MIDDLE EAST TECHNICAL UNIVERSITY

Department of Electrical and Electronics Engineering

EE464 Project-1 Report

Ćuk Converter and Full-Bridge DC/DC Converter

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1- Introduction

In this report, Ćuk converter topology is investigated through Simulink. It is a DC DC converter with similar features as the Buck-Boost converter. In Figure 1, the schematic of this converter with only DC input can be seen. The pwm frequency of the mosfet switch is 100 kHz and the values of the L1, C1, L2, Cout are 10mH, 100μF, 1mH and 660μF respectively. Later, the design processes and the reason for the preference for these values are explained and the operations are detailed.

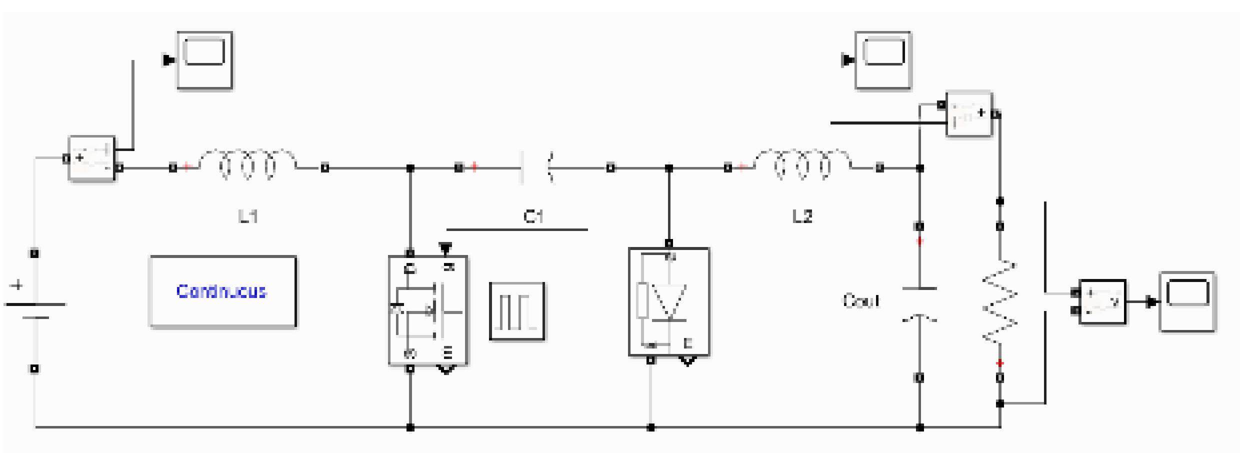

Figure 1: Schematics of the Ćuk converter design.

Results

In this part of the report, schematics and their corresponding graphs of above mentioned topologies are given.

Part a

- Output Voltage: -12 V

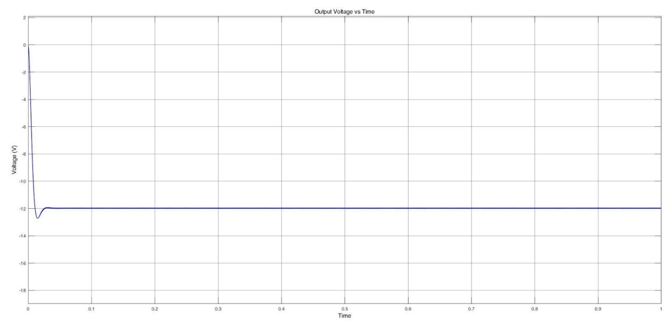

Figure 2: *Output Voltage vs Time graph of the Ćuk converter design.*

- Output Current: 3 A

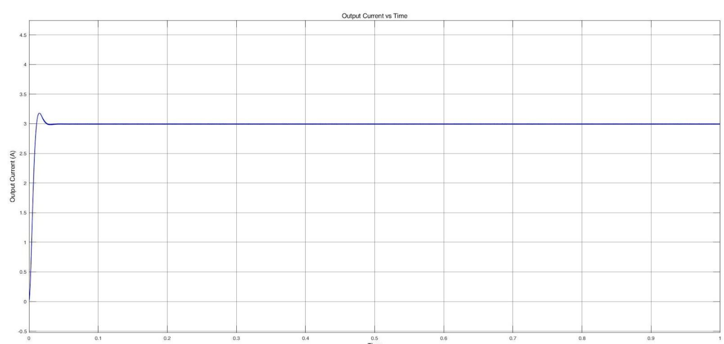

Figure 3: *Output Current vs Time Graph of the Ćuk converter design.*

- Switching frequency: 100 kHz

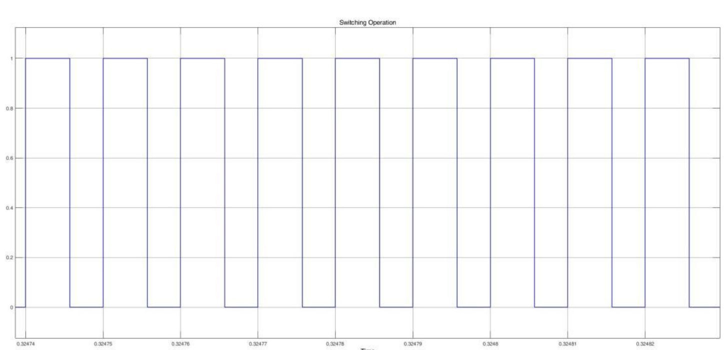

Figure 4: *Switching Operation at 100 kHz with Duty cycle of 4/7.*

- Max. Output voltage ripple: 2%

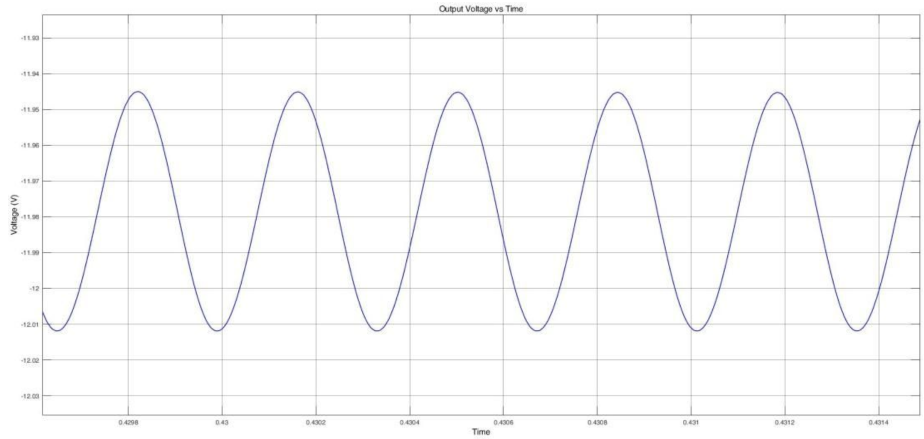

Figure 5: *Output Voltage Ripple Graph..*

The design satisfies all requirements as shown in the Figure 1,2,3,4 and 5.

L_1 is picked 10 mH to keep source current ripple as low as possible.

C_1 is picked 100 uF since it is the primary storage element it is selected large considerably. Also, ripple voltage at the capacitor is low.

L_2 is picked 1 mH. This selection was out of our design considerations.

C_{OUT} is picked 660 uF to make sure that Vout is almost constant. (large enough)

Commercial Product : KerESMH401VEN661QR55T – 660 uF 400V Electrolytic

Part b

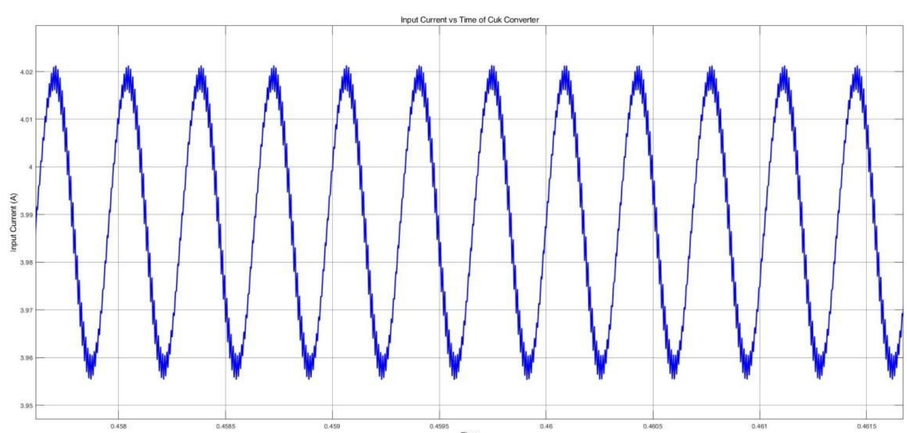

Figure 6: *Input Current vs Time graph of the Ćuk converter design.*

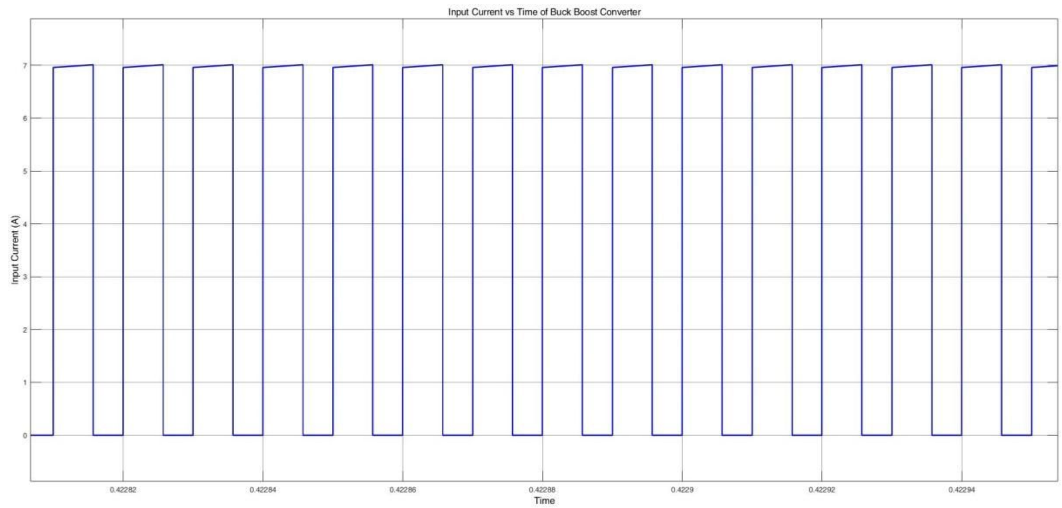

Figure 7: *Input Current vs Time of the Buck-Boost Converter design.*

As can be seen from the Figure 6 and Figure 7 :

- Input current of Cuk Converter is almost ripple free whereas input current of Buck-Boost has very high ripples.
- Cuk converter works at CCM. On the other hand, Buck-Boost Converter works at DCM.
- Input current of Cuk has a sinusoidal waveform while input current of Buck-Boost has a square waveform (THD of Cuk current is lower)
- It can be said that source current of Cuk Converter is almost constant.

Comment : In terms of input current, Cuk Converter is better than Buck-Boost Converter since it has a lot of benefits. Firstly, it works at CCM which is more preferable and input current drawn from the source is almost constant. Secondly, due to first advantage input current of cuk converter is ripple free but buck boost has very high ripples. Finally, current quality of Cuk Converter is better because its waveform is sinusoidal (lower = better THD)

Part c

$$V_{C1} = V_D + V_O = 9 + 12 = 21V$$

$$\Delta I_{L1} = \frac{V_{C1} - V_D}{L_1} \,.(1-D)\,.\,T_S = \frac{21-9}{10\,mH}\,.\left(1-\tfrac{4}{7}\right)\,.\,10^{-5} = 0.0052\,A$$

$$\Delta I_{L2} = \frac{V_O}{L_2} \,.(1-D)\,.\,T_S = \frac{12}{1\,mH}\,.\left(1-\tfrac{4}{7}\right)\,.\,10^{-5} = 0.052$$

$$\frac{\Delta I_{L1}}{I_{L1}} = \frac{0.0052}{4}\; x\; 100 = 0.13\ \%\ Ripple$$

$$\frac{\Delta I_{L2}}{I_{L2}} = \frac{0.052}{3}\; x\; 100 = 1.73\ \%\ Ripple$$

$$\Delta V_{C1} = \frac{4}{100.10^{-6}} \cdot \left(1 - \frac{4}{7}\right) . 10^{-5} = 0.172\ V$$

$$\frac{\Delta V_{C1}}{V_{C1}} = \frac{0.172}{21} x\ 100 = 0.82\ \%\ Ripple$$

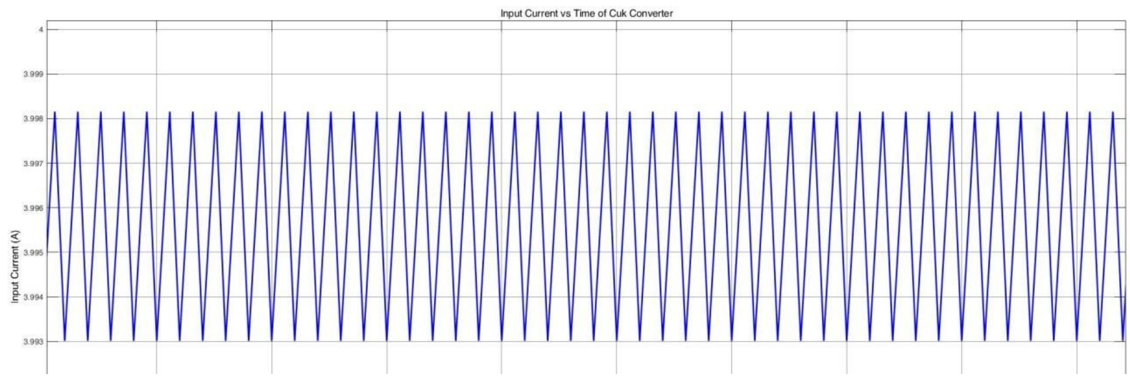

Figure 8: *ΔI_{L1} Ripples Schematics of the Ćuk converter design.*

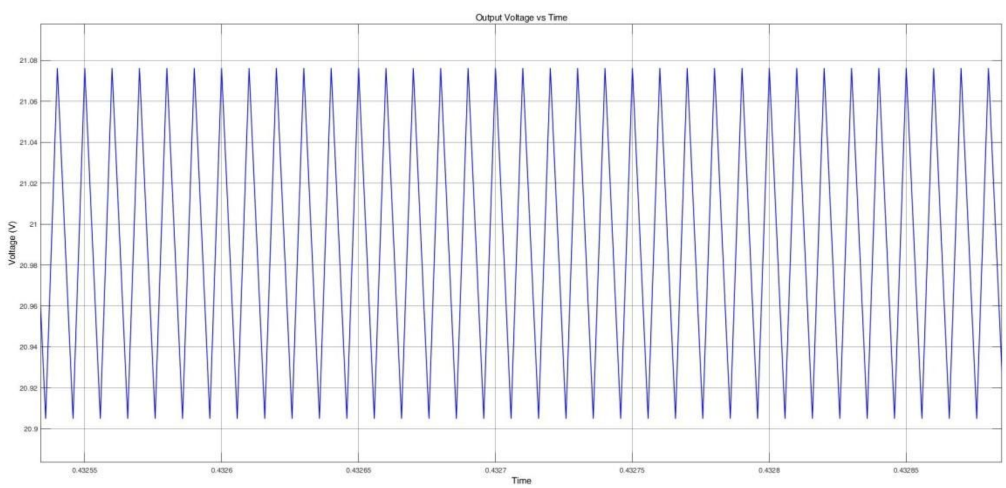

Figure 9 : *ΔV_{C1} Ripples*

As can be seen from the Figure 8 and Figure 9, simulation results and analytical calculations are consistent. In simulations ΔI_{L2} is ripple free. The reason for that is not understood,probably due to a simulation error.

Part d

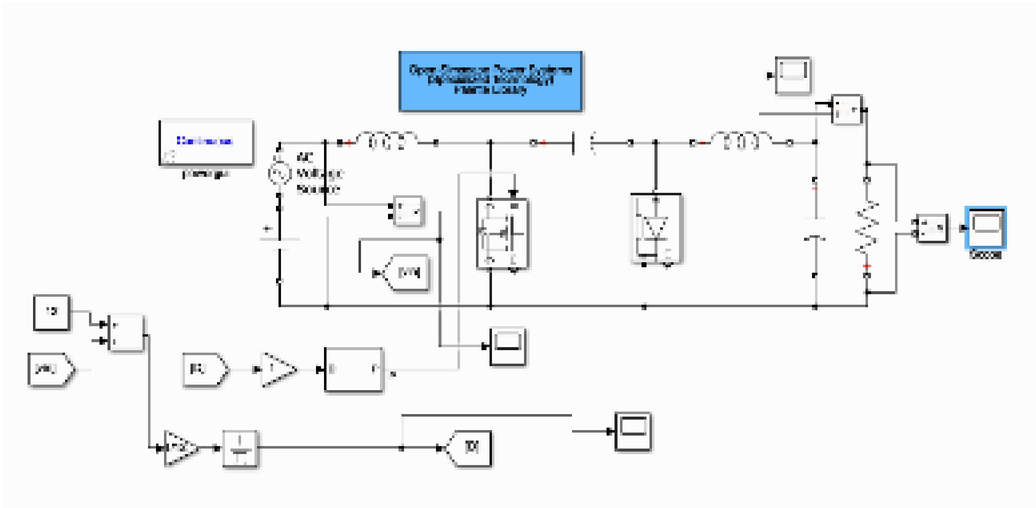

Figure 10: *Schematics of the Ćuk converter design with duty cycle adjustment for variable input voltage.*

In this part, the response of the Ćuk converter to harmonic components is investigated. The relationship between input and output is as follows for a Ćuk with purely DC input: $V_o = \frac{D}{1-D} V_d$. However this relationship is broken when the input is no longer purely DC which in this case it is 9+sin(2π*300*t). In order to account for this change the duty cycle D must be adjusted accordingly as follows:

$$9 + sin(2\pi * 300 * t)\frac{D}{1-D} = 12$$

$$=> \text{D}= \frac{12}{21+sin(2\pi*300*t)}$$

In order to achieve this, the schematic in figure 10 is used. The voltage value at the input is added with a constant which is 12 and then multiplied by 1/12. Which then its reciprocal is taken and this value is fed to the pulse generator as the duty cycle.

Another important point to emphasize is the values of the capacitors and the inductors. When the value of the first inductor is chosen too low the out

Part e

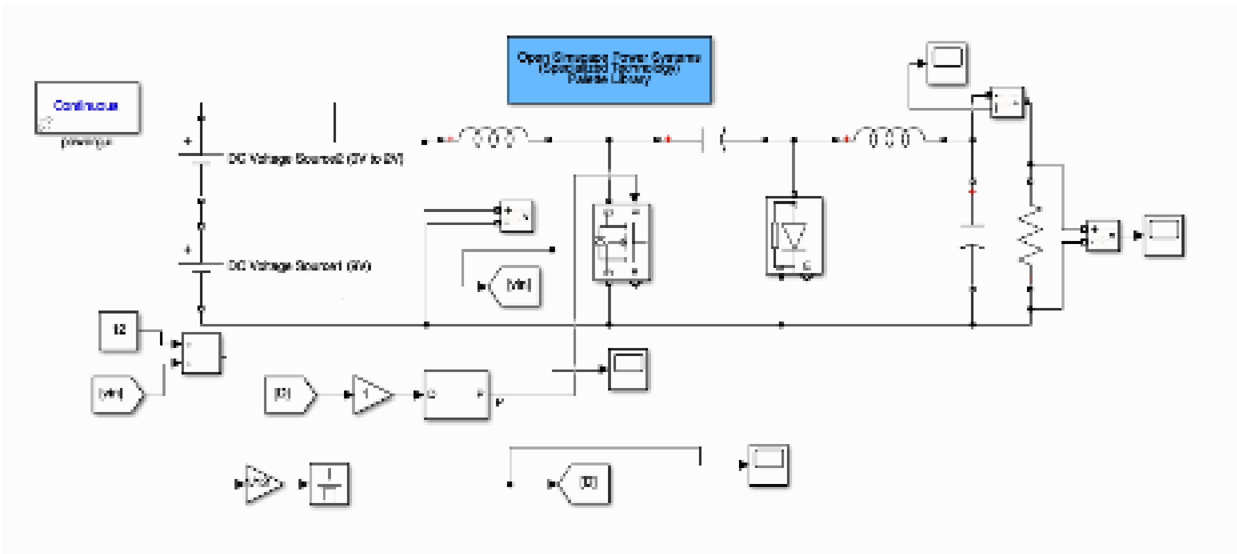

Figure 11: Schematics of the Ćuk converter design with duty cycle adjustment for input voltage of 9V to 11V.

In this part, two dc supplies are used to simulate step behavior where the value of the 2nd source is changed from 0V to 2V while the simulation is running. The effect of this can be seen in figure 12.

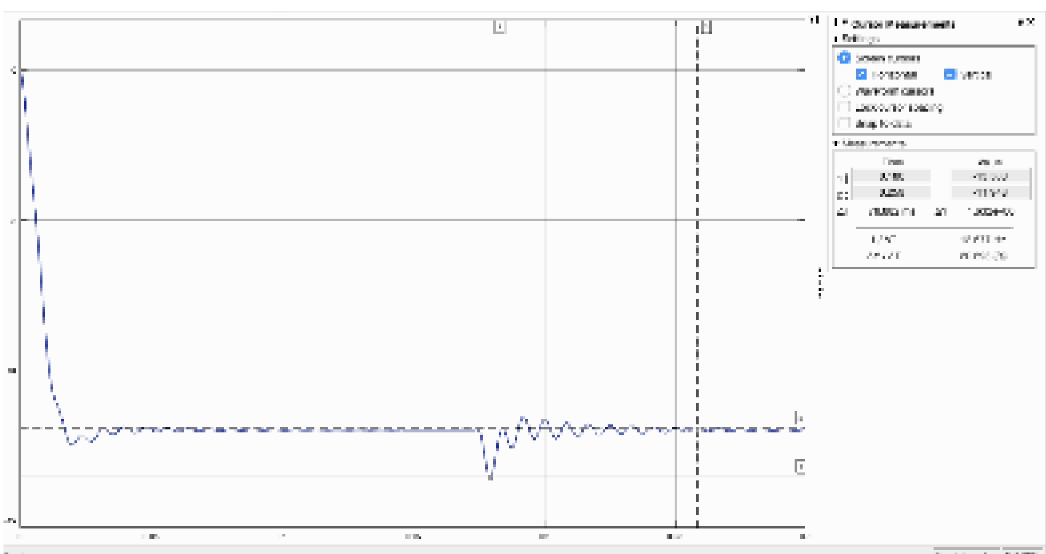

Figure 12: Input Current vs Time of the Buck-Boost Converter design.

As it is evident from figure 12, the step change in the input tries to change the output to the corresponding value which is 14.67V but the controller acts opposite to this change and tries to correct the output back to 12V by changing the duty cycle. This sudden change has an oscillating behavior but the oscillations are attenuated by the capacitors and inductors.

Conclusion

To conclude, firstly we accomplished to design a Ćuk converter. After all the design requirements are completed, we selected available commercial products for our design. Then, we observed the On/Off operation modes of the Cuk converter. Current ripples of inductors and voltage ripples of capacitors are analytically calculated and observed at simulation platform. The results were consistent except the one inductor ripple value since the simulation was not perfectly idea. We also observed the source current waveform of the both Cuk converter and similar sized Buck-Boost converter. There were many differences. Buck-Boost converter works at DCM whereas Cuk converter draws constant current from the source which means that it works at CCM mode. Input current of buck-boost converter is pulsating and have very high value ripples. Finally, we implemented a very simple controller to control output voltage according to the input voltage by tuning the Duty Cycle. The controller take the input voltage and according to the relationship between its value and the duty cycle which together determines the output voltage assign a duty cycle to the switch, but the processes is not instantaneous so oscillations are created which then attenuated by the capacitors and the inductors.