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RESEARCH ARTICLE - ENGINEERING

Flyback converter controlled by Arduino Uno

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Abstract

This paper presented the design, simulation, and implantation of a DC-DC step-up Flyback converter that regulates the output voltage to give the desired value 200 V 100 W and can be used in many applications such as power supply. To give a regulated output voltage from the Flyback converter, a feedback loop with Proportional-integral (PI) controller is used. A simulation of the Flyback converter was employed by MATLAB/Simulink under variation in the input voltage and load. Also, the practical implementation used Arduino Uno microcontroller to control the duty cycle through IR2110 driver at the change in the input voltage or resistive load. It gives better flexibility and a good response to the control system. The duty controller creates regulate output voltage by using voltage mode control (VMC).

Keywords: Flyback converter; Arduino Uno; PI controller; MATLAB; open loop; close loop. IR2110; VMC

1. Introduction

The dc-dc converter transforms a variable or constant dc voltage to a regulated output dc voltage. Because of high efficiency and power density in addition to low cost, the switch-mode power supplies (SMPS) are extended using the linear power supplies. The dc-dc Flyback converter is widely used in power electronics application such as photocopy machines, Plasma lamp, and Xenon flash lamps. It converts a fixed dc to a variable dc voltage or constant voltage [1-2]. The various industrial application has been developing to need constant output voltage at variation in the input voltage and load. In order to obtain a constant output voltage, it is necessary to establish and design a closed-loop system as feedback. There are many control methods used for power converter such as linear control, fuzzy logic, PID, etc. PI control is used because of its simplicity in design and implementation [3][4]. It consists of proportional and integral gain (KP, KI). PI control is used to eliminate overshoot and steady-state errors. It can be tunned by using Ziegler- Nichols [5]. In this paper another method was used for tunning PI by a using transfer function. DC-DC Flyback converter is interested to supply regulator voltage under input voltage change or load disturbance via voltage mode control (VMC) technique. The principle operation of VMC is a closed-loop feedback circuit that observes the output voltage through a voltage divider [6]. This paper proposed a DC-DC Flyback converter with a digital controller which is used in SMPS. It was employed to give a regulator output voltage independent of variation supply voltage and load. Also, the Flyback converter with the digital controller is more flexible, easy to update the parameter and permits achievement of complicated control algorithms [7]. This paper presents the Flyback converter that is controlled by the Arduino Uno board. It has been selected because of its simplicity in use [8-9]. The PI controller can be achieved via the programming of the Arduino Uno board. The Flyback converter is analysed as a feedback system to accomplish satisfying stability and time response. The advantage of using Arduino Uno controller is its sensitivity to

Nomenclature

ADC	Analog to Digital Converter	PI	Proportional Integral
CCM	Continuous Conduction Mode	PID	Proportional Integral Derivate
DCM	Discontinuous Conduction Mode	PWM	Pulse Width Modulation
DC	Direct Current	SMPS	Switch Mode Power Supply
FLC	Fuzzy Logic Control	TON	Turn On Time
HF	High Frequency	TOFF	Turn Off Time
IGBT	Isolated Gate Bipolar Transistor	VMC	Voltage Mode Control
MOSFET	Metal Oxide Silicon Field Effect Transistor		

environmental changes in the system such as variation in the load, temperature and input voltage. Another advantage of using Arduino Uno is that we do not need to change parameter of the circuit in case of any variation in the specification. We need variation in the program. This paper presented and developed a new technique using Arduino Uno for the implemented PI controller with Flyback converter which is a technique used for other converters [10]. It first time used with Flyback converter.

2. Flyback converter schematic

Fig. 1 shows a Flyback converter which contains from DC battery (V_{in}), switch, and output capacitor filter. Diode, transformer (ferrite core) is used to avoid saturation or two winding magnetic, inductor Lm and output resistance Rout [11]. The Flyback converter is essentially isolated, it operated buck or book. The Flyback converter has low cost and simple circuit in addition to multi-output implementation. The transformation of the DC-DC Flyback converter occurs through a transformer or magnetizing inductance by the switch on or off. When switching on the primary of the transformer connected to the input supply voltage, the primary current increased and energy stored in wining of the transformer. The voltage in the secondary winding has negative polarity, therefore the diode is reverse biased. The output resistance is supplied from output capacitor. When switching off the primary current decreases and the secondary voltage has positive polarity, so that diode is forward biased. The current flows in load and energy transform from the core of the transformer to load. Fig 2 shows the operated Flyback in switch on and off. Operation of the converter can be operated in both intervals. A microcontroller is needed to generate The Pulse Width Modulation (PWM) for Metal Oxide Silicon Field Effect Transistor (MOSFET). Arduino is used as a controller device and the output voltage is sensed through R2 and R3 and sent to pin A2 of Arduino subsequently adjust the output voltage [12]. The driven switch is PWM through IR2110.

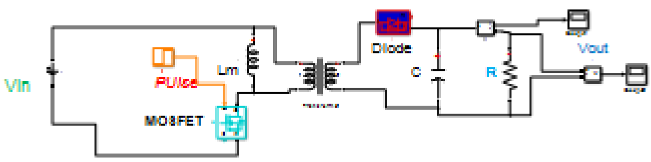

Fig.1. Circuit Diagram of Flyback converter.

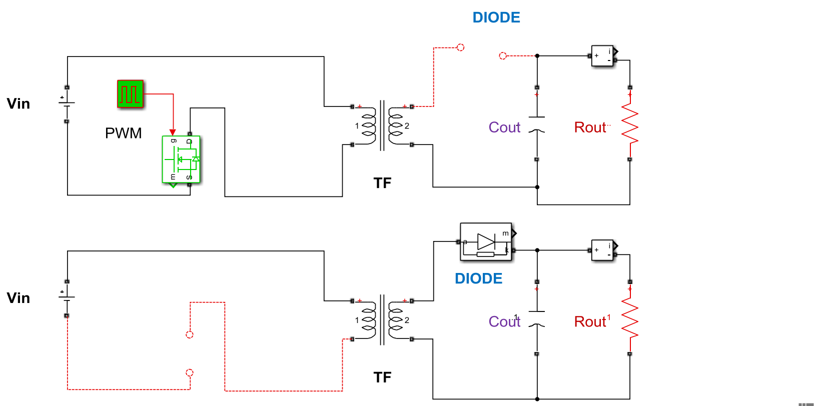

Fig. 2. Equivalent circuit of Flyback converter in turn ON and OFF states.

Flyback converter can be controlled by a digital or analog controller. A digital control will be selected here due to its adaptable parameter changes such as desired output voltage, frequency of switch MOSFET and PI controller (proportional - integral) parameter.

2.1. Feedback control loop by PI controller

The PI controller contains two terms proportional and integral. The proportional term is used for minimum steady-state errors while the integral term is used to reduce overshoot. The PI controller computation requires two parameters I and P. The two terms in the PI controller can prepare control system design for close-loop DC-DC Flyback converter. The Flyback converter is operating in voltage mode control. The feedback loop of the Flyback converter is shown in Fig 3. The output voltage is compared with the reference voltage and sent to the PI controller to change the duty cycle to adjust the output voltage [13].

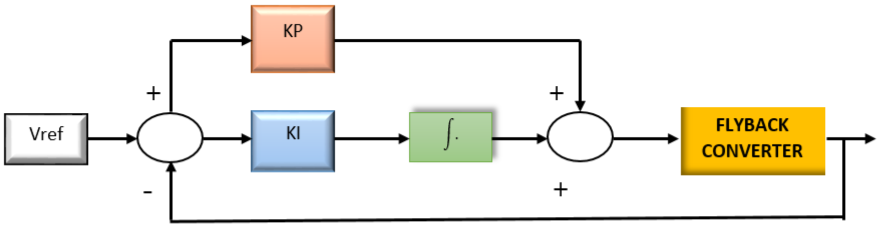

Fig. 3: Flyback converter using PI controller.

2.2. Feedback loop regulation of Flyback converter by Arduino Uno

The control part will be implemented by ARDUINO Uno board and all parameter circuit with the feedback system is shown in Fig. 3. The Pulse width generator delivers a rectangular signal at frequency 20 kHz and duty cycle (0.1-0.5) from ARDUINO Uno through IR2110 driver to supply gate of the switch. The output voltage is measured through a voltage divider (R2, R3) and reduces the voltage to the range of anlage input (A0 –A5) pins. of Arduino microcontroller (0 -5) V [14]. The value of resistors should be high to avoid power losses (p = I^2. R). The output voltage divider is sent to ARDUINO Uno to correct any change in the output voltage or input voltage of the converter. The output voltage divider should not exceed anlage input voltage of ARDUINO Uno (5V). Fig. 4 shows a Flyback converter with a feedback loop.

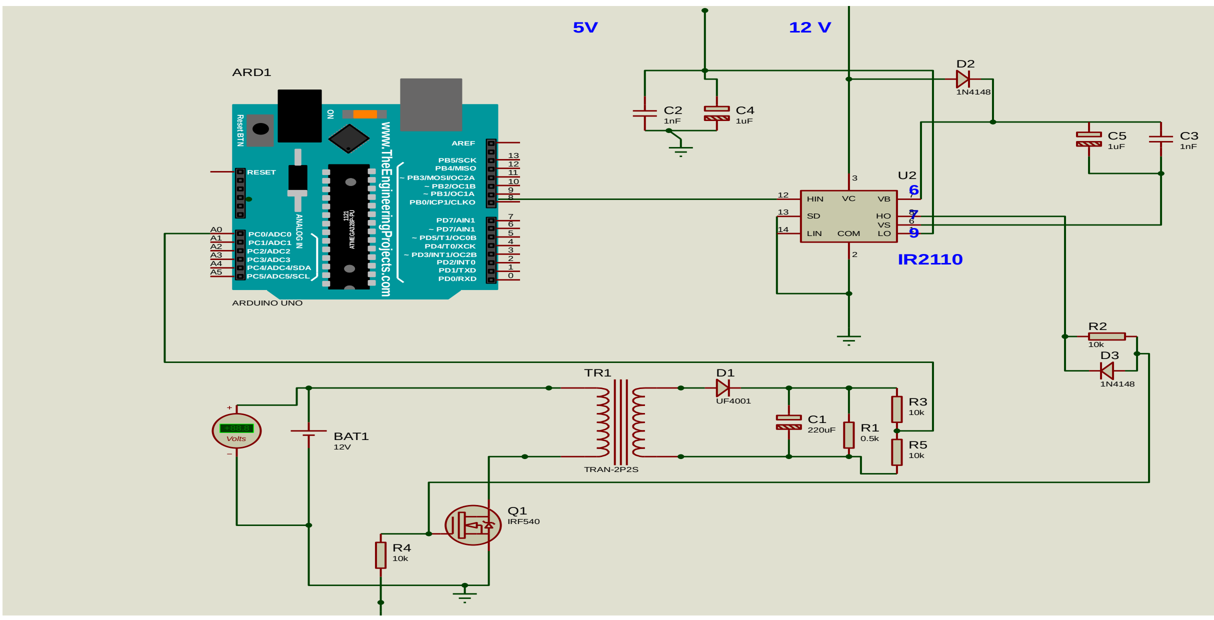

Fig. 4. Arduino controlled DC-DC Flyback converter.

The Fig. 5 shows the circuit diagram of voltage-mode control (VMC). The output voltage of the Flyback converter is monitored by the voltage divider. This voltage feeds back to create the closed-loop and compares with the reference voltage. The result comparison is entered to the amplifier to produce the error signal. The error signal supplies the controller (PI) in order to produce a control voltage which is compared with the saw-tooth wave to employ the duty cycle.

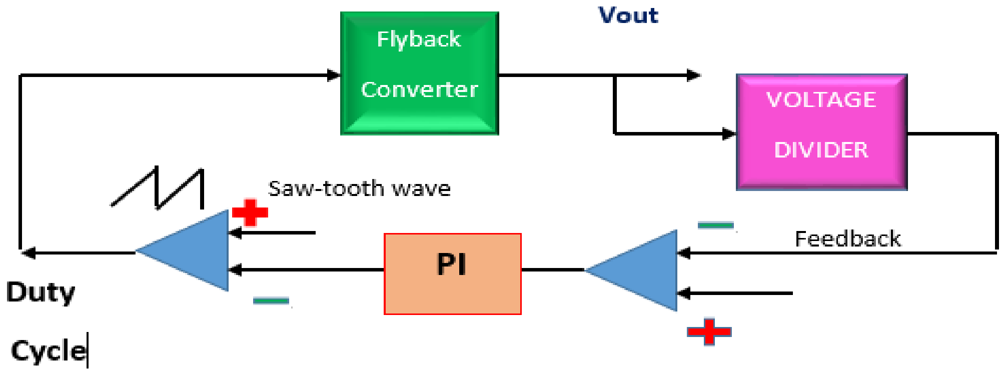

Fig. 5. VMC for Flyback converter.

3. State space of Flyback converter

Obtain transfer function of the Flyback converter to determine the Bode plots, step response , the parameter of PI controller (KP, KI) and ensure the system is stable, as Shown in Figs. 6 and 7. We can find state space from [15-17]

During switch on

$$A1 = \begin{bmatrix} 0 & 0 \\ 0 & \frac{1}{RC} \end{bmatrix},\ B1 = \begin{bmatrix} \frac{1}{Lm} \\ 0 \end{bmatrix},\ C1 = (0\ \ 1)\,. \tag{1}$$

During switch off

$$A2 = \begin{bmatrix} 0 & -\frac{n}{Lm} \\ \frac{n}{Cout} & -\frac{1}{RCout} \end{bmatrix},\ B2 = \begin{bmatrix} 0 \\ 0 \end{bmatrix},\ C2 = (0\ \ 1)\,. \tag{2}$$

$$A = A1\times d + A2(1\text{-}d) \tag{3}$$

$$B = B1\times d + B2(1\text{-}d) \tag{4}$$

$$C = C1\times d + C2(1\text{-}d) \tag{5}$$

$$E = E1\times d + E2(1\text{-}d) \tag{6}$$

$$\frac{\widehat{vout}}{\widehat{vin}} = c\,(SI - A)^{-1} \tag{7}$$

$$B = \frac{0.0495\, s^2 + 9902\, s + 2.475\times10^5}{s^2 + 2050\, s + 8.96\times10^6} \tag{8}$$

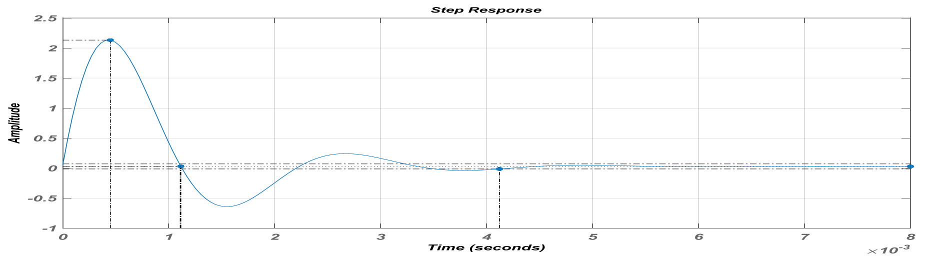

Fig. 6. Step response of Flyback converter.

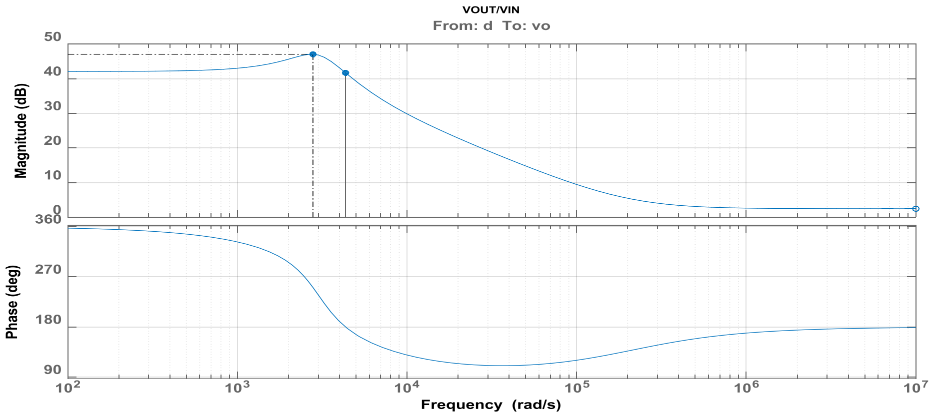

Fig. 7. Bode plot of Flyback converter.

From transfer function above. We can find parameter of PI (KP,KI) controller (shown in Fig. 8)

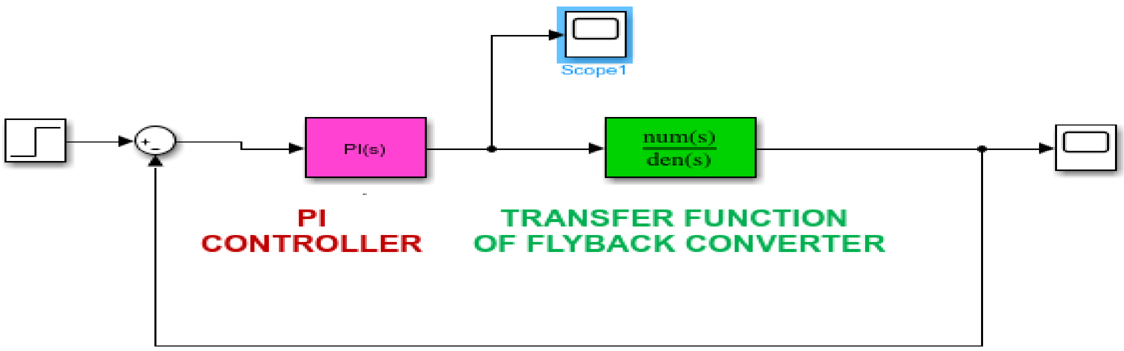

Fig. 8. Transfer function of Flyback converter with PI controller.

KP = 0.00087645

KI = 1.64747

4. Component

A DC voltage source is used to supply the Flyback converter. The Flyback converter gives output voltage greater than input voltage according to PWM produced by Arduino board. The pulse signal from Arduino supplies to a semiconductor through IR2110 driver. Table 1. Present the Performance comparison of flyback converter.

Table 1. Performance comparison of flyback converter

Parameter	Value
Magnetizing Inductor	0.44 mH
Capacitor	2200 uF
PWM Frequency	20 KHz
Input Voltage	12 Volts
Resistive load	500-1000 Ω
Output Voltage	200 Volts
Output power	100 W

5. Results and discussion

The Flyback converter with the PI controller is designed and simulated by using MATLAB R2017A as shown in Fig. 9. The PI controller provided Pulse Width Modulation and controlled on the output voltage by an increase or decrease of the duty cycle. Fig 10 shows the output voltage of the Flyback converter controlled by the PI controller with respect to simulation time.

To suppose the performance of the converter with a closed loop under variation input voltage and load is achieved.

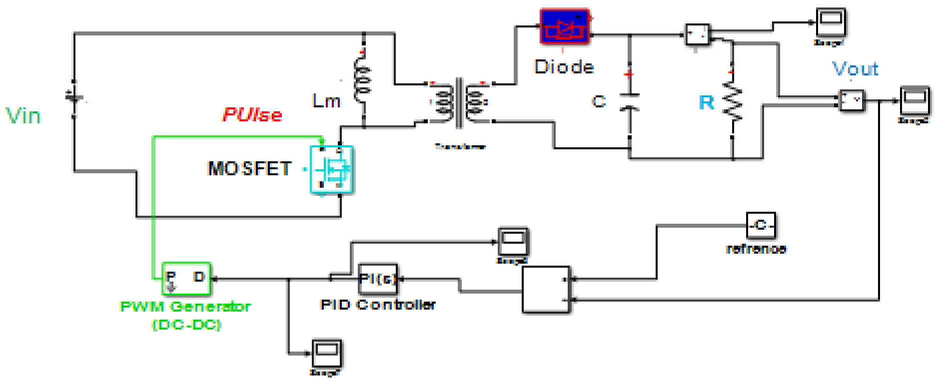

Fig.9. Flyback converter controlled by using PI controller

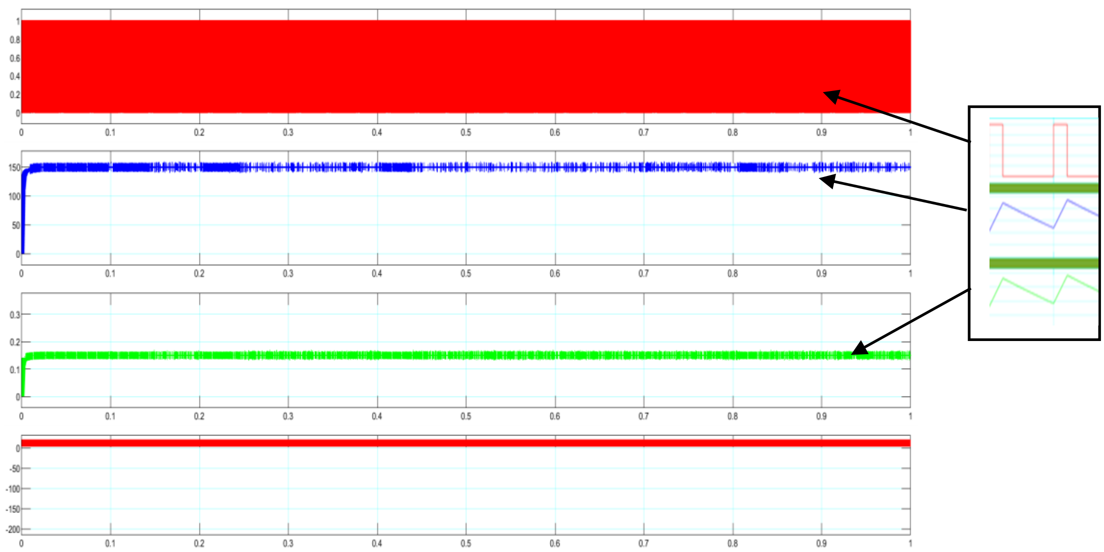

Fig. 10: Waveform of the Flyback converter using PI controller

Fig. 11 shows the effect change in the load on the Flyback converter without used controller.

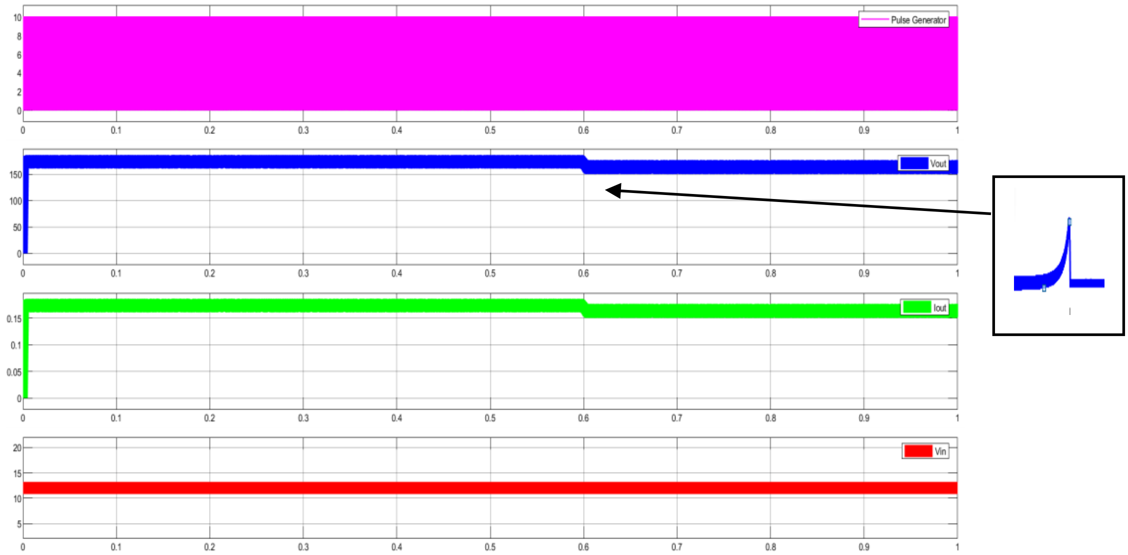

Fig 11. Effect change in the load on the output voltage of converter without PI controller

Fig. 12 shows when the change in the load occurred. The microcontroller (PI or ARDUINO Uno in Hardware circuit) corrected any change to give the desired voltage 200 V.

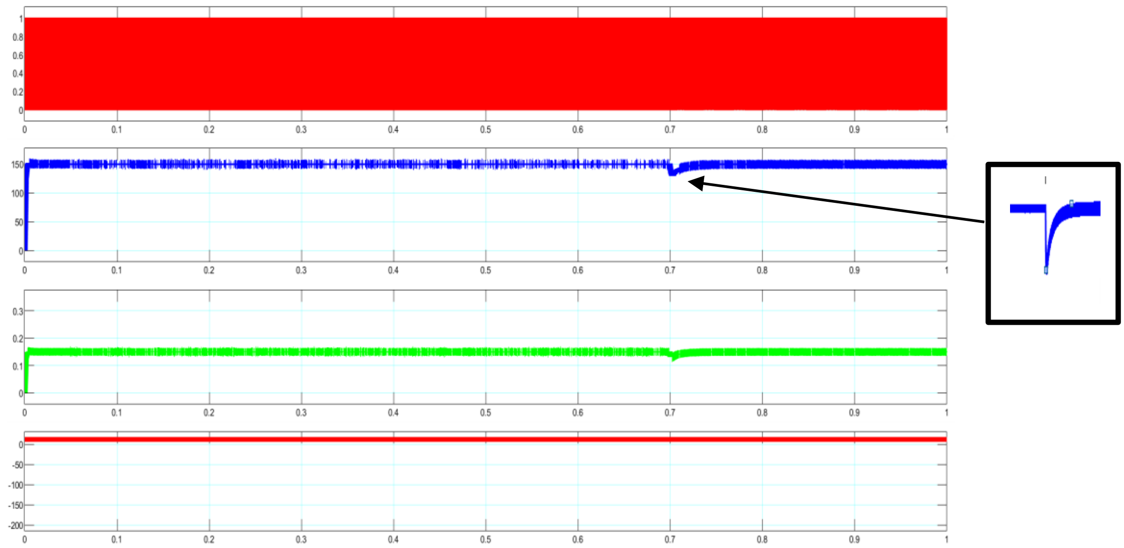

Fig 12. Output voltage of the Flyback converter controlled PI controller at change in the load

When the input voltage increased to 13 V, the output voltage remains constant at about 200 V. The microcontroller (PI or ARDUINO Uno in Hardware circuit) corrected any change to give the desired voltage 200 V (shown in Fig. 13).

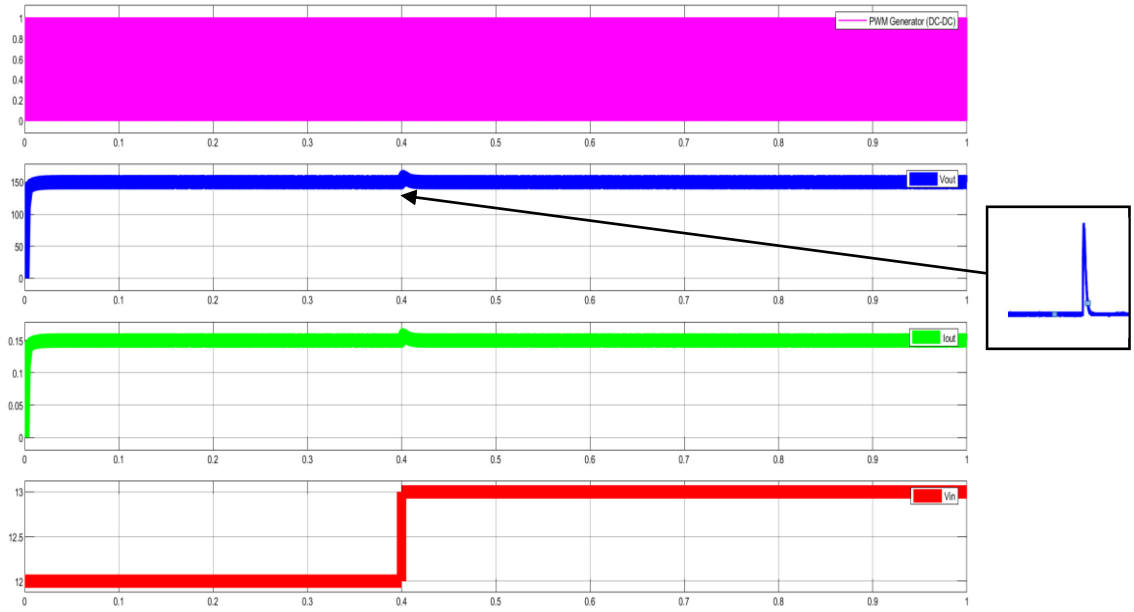

Fig 13. Output voltage of the Flyback converter controlled PI controller at change in the input voltage

Table 2 presents the output voltage constant with the change in the input voltage (constant load of 800 Ω). In this simulation the input voltage variation was from (9-14) V at 1 second. The results showed that the PI controller maintains on the output voltage constant under the change in the input voltage via variation in the duty cycle.

Table .2 Matlab simulation result of pi controlled flyback converter for input voltage variant condition

Input Voltage	Output Voltage	Output Current
9	200.322	0.2504
11	200.366	0.25045
12	200	0.250
13	200.86	0.25107
14	200.98	0.25112

When the resistive load increase or decrease from the 800 ohm (initial value) the output voltage remains about 200 V (constant input voltage 12 V). Table .3 shows the output voltage constant with change in load resistance. The PI controller prevents quickly the load disturbance and returns the output voltage to the interest voltage 200 V.

Table .3 Matlab simulation result of pi controlled flyback converter for resistor variant condition

Load resistance in Ohm	Output voltage in Volt	Output current in Ampere
500	200.222	0.4004
600	200.3256	0.3338
800	200.3451	0.250
900	200.877	0.2231
1000	200.9367	0.2009

6. Flow chart for flyback converter with digital pi controller

The program converter (Flyback or Interleaved Flyback converter) control code written by using IDE (Arduino software) and loaded via USB to the microcontroller. Microcontroller permeates calculation depend on the PI algorithm and produces the PWM. Fig. 14 shows the flowchart of the converter with a digital PI controller.

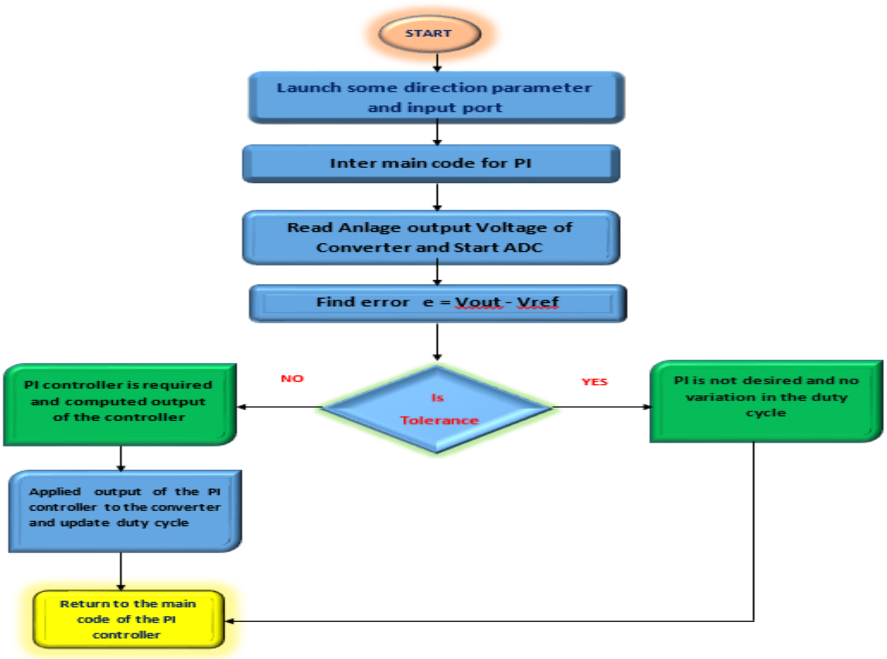

Fig.14: Flowchart of the digital PI controller

7. Hardware implementation

Figs. 15 and 16 show the hardware implementation of the Flyback converter with the Arduino controller. A PWM signal is generated by Arduino in order to trigger the switch through the IC driver (IR2110). To obtain the regulator output voltage of Flyback converter, the closed-loop should be used. The duty cycle has been supplied to switch an increase or decrease depending on the variation in the input voltage or load. The frequency of the PWM is the same as that in the simulated circuit. The Arduino (controller) receives voltage as feedback and computes error to give constant voltage under any change in load or input supply. Fig. 17 shows the secondary voltage of the transformer.

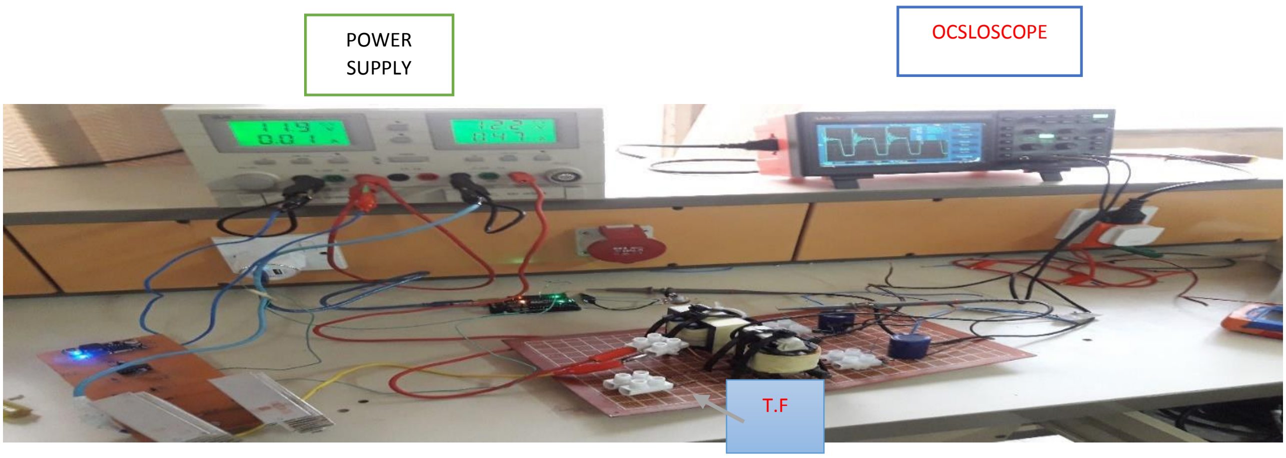

Fig 15. The hardware circuit of Flyback converter

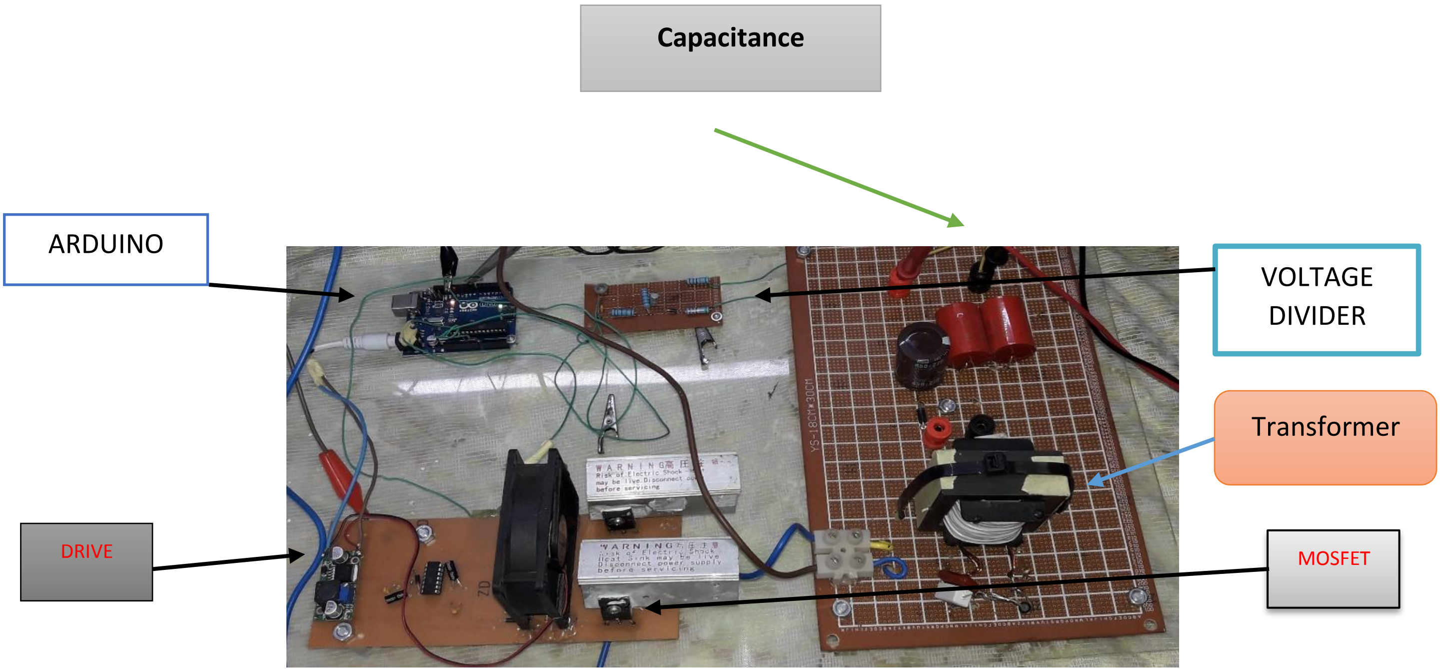

Fig 16. Hardware setup

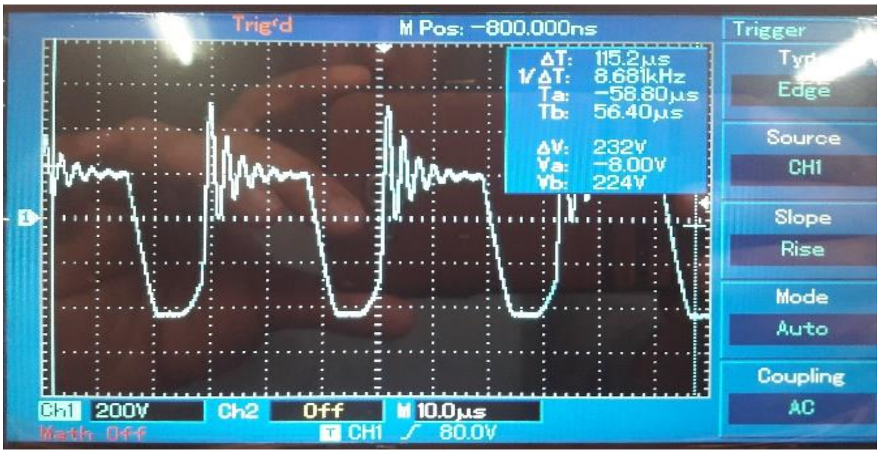

Fig 17. The output voltage from the transformer

8. **Conclusion**

This paper proposed a step-up DC-DC Flyback converter controlled by a microcontroller (Arduino Uno board). Arduino Uno is used to control on Flyback converter by generated PWM .PI controller which is widely used in the control system because of simplicity. Flyback converter used the PI controller to reduce overshoot, steady-state errors and give the desired output voltage. The PI controller was simulated by using MATLAB /Simulation. The Flyback converter implemented is by the PI controller which accomplished through Arduino Uno board. Arduino is used to giving more flexibility and avoid complex hardware to the circuit for any change in the resistive load or input voltage source. Also, it gives a fast response and proposes a low cost of the control system for any variation in input voltage and load.

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