

Switched Capacitor Boost Converter

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ABSTRACT: Switched capacitor DC-DC converter (SCC) provides DC-DC conversion with the help of capacitor where the inductor and transformer are neglected and not considered. The SCC can be used to step up, step down or invert the given supply voltage. The SCC converters are used for the low power applications in the aerospace industry. The switched capacitors converter reduces the size and weight of the converter when compared to the conventional DC-DC converters.

KEYWORDS: Switched capacitor converters (SCC), Equivalent series resistance (ESR).

I. INTRODUCTION

Switched capacitor DC-DC converter is used to convert the DC voltage from one level to another level without the use of inductors or transformers this increases the power density of the converter because the magnetic components are not used in the converter. There are different topologies of the SCC like the Dickson charge up pump, series parallel convert and the H-bridge topology [1-2]. In today's trend there is an ever increase in the compact appliance which needs the compact power supply from the mobile charger to the space industry. Power transfer in the switched capacitor converters takes place from the source to the load by charging and discharging of the capacitors. The main reason for the power loss in the switched capacitor converters is the capacitor charge up loss which is given by

$\frac{1}{2}C(\Delta v)^2$. Where Δv is the step change in capacitor voltage [3]. It is proved that Δv increases with the increase in the input output voltage difference and this is the reason of poor efficiency of the switched capacitor converters. The efficiency of the switched capacitor converter can be increased by adding a set of capacitors in series during the charging phase and connecting these capacitors in parallel during discharging phase [4].

The objective of the this paper is to study and analyse the boost SCC without the use of inductor or transformer where only two capacitor i.e. (transfer capacitor and output capacitor) is used for converting from one voltage level to another by using the PWM method..

II. PWM BASED SWITCHED CAPACITOR BOOST CONVERTER

The figure 1 shows the method of realization of switched capacitor boost converter. When the switch S_1, S_2 and S_5, S_6 closed and the switch S_3, S_4 and S_7, S_8 is open the charge transfer capacitor C_T is charged to V_{IN} in both the converters and when the switch S_1, S_2 and S_5, S_6 is open and switch S_3, S_4 and S_7, S_8 is closed the capacitor C_T discharges to output capacitor C_O in both the converters and the voltage across the capacitor C_O is V_O . When all the switches are not connected there is a dead time t_d . The output is regulated to the desired value by PWM control that adjust the duty cycle of both the converters D_1 and D_2 such that $D_1=D_2$. The charge transfer capacitor C_T is switched between the input source V_{IN} and output capacitor C_O that ensure a negligible ripple. R_1, R_7 denotes the parasitic resistance in charge up path comprising the source resistance, drain to source resistance $R_{DS(on)}$ of S_1 and S_5 and R_2, R_8 denotes equivalent series resistance (ESR) of C_T similarly R_3, R_9 denotes the parasitic resistance in the discharge circuit which includes the $R_{DS(on)}$ of S_3 and S_7 and the path resistance and R_4 and R_{10} denotes equivalent series resistance (ESR) of C_O . R_5, R_{11} and R_6, R_{12} denotes the drain to source resistance $R_{DS(on)}$ of S_2, S_6 and S_4, S_8 .

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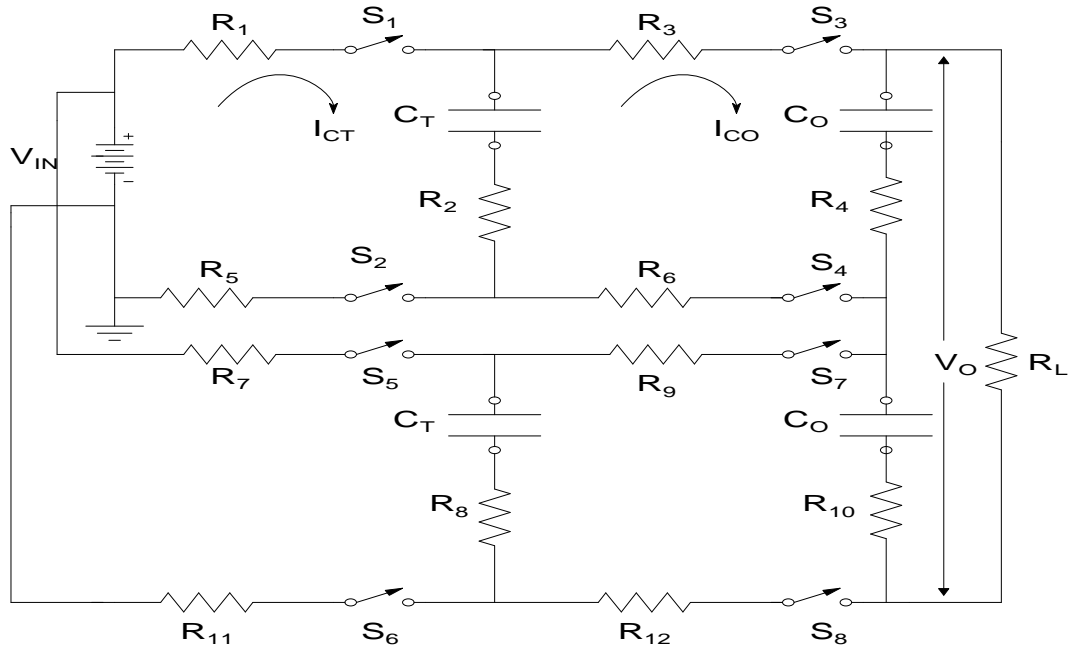


Figure 1: A boost type switched capacitor converter

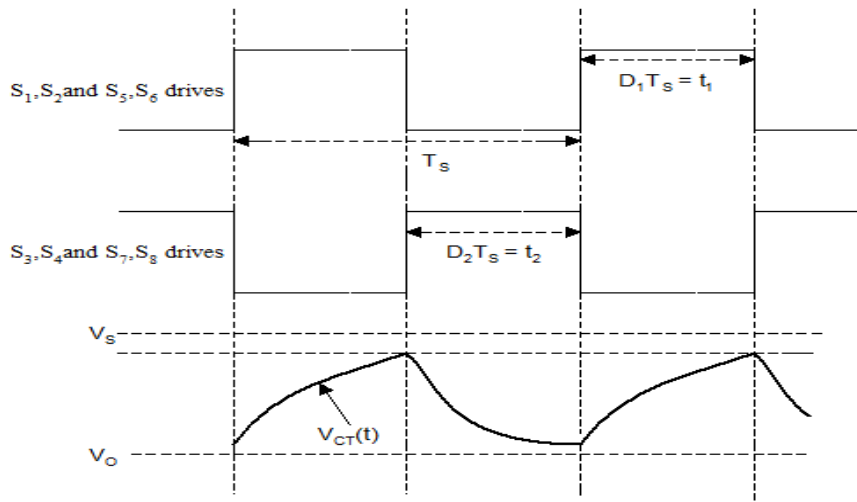


Figure 2: Drives of switch S_1, S_2 and S_3, S_4 and voltage waveform across transfer capacitor C_T of the single converter

The figure 2 shows the timing diagram of the boost SCC. The switch S_1 and S_2 is connected for the duration of time t_1 now the transfer capacitor C_T charges to V_{IN} . After the time duration t_1 the switch S_1 and S_2 is opened and the switch S_3 and S_4 is closed now C_T discharges to the output voltage V_O maintained across C_O . C_T is thus used to transfer energy from the source to the load R_L and to store energy in C_O . The function of C_O is to maintain V_O within a small band of voltage regulation while supplying output current to the load. When both the switches are closed there is a dead time t_d .

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III. EXPERIMENTAL RESULTS

A boost type switched capacitor DC-DC converter is implemented in the lab as shown in the figure 1. There are four mosfet's and two capacitors in one converter model and two converter models is rigged up and the input is connected in parallel and output is measured in series. One converter model is tuned in such a way that input is 15volt and output is 14volt and same is done for the second model so the boost converter input is 15volt and output is 28volt

Table 1: Details of the mosfet's used in the converter

MOSFET	R _{DS(on)} (ohm's)	I _{DSMAX} (Amps)
S ₁ - P Channel (IRF 9630)	0.80	6.5
S ₂ - N Channel (IRO 7250)	0.11	26
S ₃ - N Channel (IRO 7391)	0.20	22
S ₄ - N Channel (IRO 7250)	0.11	26
S ₅ - P Channel (IRF 9630)	0.80	6.5
S ₆ - N Channel (IRO 7250)	0.11	26
S ₇ - N Channel (IRO 7391)	0.20	22
S ₈ - N Channel (IRO 7250)	0.11	26

The transfer capacitor is a miniature aluminium electrolyte capacitor (Samwha SD capacitor) C_T=3μF and output capacitor is also a miniature aluminium electrolyte capacitor C_O=33μF with very low ESR (equivalent series resistance). V_{IN}=15V and V_O= 28V the input current I_{IN}= 0.5A and output current is I_O= 0.5A so the output power is 14watts. The gate signals for the mosfet are driven by the PWM IC SG3524. The choice of selecting the capacitors is explained in [2]. The totem pole switches and the buffer circuits are used to drive the P-channel mosfet since the gate signals have to be inverted and the optocoupler IC 3120 is used to drive the N-channel mosfet and the optocoupler is powered by the voltage across the transfer capacitor C_T.

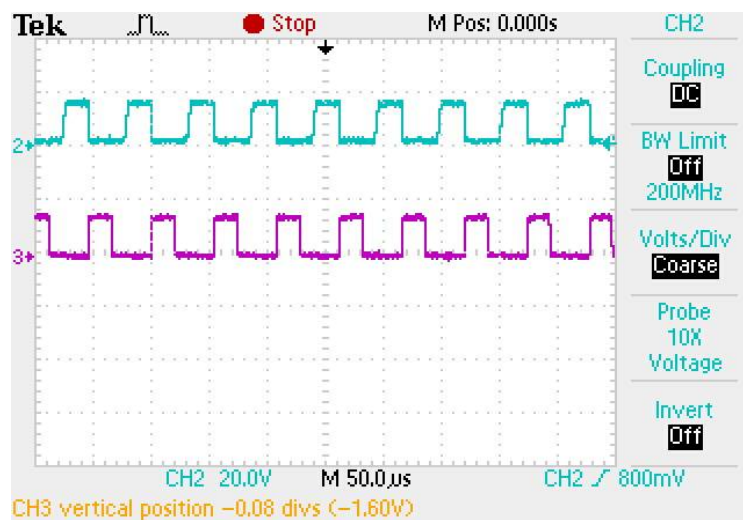


Figure 3: Drives of switches S₁, S₂, S₅, S₆ and S₃, S₅, S₇, S₈

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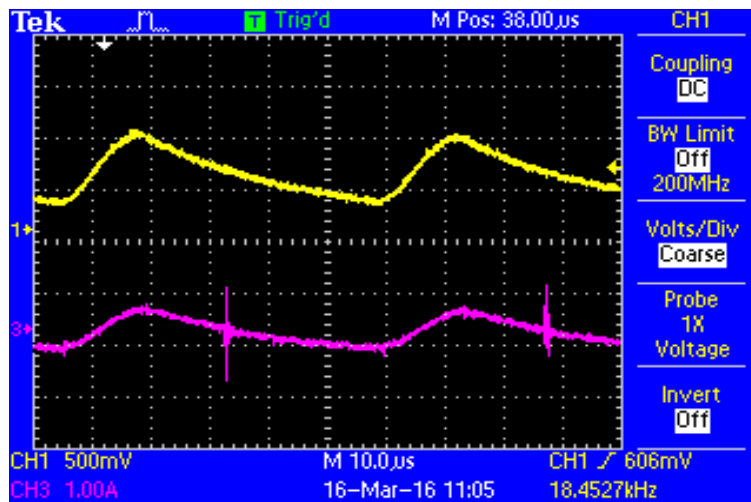


Figure 4: output voltage and output current waveform

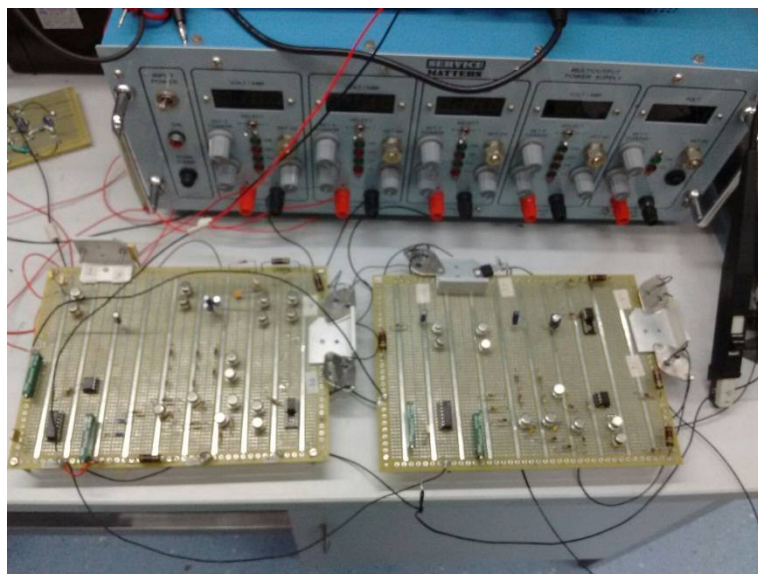


Figure 5: Hardware model of boost type switched capacitor converter

IV. CONCLUSION

The hardware model of SCC boost converter is realized with input $V_{IN} = 15V$ and $V_O = 28V$ which can deliver the power of 14watts is tested in the open loop configuration. The switch drives, voltage and current waveform is presented in the paper.

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REFERENCES

- [1] A. Ioinovici, " Switched capacitor power electronic systems," *IEEE Magazine on circuit and systems*, vol 1,issue 3, pp. 37-42, 2001
- [2] P. K. Peter and V. Agarwal, "Analysis and design of a ground isolated switched capacitor DC-DC converter," in *Proc. IEEE Int. Symp. Ind. Electron.*, Bari, Italy, 2010, pp. 632–637.
- [3] K. D. T. Ngo, and R. Webster, "Steady-state analysis and design of a switched-capacitor DC-DC converter," *IEEE Trans. Aerosp. Electron.Syst.*, Vol. 3, pp. 92–101, Jan. 1994.
- [4]P. Peter and V. Agarwal, "On the input resistance of a reconfigurable switched capacitor dc-dc converter based maximum power point tracker of a photovoltaic source," *IEEE Trans. Power Electron.*, vol. 27, no. 12, pp. 4880–4893, Dec. 2012.