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# Design and Implementation of Single level and Multi-level CUK Converter in DC load Applications

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***Abstract**: The conventional power conditioning units require a DC-DC converter to deliver the required power to the dc load. This paper presents a CUK converter topology that provides DC-DC conversion along with voltage buck and boosts depending upon the Duty cycle. When the output voltage required more than the output voltage of single level at that time multilevel CUK converter can be used. In a Multi-level CUK converter topology requires less power conversion stages and reduces the size of power conditioning units and components. In this paper, the design stages of components of the Single level and Multi-Level CUK converter are presented and hardware is implemented and results are obtained for different duty cycle.*

***Keywords: DC-DC Converter, Multilevel, CUK converter, Hardware Implementation, DC Load Application.***

## I. INTRODUCTION

We know DC voltage is available using the battery up to certain voltage level only. So using DC battery we can run only some small DC devices. But for some DC applications where higher voltages required then the battery output voltage. At that time we have to use some inverters which convert AC voltages to DC at a higher level.

In this paper, the single level CUK converter is represented which can give output higher and lower than input voltages depend upon duty ratio. And for some higher DC voltages application, the gain of DC-DC CUK converter can be increased by adding more number of capacitor and diodes as per circuit diagram and required high-level voltage can be obtained.

There are few advantages of the multilevel converter which are listed here: Bandwidth of output is high. Reduce the huge ratings of components as they are divided into small groups. Minimum to maximum value different increases which can provide better voltage regulation. Output voltage and current ripples can be reduced.

## II. SINGLE LEVEL DC-DC CUK CONVERTER

CUK converter is obtained by using the duality principle on the circuit of the buck-boost converter. Similar to the buck-boost converter, the CUK converter provides a negative-polarity regulated output voltage with respect to the common terminal of the input voltage [1].

The CUK converter is shown in the Fig.

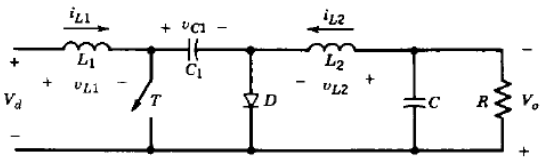


Fig 1 Single Level CUK converter configuration

Here, the Capacitor $C_i$ acts as the primary means of storing and transferring energy from input to the output.
In steady state, the average inductor voltages $V_{L1}$ and $V_{L2}$ are zero. Therefore, by inspection of Fig.

$$V_{c1} = V_d + V_0 \qquad \ldots\ldots (1)$$

 

Therefore, $V_{C1}$ is larger than both $V_d$ and $V_o$. Assuming $C_1$ to be sufficiently large, in steady state the variation in $v_{C1}$ from its average value $V_{C1}$ can be assumed to be negligibly small (i.e., $v_{C1} \sim V_{C1}$), even though it stores and transfer energy from the input to the output.

When the switch is off, the inductor current $i_{L1}$ and $i_{L2}$ flow through the diode. The circuit is shown in fig. Capacitor $C_1$ is charged through the diode by energy from both the input and $L_1$.Current $i_{L1}$ decreases, because $V_{c1}$ is larger than $V_d$. Energy stored in $L_2$ feeds the output. Therefore, $i_{L2}$ also decreases.

When the switch is on $C_1$ reverse biased the diode. The inductor currents $i_{L1}$ and $i_{L2}$ flow through the switch, as shown in Fig. Since $V_{C1} > V_0$, $C_1$ discharges through the switch, transferring energy to the output and $L_2$. Therefore, $i_{L2}$ increases. The input feed energy to $L_1$ causing $i_{L1}$ to increase.

The inductor currents $i_{L1}$ and $i_{L2}$ are assumed to be continuous.

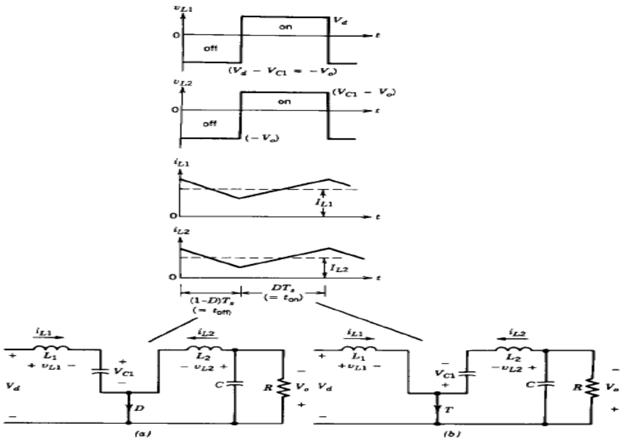

**Fig 2: Single level CUK Converter waveform: (A) switch off (B) switch on**

The voltage and current expression in steady state can be obtained in two different ways. If we assume the capacitor voltage $V_{C1}$ to be constant, then equating the integral of the voltages across $L_1$ and $L_2$ over one time period to zero yields:

$L_1$: $$V_d DT_s + (V_d - V_{C1})(1-D)T_s = 0 \quad ....(2)$$

$$\therefore \quad V_{C1} = \frac{1}{1-D} V_d \quad ......(3)$$

$L_2$: $$(V_{C1} - V_o)DT_s + (-V_o)(1-D)T_s = 0$$

$$\therefore \; V_{C1} = \frac{1}{D} V_0 \quad .......(4)$$

From above two equations

$$V_0/V_d = D/(1-D) \quad .......(5)$$

Assuming $P_d = P_o$ gives

$$I_0/ I_d = (1-D) / D \quad ......(6)$$

Where $I_{L1}=I_d$ and $I_{L2}=I_o$

## III. MULTILEVEL DC-DC CUK CONVERTER

Single level CUK converter has the limitation of output voltage up to certain voltage only, So where the voltage is required more then the output the of the single level at that time multilevel CUK converter is used [2].

A negative voltage is obtained from multilevel CUK converter. The gain of the multilevel converter can be increased by adding a number of capacitors and diodes without disturbing the main circuit.

Multilevel converter is used to the improvement of voltage regulation of the output as well overcome the limitation of a single converter.

There are few advantages of the multi-level converter which has listed below:

- Bandwidth of output is high.
- Reduce the huge ratings of components as they are divided into small groups.
- Minimum to maximum value different increases which can provide better voltage regulation.
- Output voltage and current ripples can be reduced.

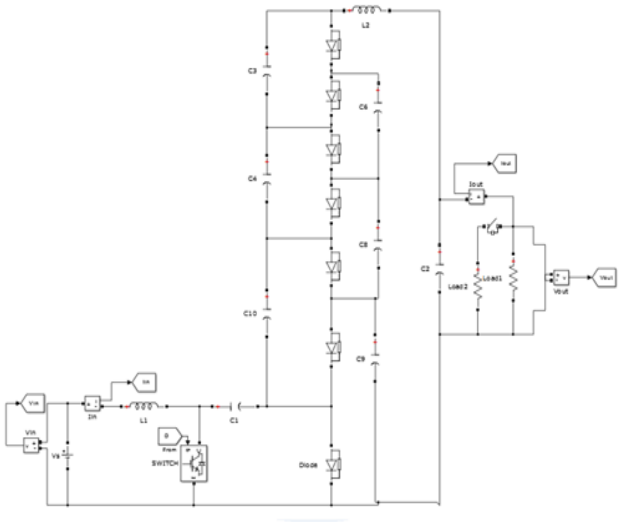

**Fig 3 Multilevel CUK converter configuration**

## IV. DESIGN PARAMETERS OF CUK CONVERTER

Circuit diagram for single level and multilevel CUK in figure converters are shown in figure 1 and 3. And also all mode of operations are shown in figure 2 [1].

Peak stress voltages on the switch and the peak current through the switch are:

$$V_{SWmax} = V_d + V_0 \quad \ldots\ldots\ldots\ldots\ldots..(7)$$

$$I_{SW\,max} = I_0 + V_d T_s/2L \quad \ldots\ldots\ldots..(8)$$

The IGBT switch is selected by Fig. 1 shows the overall circuit diagram of CUK converter. Considering above peak voltage and peak current, the inductor capacitor value of the converter is calculated by considering 10% voltage ripple and current ripple.

The following equations are used to design the CUK converter.

$$\Delta I_1 = \frac{V_{dc}.D}{L_1 f} \quad \ldots\ldots\ldots..(9)$$

$$\Delta I_2 = \frac{V_{dc}.D}{L_2 f} \quad \ldots\ldots\ldots..(10)$$

$$\Delta V_{c1} = \frac{I_S(1-D)}{C_1 f} \quad \ldots\ldots\ldots(11)$$

$$\Delta V_{c1} = \frac{\Delta I_2}{8C_2 f} \ldots\ldots\ldots\ldots(12)$$

Where, ΔI = peak to peak ripple current

ΔV = peak to peak ripple voltages
f = switching frequency of IGBT switch.
D = Duty ratio

## V. HARDWARE IMPLEMENTATION AND RESULTS

In below figures the different photos are shown for the hardware implementation using 12V battery as ainput and DC motor as a load.

### *A.* Single-Level CUK converter Hardware Setup

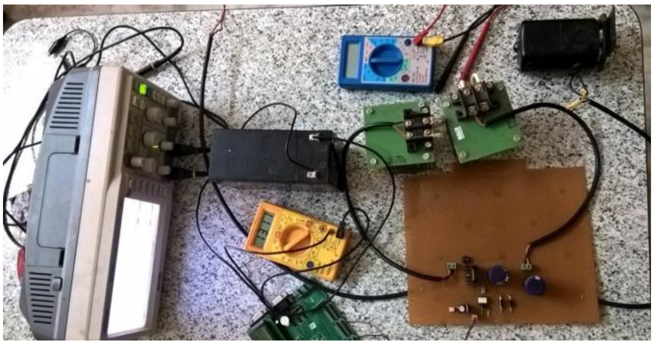

**Figure: 4 Test circuit for single level CUK converter (12V battery input and DC motor load)**

**Figure 5 circuits for single level CUK converter**

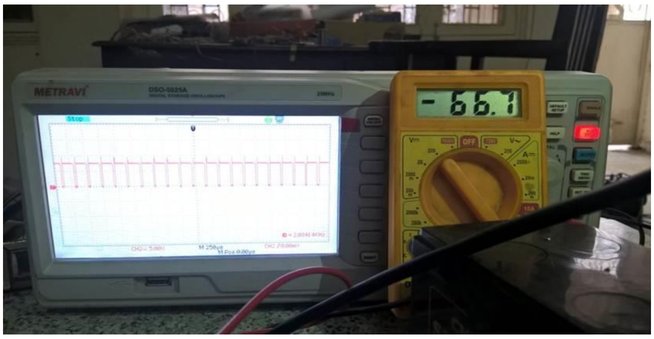


**Fig 6. Output DC voltage at 85% duty cycle**


**Fig 7. Input and output voltage at 58% duty cycle**

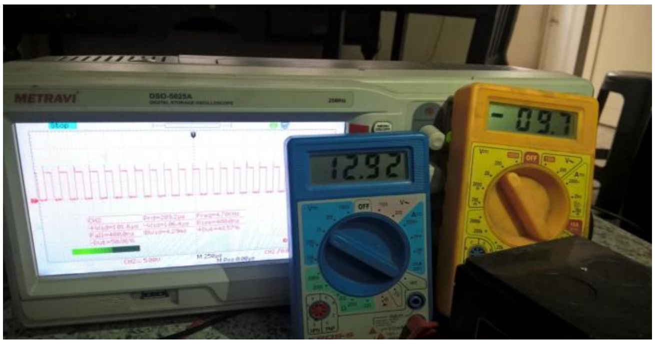


**Fig 8.Input and output Voltage at 40% duty cycle**

## *B.* Multi-Level CUK converter Hardware Setup

**Fig 9.Hardware circuit of Multilevel CUK converter**

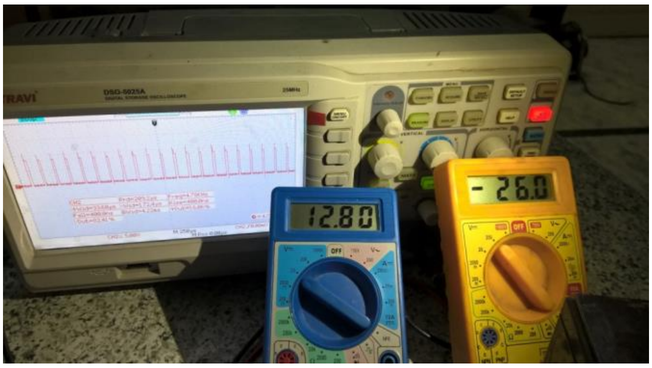


**Fig 11.input and output voltage at 25% duty cycle**

 

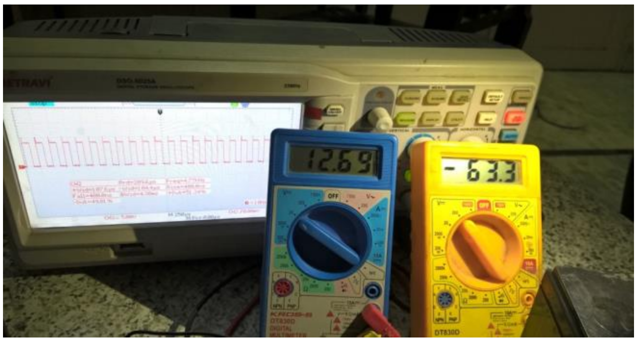


**Fig 12. Input and output voltage at 60% duty cycle**

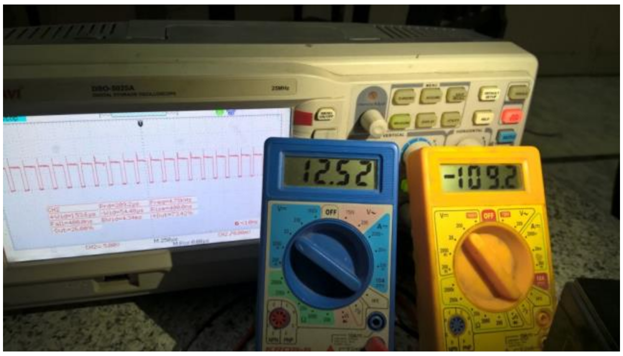


**Fig 13.Input and output voltages at 75% duty cycle**

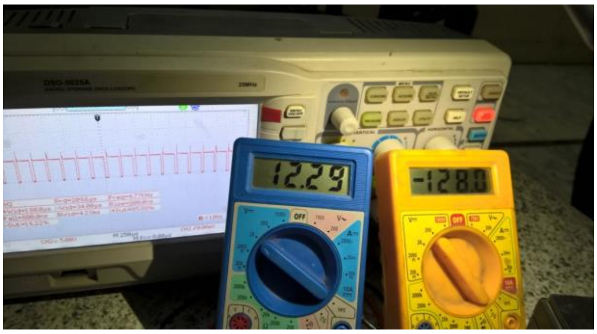


**Fig 1104. Input and output voltage at 82% duty cycle**

## CONCLUSION

Here in this paper, a hardware implementation of single level CUK converter and Multilevel CUK converter is done and results conclude that output voltages of multilevel CUK converter are much greater than the single level CUK converter. Which can be utilized to run some small dc loads. The output of multilevel CUK converter depends on the number of level (again).

DC battery have output of very low voltages so for run dc loads of higher rating the Multilevel CUK converter can be used as a step up DC –DC converter and which can be utilized to some small DC load applications. Here also output voltages for single level and multilevel CUK converters are shown for different duty ratio.

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