PAPER • OPEN ACCESS

Implementation of Cuk Converter with dSPACE1103 controller

View the article online for updates and enhancements.

Implementation of Cuk Converter with dSPACE1103 Controller

Tinoy Santra[1], Ritik Gupta[1] and R Gunabalan[1]

[1]Vellore Institute of Technology – Chennai, TamilNadu, INDIA

gunabalan.r@vit.ac.in

Abstract. This paper discusses a simple approach for the implementation of closed loop control of Cuk converter in real time using dSPACE1103 controller. The control algorithm and the proportional integral controller (PI) are constructed in MATLAB simulink with dSPACE blocksets. The converter is designed with a power rating of 18 W with 30 V output voltage for LED driver applications for an input of 12 V DC supply. The Cuk converter and the driver circuits are designed and fabricated in real time. The circuit is tested under different running conditions. Simulation and experimental results are provided to validate the performance of the converter.

1. Introduction

The demand of renewable energy resources has increased since past few years [1]. Over consumption of the non-renewable energy resources is a great threat to the mankind. Resources are depleted when it is being over used without giving time to replenish it. Developed countries continue to consume huge amounts of energy while demand is increasing in developing countries. Experts believe that according to the present rate of consumption, earth has enough coal reserves to light up our homes for 150 years and this may decrease with increase in the consumption. Also, combustion of coal releases a toxic gas that leads to global warming [2]. Therefore, people are switching to renewable energy resources as they are clean and abundant. But, the generation of power from solar is not constant and fluctuate according to the climatic conditions. For smooth operation, DC-DC converter is being used [3].

A Ćuk converter is a type of DC-DC converter which is the combination of both buck and boost converter. It can produce greater or lesser voltage than the input voltage depends on the duty ratio. The polarity of the DC output voltage is opposite with respect to the input DC voltage polarity [4]. The main advantage of this converter over buck boost converter is that the input current is continuous in nature [5]. The capacitor plays a very important role as energy saving element for this converter. For implementation of power electronic converter circuits in real time applications, microcontrollers and high speed digital signal processors are employed for switching pulse generation and for controller algorithms. dSPACE is one such platform in which control signal blocks and controllers blocks can be built easily with MATLAB simulink blocks. It is used in piezo electric energy harvesting system and solid state transformer applications [6] – [7]. It is also used for PWM control of power electronics converters [8]. In this paper, a simple experimental set up is provided with dSPACE controller for closed loop operation of Cuk converter.

2. Cuk converter

The circuit diagram of a Ćuk converter is shown in Figure 1. The circuit consists of a switch MOSFET 'S'; two inductors L_1, L_2; two capacitors C_1, C_2 and a diode D. Initially, switch is off. When supply is given to the circuit, diode D is forward biased and so current flows through inductor L_1, capacitor C_1 and diode D. the main function of capacitor C_1 is to store and transfer energy from the input side to the output side.
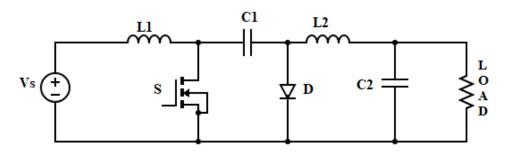

Figure 1. Cuk converter

2.1 Modes of operation

This converter operates in two different modes. First mode comes into play when switch 'S' is ON and second mode counts when switch 'S' is OFF. The output voltage is negative for this converter.

2.1.1 Mode 1: Switch ON

This mode begins when switch 'S' is closed as shown in Figure 2. The inductor current began to rise linearly and flows through the switch. The voltage across the capacitor reverse biases the diode D. The capacitor C_1 feeds the load and the output capacitor is charged.
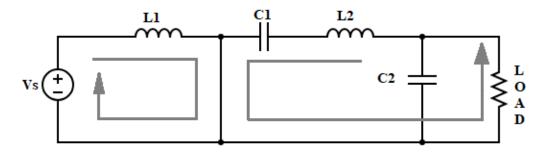

Figure 2. Mode 1 operation

2.1.2 Mode 2: Switch OFF

This mode starts when switch 'S' is turns off as shown in Figure 3. The capacitor C_1 charges towards input voltage V_{in}. The energy stored in inductor L_2 is released through load.
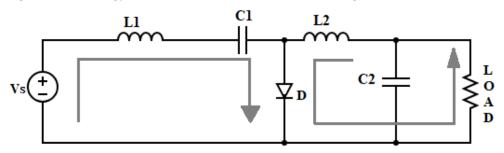

Figure 3. Mode 2 operation

3. Results and discussions

Table 1 shows the circuit specifications and component values of the converter. Figure 4 shows the experimental setup of a Cuk converter along with dSPACE1103 controller. The dSPACE1103 controller is used to generate the control signal with a switching frequency of 50 kHz. The switching pulse is generated using DS1103_DSP_PWM3 block which is available in SLAVE DSP F240 blocksets. The output pulse from the dSPACE1103 controller is obtained from the pin number 7 of slave I/O connector and is increased to 12 V with the help of TLP250 driver circuit. TLP 250 is an optically isolate driver i.e., input and output is "optically isolated". The hardware model of the Cuk converter is shown in Figure 5.

Table 1. Specifications of Cuk converter

Component details	Rating
Input voltage	12 V
Output voltage	30 V
Power rating	18 W
Inductor L_1	560 μH
Inductor L_2	2.86 mH
Capacitor C_1	2 μF
Capacitor C_2	470 μF
Diode D	MUT640
MOSFET	IRF250N

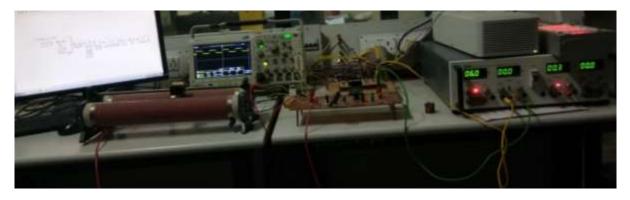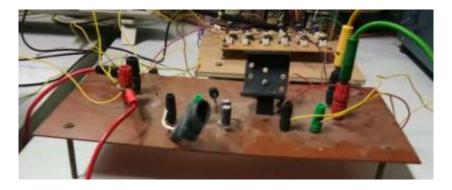**Figure 4**. Experimental set up for closed loop control of Cuk converter

Figure 5. Hardware model of Cuk converter

3.1. Open loop condition

The block diagram of the experimental set up in open loop condition is shown in Figure 6. The switching pulses are generated using PWM control blocks available in dSPACE1103 controller along with MATLAB simulink blocksets. It is very simple and no need of additional microcontroller or DSP processors. Figure 7 shows the switching pulse with the frequency of 50 kHz at 70% duty cycle. The input voltage for the circuit is 12 V and a rheostatic load of 70 Ω is connected across the load. The mean output voltages are observed in MDO3143 (Mixed Digital Oscilloscope).
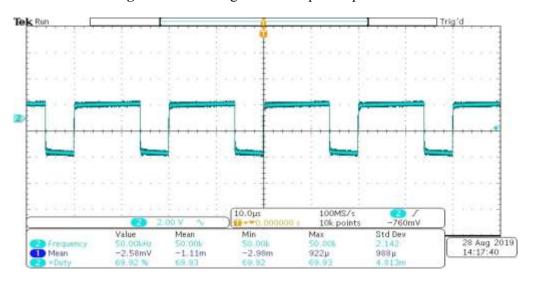

Figure 6. Block diagram under open loop condition

Figure 7. Switching pulse with 70% duty cycle - open loop condition

3.2. Closed loop condition

Closed loop control of Cuk Converter is used to obtain a constant DC output voltage. The inductor current and duty cycle decide the output voltage. The block diagram of the Cuk converter in closed loop operation is shown in Figure 8. In the closed loop process, the output voltage is compared with a reference voltage and the error value is reduced by controlling the switching pulse using PI controller. The basic operation is that if the error value is positive, the duty cycle is reduced and if the error value is negative, the duty cycle is increased to maintain constant output voltage. The dSPACE1103 controller is used to generate the switching pulse of 50 kHz. In the closed loop control, the output voltage and duty cycles are measured. Figure 9 shows the closed loop simulation of a Cuk converter in Simulink with PI controller. The Simulink file is modified with real time interface RTI library of dSPACE1103 controller. In dSPACE1103, the feedback voltage must be within the limits of ±10 V. The output voltage is stepped down using a potentiometer and given to the dSPACE1103 chip via analog to digital converter [S1103MUX ADC CON1]. For the feedback voltage of ±10V , the output voltage of ADC is ±1 V. The output analog voltage is converted into digital signal and is compared to the reference voltage in control desk. The digital pulse signal is connected via DAC. For the input range of ±1 V, the output voltage of the DAC is ±10 V. The output voltage of the DAC is fed to the TLP250 driver circuit to increase the voltage magnitude of pulses in the range of 12 V - 15 V which is sufficient to trigger the MOSFET switch. During the run time, the set voltage is varied and output

voltages are captured in multi-meter and MDO3143. The reference voltage is set in the control desk. Figure 10 shows the output voltage at 60% duty cycle.
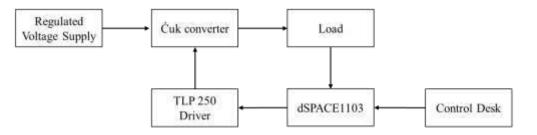

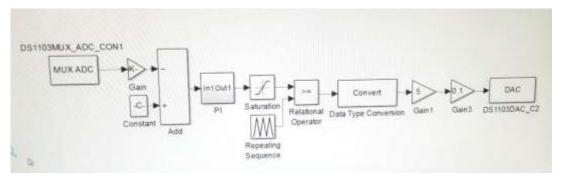**Figure 8**. Block diagram under closed loop condition

Figure 9. Closed loop circuit in simulink environment with dspace blockset
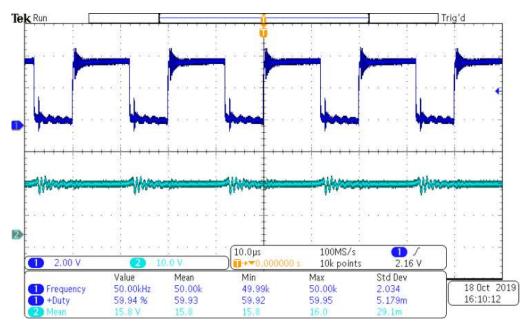

Figure 10. Output voltage at 60% duty cycle under closed loop operation

4. Conclusion

In this paper, a simple approach for implementation of Cuk converter is presented under simulink environment. The controller blocks are constructed in Simulink with dSPACE controller blocksets. The control signal is generated using PWM blocks in dSPACE without additional hardware

components. The experimental results are provided under open loop and closed loop operating conditions. Academicians and researchers can implement any type of power electronics converter circuits in real time in dSPACE environment.

References

[1]   Asok R and Ram Jeyanth K R S 2012 Outburst of renewable energy in India is it towards the target? *Proc. Int. Conf. on Advances in Engineering, Science and Management*.

[2]   Stefanos T T, Apostolos I K and Angelos G C 2016 Natural or anthropogenic is the unbalance of the radiation on earth and the related global warming — Climate change? parameters, answers and practice *Proc. Conf. on Power Generation, Transmission, Distribution and Energy Conversion*.

[3]   Bhushan P M and Vadirajacharya K 2017 Extensive modeling of DC- DC Cuk converter operating in continuous conduction mode Proc. *Int. Conf. on Circuit, Power and Computing Technologies*

[4]   Marcos   V   D   and   Romero   L   A   2015   Dynamic modeling and design of Cúk converter applied to energy storage systems *Proc. Brazilian Power Electronics Conf.*

[5]   Shringi S, Santosh K S and Kuldeep Singh R 2019 Comparative study of buck-boost, Cuk and Zeta converter for maximum output power using P&O technique with solar *Proc. Int. Conf. on Power energy, environment and intelligent control*.

[6]   Sarker M R and Mohamed M 2019 dSPACE controller-based enhanced piezoelectric energy harvesting system using PI-lightning search algorithm *IEEE Access* **7** 3610–26.

[7]   Meshram R V, Bhagwat M, Khade S, Wagh S R, Stankovi A M and Singh N M 2017 Port-controlled phasor hamiltonian modeling and IDA-PBC control of solid-state transformer *IEEE trans. control sys. tech*, **27**, 161–74.

[8]   Amalrajan R, Gunabalan R and Nilanjan Tewari 2019 dSPACE1103 controller for PWM control of power electronic converters *Proc. Int. conf. on PECCON'2019*