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Design of Single Inductor and Two Output DC – DC Converter

S. Inbasakaran[1], Dr. Mahesh. K[2], Lithesh. J[3]

[1]EEE Department, New Horizon College of engineering, Bangalore, Karnataka, India
[2]EEE Department, Sir M Visvesvaraya Institute of Technology, Bangalore, Karnataka, India
[3]EEE Department, New Horizon College of engineering, Bangalore, Karnataka, India

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ABSTRACT

A DC-DC converter is used to convert from one DC voltage level to another DC voltage level. The output voltage may be increased or decreased when compare to the input voltage based on the circuit topology. DC – DC converters are mainly used as a regulated and isolated power supplies in many applications. Regulated dc power supplies are needed for most analog and digital electronic systems. Most power supplies are designed to meet some or all of the following requirements:
Regulated output: The output voltage must be kept constant with respect to the change in output loading.

Isolation: The output may be required to be electrically isolated from the input.

In addition to these requirements, common goals are to reduce power supply size and weight and improve their efficiency. A few applications of DC-DC converters are where 5V DC on a personal computer motherboard must be stepped down to 3V, 2V or less for one of the latest CPU chips; where 1.5V from a single cell must be stepped up to 5V or more, to operate electronic circuitry. The main focus in this paper is to generate dc voltage from a one level to other level with minimum loss. The need for such converters has risen due to the fact that transformers are unable to function on dc.
Keywords: Single Inductor, Two Output, DC – DC Converter.

I. INTRODUCTION

Multi-output DC-DC Converters:

There are many developments in the field of DC-DC converters in recent years in order to reduce their size and increase their efficiency. Many devices like laptops, cellular phones etc. require multiple outputs from a single input. Conventionally, for this purpose transformers are used with multiple secondary windings as individual outputs, but these have the disadvantages of increased size and weight especially for portable device. A single inductor multi-output converter is one such approach of reducing the effective size and weight of the converter. But it has voltage regulation problem, i.e. if the load changes in one output the other outputs are also affected, so a suitable controller has to be implemented to keep voltage constant.

The basic two types of control for DC-DC converters are:

1. Voltage mode control
2. Current mode control

Conventional Multi-Output Converter:

In the conventional multiple output converter, to obtain the multiple outputs transformers were used. Multiple tapings are put on the transformer secondary and the loads are connected in each of them. Fig shows the conventional multi-output converter [1].

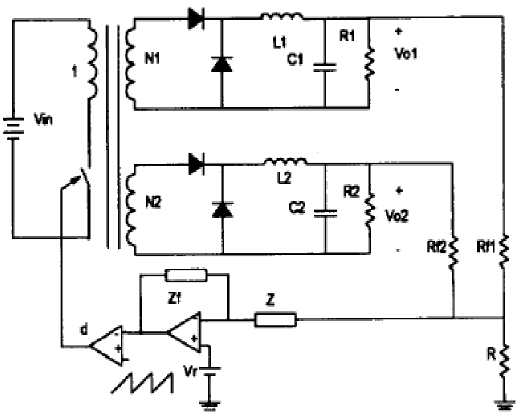

Fig.1 Conventional multi-output DC-DC converter with controller. [1]

Single Inductor Multi-Output Converter:

The main disadvantage of the conventional multi-output converter is size and weight. In order to reduce the size and component count, the single inductor multi-output converter is used. Because, even there are n number of outputs the circuit will have single inductor.

Many electronic systems require multiple power supplies for different modules in different semiconductor processes. Each additional power supply costs additional components. For applications like cell phones and PDA's these additional components may result in more area and weight. In recent years a lot of effort is put to integrate the

Control of DC-DC Converters:

power supplies in the single chip and to reduce the external off-chip components. Single Inductor Multi Output (SIMO) converter is one such approach in which multiple supply voltages are generated using a single inductor. Since the single inductor is used for multi-output, the regulation problem will be present in such type of the converter.

Using this type of the converter the various other types of converters such as buck and buck-boost converters can be realized, just by changing the configuration of the input and output. [8]

MODE OF OPERATION

SINGLE INDUCTOR MULTI-OUTPUT CONVERTER

The circuit diagram of the single input multi-output boost converter is as shown in Fig.2. The single input single output converter will have one inductor and one filter capacitor along with the load. In single inductor multi output converter it will have only one inductor and 'n' number of outputs with capacitors and loads. [12]

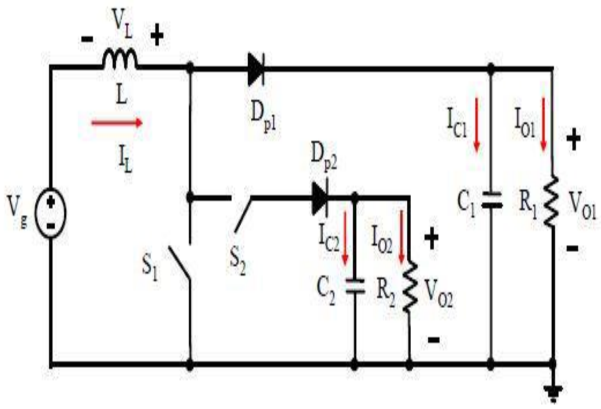

Fig.2 Single Input Multi-Output Boost Converter [10]

Mode 1:

The circuit diagram for the first mode of operation is as shown in the Fig. Here when the switch s1 is ON the inductor is charged to the value that of the supply voltage, (i.e. Vg). Even though the switch s2 is ON the current does not flow through Dp2, since the voltage at V02 is greater than Vg which appears across the inductor. [12]

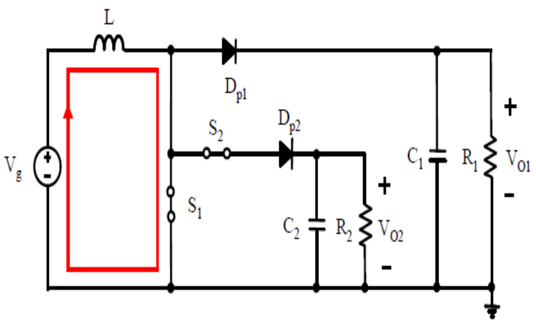

Fig.3 Mode 1 Operation [10]

Hence the diode is reverse biased. Until the diode is forward biased the capacitors C1 and C2 will be supplying the loads R1 and R2 respectively. The duty cycle for this mode is D1.

Mode 2:

The circuit diagram for the second mode of operation is as shown in the Fig.4 Here when the switch S1 is OFF, the switch S2 is still ON, and hence now the diode Dp2 will be forward biased. The inductor voltage as well as the supply voltage will appear across R2. During this time the capacitor C1 will be supplying the load R1.

The load connected to the second output should be lesser than that of the first output. [12] If the first output is connected with the lighter load than the second load, and since the switch is not connected in series with the Dp1 the current takes the least resistance path and hence the current does not enter the second load and hence it acts as a single output boost converter.

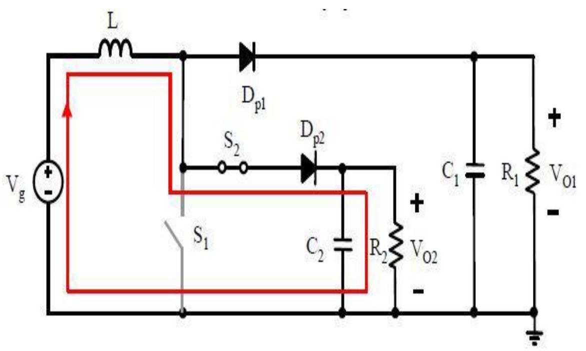

Fig.4 Mode 2 Operation [10]

If the lighter load has to be connected with the first output then the switch has to be connected with in series with the diode Dp1, and the duty cycle for that switch will be as the inverse of the duty cycle applied to the switch S2. The duty cycle for this mode is (D2-D1). Waveforms of various parameters are as shown as stage2 in Fig.6

Mode 3:

The circuit diagram for the third mode of operation is as shown in the Fig.5 The path of the current when the switches S1 and S2 both are OFF, is as shown in Fig.5

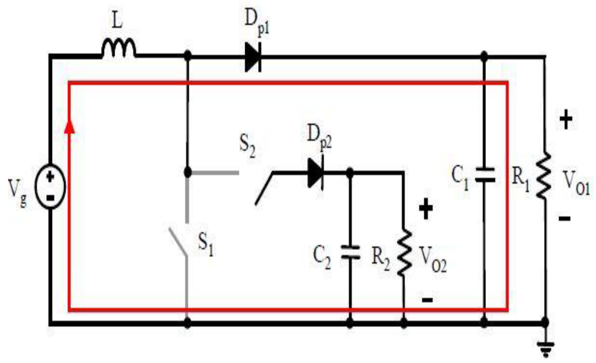

Fig.5 Mode 3 Operation [10]

During this mode the second output will be supplied by the capacitor C2. The inductor voltage and the supply voltage will appear across the load R1. The duty cycle for this mode is (1-D2). Waveforms of various parameters are as shown as stage3 in Fig.6

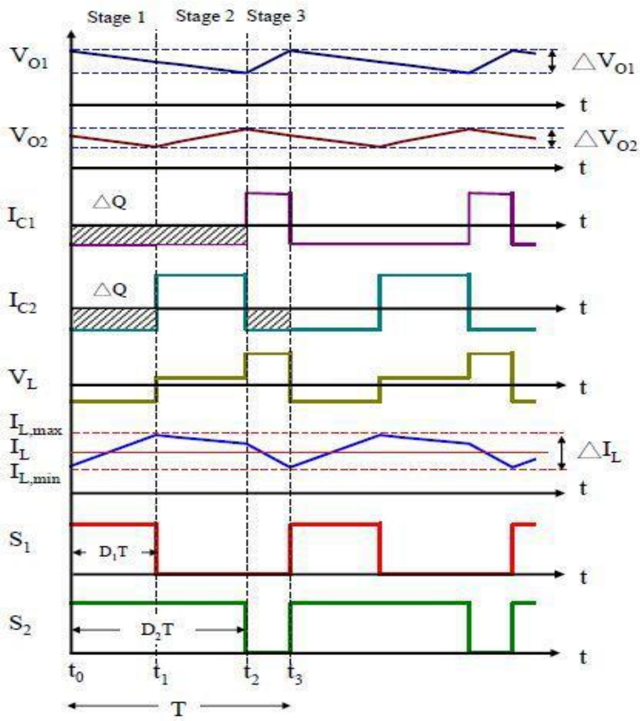

Fig.6 Waveforms of v01, v02, ic1, ic2, vl, il, vgs1 and vgs2 [10]

II. SIMULATION OUTPUT

Simulation of the single inductor multi-output boost converter:

The circuit of the open loop simulation of the single inductor boost converter is as shown in the Fig.7 here the ideal switches are used as the switches and the internal resistances of the components are neglected. The pulses are generated using pulse generators.

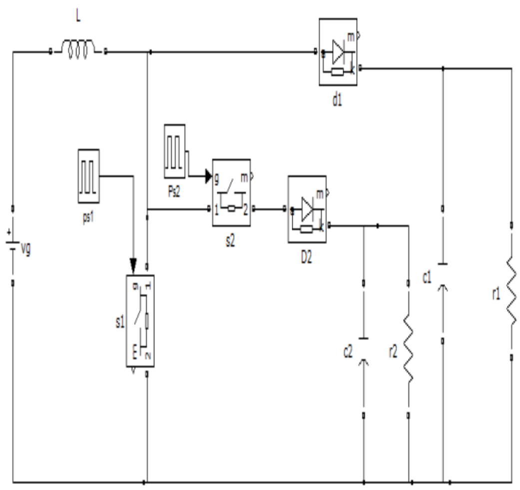

Fig.7 MATLAB model of the SIMO boost converter

Table 1: Ratings of the converter

PARAMETER	RATINGS
Vg	10V
C1	470µF
C2	330µF
R1	70Ω
R2	40Ω
PARAMETER	RATINGS
L	560µH
V01	24V
V02	12V

Output Voltages:

X-Axis is Time (sec) and Y-Axis is Voltage (V)

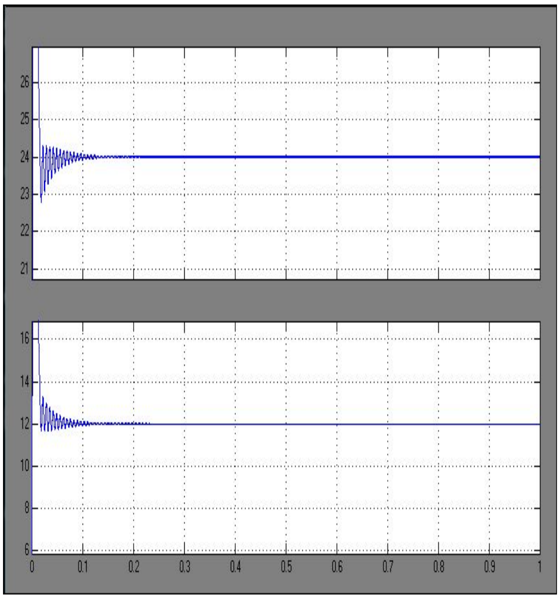

Fig.8 Output Voltages

Without any load change the output voltages of both the loads are maintained constant, i.e. V01 = 24V and V02 = 12V, the larger the capacitance value, lesser the output voltage ripples.

Output voltage ripples and pulses:

X-Axis is Time (sec) and Y-Axis is Voltage (V)

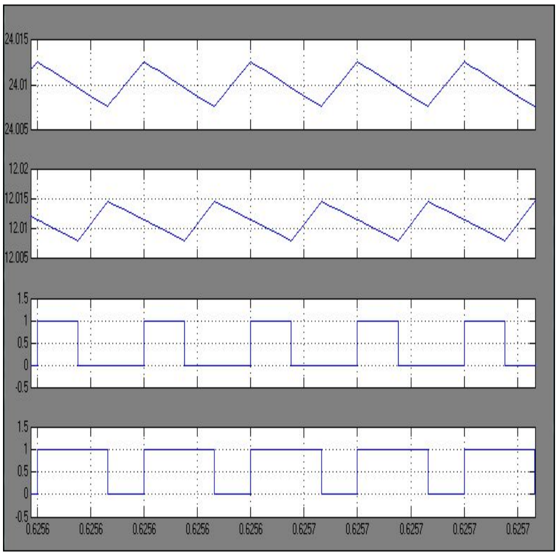

Fig.9 Voltage ripples and control pulses

The voltages waveform with the switching pulses are as shown above. The ripples in the voltages can be made less with a suitable filter capacitor. The capacitor charges when their respective switches are on and discharges to the load when the switches are off.

Capacitor currents and pulses:

The wave forms of the capacitors current and the switching pulses are as shown below. The capacitor current will reach maximum when their respective switches are on. The capacitor current will reach minimum when their respective switches are off. (X-axis – Time in sec and Y-axis – current in A)

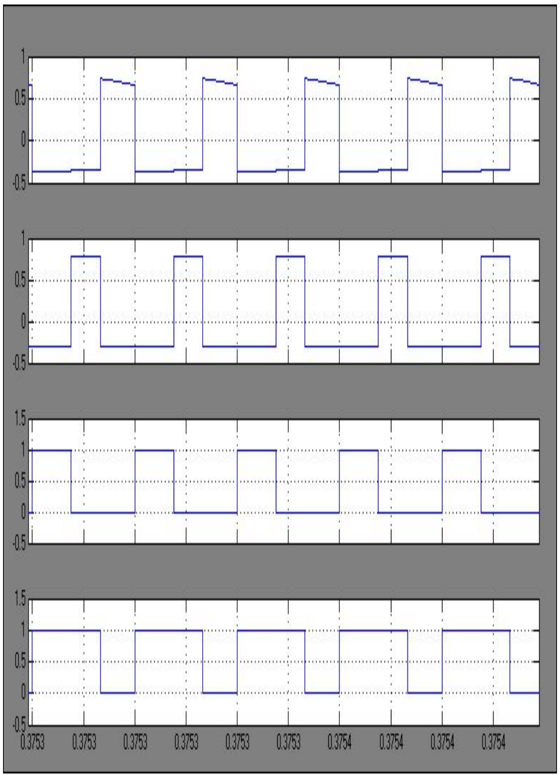

Fig.10Capacitor current and Control pulses

Inductor voltage, inductor current and pulses

The inductor voltage and the inductor current waveforms with the switching pulses are as shown in the figure. The inductor voltage is charged to 12V when the switch S1 is ON, when the switch S1 is OFF the inductor is discharged to (Vg – V02) V and when the switch S2 is OFF the inductor is discharged to (Vg – V01) V. The inductor charging in the first mode, it is discharging to the second load in the second mode and discharging to the first load. The slope of the inductor current depends on the loads connected at the outputs.

(X-axis – Time in sec and Y-axis –Voltage in V and Current in A)

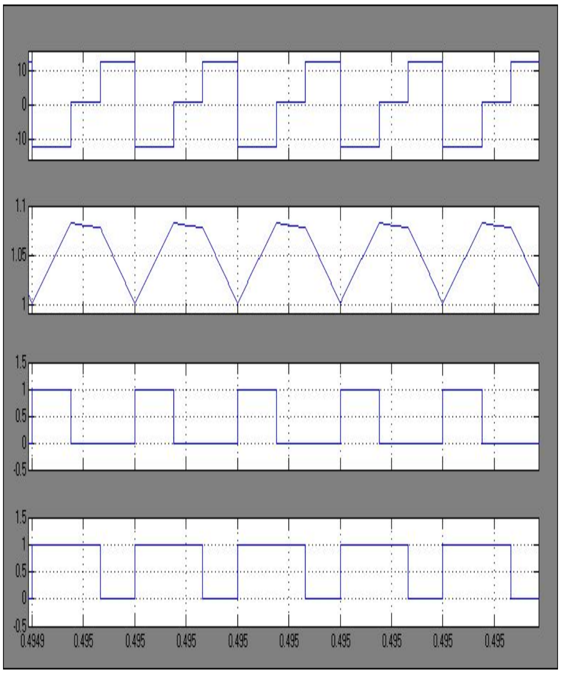

Fig.11 Inductor voltage, current and control pulses

III. CONCLUSION

The open loop simulation of single inductor multi output boost converter is carried out and obtained results are compared with the expected results. The ripple value in the input current and output voltage is reduced by using single inductor. If the closed loop control is implemented with suitable controller design the ripple value of input current and output voltage can be reduced further. A high degree of regulation of multiple – output can be obtained.

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