An Efficient and Flexible DC to DC Converter With Feedback Control for Communication System

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Abstract— **Many industrial, sciencetific, medical, communication and defence equipments require 32 or 48 volt power suppply. These equipments can be operated in a fixed placed as well as in a mobile unit. Unfortunately, many power supply, especially in a mobile unit, available only in 12 volts. These 12 volt power may come from car battery or solar cell. In this research, a 12 volt DC to 48 volt DC converter is designed, implemented and tested. The power supply is designed as a swithcing mode power supply (SMPS) with feedbcak regulator for efficiency and operasional flexibility. This way, the output voltage can be adjusted by the user to meet their need. The performance of the power supply is obtained by varying the input voltage and varying the output voltage. The power supply is also tested by applying the converter using car battery as its input and loading the power supply. Test results show that the power supply could deliver power from 26.6 to 55 volt DC for input voltage of 9.8 to 12 volt. For output of 48 volt, the converter yields an efficiency of 85% with ripple voltage of 50 milli volt peak to peak.**

Keywords— **DC converter, SMPS, power supply**

I. INTRODUCTION

DC – DC converter is an electronic device used to convert efficiently from one voltage level to another. DC – DC converter is used in many applications such as power supply for personal computer, office equipment, laptops, communication devices, DC motor driver [1] and particle accelerator [2, 3].

In automotive industry, DC – DC converter is needed in the electrical system. In electric and hybrid car, the deivce is used in power regulator to gain car efficiency [4]. In renewable energy system, DC – DC converter is used to convert voltage level from energy source to the battery for storing energy. It could also be used for converting voltage level from battery or energy source to a device [5]. In a computer system, the converter could be used to convert voltage to 3.5V, 5V and 12V [6].

In a satellite communication system, DC – DC converter is used to provide higher voltage from lower voltage sources such as battery or solar cell. In a lower radio frequency communication system, MOSFET and LDMOS RF power amplifier require voltage between 28V to 50V. Thus, also requiring DC – DC converters [7,8,9,10].

A number of converters have been reported in the literatures. For example, Hartwell II [5] developed 120V DC to 1500V DC converter. The input source is a single phase 120V or 240V AC. The output is between 1100 – 1500V and 50 - 570mA. Motorola [11] developed a switch mode pulse width modulation control circuit which converts 8 – 20V power supply to 28 volt, 0.2 ampere power supply. The development of a 12V DC to 48V DC converter is discussed in this paper. The converter is suitable for MOSFET and LDMOS-based RF power amplifier.

II. THE PROPOSED CONVERTER

The proposed DC – DC converter is shown in Fig. 1. The converter consists of four main modules and a number of supporting modules. The output voltage sensor is part of the feedback control element of the converter. The main modules are PWM generator and controller, Push-pull driver, Push-pull MOSFET switching, and high frequency transformer.
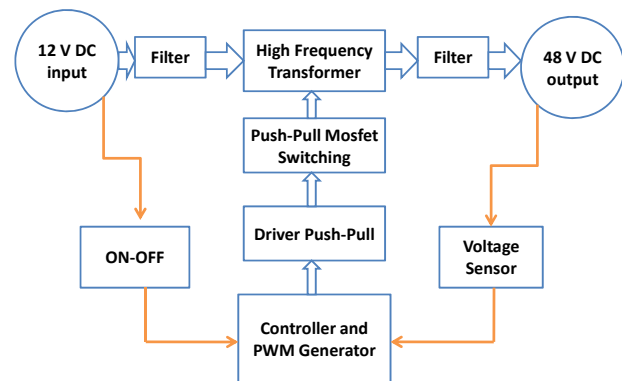

Fig 1. The proposed DC to DC converter

The feedback controller module is intended to control and stabilize output voltage of the converter. The module consists of oscillator, reference voltage, voltage sensor and voltage scale regulator, comparator, OR logic gate, D flip-flop, MOSFET driver, amplifier differentiator, soft start system, and protection system. The oscillator is used as a clock generator to produce saw tooth signal and PWM generator and MOSFET array switching controller. The oscillator is set at 80 KHz. The output voltage sensor is made of voltage divider circuit using variable resistor. The soft start system is used to control the conversion process to avoid sudden current change that may damage the transformer.

The intended output is achieved by way of controlling the signal width of the PWM. A narrow to wide signal width approach is adopted. In this design, the time required to achieve the intended voltage is determined in advance. The voltage controller compares between the output voltage sensed by the voltage sensor and the reference voltage. When the output voltage is below the reference voltage, the width of the PWM is increased. The width is no longer increased when the output voltage is equal to the reference voltage. The PWM is equipped with driver circuit to trigger the MOSFET array which is the switching system of the DC – DC converter.

Extra spool is added in the transformer's secondary spool to avoid voltage drop due to transformer loading or voltage drop in the input voltage. A compensator circuit is added to improve the shape of the switching signal. Improving switching signal will minimize noise and ripples of the converter. The compensator is made up of resistor and capacitor connected in series. The compensator is connected in parallel with the switching output.

The filter in the converter is a low pass filter. It is made up of inductor and capacitor. The filter is applied to the input and output of the converter as seen in Fig. 1.

III. EXPERIMENTAL RESULTS

The designed converter is implemented, tested and evaluated. The converter is tested by varying input voltage, controlling output voltage, and applying the converter on a car.

A. Feedback Control System

The implementation of the feedback control system is shown in Fig. 2. Initially the PWM is tested to evaluate the PWM signal generated by the unit. Next, the controller is tested by varying the input voltage and controlling the output voltage. The experimental result shows that the controller is capable of maintaining the output voltage at 48V DC when the input voltage is 9.8V or higher. When the input voltage is 12V, the controller is capable of controlling the output between 26.6V to 55V DC.
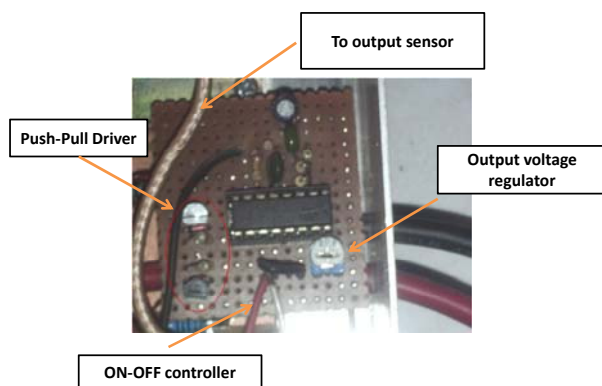

Fig. 2 The control system

B. Title and Author Details

The shape of the output signal before signal compensator is added is shown in Fig. 3(left). It is observed that ripples are present in the signal. For that reason, a compensator was added to the converter, resulting in a better output signal as shown in Fig. 3(right).

Fig. 3 PWM signal before (top) and after a compensator is added (bottom)

C. Loading Test

This test is used to evaluate the performance of the converter when a load is applied to the controller. The input voltage is 12.5V and is taken from a car battery. The output voltage is set at 48.5V before a load is applied. When a load of 8.78A is applied to the converter, the output voltage is stable at 48.5V (sometime blinking at 48.4V) as shown in Fig. 4. At this condition, the input current is recorded to be 40A. Thus,

$$Efficiency = \frac{8.78 \times 48.5}{12.5 \times 40.0} \times 100\% = 85.17\% .$$

The ripple voltage is observed to be 50mV.

D. Input Voltage Variation Test

This test is used to evaluate the performance of the converter due to input voltage variation. In this test, the input voltage is varied between 9.8V to 15,7V. The output voltage is set to 47.9V. The experimental result shows that the output voltage is stable at 47.9V when the input is varied between 9,8V to 15,7V.

Fig. 4 Load and output voltage on loading test

IV. CONCLUSIONS

A DC – DC converter has been successfully developed and tested. The converter is capable of maintaining output voltage at 47.9 volt when input voltage is varied from 9.8 volt to 15.7 volt. When input voltage is maintained at 12 volt, the DC – DC converter is capable of delivering output voltage from 26.6 volt to 55 volt. When input is set at 12.5 volt, load at 8.78 ampere, and output voltage at 48.5 volt, the converter give an efficiency of 85.17%. The ripple voltage is found to be 50 mV peak to peak or 0.4%.

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REFERENCES

[1] R.W. Erickson, A DC-DC Power Converters, Wiley Encyclopedia of Electrical and Electronics Engineering, (1995), http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.122.8642 & rep=rep1&type=pdf Accessed: 22 September 2011.

[2] M.W. Ingram, J.A. Andrews, and D.A. Bresie, An Actively Switced Pulsed Induction Accelerators, IEEE Trans. on Magnetics, 27 (1991) 591-595

[3] M. Wake, Y. Arakida, K. Koseki, Y. Shimosaki, K. Takayama, K. Torikai, W. Jiang, K. Nakahiro, A. Tokuchi, and A. Sugiyama, Switcing Power Supply For Induction Accelerators, (2008) http://www.accelconf.web.cern.ch/accelconf/p07/PAPERS/MOPAN 042.pdf

[4] Z.F. Peng, F. Zhang, and Q. Zhaoming, A Magnetic-Less DC-DC Converter for Dual Voltage Automotive Systems. IEEE Trans. on Industry Applications, 39 (2003)

[5] S. Jalbrzykowski, T. Citko, A Bidirectional DC-DC Converter for Renewable Energy Systems, Bulletin of the polish academy of sciences technical sciences, 57 (2009)

[6] D.H. Lark, A Soft Switching DC-DC Converter With High Voltage Gain, IEEE Trans. on Power Electronics, 25 (2010)

[7] NXP, Applications and Design Manual for High Performance RF Products, (2012), http://www.nxp.com/documents/selection_guide/75017272.pdf Accessed: 28 April 2013

[8] NXP, High Performance RF for Wireless Infrastructure, http://www.nxp.com/documents/ brochure/75017347.pdf Accessed: 28 April 2013

[9] S.J.C.H. Theeuwen, W.J.A.M Sneijers, J.G.E. Klappe, and J.A.M. de Boet, High Voltage RF LDMOS Technology for Broadcast Applications, (2008) http://213.201.145.99/documents/ other/high_voltage_rf_ldmos_technology_for_broadcast_applicatio ns.pdf Accessed: 28 April 2013

[10] A. Tombak, D.C. Dening, M.S. Carroll, J. Costa, and E. Spears, High-Efficiency Cellular Power Amplifier Based on Modified LDMOS Process on Bulk Silicon and Silicon-On-Insulator Substrates With Integrated Power Management Circuit, IEEE Trans. Microwave Theory and Techniques, 69 (2012)

[11] Motorola, TL494 Switchmode Pulse Width Modulation Control Circuit, (2007) http://www.datasheetcatalog.com