

Low-Cost Multi-Phase DC/DC Buck Converter Test Circuit with Simple Control for Testing Multi-Phase Inductors

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Abstract — In this work six-phase DC/DC converter with simplified low-cost topology will be represented. Circuit control block has been developed as direct control concept, without control loop for output signal. Different operating modes are easily adjustable with DIP-4 switch. Duty cycle in all operating modes is 50%. Small resistance power resistor with 50 mΩ resistance has been positioned between ground point and load to provide possibility to circuit user to analyse transient response of test circuit. Operating frequency of circuit is externally adjustable with laboratory frequency counter. The circuit is simple for use and variable inductor topologies, single or multiphase inductors can be tested with this circuit.

Keywords - Circuit topology, DC-DC power converters, Inductors, Testing

I. INTRODUCTION

In order to power the next generation microprocessors which require about 1 V voltage and up to 100 A current, the number of phases in the interleaved multi-phase synchronous buck converter has been increasing. Some of today's designs require as many as 8 phases. Selecting the optimum number of phases is determined by many factors, e.g. output current, system efficiency, the transient requirement, thermal management, costs of capacitors, MOSFET performance, size restriction, and overall system cost. Phase selection is further complicated due to continually changing current requirements making a scalable multiphase converter necessary [1]. A tendency to miniaturize electronic components began in the 1990s. Progress also occurred in surface-mounting technology, and attempts have been made to accomplish high density, incorporation of ferrite inductors into a printed circuit board [2]. Recent technological developments concerning electrical devices demand higher performance of the inductor i.e. higher frequency application and further miniaturization [3]. One of the major advantages of the multiphase buck converter is the ripple cancellation effect, which enables the use of a small inductance to improve the transient response

and to minimize the output capacitance [4]. Thus, there are many designers working on development of new inductor topologies in order to improve performances of modern DC/DC converters.

One of the main steps in process of inductor development are operating tests which provide good feedback to designers about performances of developed inductor topologies. While working on development of new multi phase inductor topology, authors developed six-phase test circuit presented in this work.

II. TEST CIRCUIT TOPOLOGY

Six-phase DC/DC converter is built as a test circuit in order to test inductors in operating conditions. Test circuit was divided in two functional blocks: Control block and Power block.

Main part of simple control block represented in Fig. 1. is Atmel's AT TINY26 controller. This micro-controller sending control signals via circuit (M74HCT541B1R) to the power block of test circuit, actually to the gates of power MOSFETs. Control circuit was designed in such way that can be synchronized by external frequency counter, instead with crystal oscillator. This kind of realization make possible for user to change frequencies of control signal very easy during tests with simple change of synchronizing signal frequency generated at frequency counter and connected to XTAL input of controller. This control block is able to create test signal at maximal driving frequencies about 5 MHz depending on selected operation mode. DIP SW in control circuit is used to select operation modes of test circuit. Operating modes of this circuit are as follows: 1x1, 2x1, 3x1, 4x1, 5x1, 6x1, 3x2 and 2x3. In order to test on e.g. six-phase inductor performance, test circuit operating modes 6x1, 3x2 and 2x3 have been used.

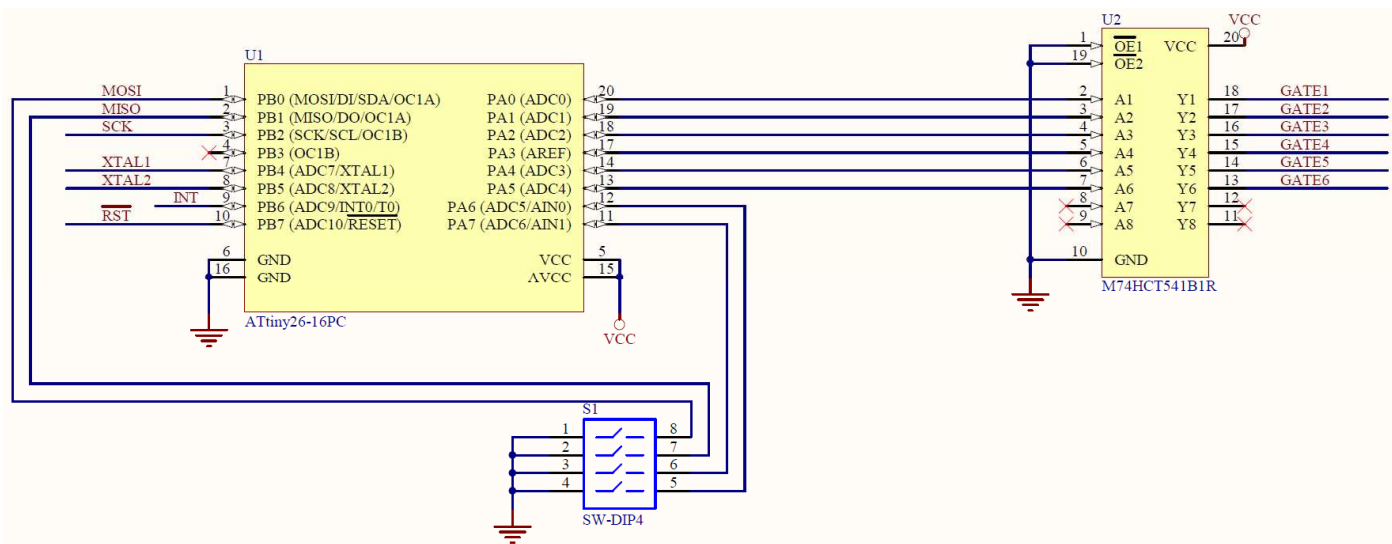


Fig. 1. Control block of test circuit

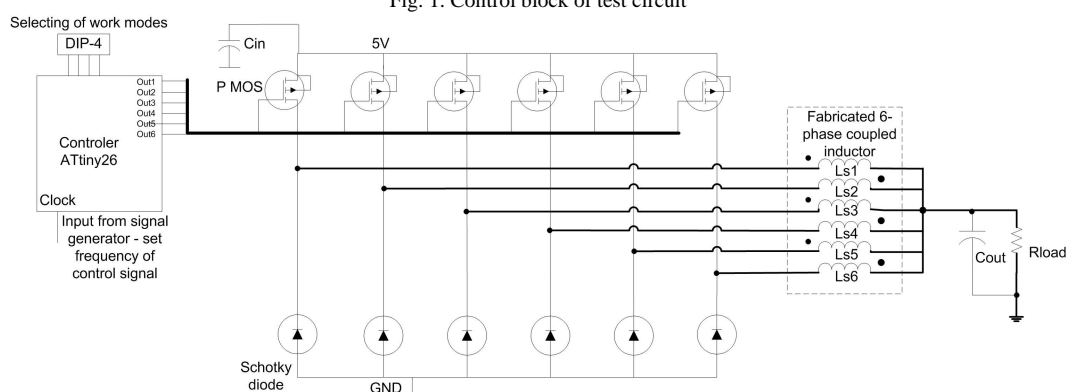


Fig. 2. Simplified schematic of test circuit

Schematic of test circuit power block was developed as simplified Buck converter concept (MOSFET-diode combination) realized with six phases. SMD P-MOS transistors IRF5305 are selected as power switch component in combination with fast Schottky diode for inductor relaxation cycle. All phases are interconnected at circuit output and provide controlled power supply signal to the load. Schematic with simplified control block and complete power block is shown in Fig. 2. Test circuit hardware with tested inductor sample is presented in Fig. 3.

III. HARDWARE IN OPERATION MODE

Test circuit during operating tests is presented in Fig. 4a. Test equipment and frequency counter are shown in Fig. 4b. Six-phase inductor sample has been tested in the test circuit in operating mode 6x1 (Fig. 5a). Circuit output Voltage and AC current with 1 Ω power load were measured at Tektronix TDS 2024B oscilloscope and have been presented in Fig. 5b. Operating frequency was 1.1 MHz and phase inductance of inductor was 250nH.

Efficiency of the circuit is around 73% depending on selected operation mode and properties of tested inductor. In the future this efficiency can be increased by implementing additional input and output condensers and optimizing control signal operating frequency. For the purpose of initial operating analysis of inductor samples efficiency of the circuit is not important, because most of the comparative tests between commercially available and developed inductors in operation mode can be easily conducted with this circuit.

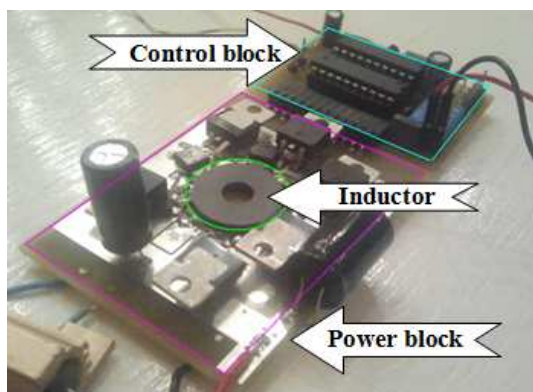
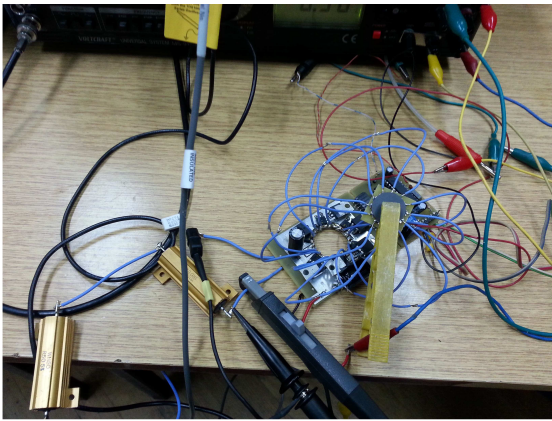
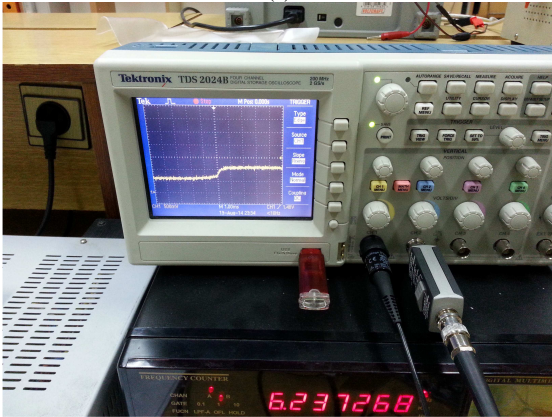


Fig. 3. Test circuit hardware

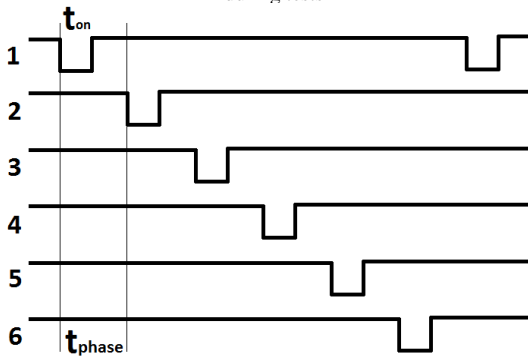


(a)

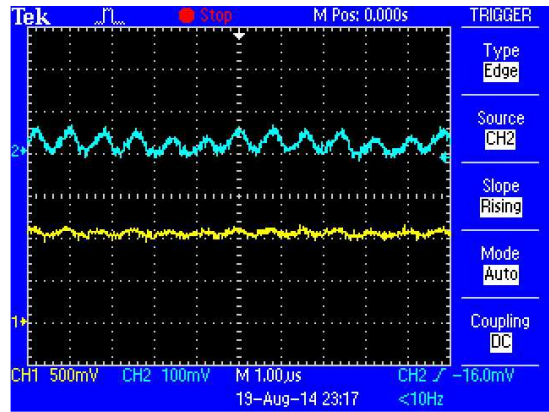


(b)

Fig. 4. Operating tests of inductor sample in the test circuit: a) active hardware with attached test probes and b) frequency counter and oscilloscope used during tests



(a)



(b)

Fig. 5. 6x1 operating mode: a) control signal and b) output voltage and AC current signal of test circuit in 6x1 operating mode

IV. CONCLUSION

Six-phase DC/DC buck converter circuit was developed with intention to test different prototypes of inductors. This test circuit was not designed to be high efficiency power supply. The main purpose of such circuit is to provide easy testing procedure to user. Operating modes can be selected easily by change of active phases in DIP4 switch combination. Adjusting of operating frequency by the external frequency counter provide comfort work with the test circuit. Different types of single inductors or multi-phase inductors up to six phases can be tested with this circuit.

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