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COMPARATIVE STUDY OF SELF-LIFT DC-DC CONVERTERS WITH HIGH VOLTAGE GAIN

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Abstract— This paper discussed about two DC-DC converters with same design and different voltage gain. The voltage conversion ratio is different. Compared with the classical Cuk and buck–boost converters, the converter increases the voltage boost ability significantly using the switched capacitor and self-lift techniques. Here we discussed enhanced self-lift Cuk converter and self-lift Luo converter. It is featured with single power switch operation, common ground, transformerless structure, and clear energy delivery process. This compare study is done by MATLAB 2013a.

Keywords— Boost ability, DC–DC converter, Voltage gain, Cuk converter, Luo converter.

INTRODUCTION

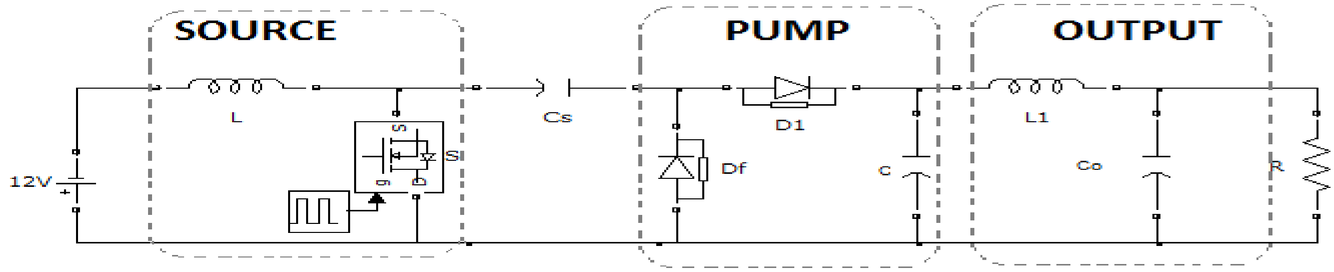
Many applications of switch-mode DC-DC converters require higher conversion rates. An alternative solution to this problem is to use n-stages connected in cascade, Such that the total conversion rate can be increased by an order of n. However, the resulting problems, energy losses, multiple power switches, and large switching surges in transformers significantly increase the control complexity and the cost of these converters [1]. The use of the voltage multiplier technique applied to the classical non-isolated DC–DC converters in order to obtain high step-up static gain, reduction of the maximum switch voltage, zero current switching turn-on. The diodes reverse recovery current problem is minimized and the voltage multiplier also operates as a regenerative clamping circuit, reducing the problems with layout and the EMI generation. These characteristics allows the operation with high static again and high efficiency, making possible to design a compact circuit for applications where the isolation is not required. The operation principle, the design procedure and practical results obtained from the implemented prototypes are presented for the single-phase and multiphase DC–DC converters [2]. The derived circuits can increase the voltage-conversion ratios under the single power switch condition, but the number of passive components is also obviously increased. Classical nonisolated DC–DC topologies, such as switched-capacitor (SC), switched-inductor (SL), hybrid SC/SL, and voltage-lift (VL) techniques, have been greatly explored. The main advantage of SC techniques is the absence of inductors, thus making it very small in size and high in power density[3][4]. Switched-capacitor technology is widely used in low power DC–DC converter. This method can reduce the high pulse current which usually causes serious problem in traditional converters. The well-known one is the charge pump circuits. They are widely used in low power DC–DC converter, especially in power management of the integrated circuits. Usually, they use high-frequency switching actions and only use capacitors to transfer the energy [5]-[8].

In this paper, the concept of the voltage self-lift techniques has been integrated into an SC cell, and consequently, a new step-up circuit is proposed on the basis of the classical converter.

SELF-LIFT CUK CONVERTER

Introduction

The concept of the voltage self-lift techniques has been integrated into an SC cell, and consequently, a new step up circuit is on the basis of the classical Cuk converter. As shown in Fig 1. Compared with the conventional Cuk prototype, two additional components (diode D_1 and capacitor C_1) are added into the circuit. However, the relative positions of the other components are kept invariant in the new circuit. Different from the Cuk prototype, a π-type low-pass filter C_1-L_1-C_o is constructed, and it results in the different voltage conversion mechanism. The voltage gain will be increase from D/(1-D) to (1)/(1-D). The voltage conversion is negative to positive polarity [9].

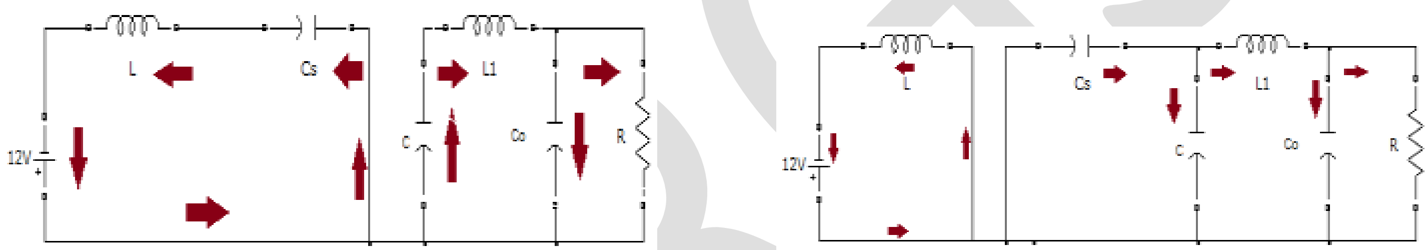


Self-lift cuk converter.

For the convenience of analysis, the whole circuit is divided into three different sections, as described in Fig. 1. L_1 belongs to the source section, and it performs the function of storing and transferring the energy from the source voltage V_{in} to C_s under the switching operation of S. C_1, D_1, and D_f form a pump section, in which C_1 is charged by C_s during each cycle and absorbs the energy stored in C_s like a pump. An output section formed by L_1 and C_o is combined with the pump section to perform the output filter function for the voltage of C_1.

Working Principle

The converter structure operates in Continuous Conduction Mode (CCM). This circuit contains two mode of operation: a) ON Period, b) OFF Period.



(a) (b)

Equivalent circuits. (a) Switching ON. (b) Switching OFF.

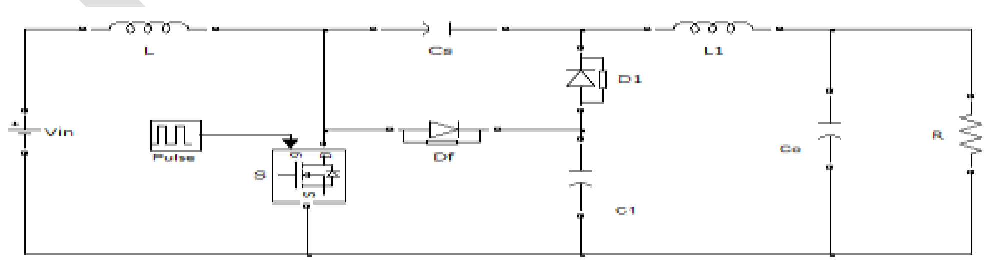
Mode 1 (During Switch ON): The equivalent circuit during switching ON is shown in Fig 2(a) When switch S turns ON, D_1 is ON, and D_f is OFF. C_1 performs characteristics to lift the output capacitor voltage V_{co} by the capacitor voltage V_{cs}.

Mode 2 (During Switching OFF): The equivalent circuit during switching OFF is shown in Fig 2(b). When S turns OFF, D_1 is OFF, and D_f is ON. C_1 performs characteristics to lift the output capacitor voltage V_{co} by the capacitor voltage V_{cs}.

SELF-LIFT LUO CONVERTER

Introduction

Voltage-lift technique is a popular method used in electronic circuit design. Applying this technique can effectively overcome the effect of the parasitic elements, and largely increase the voltage transfer gain.

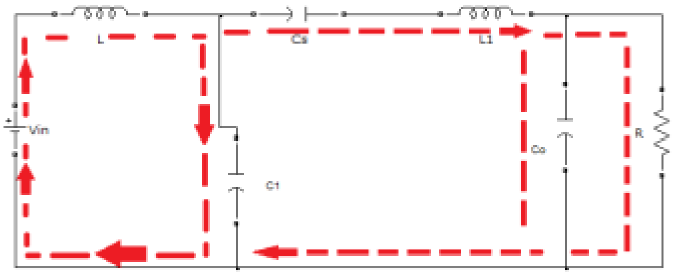


Self-lift cuk converter

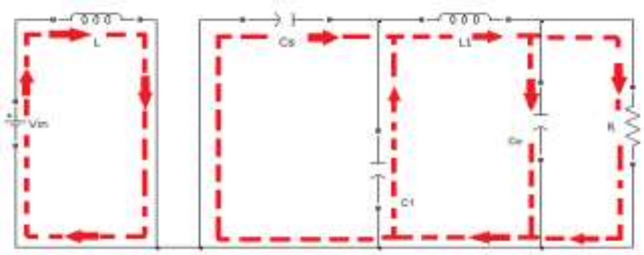
Compared with above converter, number of the elements is equal and same design. The arrangements of the circuits are different. In this arrangement the voltage gain will be increase from D/(1-D) to (2-D)/(1-D). The voltage conversion is positive to positive polarity [10]-[12].

Working Principle

The converter structure operates in Continuous Conduction Mode (CCM). This circuit contains two mode of operation: a) OFF Period, b) ON Period



(a)



(b)

Equivalent circuits. (a) Switching OFF. (b) Switching ON.

Mode 1 (During Switching OFF): The equivalent circuit during switching OFF is shown in Fig 4(a) When S turns OFF, D_1 is OFF, and D_f is ON. The capacitors C_1 and C_s are charging by source. C_1 and C_s perform characteristics to lift the output capacitor voltage V_{co}.

Mode 2 (During Switching ON): The equivalent circuit during switching ON is shown in Fig 4(b) When switch S turns ON, D_1 is ON, and D_f is OFF. The capacitors C_1 and C_s are discharging through load. C_1 and C_s perform characteristics to lift the output capacitor voltage V_{co}.

DESIGN OF COMPONENTS

Design of Inductor L

Take input voltage $V_{in} = 12\,V$ and output voltage $V_o = 32\,V$, so the duty ratio $D = 0.63$ refers in equation Switching frequency $f = 50kHz$ and $\Delta iL = 0.3\,A$. The peak to peak current variation of iL $\Delta \boldsymbol{i_L} = \frac{\boldsymbol{DV_{in}}}{\boldsymbol{Lf}}$

$$\therefore \boldsymbol{L} = \frac{\boldsymbol{DV_{in}}}{\boldsymbol{\Delta i_L . f}} \qquad (1)$$

Design of Capacitor C_s

The peak to peak current variation of V_{cs}, $\Delta V_{cs} = \frac{V_o}{R.f C_s}$, Ripple voltage $\Delta V_{cs} = 0.06\,mV$ and load resistance $R = 100\,\Omega$.

$$\therefore \boldsymbol{C_s} = \frac{\boldsymbol{V_o}}{\boldsymbol{R.f\Delta V_{cs}}} \qquad (2)$$

Design of Capacitor C_1

The peak to peak current variation of V_{c1}, $\Delta V_{c1} = \frac{V_o(1-D)}{R.f.C_1}$, Ripple voltage $\Delta V_{c1} = 0.1\,mV$ and load resistance $R = 100\,\Omega$.

$$\therefore \boldsymbol{C_1} = \frac{\boldsymbol{V_o(1-D)}}{\boldsymbol{R.f.\Delta V_{c1}}} \qquad (3)$$

Design of Inductor L_1

The peak-to-peak current variation of iL_1 can be calculated by the area A of a triangle with width T/2 and the height $V_{c1}/2$,

$$\boldsymbol{L_1} = \frac{\boldsymbol{V_O(1-D)}}{\boldsymbol{8RC_1 f^2 \Delta i_{L1}}} \qquad (4)$$

Design of Capacitor C_o

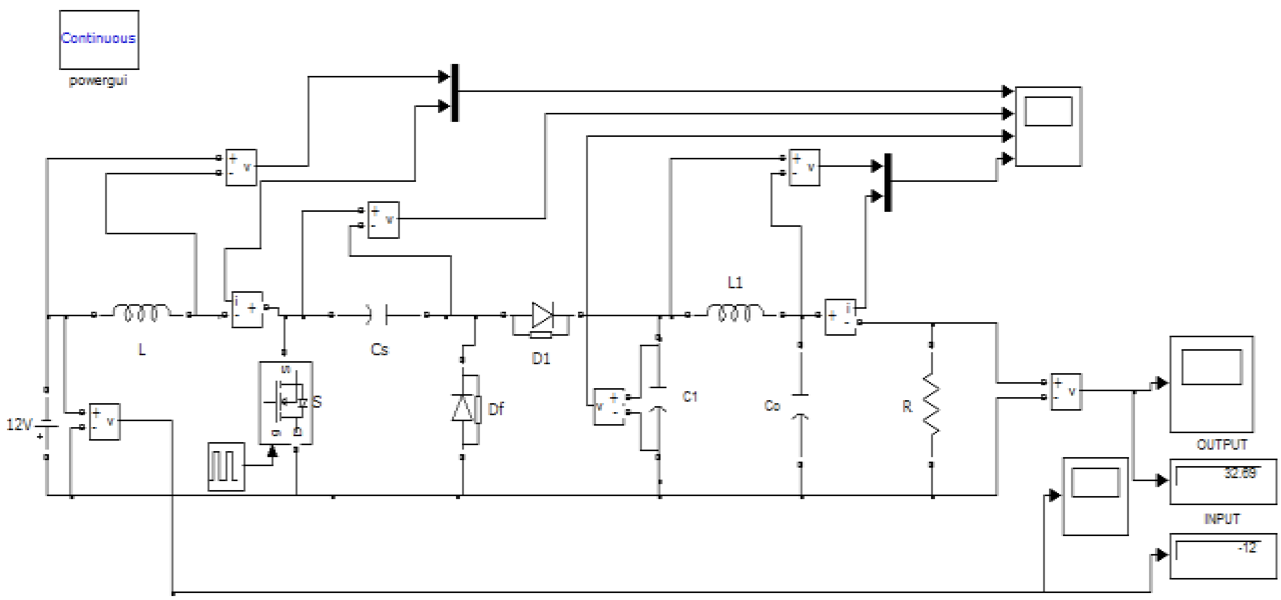
The peak-to-peak voltage variation of V_o is calculated by the area B of a triangle with width $T/2$ and the height $\Delta iL_1/2$

$$\therefore C_o = \frac{V_o(1-D)}{64R.f^3.L_1C_1\Delta V_{co}} \tag{5}$$

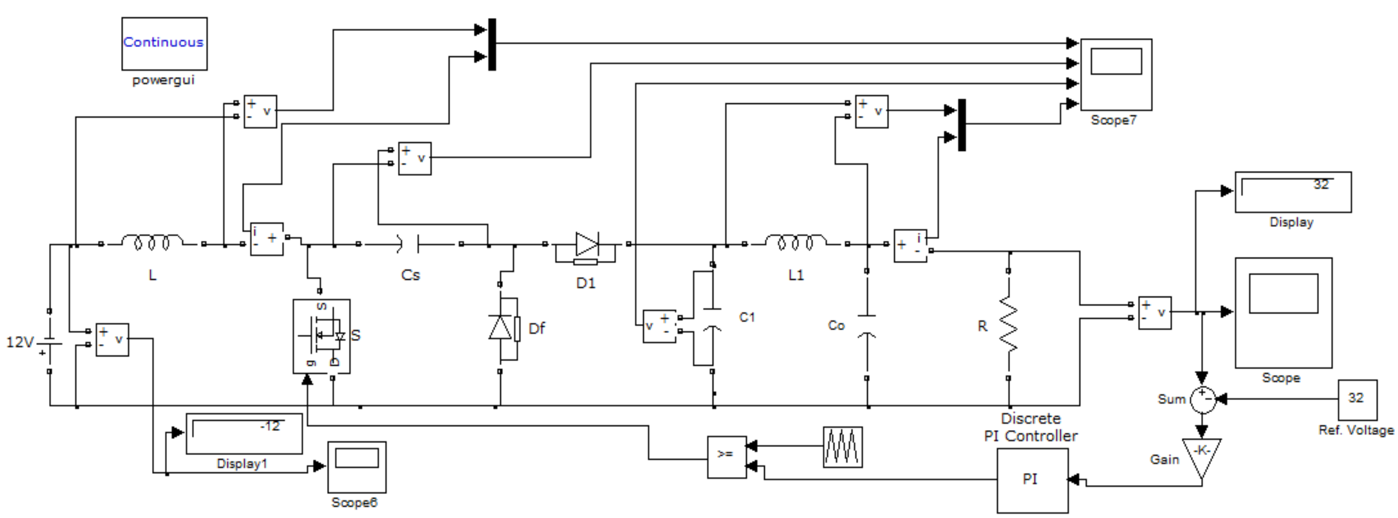
SIMULATION MODEL AND RESULTS

Self-Lift Cuk Converter Model

The simulation of the Cuk converter is done with the help of MATLAB SIMULINK. Here, discussed about two type of model, one is open model and other one is closed loop. In closed loop, PI controller is used for feedback signal.



(a)



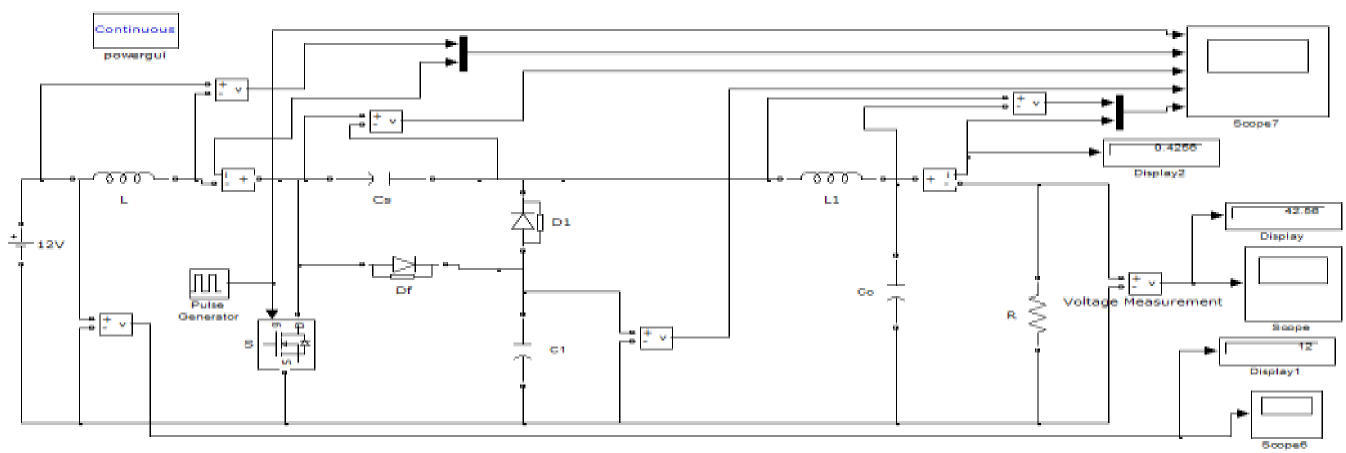
(b)

Self-lift Cuk converter model. (a) Open. (b) Closed.

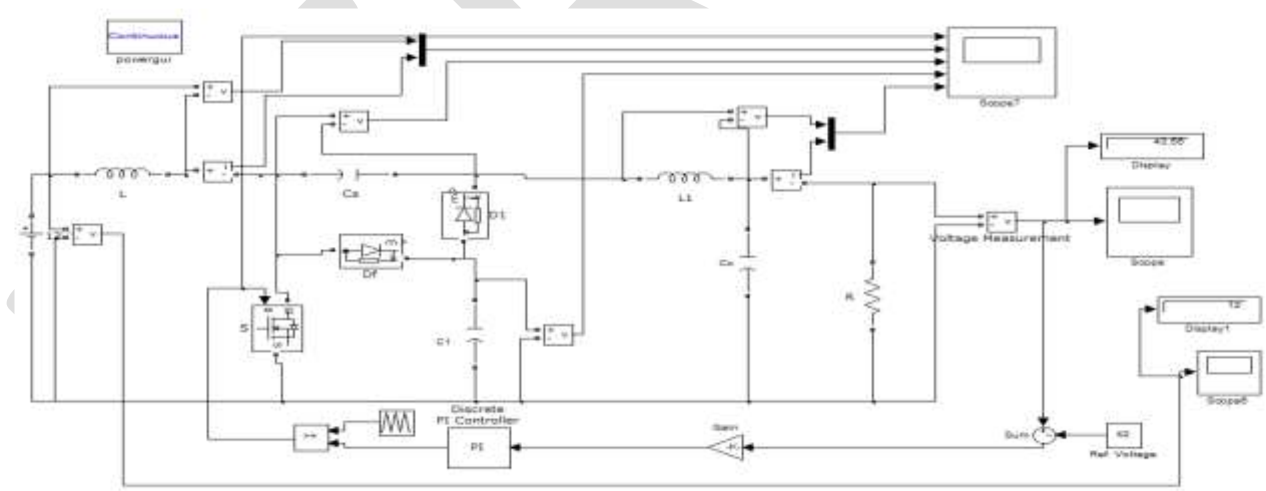
The main circuit parameters are chosen as follows: For an input voltage is 12V with load $= 100\Omega$, $L = 500\mu H$, $C_s = 110\mu F$, $C_1 = 22\mu F$, $L_1 = 500\mu H$, $C_o = 47\mu F$ and $f = 50\ kHz$. All the components are assumed ideal, and the voltage conversion aim is set as +32 V, as shown in Fig. 5(a). In order to increase the performance of the system closed path is provided. PI controller is used for controller purpose. The closed loop configuration of converter using PI controller, with Kp=0.01 and Ki=0.75 Pulse is created with the help of relational operator. Direct output of relational operator is given to gate signal.

Self-Lift Luo Converter Model

The simulation of the luo converter is done with the help of MATLAB SIMULINK. Here, discussed about two type of model, one is open model and other one is closed loop. In closed loop, PI controller is used for feedback signal.



(a)



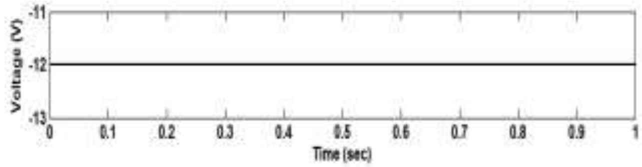
(b)

Self-lift Luo converter model. (a) Open. (b) Closed.

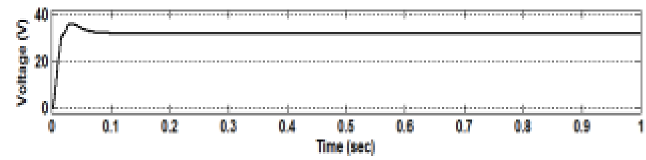
The models of self-lift Luo converter in open and closed model are shown in Fig. 6(a) and (b), respectively.

Self-Lift Cuk Converter Results

The input voltage of the converter is 12 V. Input voltage wave form is shown in Fig 7(a). Output voltage of the Cuk converter in open model is 32.69 V is shown in Fig 7(b). The output voltage of the Cuk converter in closed model is 32V and reference voltage is 32 V is shown in Fig 7(c). Input current of the converter is 1.92 A is shown in Fig 7(d). Output current of the converter is 3.269 A, current waveform is shown in Fig 7(e). Duty ratio is 63% as shown in Fig. 7(f).



(a)



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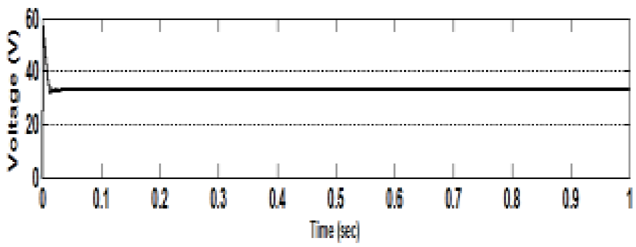

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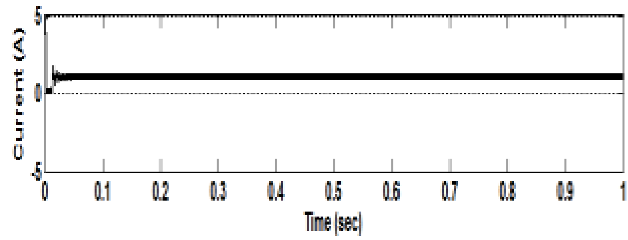
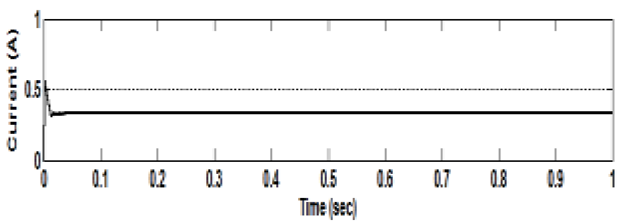
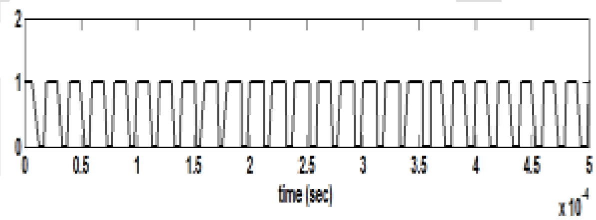


(d)



(e)

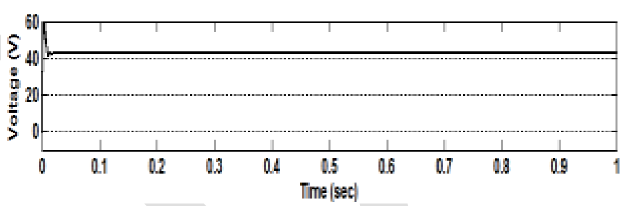


(f)

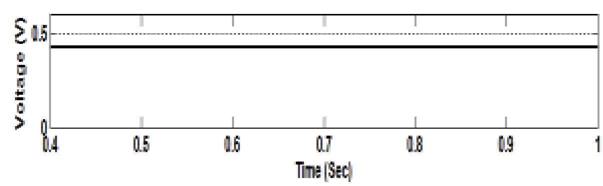
Simulated results in self-lift Cuk converter (a) Input Voltage (b) Output Voltage in open (c) Output Voltage in Closed (d) Input Current (e) Output Currnet, (f) Switching pluse

Self-Lift Luo Converter Results

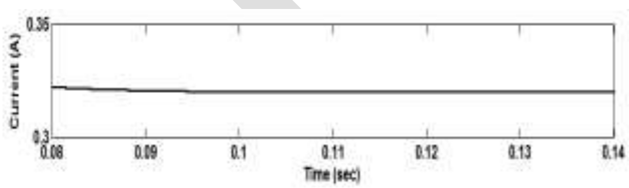
The input voltage of the converter is 12 V. Output voltage of the Cuk converter in open model is 42 V is shown in Fig 8(a). Output current of the converter is 0.42 A, current waveform is shown in Fig 8(b).Input current of the converter is 3.4 A is shown in Fig 8(c). Duty ratio is 63% as shown in Fig. 8(f).



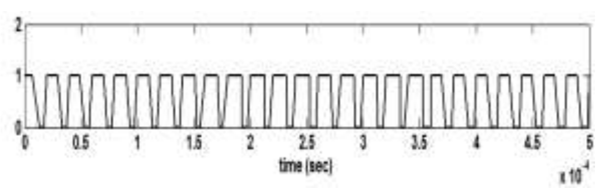
(a)



(b)



(c)



(d)

Simulated results in self-lift Luo converter (a) Output Voltage (b) Output Currnet (c) Input Current,(d) Switching pluse

CONCLUSION

By an in-depth topology analysis, it is known that the circuit (i.e., enhanced self -lift Cuk converter) can increase the voltage boost ability of the classical Cuk converter to a higher level. A negative to positive conversion path is provided to make it suitable for negative DC-voltage source with respect to the common ground. It also has the characteristics of high efficiency smooth currents at both sides, and small ripples in simple structures. It might be developed and used in the areas of various DC distributed power systems. Here input voltage is -12 V, and output is 32v

In Luo converter voltage boosting capability is increase, with equal number of elements and same design. A positive to positive conversion path is provided. Here input voltage 12V and output is 42 V. These works is done by MATLAB SIMULINK 2013a

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