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Design and Implementation of Closed loop control for Flyback Converter

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Abstract

One of the high frequency switching power supply circuits is the flyback converter. Due to its inexpensive cost and electrical isolation properties, it is mostly employed in low power applications. It is well known that high frequency switching results in losses and lowers inverter efficiency, particularly at low powers. Consequently, a flyback DC-DC converter that is run in a closed control loop is explained in this study. Closed-loop control is the proposed topology for the flyback converter. For the same input/output conditions, the findings from the closed-loop converter are compared to those from the open-loop feedback topology. A closed-loop flyback has been found to be more effective than an open-loop flyback. MATLAB simulates the outcomes. One of the high frequency devices is the flyback converter.

Keywords: Flyback converter, closed loop, open loop MATLAB, isolation.

1. Introduction

Power electronics frequently employ DC-DC converters, so finding more effective converters has grown to be a significant topic of study [1-3]. In low power applications, flyback converters are the most popular because they are simpler to utilise than alternative topologies [4]. Cell phones, laptop computers, and LCD TVs all use them as power circuits. Flyback converters are frequently used in switched mode power supplies (SMPS) due to their low cost, many isolated outputs, high voltage, and high efficiency. In flyback conversion, transformers

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are utilised for output power conversion, input/output isolation, and energy storage. The winding polarity of a flyback transformer is set up to ensure that one winding is does not conduct when the other winding is does

A closed loop control system, (feedback control system), is one that uses an open loop in the forward - path while incorporating one or more feedback loops or paths between outputs. When the term "feedback" is used, it refers to the process whereby the output of a system is "fed back" to its input.

1.1 Overview

The flyback converter is an adaptation of the current boost converter where the holding winding is divided into two windings to achieve galvanic isolation. Note that the transformer used in fly back converters works very differently from the one used in the previous converters: the energy gap that results in the generation of a strong magnetizing current is used to store energy. There is no direct energy transfer between the first (n1) and the second (n2); instead, two different phases are observed: the storage phase in which the energy is stored in the magnetic circuit by the primary winding (for the interval [0; α.Td]); this is a stage of secondary energy release; wrap (for the rest of the season). The interest in critical mode operation (full power output at the end of switching period Td) is obvious for the current boost converter; This allows optimal use of transformers and switches. In this context, the continuous and discontinuous transmission modes of this converter are not considered, because these points are completely covered for step-up converters (this result is the same for non-isolated converters and isolated converters).

1.2 Objective

- To design the feedback system for Fly-back converter using PID Controller.
- To analyze the results of open loop and closed loop control for the flyback converter.
- To control the load system for any input variations.

2. Literature Review

Ravichandrudu and Kumar discussed the importance of flyback converters for electric vehicles in [1]. The objective of this article is to construct a flyback converter with an input voltage of 5V DC and an output voltage of 15 VDC. An application for a variable DC power source that is electrically separated is the flyback converter. DC voltage from 5Vdc to 15Vdc is converted using a dc-dc converter circuit. An entirely closed or completely functional MOSFET switching element is used in the flyback converter. An input voltage of 5V dc can increase to 15V dc. Electrical isolation in the flyback converter is provided by a high frequency isolation transformer. The usage of high frequency transformers is made possible by their light weight and tiny size. As a result, the circuit will produce an output value that is accurate.

Singh et al. proposed a closed-loop control system for a flyback converter with photovoltaic as a source in [2The current situation necessitates the search for alternatives due to the scarcity of conventional resources and the environmental harm caused by the methods used to produce electricity. The answer appears to be renewable energy, particularly photovoltaic (PV) sources. This is true because an inverter connects the PV source to the grid. The use of power electronics converters is currently essential in systems that produce electricity from renewable sources. The two control modes of a flyback converter using PV and maximum power point tracking (MPPT) as sources are investigated in this study. When type 2 compensation is used, the closed-loop control of the system maintains stability regardless of any system changes. In MATLAB/SIMULINK, the proposed approach is simulated, and the outcomes are examined.

Lee discussed practical feedback loop design considerations for flyback converters using the UCC28740 controller in [3]. We advise using a fly-back converter while multiplying. The most popular circuit today isolates the feedback loop using a TL431 and an optocoupler. The TL431 is marketed as a trans condensation amplifier, however it can also be used as a typical type II error amplifier with the right connections. In any feedback or control circuit, the TL431 and the optocoupler are essential components. The design factors for balancing the complete loop for the appropriate operation of flyback converters are covered in this application note.

Wang proposed a feedback control design for an offline flyback converter in [4]. Electrical engineers frequently struggle to understand how to control the noise of an off-line flyback converter since it involves both a converter-mode converter (DCM) and a small-signal converter-mode model (CCM). The TL431 regulator's unusual feedback compensation arrangement with the optocoupler makes it difficult to adjust the feedback parameters. This application note offers thorough design guidance, from the definition of the current transfer function through the circuit design for the TL431 and optocoupler, to assist system designers in obtaining an adequate phase margin to meet transient stability requirements. At this point, Mathcad software was used to make theoretical calculations, and Simplis was used to confirm the results. All applications utilising external flight controllers from the RT773x series will employ this technique

Ramos et al. designed and controlled a battery charger/discharger based on the flyback topology in [5]. The converter that connects the elements with the microgrid is designed in such a way as to provide the necessary security. As a result, this study suggests a design for the power and control states of a battery charger. It is suggested that the battery, flight, DC bus, and control scheme be included in the battery charger's structural design. The battery charger/charger was then demonstrated using three models; displacement models, averaging models, and steady state models are utilised to determine the system's static and dynamic behaviour as well as the design equations. On the basis of the concept, the sliding mode with one-parameter adaptive computing was created. Last but not least, the method for choosing the HFT flyback, output.

Abu-Rub et al. proposed a digital control system for flyback DC-DC converters in their works [6] and [12]. They focused on improving the performance of the converter by using a high-performance digital control system with active clamp and input voltage feedforward. The proposed control system achieved better dynamic response and reduced output voltage ripple.

Kim et al. designed and implemented a closed-loop control for a flyback converter using a digital signal processor in [7]. They achieved good performance in terms of stability and resilience by regulating the output voltage using a proportional-integral (PI) controller.

Lee et al. proposed a digital PWM controller for a flyback converter in [8]. They used a digital signal processor to implement the controller and achieved good performance of stability and efficiency.

Liu et al. proposed a digital control method for flyback converters with improved dynamic response in [9]. They used a novel voltage control method and achieved faster transient response and reduced output voltage ripple.

Zhao et al. designed and implemented a digital current-mode control system for flyback converters in [10]. They used a PI controller and achieved good performance in terms of stability.

Tsai et al. proposed a digital control method for flyback converters with constant on-time control in [11]. They used a digital signal processor to implement the control system and achieved good performance in terms of stability and efficiency.

Du and Liu proposed a digital control system for flyback converters with input voltage feedforward in [13]. They used a novel voltage control method and achieved better dynamic response and reduced output voltage ripple.

Zhang et al. proposed a digital control system for flyback converters with adaptive dead-time compensation in [14]. They used a digital signal processor to implement the control system and achieved good performance in terms of stability and efficiency.

In summary, the works reviewed in this section have proposed various digital control methods for flyback converters, including PI control, voltage control, and constant on-time control, among others.

3. Basic Working Methodology

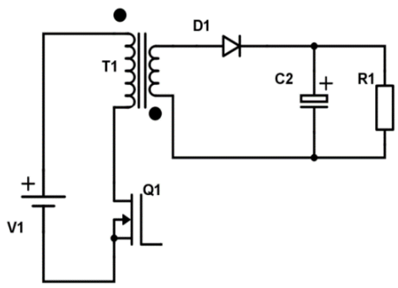

Figure 1. Fly-back converter

The flyback converter's typical model is depicted in Figure 1. It can be obtained, in swapping out the inductor in a buck boost converter for a transformer, and the main and secondary winding of the transformer should be positioned in opposition to one another. The converter's input and output are. This converter's voltage gain expression is

$$\frac{V_{out}}{V_{in}} = \frac{N_2}{N_1} * \frac{D}{1 - D}$$

Where

N_1- No. of turns on the primary of the transformer

N_2- No. of turns on the secondary of the transformer

The voltage gain expression of the converter is calculated using the two switch modes (Q1). It briefly explained in Figures 2 and 3.

When Q1 is turned on, input voltage is visible there, increasing the stored energy in the transformer's primary inductance L_m. Due to the polarity of the dots, negative voltage forms across the diode D1 in Figure 1, preventing it from conducting. In this situation, the associated load's current requirement is satisfied by the capacitor (C2).

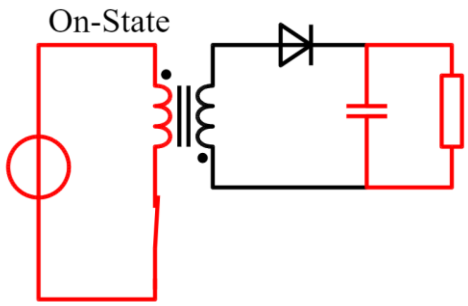

Figure 2. Flyback converter when Q1 is ON

Current in L_m cannot instantly drop to zero when Q1 is turned OFF. As a result of Faraday's law of electromagnetic induction, the diode (D1) begins to conduct, and energy stored in the inductor transferred to the output capacitor (C2).

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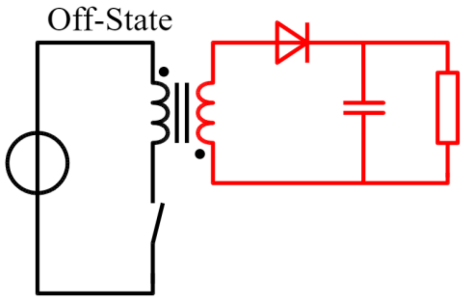

Figure 3. Flyback converter when Q1 is OFF.

Figure.4 shows the waveform for the voltage and current of Q1 in both the ON and OFF states. Ip in the plot denotes the maximum current flowing through the transformer's (T1) main side.

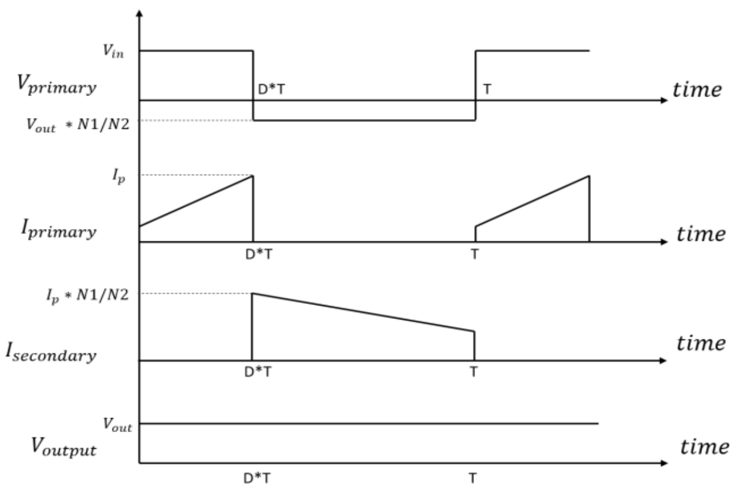

Figure 4. displays the output voltage, secondary current, primary current, and primary voltage waveforms for a flyback converter using PWM switching.

To determine the voltage gain expression, use the primary side of the transformer (T1) and the average voltage technique. It offers

$$V_{in} * D * T - V_{out} * \frac{N_1}{N_2} * (1 - D) * T = 0$$

$$\frac{V_{out}}{V_{in}} = \frac{N_2}{N_1} * \frac{D}{1 - D}$$

Where,

Duty Cycle, D = $\frac{\text{Ton}}{T}$

Total Time, T = Ton + Toff (seconds).

4. Proposed Work

4.1 Block Diagram

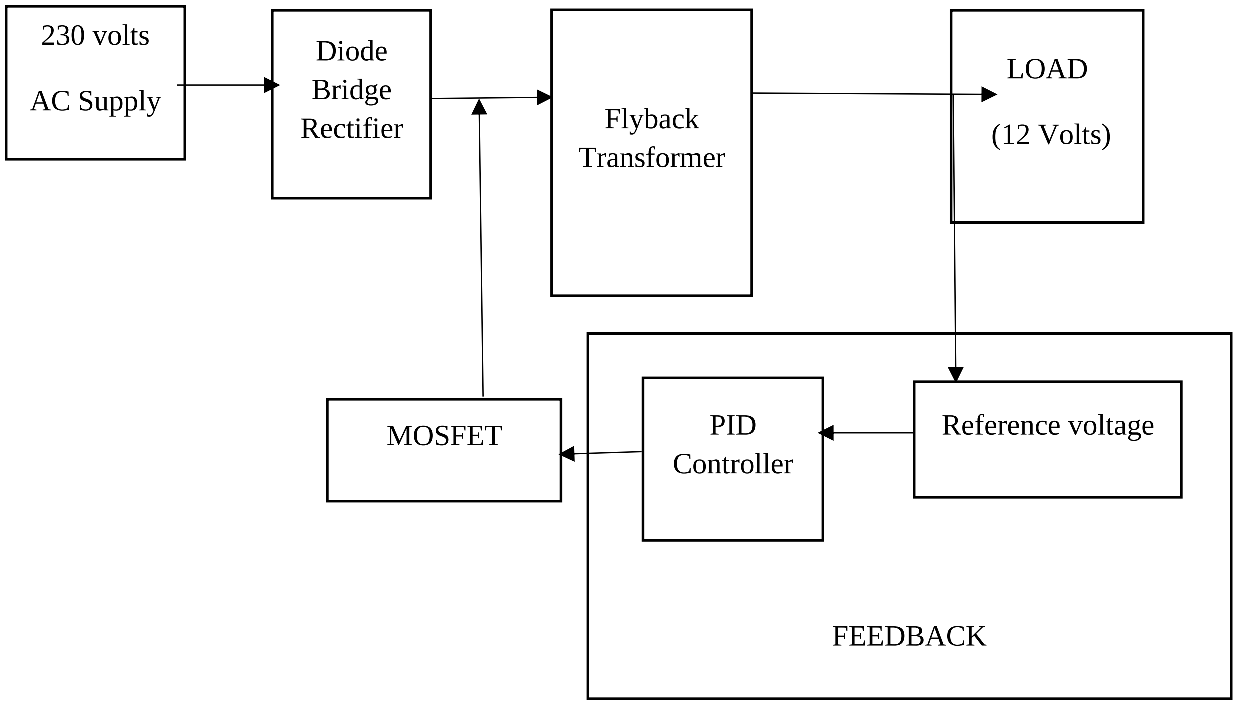

Figure 5. Block Diagram

The suggested system's block diagram is shown in Figure 5. Here, the 230V AC input voltage is given. The Diode rectifier is provided with the input supply. The input AC voltage is converted to DC using a rectifier. The flyback transformer is then provided the DC supply. In this simulation, only a linear transformer was used. The transformer's secondary winding is wired to the load in the opposing direction. The primary side of the transformer is connected in series with the MOSFET switch. As a result, the primary winding saves energy when the switch ON, and the secondary winding receives energy when the switch OFF. Step down transformer (230V - 12V) is the type of transformer utilised. The secondary winding is directly attached across the load. The load side is where the voltage sensor is located. We set the reference voltage on our own. The PID controller receives both the reference voltage and the actual voltage. The MOSFET Switch receives the error signal after it has been transformed into the required pulse signal.

4.2 Prototype Design

The final application defines design inputs, or the designer may choose them. Input and output voltage, capacity, fibre factor, and duty cycle are only a few of these variables. A list of the design inputs for the circuit under discussion is presented in Table 1.

Table 1. Design specification

Design Input	**Value**
Input voltage (V_{IN})	5V to 24V
Output voltage (V_{OUT})	12V
Output current (I_{OUT})	1A
Maximum duty cycle (D_{MAX})	0.5
Switching frequency (f_{SW})	100kHz
Estimated efficiency (η)	80%

The same MOSFETs and diodes are used, with the maximum duty cycle set at 50% to reduce stress. One hundred kHz is used as the switching frequency. Determined is the converter's approximative efficiency in order to make the calculation more accurate. Due to the fact that this is a typical figure for low power flyback converters, the efficiency is considered to be quite low (about 80%).

4.3 Simulation

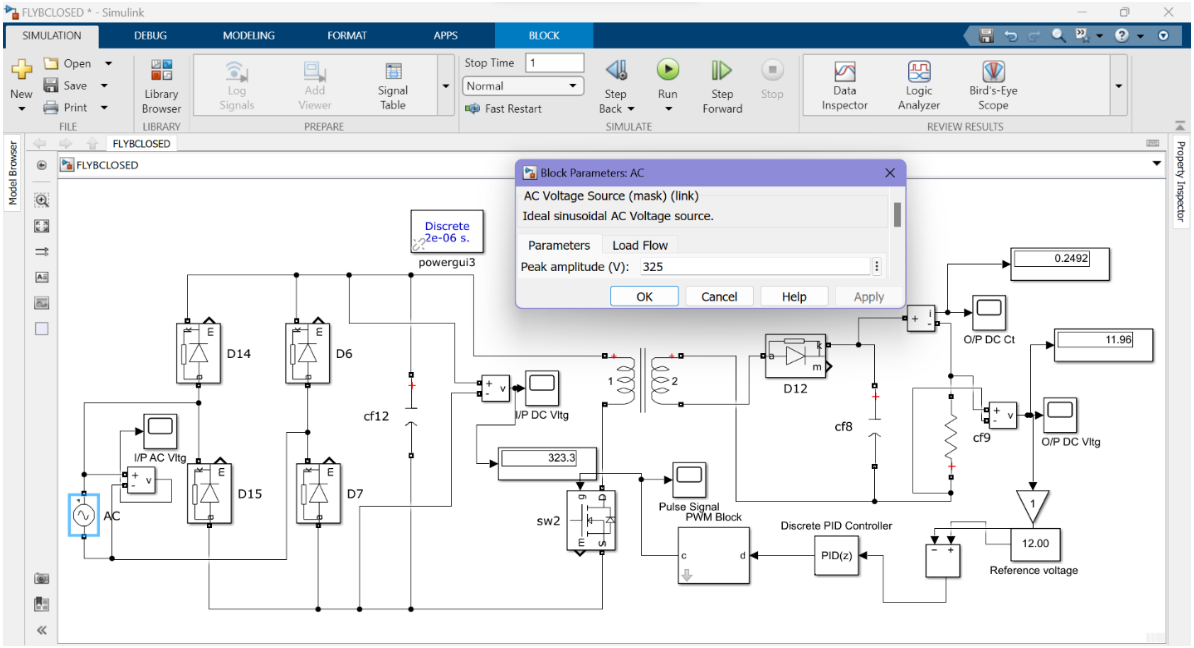

Figure 6. Schematic view of flyback converter with Closed loop system using PID Controller.

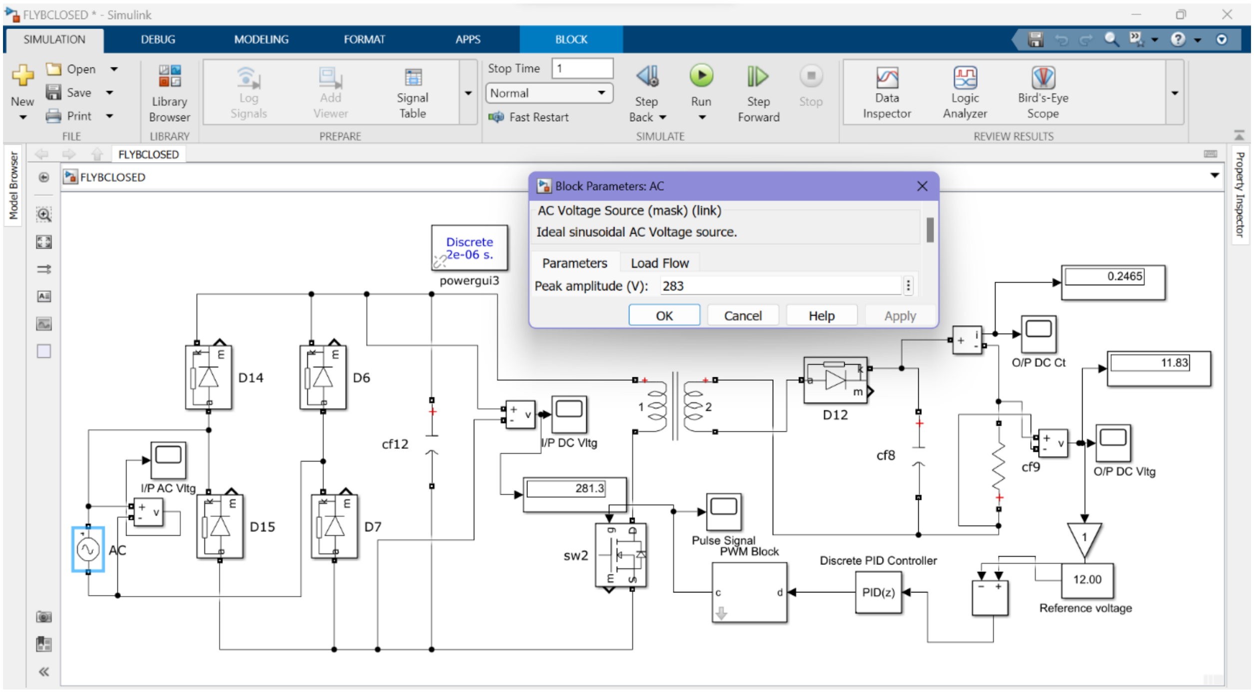

Figure 7. Schematic view of flyback converter with Closed loop system using PID Controller.

Schematic views of flyback converters with closed-loop systems are shown in Figures 6 and 7. Matlab is also used for this. Here, the diode bridge rectifier receives the input AC supply and converts it to a DC supply. The output of the bridge rectifier is fed to flyback converter. In this simulation, only a linear transformer was used. The transformer's secondary winding is wired to the load in the opposing direction. The primary winding is connected in series with the MOSFET switch. As a result, while the switch is ON, it stores energy in the transformer's main winding and releases it into the secondary winding when the switch is OFF. Step down transformer (230V - 12V) is the type of transformer utilised. Direct secondary winding connections were made across the load. The load side is where the voltage sensor is located. We set the reference voltage on our own. The PID controller receives the reference voltage and the actual voltage. The MOSFET Switch receives the error signal after it has been transformed into the required pulse signal.

Table 2. I/P & O/P Voltage of Closed loop flyback converter

INPUT VOLTAGE	OUTPUT VOLTAGE
200	11.79
230	11.93
250	11.89
280	11.95
300	11.96
325	11.96

Table.2 shows the voltages of a closed loop flyback converter system's input and output. It is observed in this closed loop system that changing the input voltage has no effect on the output voltage.

5. Result and Discussion

In open loop system the output voltage is fluctuating while the input is varied. But in the closed loop, The voltage remains constant of 12V for different inputs.The inbetween operation with rectifier and transformer is also expalined with the required equations.

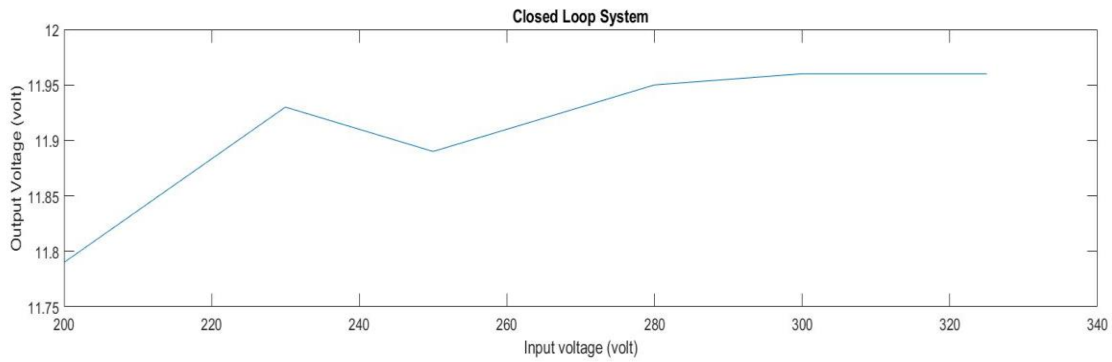

Figure 8. Closed loop system input and output voltages

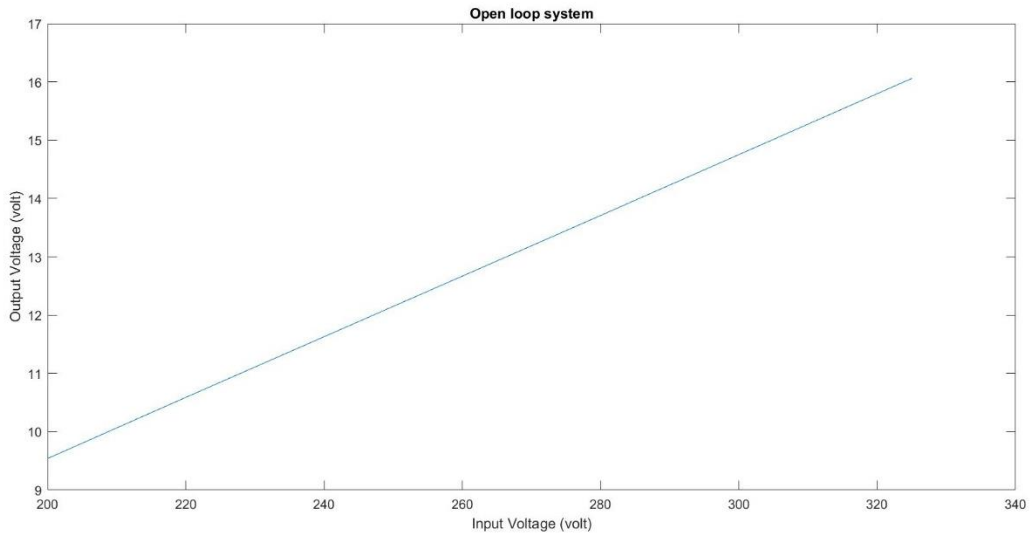

Figure 9. Open loop system input and output voltages

Figures 9 and 8, respectively, depict the graph between the i/p & o/p voltages of the open and closed loop systems of the flyback converter. The i/p & o/p voltages of the open loop converter are shown in Figure 9. As the i/p voltage increases, the o/p voltage increases linearly. The i/p and o/p voltages of the closed loop system are shown in Figure 8. As the i/p voltage rises, the o/p voltage stays constant.

Conclusion

In conclusion, flyback converter with closed loop system is a very intriguing technology and have several exciting potential applications. While there is an increase in and demand for the electric vehicle and charging stations and converters the flyback converter plays a major role in isolated converters. In constant voltage applications flyback converter offers a closed loop control and isolation between high and low voltages.

Future scope

The future of flyback converter is not only depending on the battery applications, it also depends on the other applications such as solar PV and other DC-DC conversion applications. The closed loop system can further be developed with analysing with frequency and time response analysis with use of Nyquist and BODE plots. The real time steady state analogy can be done using flyback converter. Evolving semiconductor applications leads to creating a very small integrated circuits which reduces the size and ease design and implementation of the converters.

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