Proceeding of International Conference on Electrical Engineering, Computer Science and Informatics (EECSI 2014), Yogyakarta, Indonesia, 20-21 August 2014

Electrical Discharge Machining Flyback Converter using UC3842 Current Mode PWM Controller

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***Abstract*—This paper presents a current mode Pulse Width Modulation (PWM) controlled Flyback converter using UC3842 for Electrical Discharge Machining current generator control circuit. Circuit simplicity and high efficiency can be achieved by a Flyback converter with current mode PWM controller. The behaviors of the system's operation is analyzed and discussed by varying the load resistance. Matlab software is used to simulate the Flyback converter where a prototype has been built and tested to verify it's performance.**

Keywords—Electrical Discharge Machining, Flyback converter

I. INTRODUCTION

Electrical Discharge Machining (EDM) is a well known non-traditional machining technique since more than fifty years. Advantages of EDM over traditional methods are multiple. Any high-strength and wear-resistant materials can be machined, since the hardness of the workpiece has no effect on the process. Machining performance of EDM is determined by the characteristic of electrical discharge pulse. The machining performance highlighted here is the productivity and surface integrity. Productivity referred as the material removal rate (MRR) while surface integrity is expressed through surface roughness [1] . Discharge current is selected as the most important electrical pulse parameters for evaluating the machining performance [2].

MRR increases with increase in discharge current while rough surface is produced with high discharge current [3]. Lin et al. [4] agreed that, increasing discharge current will cause more energy to be discharged and cause more vaporizing and melting on the machining area . On the paper by Che Haron et al. [5] shows that material removal rate not only dependent on the diameter of the electrode but also with the supply of current The open gap voltage and the discharge voltage need to stays constant during discharge process in order to control the discharge current for required machining performance. Designing power generator which can stabilize the voltage is the main objective in this paper.

Flyback converter is the most commonly used SMPS circuit for low output power application. The overall circuit topology of this converter is simpler than other SMPS circuits because of its output power level less than 150 W. A study by Odulio et. al [6-7] has proposed the flyback converter for EDM due to its low power application. Here, the circuit proposed consist of a power circuit and a control circuit which use to deliver the brute force needed to remove the material.

Current mode control is implemented through two control loops, namely current control loop and a voltage loop. Current control loop monitor the inductor or transformer primary current information, creates the voltage controlled current source. Voltage control loop monitors the converters output voltage (flyback converter), and constantly program the controlled current controller (UC3842) to regulate the output voltage at a given set point.

UC3842 has been proposed as the integrated Pulse Width Modulation (PWM) for EDM because it provides an inexpensive controller with good electrical performance of current mode operation. In addition, UC3842 is optimized for efficient power sequencing of DC to DC converter which is implemented in this paper.

This paper covers a closed loop current mode controlled flyback converter. MOSFET is used as the switching element where UC3842 is used as the current mode PWM controller . MATLAB software is adopted to simulate the behaviors of the converter.

II. OPERATING PRINCIPLE OF FLYBACK CONVERTER

Fig. 1 shows the flyback converter circuit with voltage control circuit and UC3842 as current mode control PWM controller. All components are assumed to be ideal. The working principle of flyback differs from other SMPS topology structure. The output voltage and current can be adjusted by altering the duty cycle of the main switch through the feedback control circuit [8]. UC3842 has been implemented to generate PWM in the proposed circuit.

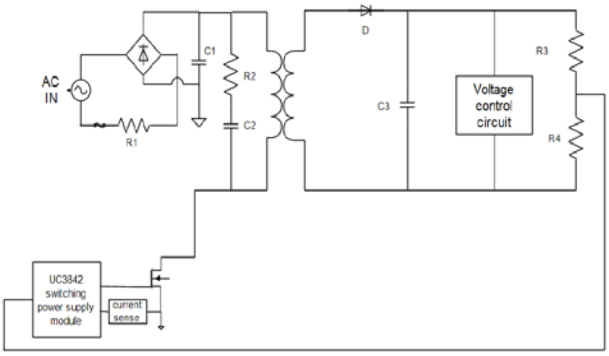

Fig. 1 Circuit diagram of current mode controlled flyback converter

Fig. 2 and 3 shows the equivalent circuit of Mode 1 and Mode 2 operation corresponding to the Switch either in the on or off state respectively.

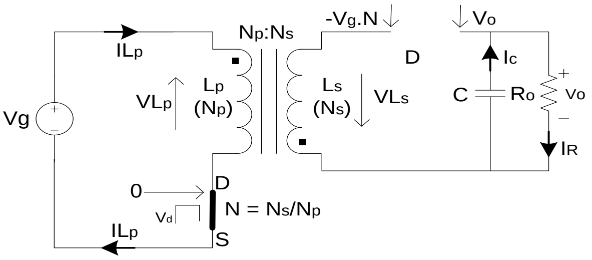

Fig. 2. Mode 1; when Switch on

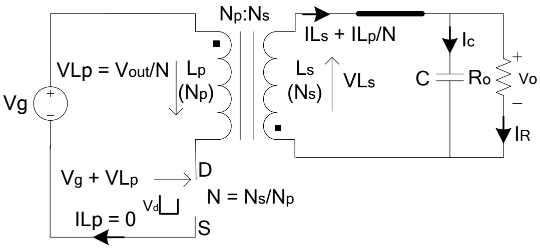

Fig. 3. Mode 2; when Switch off

Fig. 2 [9] shows a parasitic-elements-free flyback when switch (SW) is closed. The primary of the transformer is directly connected to the input voltage. Thus, the voltage across the primary inductor L_p is equal to the input voltage. During this time, there is no current flowing in the secondary side inductor. During the on time, the diode anode swing negative, thus blocking the current from circulating in the secondary side. The output capacitor supplies energy to the output load.

Fig. 3 [9] shows a parasitic-elements-free flyback when switch (SW) is opened. When the switch is turned off, the voltage across the primary inductor reverses, in an attempt to keep the ampere-turns constant. However, as the secondary diode now senses a positive voltage on its anode, allowing current to flow from the transformer. The secondary-side-transformer terminal is now biased to the output voltage, V_{out}, by neglecting the diode forward drop. The energy from the transformer core recharges the capacitor and supplies the load.

A. *UC3842 structure*

Fig. 4 [10] shows the structural block diagram of UC3842. The structure consist of 6 main blocks. Fully compensated Error Amplifier is provided (A) with access to inverting input and output. The non-inverting input is internally fixed at the reference voltage of 2.5 V and not pinned out. The under-voltage lockout (B) ensure that V_{cc} is adequate to make UC3842 fully operate before enabling the output stage. The oscillator (C) frequency is fixed by external timing capacitor, C_T and timing resistor, R_T. The oscillator converts the triangle waveform into rectangular pulse train controlling the operating conditions of the digital circuit forming the shape of the output pulses (E). The circuit consist of RS flip-flop and logic gate. The current sense comparator (D) ensures only a single pulse appears at the output during any given oscillator cycle. The output continues until the voltage at the current sense exceeds the voltage value at the comparator inverting input. The UC3842 PWM (F) has a single totem-pole output which can be operated to ± 1 A peak for driving a MOSFET.

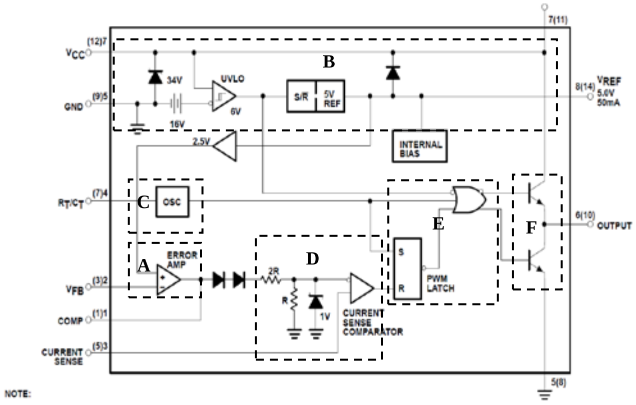

Fig. 4. UC3842 block diagram

B. *Working Principle of the feedback control circuit*

There are two loop implemented by using UC3842 namely voltage feedback loop and current feedback loop. Voltage feedback loop consist of reference voltage of 2.5 V and error amplifier. It is connected with peripheral components by COMP and FB pin where the gain and bandwidth of the error amplifier can be adjusted. Reference voltage of current comparator is the acquired voltage from partial voltage of R resistance after output voltage of error amplifier passes through 2R.

Current feedback loop consist of peripheral current sampling circuit and internal current comparator where reference voltage is acquired from partial voltage of output voltage of error amplifier. Output pulse will be cut off if comparing the voltage with DC feedback voltage directly. Width of output pulse can be reached by changing gain of error amplifier of parameters of current feedback sampling circuit.

The control circuit consist of following component as shown in Fig. 5.

1) Resistance R_s is used as the current sensor. When SW turn on, the current flow through the Rs; once the voltage at pin 3 reaches the threshold value, current limiting occur.

2) Oscillator timing capacitor, C_t is charged by V_{ref} through R_t and discharged by an internal current source where $F_s = 1.72/R_tC_t$. R_t and C_t determine both oscillator frequency and maximum duty cycle.

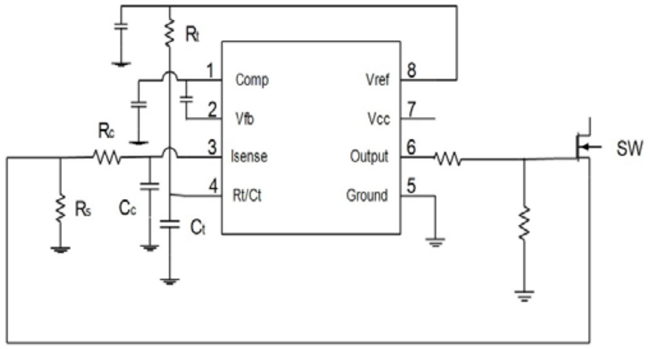

Fig. 5. Control circuit

III. SIMULATION RESULT

Fig. 6 shows the simulation circuit in Matlab. Entire control circuit is replaced by error comparator for voltage feedback loop and PWM generator. In this study, the analysis is done by varying the load resistor in order to study the consistency of the output voltage obtain before an experiment conducted. The load resistor varied from 92.1 Ω to 1014.5 Ω.

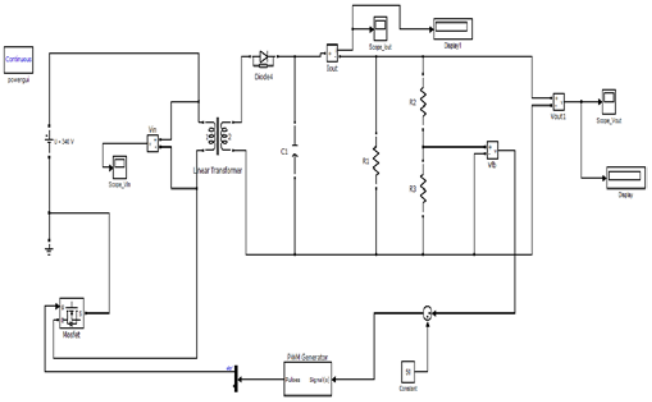

Fig. 6. Matlab circuit for flyback converter

Fig 7 illustrated the waveform of output voltage during simulation. The output voltage regulated in between 98 V to 99 V which is the required voltage.

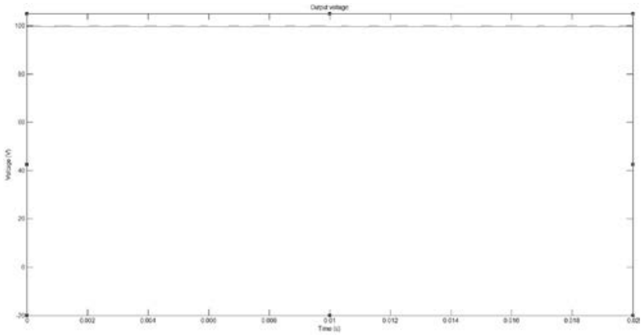

Fig. 7. Output voltage during simulation

Table 1 discussed the average of output voltage and output current respectively. Since output voltage has been stabilized, the output current can be adjusted by varying the load resistor without changing the voltage. Thus, the voltage can stays in the required range in order to obtain required discharge current.

TABLE 1. VARIATION OF OUTPUT CURRENT AND OUTPUT VOLTAGE DURING SIMULATION

Resistance (Ω)	Output Current (A)	Output Voltage (V)
92.1	1.0740	98.82
122.9	0.8073	99.04
155.0	0.6414	99.20
184.3	0.5402	99.29
312.3	0.3200	99.49
379.2	0.2639	99.54
477.1	0.2102	99.60
1014.5	0.0998	99.69

IV. EXPERIMENTAL RESULT

Since simulation using Matlab shows positive response, thus experiment is conducted to verify the performance of the flyback converter as illustrated in Fig 8. The UC3842 now is implemented as switching module for flyback converter.

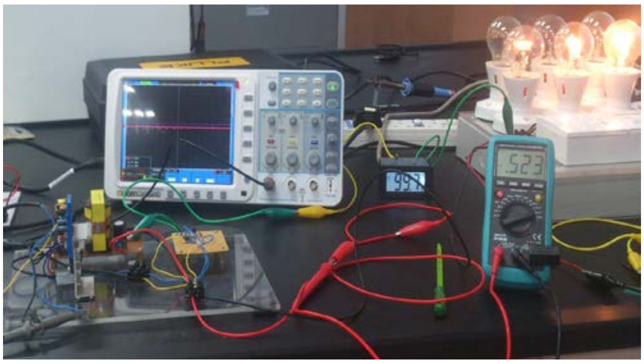

Fig. 8. Experimental set up

Fig. 9 illustrates the Pulse Width Modulation (PWM) waveform measured from the output pin (Pin 6) of UC3842. The measured frequency is 21.8 kHz.

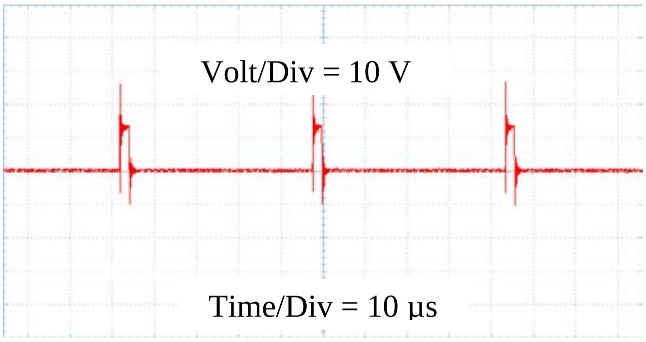

Fig. 9. Pulse Width Modulation (PWM) waveform

The output voltage and output current measured from the experiment are tabulated in Table 2. The voltage varied in the range of 91 V to 111 V, which is still in the required range.

TABLE 2. VARIATION OF OUTPUT CURRENT AND OUTPUT VOLTAGE DURING EXPERIMENT

Resistance (Ω)	Output Current (A)	Output Voltage (V)
92.1	0.99	91.2
122.9	0.75	92.2
155.0	0.60	93.0
184.3	0.51	94.0
312.3	0.31	96.8
379.2	0.26	98.6
477.1	0.21	100.2
1014.5	0.11	111.6

V. CONCLUSION

The performance of flyback converter has been simulated using MATLAB and the corresponding outputs are tabulated. The results highlighted the significant of current mode control which consist of two feedback loop namely current feedback loop and voltage feedback loop along with a controller UC3842 for obtaining regulated output of 100V. The hardware model has been constructed. The pulses generated from the controller UC3842 which uses Pulse Width Modulation technique, drive the gate of the MOSFET to work as the switch. The output voltage during simulation and experiment is found to be constant and stable.

ACKNOWLEDGMENT

The authors would like to acknowledge the financial support of Research Management Centre (RMC) Universiti Teknologi Malaysia

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