as the main switch and the auxiliary switch are driven complimentarily. Addition of a power MOSFET and two clamping diodes to the single-switch flyback converter leads to the two-switch flyback PWM DC–DC converter, which effectively limits the switchover voltage.

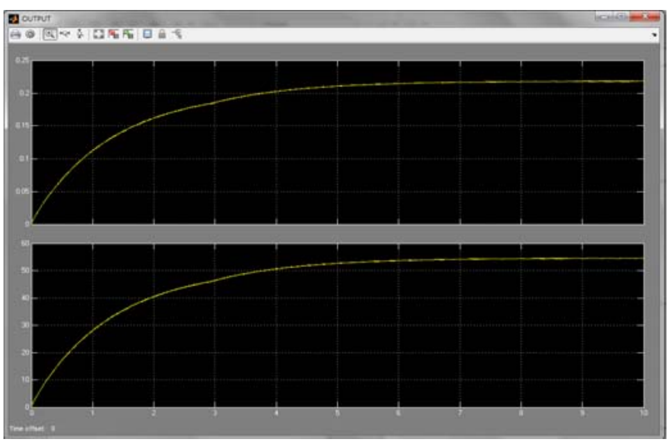

Fig 4: Dual Switch Flyback Output Current & Output Voltage

The advantages of Dual Switch Flyback Converter can be listed as below [5]:

- Low Standby Power Consumption
  - ➢ $P_{IN}$<0.5W @230$V_{ac}$ with $P_O$=0.25W
  - ➢ $P_{IN}$<0.25W@ 230$V_{ac}$ with no load
- High Efficiency
  - ➢ Leakage inductance energy is recycled to the input and snubber circuitry is not required
  - ➢ 500V MOSFETs can be used in the primary side
  - ➢ Low switching loss with valley switching in the primary side
  - ➢ Lower voltage stress on the secondary side rectifier
  - ➢ Variable PFC output voltage technique can be used to improve low line efficiency of the entire system
- Easy Design
  - ➢ Same as well known conventional Flyback converter design
  - ➢ Easy transformer mass production
  - ➢ Ultra low profile transformer can be used without concern of leakage inductance
- Low Electro Magnetic Inductance
  - ➢ Drain voltage overshoot is clamped to input voltage
  - ➢ Valley switching

## 4. Dual Switched Forward Converter

The forward converter remains as an industry workhorse in low-power DC/DC conversions. Recent development has significantly enhanced the performance and, in the mean time, increased the number of forward topologies that are available for a designer to choose from. Hence, selecting a best suitable forward topology for a given application becomes an important and challenging task. Dual-switch forward converter is the preferable candidate in occasion of medium-low power range application under high-line input due to lower voltage stress of switches for the very topology.

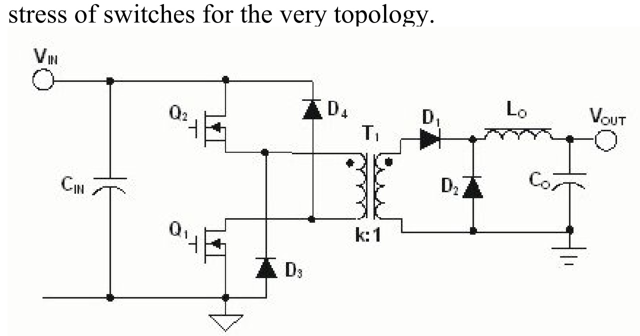


Fig 5: Dual Switch Forward Converter

The basic operation is as follows. Fig. 1a shows transistors Q1 and Q2, which turn on together, transferring energy through the transformer primary into the secondary. On the secondary, the forward rectifying diode conducts, transferring the energy into the output filter and load. When transistors Q1 and Q2 are turned off, the transformer magnetizing current flows through the now forward-biased diodes D1 and D2 and then back into the source as shown in fig. 1b. The diodes conduct until all the magnetizing energy in the primary, along with the energy stored in the leakage inductances, is returned to the input supply. Since diodes D1 and D2 clamp the input voltage, no snubber circuit is required. Any overshoot beyond the input voltage needs to be managed with a proper circuit layout to minimize stray inductances[6]. On the secondary, the freewheeling diode conducts as shown, transferring the output inductor energy to the load. During the non-power delivery cycle of the primary, proper transformer reset time is achieved when the ON time is less than its OFF time (duty cycle is less than 50 %). In other words, the primary winding itself acts as the reset winding. Having the OFF time longer than the ON time will always reset the transformer.

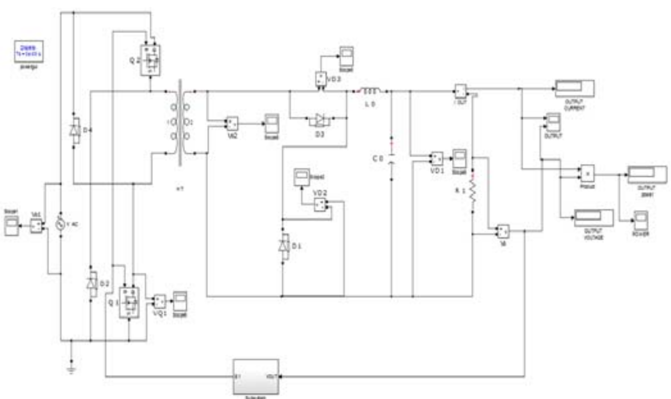

Fig 6: Simulink diagram of Dual Switch Forward Converter

However duty cycle of the conventional dual-switch topology is less than 50%, which influences its adaptability of wide-range input application. In order to supply appropriate topology for application of medium-low power range under high-line input, asymmetrical dual-switch forward topology is presented in this paper.

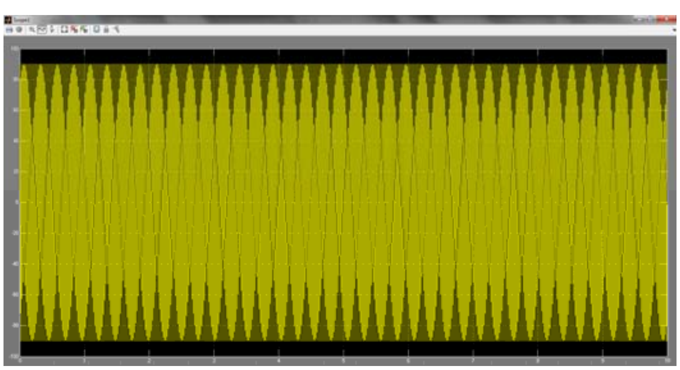

Fig 7: Dual Switch Forward Converter Input Voltage

The presented topology features both lower voltage stress of switches and good adaptability of wide range input.

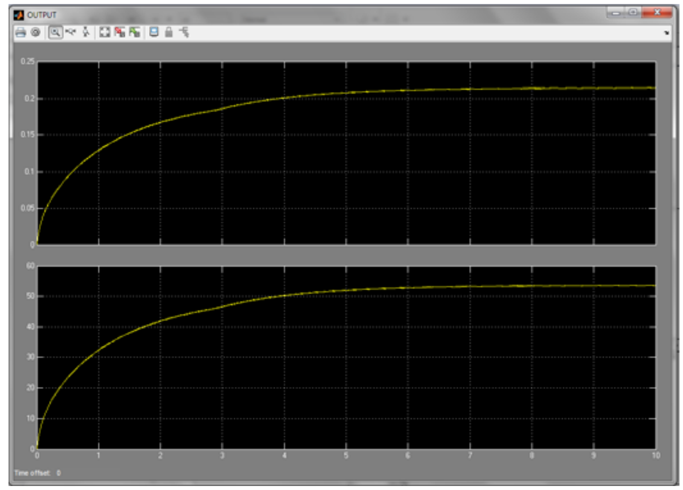

Fig 8: Dual Switch Forward Output Current & Output Voltage

In the case of the two-switch forward, the core is demagnetized via both diodes so that no auxiliary winding is required. For the active-clamp forward, the capacitor on the transformer generates a higher negative voltage, so that the demagnetization is achieved in a shorter time. This means that duty cycles higher than 50% are possible.

The two-switch forward converter is a widely used topology and considered to be one of the most reliable converters ever. Its benefits include the following[7]:

- Bullet proof operation: no timing issues or dead time requirements, and no chance of "shoot-through"
- No MOSFET body diode conduction under any condition
- No snubber circuitry required
- MOSFET voltage stress is limited to maximum supply voltage
- Simplicity of operation over a wide range of input voltages and load conditions
- Ability to handle multiple isolated outputs

## Conclusion

Flyback and forward topologies are good candidates for step up DC-DC converter application due to their simplicity and low cost, while achieving high efficiency and wide voltage operation range. In contrast with the flyback converter, where there are two distinct phases for energy storage and delivery to the output, the forward converter uses the transformer in a more traditional manner, to transfer the energy directly between input and output in the one step. Derived from the simple buck converter, the forward converter delivers energy from the input source to the output filter inductor during the on time of the main switch. In contrast, the flyback converter delivers energy to the output filter capacitor only during the off-time of the main power switch. The forward converter, when compared with the fly-back circuit, is generally more energy efficient and is used for applications requiring little higher power output (in the range of 100 watts to 200 watts). For comparison, a flyback converter stores energy as a magnetic field in an inductor airgap during the time the converter switching element (transistor) is conducting. When the switch turns off, the stored magnetic field collapses and the energy is transferred to the output of the flyback converter as electric current. In contrast the forward converter (which is based on a transformer) does not store energy during the conduction time of the switching element -transformers cannot store a significant amount of energy unlike inductors. Instead, energy is passed directly to the output of the forward converter by transformer action during the switch conduction phase. The Dual Switch Flyback is ideal for 75-200W and has good efficiency with OFF time modulation providing excellent standby power performance with burst operation. A simulation model in MATLAB/Simulink is built and characteristic of these topologies are analyzed in detail and comparison between the two of them is done..

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