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Design and Implementation of Synchronous Buck converter for Space Applications

Latha G¹, Dr. Umavathi M², Bhoopendra Kumar Singh³, Dr Ravichandran C⁴, Prasanna Kumar R⁵

Abstract: The synchronous Buck converter is used to step down voltage from higher to lower level. Now a days, Efficiency is the major concern in designing any converters hence power converter design must be optimized to increase the performance of converter and to meet the requirement of load demand. The proposed work aims at design and Implementation of 6W synchronous buck converter using LT3845 synchronous step-down controller IC which is suitable for High Efficiency application. The compactness of device is also a major concern for proposed work, hence the current mode topology makes the power converter module more compatible and efficiency. The proposed work is designed for output power 12V/0.5A(6W) for an Input voltage from 24-30V. The system frequency of converter is 150Khz. The results are obtained for Hardware Implementation using LT3845 IC.

Keywords: Synchronous buck converter, LT3845 step down controller IC, Switch mode power supply, Current mode control.

I. INTRODUCTION

In recent times, Switch Mode Power Converters (SMPS) are playing a prominent role in various applications due to their high efficiency solutions. These converters can be found in power supplies, electric tools, televisions and other electronic devices. The most popular converter among the other converters is the buck converter. Buck converter is one of the DC-DC converters which steps down the direct current (DC) voltage from one level to another level, this voltage level which is stepped down is used for particular applications and it is designed accordingly.

It is considered because of its simple construction. The peak current rating selected for the device should be minimum 1.5 times higher than the maximum output current. In a conventional buck converter, the diode will not conduct, if the main switch is on. When the switch is turned off the diode starts conducting, due to this there is a voltage drop across the diode and this drop is considered as loss. The conduction loss in diode might affect the efficiency of the buck converter[1]. Therefore, to enhance the efficiency and to minimize the conduction losses, Synchronous Buck converter using integrated chip (IC) LT3845 can be implemented. This paper focuses on design and analysis of synchronous buck converter using IC LT3845 at switching frequency of 150 kHz.

II. SYNCHRONOUS BUCK CONVERTER TOPOLOGY

As shown in figure, the basic circuit diagram of a synchronous buck converter. The two switches S1 and S2 in Synchronous converter are operated such that there is no overlap that is during the ON time of one switch the other one will be OFF. This introduction of second switch in place of a diode, decreases the voltage drop from about 1V to about 0.3V [2]. In addition, this enhances the efficiency of the converter considerably [2].

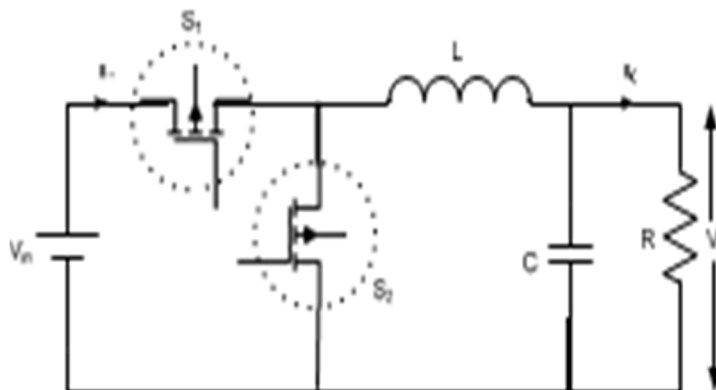


Figure 1: Synchronous Buck Converter

There are two cases in which synchronous buck converter operates. In case 1, switch 1(S1) is turned 'on' while the switch 2(S2) is turned 'off'. During this the inductor and capacitor gets charged. In case 2, switch 2(S2) is turned 'on' while the switch 1(S1) is turned 'off'. During this the inductor discharges through the body diode of S2. In case 2, on-state power loss is less because of the synchronous switch which is as shown in figure 2 [3-6].

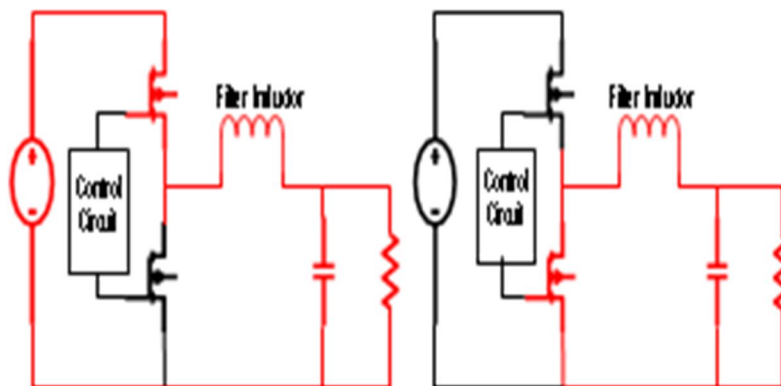


Figure 2: Operation of synchronous buck converter in both Cases

III. SYNCHRONOUS BUCK CONVERTER'S DESIGN AND HARDWARE IMPLEMENTATION

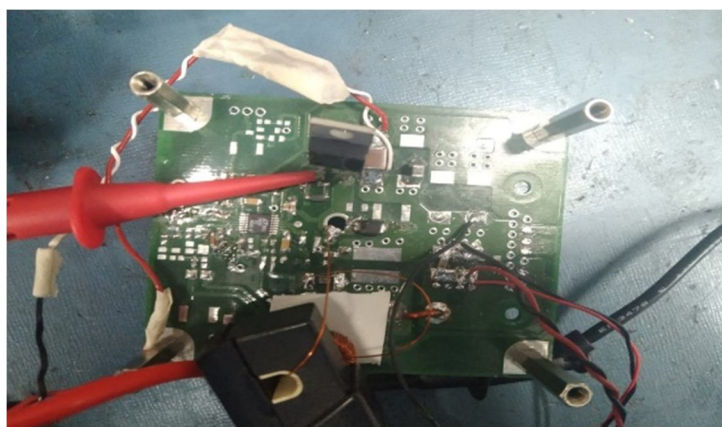


Figure 3: synchronous buck converter

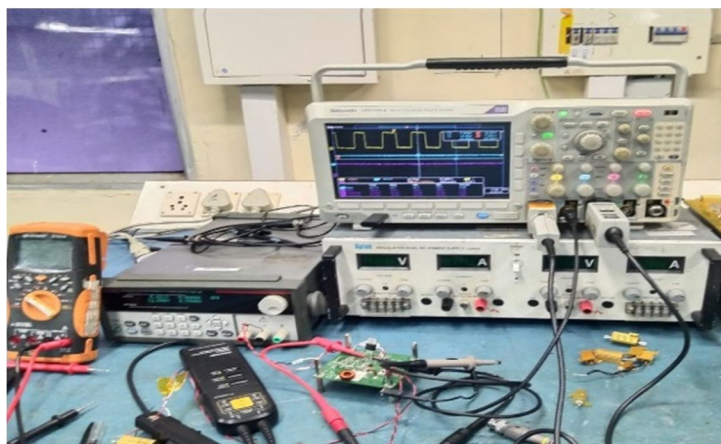


Figure 4: Prototype model setup of Synchronous Buck Converter

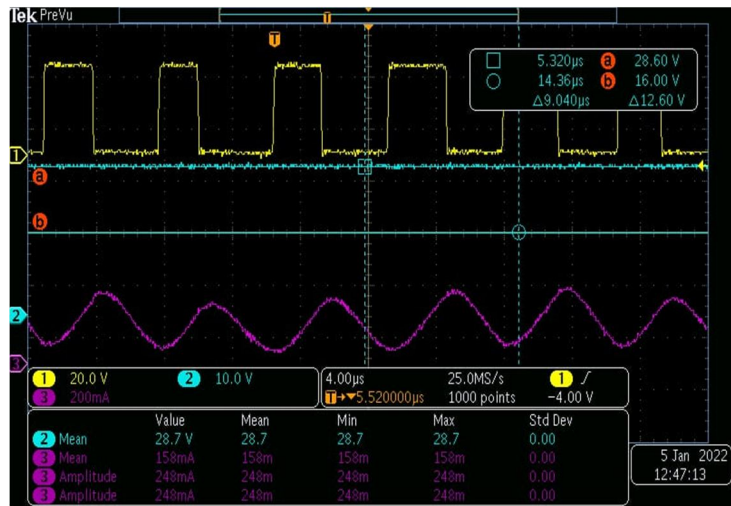


Figure 5: Hardware Input Waveforms: Yellow-Gate-source Voltage, Blue-Input Voltage, Purple-Input Current



Figure 6: Hardware Input Waveforms: Yellow-Gate-source Voltage, Blue-Input Voltage Purple-Input Current

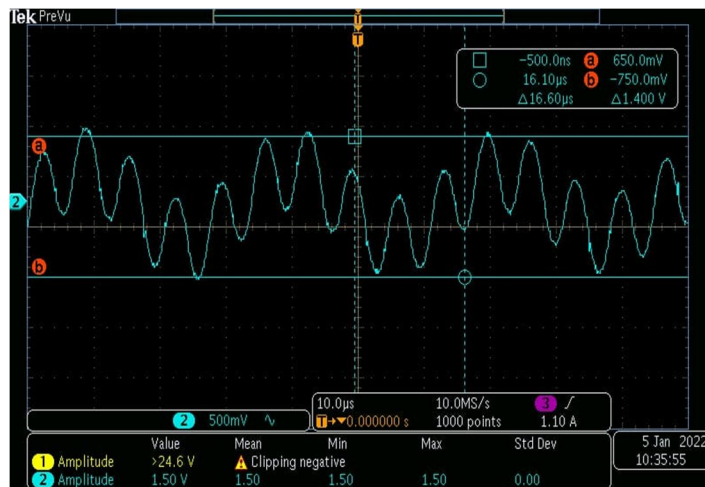


Figure 7: Ripple Waveforms

IV. DESIGN STEPS FOR SYNCHRONOUS BUCK CONVERTER

A. Input

Minimum input voltage $V_{in_min} := 24$ Volts

Maximum input voltage $V_{in_max} := 42$ Volts

Nominal input voltage $V_{in_nom} := 28$ Volts

Switching Frequency $F_{sv} := 150.10^3$ Hz

$$T_s := \frac{1}{F_{sv}}$$

$T_s = 6.6667.10^{-6}$ Second

B. Output Voltage & Current

$V_{out} := 12$ Volt

$\Delta V_{out} := 30.10^{-3}$ Volt

$I_{out_max} := 0.5$

$I_{out_min} := 0.1$

C. Duty Cycle Calculation

$$D_{max} := \frac{V_{out}}{V_{in_min}} = 0.5$$

$$D_{min} := \frac{V_{out}}{V_{in_max}} = 0.2857$$

$$D_{nom} := \frac{V_{out}}{V_{in_nom}} = 0.4286$$

D. Output Resistance Calculation

$$R_{out_min} := \frac{V_{out}}{I_{out_max}} = 24$$

$$R_{out_max} := \frac{V_{out}}{I_{out_min}} = 120$$

Nominal := 40

E. Input & Output Power Calculation

$P_{out_max} := V_{out} \cdot I_{out_max} = 6$

$P_{out_min} := V_{out} \cdot I_{out_min} = 1.2$

$\eta := 0.85$

$$P_{in_max} := \frac{P_{out_max}}{\eta} = 7.0588$$

$$P_{in_min} := \frac{P_{out_min}}{\eta} = 1.4118$$

F. Input Average Current Calculation

$$I_{in_max_min} := \frac{P_{in_max}}{V_{in_min}} = 0.2941$$

$$I_{in_max_nom} := \frac{P_{in_max}}{V_{in_nom}} = 0.2521$$

$$I_{in_max_max} := \frac{P_{in_max}}{V_{in_max}} = 0.1681$$

$$I_{in_min_min} := \frac{P_{in_min}}{V_{in_min}} = 0.0588$$

$$I_{in_min_nom} := \frac{P_{in_min}}{V_{in_nom}} = 0.0504$$

$$I_{in_min_max} := \frac{P_{in_min}}{V_{in_max}} = 0.0336$$

Pk -Pk ripple factor @ V_{max} $K := 0.2$

$I_{ripple} := k \cdot I_{out_max}$

G. Output Inductor Selection

$$L := V_{out} \cdot \frac{(V_{in_max} - V_{out})}{F_{sv} \cdot V_{in_max} \cdot I_{ripple}} = 0.0006(667 \text{ micro}) \text{ Note : Select L greater than the calculated value}$$

OUTPUT CAPACITOR ESR CALCULATION

$$ESR_{max} := \frac{(\Delta V_{out} \cdot L \cdot F_{sv})}{V_{out} \cdot (1 - \frac{V_{out}}{V_{in_max}})}$$

$$ESR_{max} = 0.3$$

$$ESR_{max} := 0.02$$

H. Output Capacitor Selection

$$C_{out} := \frac{I_{ripple}}{8 \cdot (\Delta V_{out} - I_{ripple} \cdot ESR_{max}) \cdot F_{sv}} = 2.9762 \cdot 10^{-6}$$

$$C_{out} = 2.9762 \cdot 10^{-6}$$

$$\Delta V_{in} := 0.1$$

I. Input Capacitor Selection

$$C_{IN} \text{ (BULK)} := I_{out_max} \cdot \frac{V_{out}}{\Delta V_{in} \cdot F_{sv} \cdot V_{in_min}} = 1.6667 \cdot 10^{-5}$$

$$I_{CIN} \text{ (RMS)} := I_{out_max} \cdot \sqrt{\frac{V_{out} \cdot (V_{in_max} - V_{out})}{V_{in_max}^2}} = 0.2259$$

J. R Sense Calculation

$$R_{Sense} := 70 \cdot \frac{mV}{I_{out_max}} = 0.14 \text{ V}$$

R_Set calculation

$$R_{set} \text{ (K}\Omega) := (8.4) \cdot 10^4 \cdot F_{sv}^{(-1.31)}$$

$$R_{set} := 118 \text{ K}\Omega$$

V. HARDWARE IMPLEMENTATION RESULTS

Table1: synchronous Buck converter Hardware results

Input Voltage(V)	Input current(I)	Input power(W)	Output voltage(V)	output current(I)	output power(w)	Efficiency n (%)
24	0.156	3.7	11.963	0.299	3.5769	95.513
25	0.150	3.75	11.963	0.299	3.5769	95.36
26	0.144	4.277	11.963	0.299	3.5769	95.51
27	0.139	4.3065	11.963	0.299	3.5769	95.28
28	0.134	4.3372	11.963	0.299	3.5769	95.31
29	0.129	4.3645	11.963	0.299	3.5769	95.59
30	0.125	4.3920	11.962	0.299	3.5769	95.36

The Hardware Implementation of synchronous buck converter using LT3845 was carried out for the given specifications and the results and waveforms are given below[6-7]. The output voltage, output current and efficiency is as shown in Table 1. The resulted waveform of Synchronous buck converter for 28V input is shown in figures. Efficiency of the converter is also tested for 24V and 30V inputs and it is shown in Table-1.

VI. CONCLUSION

Current mode controlled high efficiency synchronous buck converter is designed. Hardware results are verified, the load of the converter is 40 ohms, with an input voltage range of 24 to 30V. Efficiency of more than 95% is obtained by using LT3845 Synchronous stepdown controller IC.

VII. ACKNOWLEDGEMENT

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