FLYBACK CONVERTER

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This Report Is Submitted In Partial Fulfillment Of Requirements For The Degree Of Bachelor In Electrical Engineering (Industry Power)

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MAY 2006

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references.."

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"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)."

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Date: 7/5/2006..

Dedicated to my beloved parents …

ACKNOWLEDGMENT

Alhamdulillah, first and foremost I would like to thank Allah s.w.t. for His blessing and bestowal, I managed to complete this project as required completing my study in Kolej Universiti Teknikal Kebangsaan Malaysia.

In this opportunity, I would like to express my gratitude to my supervisor, Mr. Kasrul Abdul Karim for all the guidance, ideas, support and encouragement that he gave to me during doing this project. Without his support, there will be no progression for this project.

Besides, I also would like to express my appreciation to all lecturers and lab assistant that help me especially along this project and my studied in Kolej Universiti Teknikal Kebangsaan Malaysia.

Not forgetting, my beloved family for their moral and financial support. Thank you for believing in me and your undoubted love and encouragement had kept me going.

Finally, I would like to thank to my friends for their support and help for me while doing this project. Thanks for all. Only Allah will pay for their contributions, InsyaAllah.

ABSTRACT

The purpose of this project is to Design a flyback converter that has an input voltage of 12V dc and the output voltage of 240Vdc. Flyback converter is one of the switching dc power supplies applications with electrical isolation. The transformation of dc voltage from 12Vdc to 240Vdc is accomplished by using dc-to-dc converter circuits. The switching element used in this flyback converter is MOSFET (metal oxide semiconductor field effect transistor), which is operating completely off or completely on. This is because MOSFET has high power rating and high switching speed. The output of the MOSFET is fed to high frequency transformer. The snubber circuit is connected parallel to the MOSFET for protection. The input voltage of 12Vdc will be step up to 240Vdc. A high-frequency isolation transformer provides the electrical isolation in Flyback Converter. The high frequency transformers were used due to the small size and small weight. Consequently, the design circuit will deliver accurate output value with low power losses. On the whole, the undertaken task would provide to understand the operation of the Flyback Converter circuit practically.

ABSTRAK

Tujuan projek ini adalah untuk merekabentuk sebuah 'Flyback Converter' yang menghasilkan voltan keluaran sebanyak 240Vdc daripada voltan masukan sebanyak 12Vdc. 'Flyback Converter' merupakan salah satu aplikasi pengsuisan bekalan kuasa DC dengan pengasingan elektrik. Pengubahan voltan DC daripada 12V kepada 240V dapat di capai dengan menggunakan litar penukar DC-DC. 'Flyback Converter' menggunakan MOSFET sebagai peranti pensuisan. Ini kerana MOSFET mempunyai kadar kuasa yang tinggi dan kelajuan pensuisan yang pantas. Voltan keluaran MOSFET merupakan masukan bagi transformer berfrekuensi tinggi. Litar snubber disanbungkan pada MOSFET untuk tujuan keselamatan bagi komponen terlibat. 12Vdc akan di naikkan sehingga 240Vdc. Berikutan harga yang murah, bersaiz kecil dan beratnya yang ringan , transformer berfrekuensi tinggi digunakan. Litar yang direka ini akan menghasilkan keluaran yang dikehendaki dan kehilangan kuasa yang minimum. Secara keseluruhannya, projek ini mendedahkan pengoperasian litar 'Flyback Converter' secara praktikal.

CONTENTS

CHAPTER 1

INTRODUCTION

1.1 DC-DC CONVERTER BASICS

A DC-to-DC converter is a device that accepts a DC input voltage and produces a DC output voltage. In many industrial applications, it is required to convert a fixed voltage dc source into variable voltage dc source. Typically the output produced is at a different voltage level than the input. [1]

In any type of DC-DC Converter circuit, the selection of power device for a particular application not only the required voltage and current levels but also it's switching characteristic. The key parameters to look for in the transistor are the switching time and current rating. These two parameters greatly affect the maximum switching frequency of the converter, and also how much current the converter can be designed for. Because switching speed and associated power losses are very important in the power electronics circuits. For the example, the BJT transistor is minority-carrier device, whereas the MOSFET is a majority-carrier device that does not have minority-carrier storage delays, giving the MOSFET advantage in switching speeds. BJT transistor switching time may be a magnitude longer than for the MOSFET. Therefore, the MOSFET generally has lower switching losses. A DC-DC Converter is normally chosen because of its high efficiency in converting the input power to output power. [3]

1.2 DC-DC CONVERTER WITH ELECTRICAL ISOLATION [5]

In many DC-DC applications, multiple outputs are required and output isolation may need to be implemented depending on the application. In addition, input to output isolation may be required to meet safety standards and / or provide impedance matching. The electrical isolation is switching DC power supplies are providing by high frequency isolation transformer [5]

1.3 PROJECT OBJECTIVES

The objectives of this undertaken project are:

1.3.1 Design and build a converter that capable to step up 12Vdc to 240Vdc

1.3.2 Use a high frequency transformer to reduce the size and weight of the Flyback Converter

1.3.3 Design and simulate the circuit stage by stage by using Proteus Lite software.

1.3.4 Study and analysis the Flyback Converter performance and characteristics.

1.3.5 Build the Flyback Converter as simple as possible with the reasonable circuit protection.

1.4 PROJECT SCOPES

The scopes for this project are:

1.4.1 The construction of the Flyback Converter that converting input voltage of 12Vdc to output of 240Vdc

1.4.2 The Flyback Converter designed will consists of switching circuit, high frequency step up transformer, snubber circuit, and rectifier and filter circuit.

1.4.3 This Flyback Converter is open loop system because there is no feedback to monitor output voltage.

1.5 APPLICATIONS OF FLYBACK CONVERTER

There were a few applications using the Flyback Converter:

1.5.1 DC power supply

1.5.2 DC-AC inverter

1.5.3 Uninterruptible power supply

1.5.4 Mosquito rackets

1.5.5 Stun gun

CHAPTER 2

LITERATURE REVIEW

The DC-DC converters are widely used in regulated switch mode DC power supply and in DC motor drives. Switch mode DC-DC converters are used to convert the unregulated DC input into a controlled DC output at a desired voltage level. There are four types of DC-DC converter:

1) Boost Converter
2) Buck-boost Converter
3) Push-pull Converter
4) Flyback Converter

The figure 2.1 showed that block diagram of DC-DC system. The DC (unregulated) supply is fed to the DC-DC converter to be step up to the higher voltage, so that it can be used for the load which is use high voltage.

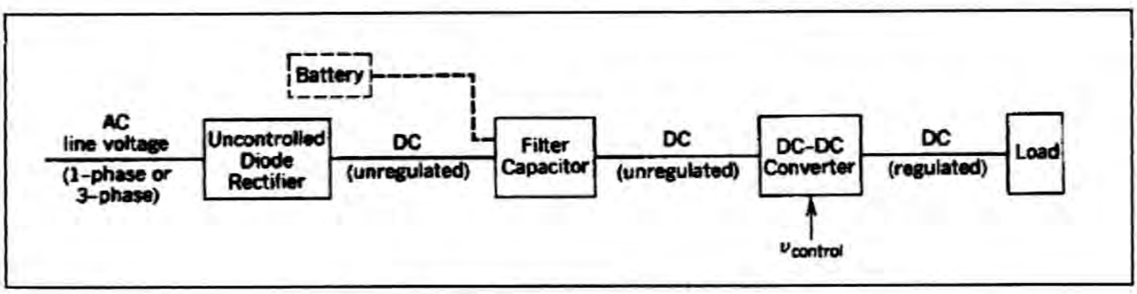

Figure 2.1: DC-DC converter system [5]

2.1 BOOST CONVERTER [1]

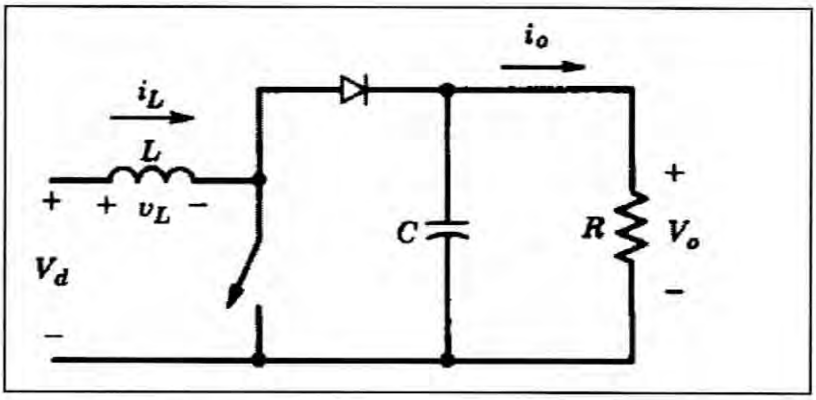

Figure 2.2: Boost converter Circuit [18]

The figure 2.2 showed circuit of the Boost Converter. In Boost Converter the output voltage is greater than the input voltage. The semiconductor switches can be designed with bipolar transistors, metal-oxide semiconductor field-effect transistor (MOSFET), diodes and thyristors. The circuit operation can be divided into two modes. Mode 1 for switch is closed; Figure 2.3 (a) and mode 2 for switch is open; Figure 2.3(b).

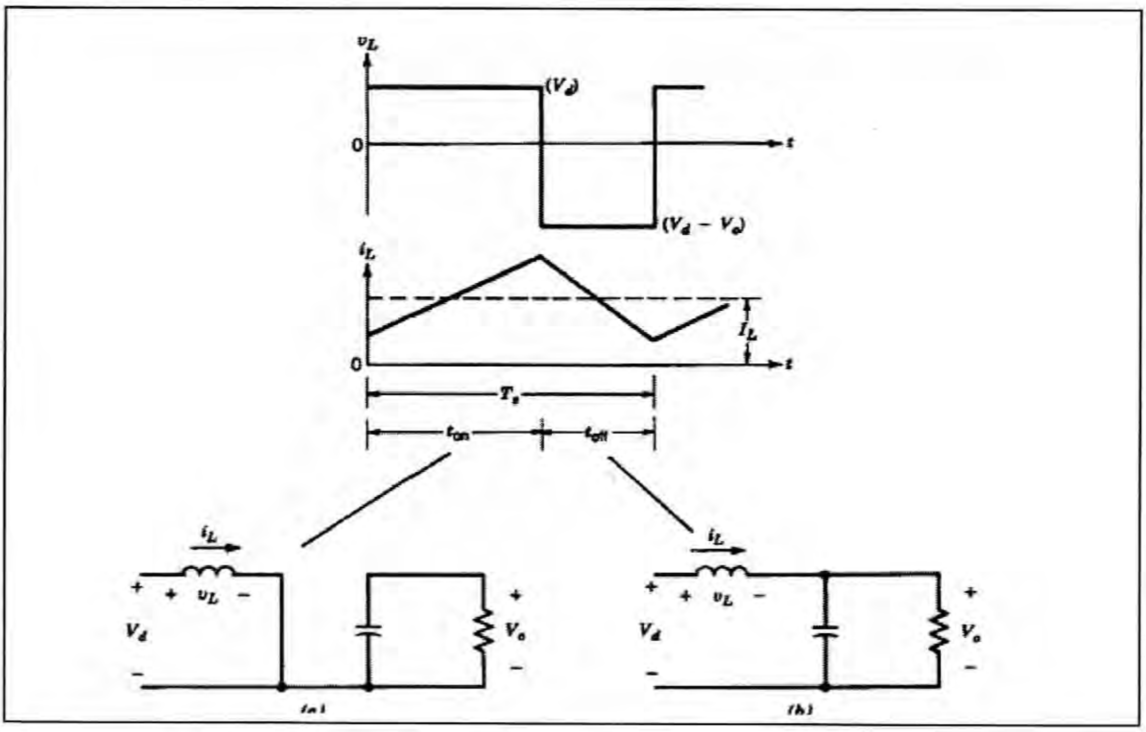

Figure 2.3: Boost Converter waveform: a) switch is closed; b) switch is open [18]

2.2.1 Mode 1 (Switch Closed)

When switch is closed, the diode is reverse biased. Kirchoff's voltage law around the path containing the source, inductor and closed switch is:

$$V_L = V_s = L\frac{di_L}{dt} or \frac{di_L}{dt} = \frac{V_s}{V_L} \tag{2.1}$$

The rate of change of inductor is a constant, so the inductor current increases linearly while the switch is closed as shown in Figure 2.3(a). The change in inductor current is computed from:

$$\frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_s}{L}$$

Solving for Δi_L for the switch closed,

$$(\Delta i_L)_{closed} = \frac{V_s DT}{L} \tag{2.2}$$

2.2.2 Mode 2 (Switch Open)

When switch is opened, the inductor current cannot change instantly, so the diode becomes forward biased to provide a path for inductor current. Assuming that the output voltage *Vo* is a constant, the voltage across the inductor is

$$V_L = V_s - V_o = L\frac{di_L}{d_t}$$

Rearranging,

$$V_L = V_s - V_o = L\frac{di_L}{d_t}$$

The rate of change of inductor is a constant, so the current must change linearly while the switch is open. The change in inductor current while the switch is open is:

Solving for Δi_L $$\frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1-D)T} = \frac{V_s - V_o}{L}$$

$$(\Delta i_L)_{open} = \frac{(V_s - V_o)(1-D)T}{L} \quad (2.3)$$

For steady state operation, the net change in inductor current must be zero. Using the equations (2.2) and (2.3),

$$(\Delta i_L)_{open} + (\Delta i_L)_{closed} = 0$$

Solving for V_o: $$\frac{V_s DT}{L} + \frac{(V_s - V_o)(1-D)T}{L} = 0$$

$$V_s(D + 1 - D) - V_o(1-D) = 0$$

$$V_o = \frac{V_s}{(1-D)}$$

A Boost Converter can step up the output without a transformer. Due to a single transistor, it has a high efficiency. The input current is continuous. However, a high-peak current has to flow through the power transistor. The output voltage is very sensitive to changes in duty cycle; *k* and it might be difficult to stabilize the regulator. The average output current is less than the average inductor current by a factor of *(1-k)*, and a much higher rms current would flow through the filter capacitor, resulting in the use of a larger filter capacitor and a larger inductor than those of a buck regulator.

2.2 BUCK-BOOST CONVERTER [5]

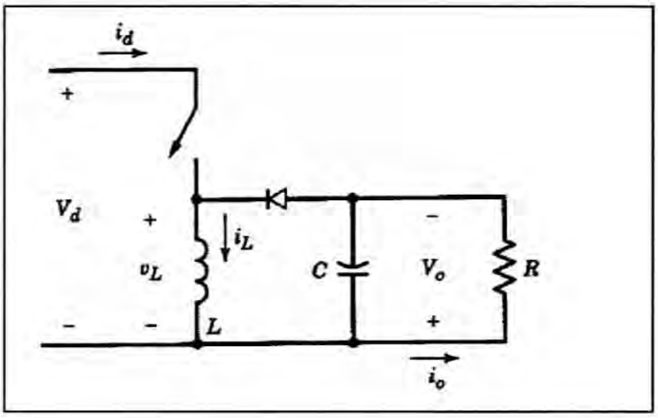

Figure 2.4: Step-up DC-DC converter that output voltage must be greater than the input [18]

The figure 2.4 showed circuit of the step up DC-DC converter or Buck-boost Converter. The main applications of a step-down/step-up or Buck-boost converter is in regulated DC power supplies, where a negative-polarity output may be desired with respect to the common terminal of the input voltage, and the output voltage can be either higher or lower than the input voltage.

A Buck-boost converter can be obtained by the cascade connection of the two basics converter: the step-down and the step-up converter. In steady state, to output-to-input voltage conversion ratio is the product of the conversion ratios of the two converters in cascade; assuming that switches in both converters has the same duty ratio. This allows the output voltage to be higher that input voltage based on the duty ratio, D.

The cascade connection of the step-up converters can be combined into single Buck-boost converter shown in Figure 2.5(a) and Figure 2.5(b), when the switch is on, the input provides energy to the inductor and the diode is reverse biased. The voltage across the inductor is:

$$V_L = Vd = L\frac{di_L}{dt}$$

$$\frac{di_L}{dt} = \frac{Vd}{L}$$

The rate of change of inductor current is a constant, indicating a linearly increasing inductor current. The preceding equation can be expressed as:

$$\frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{\Delta T} = \frac{Vd}{L}$$

Solving for Δi_L when the switch is closed,

$$(\Delta i_L)_{closed} = \frac{VdDT}{L} \tag{2.4}$$

and the waveform for the equation (2.4) during the on state is shown in Figure 2.5 (a).

Figure 2.5 (b) shows the off state. When switch is off, the current in the inductor cannot change instantly, resulting in a forward biased diode and current into the resistor and capacitor. In this condition, the voltage across the inductor is:

$$V_L = V_o = L\frac{di_L}{dt}$$

$$\frac{di_L}{dt} = \frac{Vo}{L}$$

Again the rate of change of inductor current is constant, and the change in current is:

$$\frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1-D)T} = \frac{Vo}{L}$$

Solving for Δi_L,

$$(\Delta i_L)_{open} = \frac{Vo(1-D)T}{L} \qquad (2.5)$$

And the waveform for the equation (3.21) during the on state is shown in Figure 2.5.

For steady state operation, the net change in current must equal to zero over one period. Using equation (2.4) and (2.5),

$$(\Delta i_L)_{open} + (\Delta i_L)_{closed} = 0$$

$$\frac{VdDT}{T} + \frac{Vo(1-D)T}{L} = 0$$

Solving for Vo,

And the voltage waveform at the inductor is shown in Figure 2.5

$$Vo = -Vd\left(\frac{D}{1-D}\right) \tag{2.6}$$

Equation (2.6) shows that the output voltage has opposite polarity from the source voltage. Output magnitude of the Buck-boost Converter can be either less than or greater than the source, depending on the duty ratio of the switch. If D>0.5, the output is larger than the input, and if D<0.5, the output is smaller than the input.

Therefore, this circuit combines capabilities of the buck and boost converters. Polarity reversal on the output may be disadvantages in some applications, however. Noted that the source is not connected directly to the load in the Buck-boost converter is also referred to as an indirect converter.

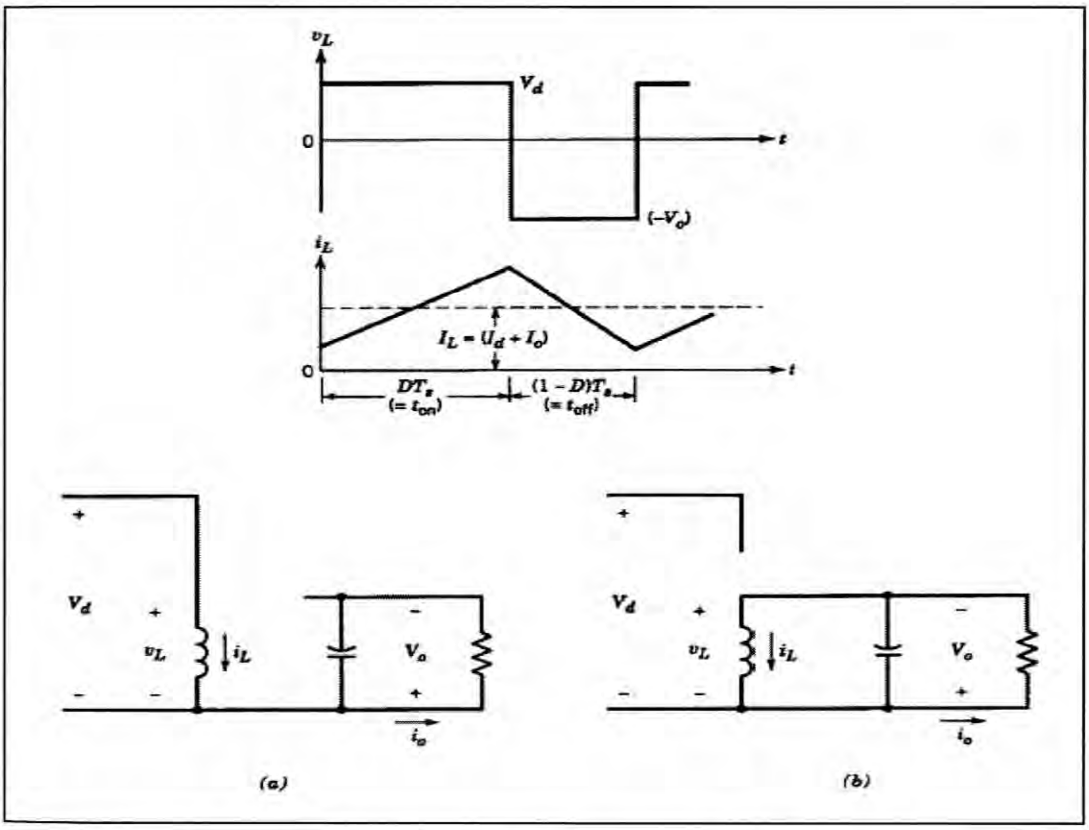

Figure 2.5: Buck-boost $i_L > 0$; a) switch on,(b) switch off [18]

2.3 PUSH-PULL CONVERTER [9]

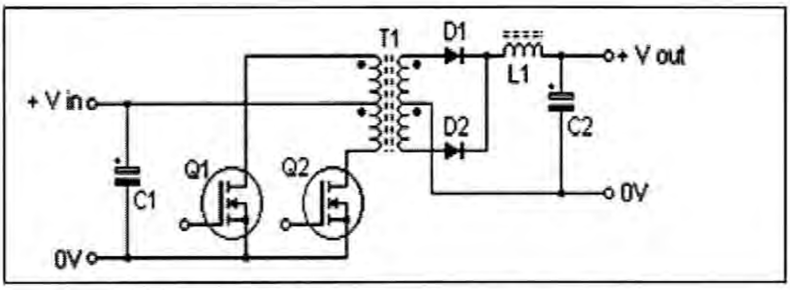

Figure 2.6: Push-pull Converter circuit [9]

The push pull converter belongs to the feed forward converter family. With reference to the Figure 2.6, when Q1 switches on, current flows through the 'upper' half of T1's primary and the magnetic field in T1 expands. The expanding magnetic field in T1 induces a voltage across T1 secondary, the polarity is such that D2 is forward biased and D1 reverse biased. D2 conducts and charges the output capacitor C2 via L1. L1 and C2 form an LC filter network. When Q1 turns off, the magnetic field in T1 collapses and after a period of dead time (dependent on the duty cycle of the PWM drive signal), Q2 conducts, current flows through the 'lower' half of T1's primary and the magnetic field in T1 expand. Now the direction of the magnetic flux is opposite to that produced when Q1 conducted. The expanding magnetic field induces a voltage across T1 secondary, the polarity is such that D1 is forward biased and D2 reverse biased. D1 conducts and charges the output capacitor C2 via L1. After a period of dead time, Q1 conducts and the cycle repeats.

There are two important considerations with the push pull converter:

1. Both transistors must not conduct together, as this would effectively short circuit the supply. Which means that the conduction time of each transistor must not exceed half of the total period for one complete cycle, otherwise conduction will overlap.

2. The magnetic behavior of the circuit must be uniform, otherwise the transformer may saturate, and this would cause destruction of Q1 and Q2. This requires that the individual conduction times of Q1 and Q2 be exactly equal and the two halves of the centre-tapped transformer primary be magnetically identical.

The control and drive circuit and the transformer must satisfy these criteria. The output voltage Vout equals the average of the waveform applied to the LC filter:

$$Vout = Vin \times \frac{n_2}{n_1} \times freq \times \left(Ton,q_1 + Ton,q_2\right)$$

Where:

Vout=Average output voltage (Volts)

Vin=Supply Voltage (Volts)

n_2=half of total number of secondary turns

n_1=half of total number of primary turns

freq = frequency of operation (Hertz)

Ton,q_1 = time period of Q1 conduction (Seconds)

Ton,q_2 = time period of Q2 conduction (Seconds)

The control circuit monitors Vout and controls the duty cycle of the drive waveforms to Q1 and Q2. If V_{in} increases, the control circuit will reduce the duty cycle accordingly, so as to maintain a constant output. Likewise if the load is reduced and V_{out} raises the control circuit will act in the same way. Conversely, a decrease in V_{in} or increase in load will cause the duty cycle to be increased. The figure 2.7 shows associated waveforms from the push pull converter.

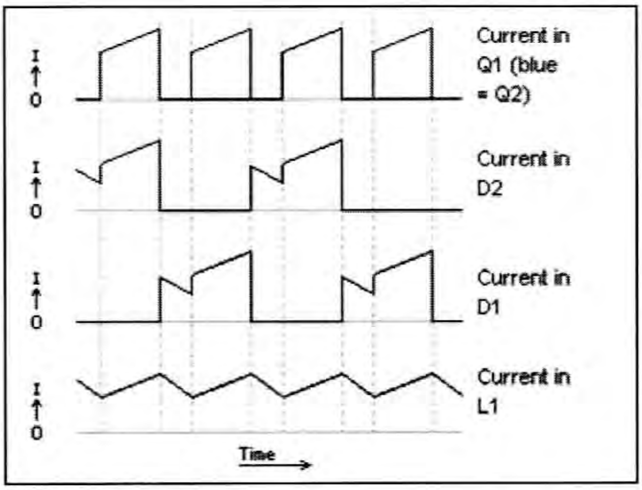

Figure 2.7: Waveform from Push-pull Converter [9]

2.4 FLYBACK CONVERTER [5]

Flyback Converter is derived from Buck-boost Converter. It was one of the DC-DC Converters with electrical isolation that is provided by a high frequency isolation transformer. By placing a second winding on the inductor, it is possible to achieve electrical isolation, as shown in Figure 2.8.

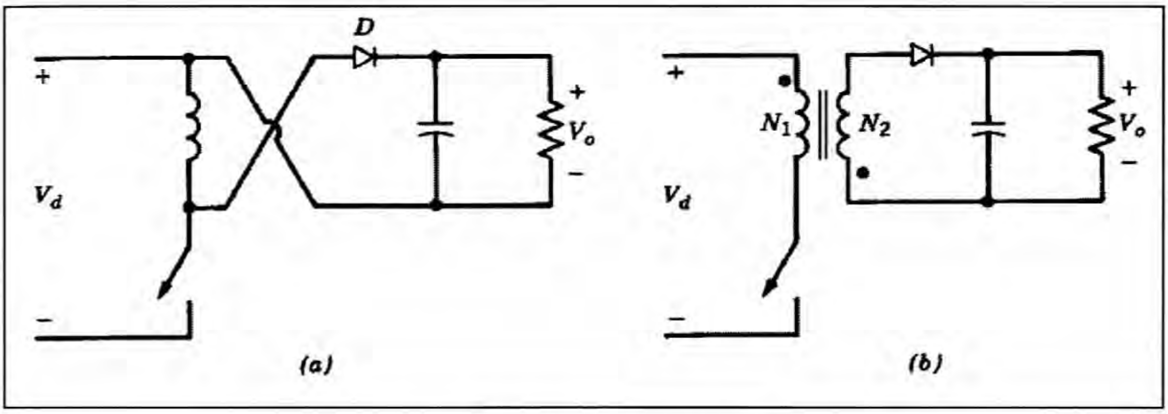

Figure 2.8: Flyback Converter [18]

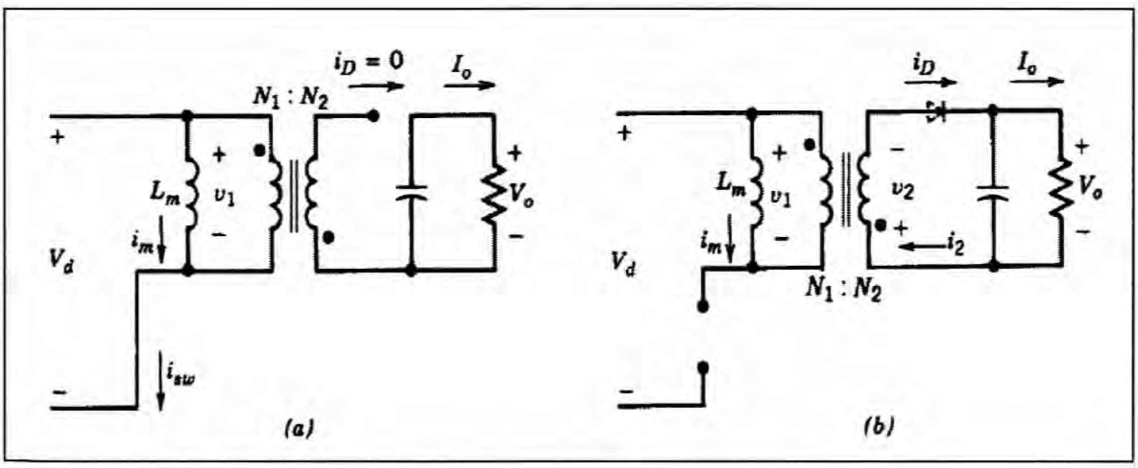

Figure 2.9: Flyback Converter; a) switch on and b) switch off [18]