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Performance Evaluation of a Cûk Converter in DC/DC Conversion System and Performance Improvement by Stage Cascading Technique

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Abstract

Normally the Cûk converter is used as DC/DC converter that has two types of output voltages in magnitude that is; the output is either greater than or less than the input voltage magnitude. The basic construction of a Cûk converter is essentially a boost converter followed by a buck converter coupled by a capacitor. Unlike buck-boost converter the energy delivered by a Cûk converter is stable, easily attainable to the desired level and energy efficient. In this paper, the performance of a Cûk converter is investigated and shown that the performance can be significantly improved by two or more stage cascading.

Keywords:Cûk converter, Cascading, Buck-boost, MOSFET etc.

I. NTRODUCTION

A DC/DC converter is a device that takes a DC voltage as input and produces a DC output voltage. The output produced is of a different voltage level than the input. Moreover, DC-to-DC converters are used to provide noise isolation, power bus regulation, etc [1]. A DC to DC converter in electronic engineering is a circuit which converts a source of direct DC from one voltage level to another. It is a typical class of power converter. The purpose of a DC/DC converter is to supply a regulated DC output voltage to a variable-load resistance from a fluctuating DC input voltage. In many cases the DC input voltage is obtained by rectifying a line voltage that is changing in magnitude [2]. DC-DC converters are commonly used in applications requiring regulated DC power, such as computers, medical instrumentation, communication devices, television receivers, and battery chargers [3].

DC converters are used as switching mode regulators to convert a dc voltage, normally unregulated, to a regulated dc output voltage. The regulation is normally achieved by PWM (Pulse Width Modulation) at fixed frequency and the switching device is normally BJT, MOSFET or IGBT [4].

Pulse-width modulation (PWM) of a signal or power source involves the modulation of its duty cycle, to either convey information over a communications channel or control the amount of power sent to a load [5]. The simplest way to generate a PWM signal is the intersective method, which requires only a sawtooth or a triangle waveform (easily generated using a simple oscillator) and a comparator. When the value of the reference signal is more than the modulation waveform, the PWM signal is in the high state, otherwise it is in the low state [6].

Switching regulators are commercially available as integrated circuits. The designer can select the switching frequency by choosing the value of R and C of the frequency oscillators. Basic converters are of four types: Buck Regulator, Boost Regulator, Buck-boost Regulator and Cûk Regulators [7].

Unlike other DC/DC converters (buck, boost and buck-boost), the Cûk converter uses capacitor for transferring energy between input and output and the analysis is based on the current balance of the capacitor [8]. Whereas the buck, boost and buck-boost converters transfer energy between input and output use the inductor, analysis being based on the voltage balance across the inductor [9].

The Cŭk converter is a DC/DC converter which uses a power bipolar junction transistor as a switching device [10]. Similar to the buck-boost converter, the Cŭk converter provides an output voltage that is less than or greater than the input voltage, but the output voltage is opposite to that of the input voltage [11]. It is named after its inventor.

II. SYSTEM BLOCK DIAGRAM

The block diagram of a double stage Cûk converter is shown in fig 1. The system consists of an input block, Cûk converter stage 1 and 2 and the output block. In this conversion system, the input DC voltage is processed by two stages of Cûk converter topology to achieve a higher and efficient DC output.

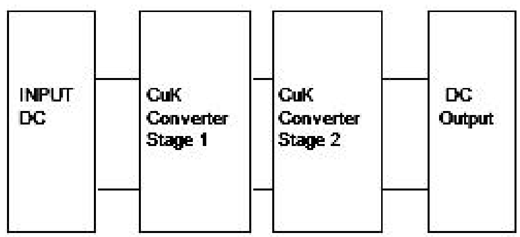


Fig 1: Double stage Cûk converter block diagram

III. ANALYSIS OF CÛK CONVERTER

A. Single Stage Cŭk Converter

The schematic of a Cûk converter is shown in fig 2. When the input voltage is turned on and the switch is in off state, the diode D_m is forward biased and capacitor C_1 is charged though L_1, D_m, and the input supply V_{in}. It has two operating states; Switch On state and (Mode 1) Switch Off state (Mode 2).

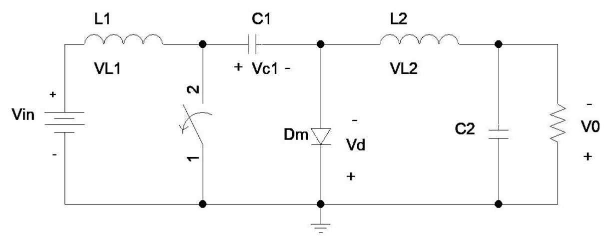


Fig 2: Schematic of a single stage Cûk converter.

Mode 1 begins when the Switch is turned on at t = 0. The current though inductor L_1 rises. At the same time the voltage of capacitor C_1 reverse biases diode D_m and turns it off. The capacitor C_1 discharges its energy to the circuit formed by C_1, C_2, the load, and L_2.

Mode 2 begins when the switch is turned off at $t = t_1$. The capacitor C_1 is charged from the input supply and the energy stored in the inductor L_2 is transferred to the load. The diode D_m and the switch provide a synchronous switching action. The capacitor C_1 is the medium for transferring energy from the source to the load.

B. Analysis of Single Stage Cŭk Converter

From the above configuration (fig 2), if the duty cycle of operation is D, T_s in the time on and (1-D)T_s is the time off period then, applying current balance condition in the inductor we get [12],

$$V_d DT_s + (V_d - V_{c1})(1-D)T_s = 0 \qquad (1)$$

$$or,\ V_{c1} = \frac{1}{1-D} V_d \qquad (2)$$

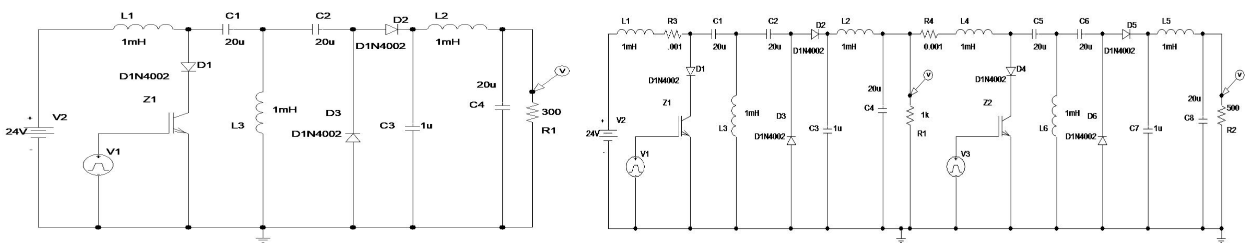
$$Again,\ (V_{c1} - V_0)DT_s + (-V_0)(1-D)T_s = 0 \qquad (3)$$

$$or\ V_{c1} = \frac{1}{D} V_d$$

$$\therefore V_0 = \frac{D}{1-D} V_d \qquad (4)$$

C. Design of Double Stage Cŭk Converter

Following the previous section, the basics of a Cûk converter is used to design an energy efficient double Cûk converter. The basic circuit configuration is supported by some voltage stabilizers/boosters and suitable couplers. The schematic of this design is shown in Fig.3. The output of each stage is shown by suitable marker in the schematic.



(a) **(b)**

Fig 3: (a) Schematic of single stage Cûk converter (b) Double stage Cûk converter

The parameters is used for the switching voltage (Vpulse) are; $V_{dc} = 0$, $V_{ac} = 0$, $V_1 = 0$, $V_2 = 10V$, $T_D=0$, $T_R=0.001ms$, $T_F = 0.001ms$, PW = 0.12ms, and PER = 0.15ms for both the 1st stage 2nd stage Cûk converter. The input voltage is 6V, 12V, and 24V for different simulation phases [12].

IV. RESULT AND DISCUSSION

In this paper, we have developed an efficient model Cûk converter for the DC/DC network. The Cûk converter being superior to all other converters, i.e., can supply a stable output irrespective of load variation, once double stage is added it's an unique tool as energy efficient converter.

The performance of the Cûk converter has been evaluated by PSpice simulation with single and double stages and the simulation result is shown in fig 4 to 10. In figs 5 to 7, the output of a single stage Cûk converter is shown for different input voltages. In this simulation the input voltages of 6V, 12V and 24 DC are taken to observe the response of the Cûk converter in. It has been observed that for stage Cûk converter the output voltage increases with the increase of input voltage.

In figs 8 to 10, the response of a specially designed double Cûk converter to depicted. It has been observed that the double stage Cûk converter output is significantly increased compared to the single stage with the same input voltage. The comparison of the single stage output voltages and double stage output voltages are shown in table1.

TABLE 1. COMPARISON OF SINGLE AND DOUBLE STAGE OUTPUT VOLTAGES

Input Voltage	Single stage output	Double stage output	Increase in voltage
6V dc	18V dc	26V dc	8V dc

12V dc	45V dc	75V dc	30V dc
24V dc	75V dc	82V dc	7V dc

In fig 4, the comparison of single stage and double stage Cûk converter has been shown. The data of table 1 has been plotted by MatLab simulation which shows that the Cûk converter in most energy efficient at an input voltage of 12V dc. At 6V and 25V dc input the efficiency is mostly same and nominal.

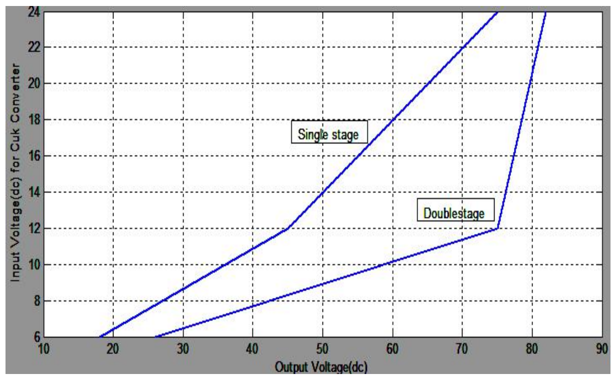


Fig 4: Output of Cûk converter single stage (when 2nd stage is not connected); input 6V dc.

The performance of a Cûk converter can be significantly improved by increasing the number of stages (double stage) and the simulation result show that there is additional amount of improvement of the system over a single stage Cûk converter by this proposed technique. However, the optimum number of stages of the Cûk converter can be used for best performance is not calculated, remain as future works.

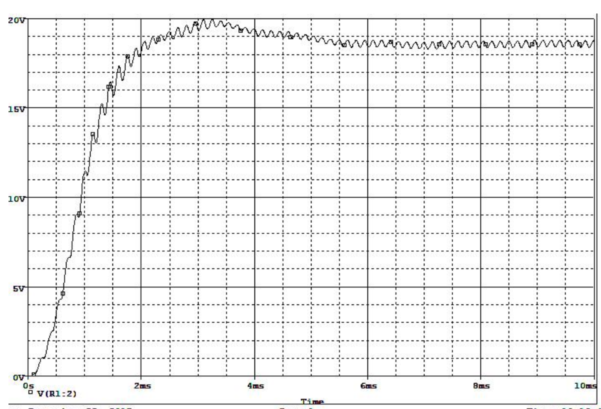


Fig 5: Output of Cûk converter single stage (when 2nd stage is not connected); input 6V dc.

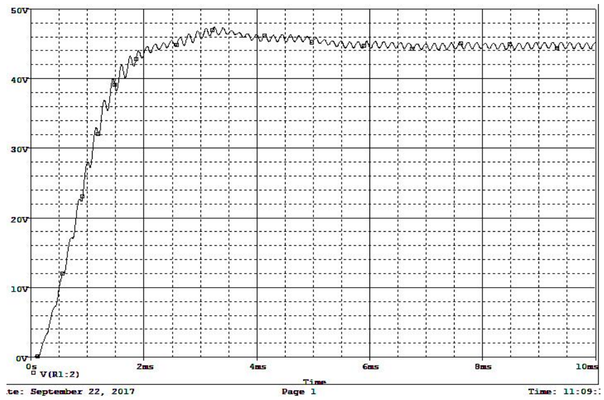


Fig 6: Output of Cûk converter single stage (when 2nd stage is not connected); input 12V dc.

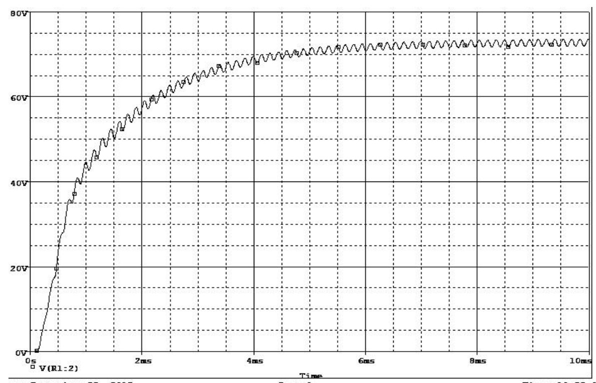


Fig 7: Output of Cûk converter single stage (when 2nd stage is not connected); input 24V dc.

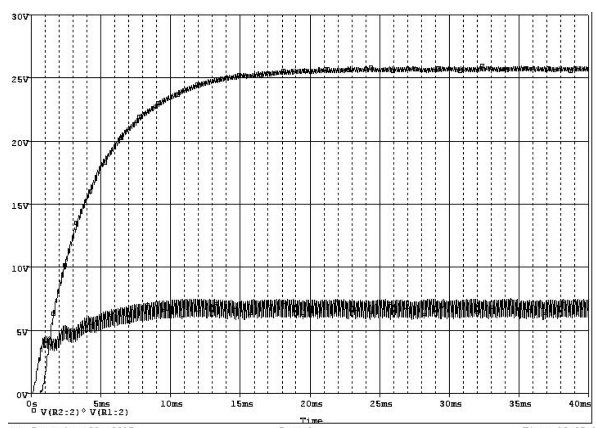


Fig 8: Output of double stage Cûk converter; input 6V dc.

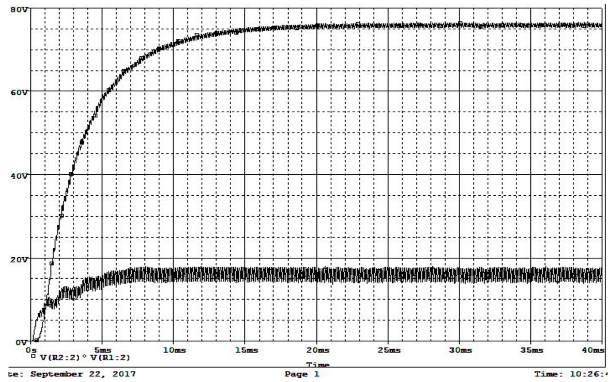


Fig 9: Output of double stage Cûk converter; input 12V dc.

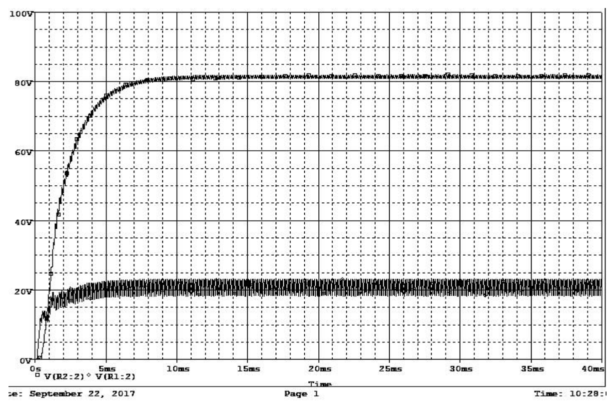


Fig 10: Output of double stage Cûk converter; input 24V dc.

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