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A Transformer-Less Step-Down DC-DC Converter with Low Switch Voltage Stress

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ABSTRACT

In this paper, a novel transformer-less direct current dc-dc converter that feature low switch voltage stress and uniform current sharing. An interleaved voltage divider operating from 200v dc bus is used the proposed converter enable uniform current sharing of the interleaved phases without adding any extra circuitry or complex control methods. The operation of the principles and performance analyses of the proposed converter are presented, and its effectiveness is verified by a prototype circuit that converts 200V input voltage into 100V output voltage to achieve major objectives, reduced voltage stress of active switches and diodes. As a result, the proposed converter permits the lower voltage rating MOSFETs to reduce both switching and conduction losses, thereby improving overall efficiency.

Keywords—*high step-down converter , low conduction losses, low switch voltage stress,phase shift, uniform current sharing.*

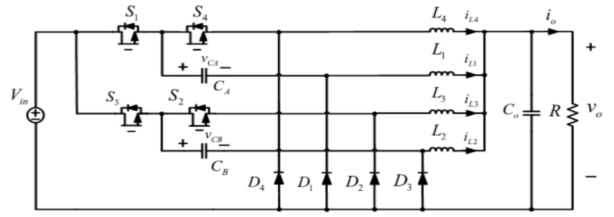
I. INTRODUCTION

In recent years, the step-down direct current (dc) converter have displayed increasing interests in high output-current application, such battery charges, and distributed power system and home appliances. This non-isolated application where low output current ripples are required, the interleaved buck converter (IBC) considered due to simple structure. Quadratic buck converter built with a cascade dc-dc buck converter which achieve a high step down conversion ratio(1). These converters can be used fewer topologies to attain improved characteristics, such as size and simplified driver design but it require additional power stage that reduce the efficiency.

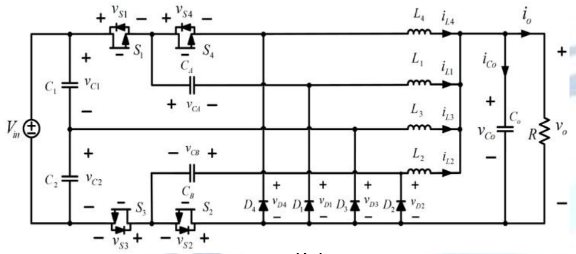
A three level buck converter was proposed in to lower the switch voltage stress to half of the input voltage. By using metal-oxide-semiconductor field-effect transistors (MOSFET), improve efficiency and performance and achieved as compare to convention buck converter whose switches must be rated for the full load dc voltage. An IBC with the single capacitor turnoff snubber was introduced in [5] which reduce the switching loss associated with turn-off transition.

However, a single coupled inductor implements the converter it can only be operate at the discontinuous conduction mode (DCM) and, all elements suffer from high current stress and conduction and core losses. Recently, step-down converter with efficient ZVS operation and varied load present in where an auxiliary switch, and diode, and coupled winding are used to the buck inductor for the ZVS operation.

The two winding-coupled inductors, which can operated in continuous conduction mode was introduced in (12). The switching losses of active switches are reduced by adjusting the turn ratio of the coupled inductor and achieve high step-down conversion ratio.



(a)



(b)

Fig.1. (a) Four phase extended duty ratio buck converter (b) four phase uniform current sharing interleaved buck converter

In this paper , we proposed a novel transformer-less step down dc-dc converter that feature low switch voltage stress and uniform current sharing. An interleaved two phase divider is used to achieve a high step down conversion ratio. This proposed converter architecture provide high step-down conversion ratio and low switch voltage stress compare to the conventional system. The proposed system operating active switches are reduced from conventional system but produce reduced switching and conduction losses without compromising of the efficiency. The driver circuit and switches arrangements are reduced here so both cost and weights of the system are reduced.

II. PROPOSED BLOCK DIAGRAM

The proposed converter block diagram shown in figure (2), which is derived from four phase IBC with an extended duty ratio in (5). The proposed converter consists of two inductor, two active switches, two blocking capacitors and two diodes.

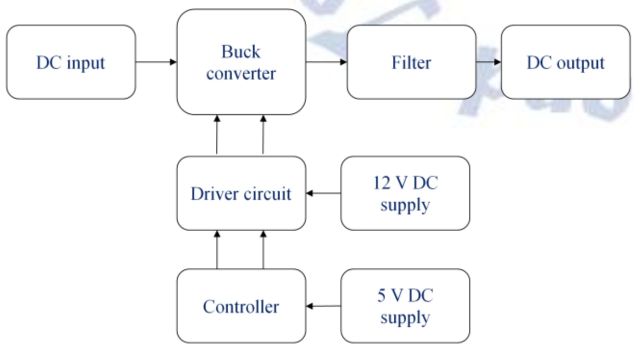


Fig.2.The block diagram for proposed converter

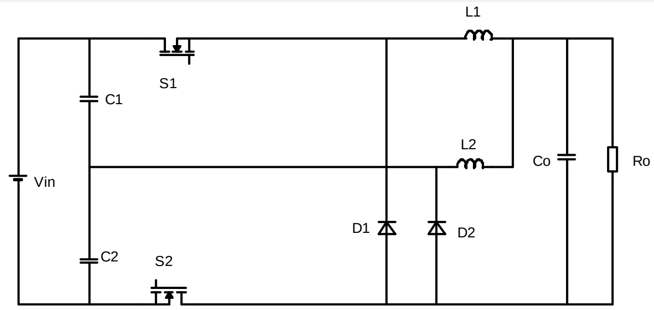


Fig.3 .The circuit configuration of proposed configuration

The proposed converter uses only two active switches and two passive diodes, couple of inductors to produce step-down dc voltage with low switch voltage stress, low conduction losses. This design utilized less no of operating components to achieve high efficiency compare to conventional IBC structure so the proposed converter size and weight of the system reduced.

In this proposed system operated in continuous conduction mode, when the system operate in below 0.5 duty cycle then only this system operate continuous conduction mode and produce low switch voltage stress.

On the other hand, when the duty cycle increases higher than 0.5 the system operate discontinuous conduction mode so switch voltage stress of the active switches is increased.

III. OPERATING PRINCIPLE

Mode 1

In this mode, switch S1 is turned on, and switches S2 are OFF. Hence, diode becomes D1, D2, ON. The corresponding equivalent circuit is shown in Fig(a). It is clear that the stored energy of C1,C2 is discharged to L1, L2, and the output load, and freewheeling through D1,D2,and L1, L2 respectively.

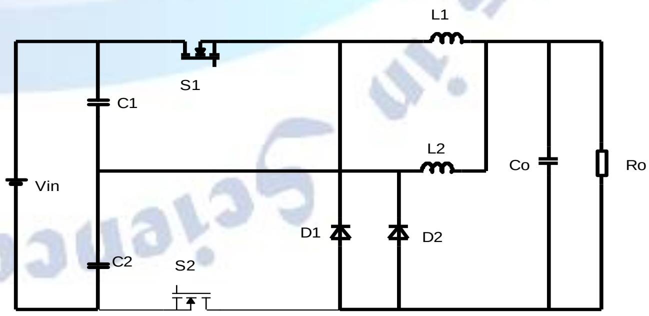
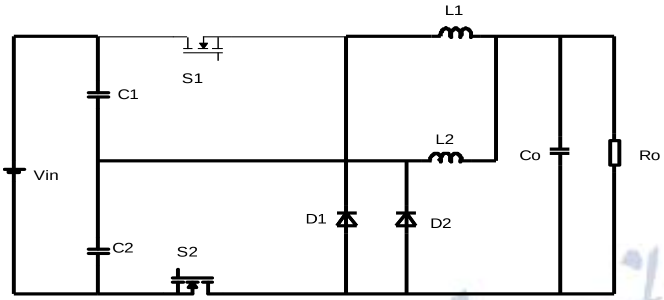


Fig.4.mode of operation (a)

Mode 2

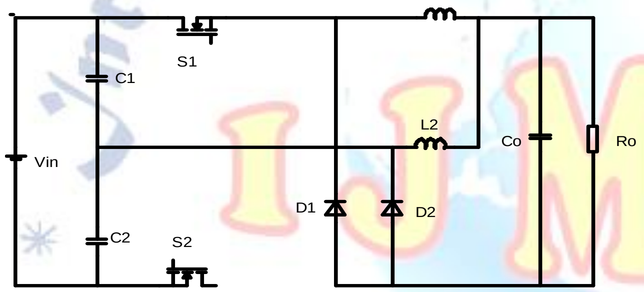
In this mode, switch S2 is turned on, and switches S1 are OFF. Hence, diode becomes D1, D2, ON. The corresponding equivalent circuit is shown in Fig (b). It is clear that the stored energy of C1, C2 is discharged to L1, L2, and the output load, and freewheeling through D1, D2, and L1, L2 respectively.



(b)

Mode 3

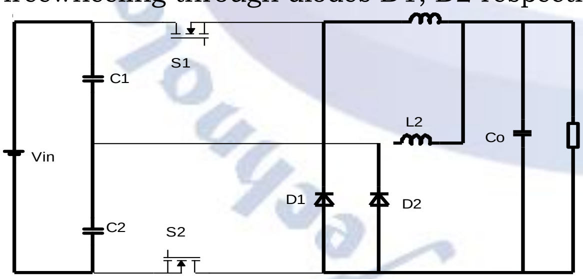
In this mode, switch S1, S2 is turned on, Hence, diode becomes D1, D2, ON. The corresponding equivalent circuit is shown in Fig (c). It is clear that the stored energy of C1, C2 is discharged toL1, L2, and the output load, and freewheeling through D1, D2, and L1, L2 respectively.



(c)

Mode 4

In these modes, CapacitorC1, C2 charge and switches S1, S2 are OFF. The corresponding circuit is shown in Fig (d). In this case, L1, L2 are freewheeling through diodes D1, D2 respectively.



(d)

b. Buck converter step down converter

In this circuit the transistor turning ON will put voltage V_{in} on one end of the inductor. This voltage will tend to cause the inductor current to rise. When the transistor is OFF, the current will continue flowing through the inductor but now flowing through the diode. We initially assume that the current through the inductor does not reach zero, thus the voltage at V_x will now be only the voltage across the conducting diode during the full OFF time. The average voltage at V_x will depend on the average ON time of the transistor provided the inductor current is continuous.

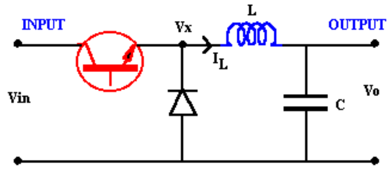


Fig .5. Buck Converter

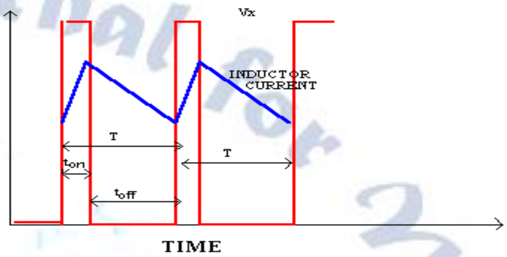


Fig 5.1 Voltage and Current

To analyses the voltages of this circuit let us consider the changes in the inductor current over one cycle. From the relation

$V_x - V_o = L\, di/dt$

The change of current satisfies

$di = \int_{on}(V_x-V_o)dt + \int_{off}(V_x-V_o)dt$

For steady state operation the current at the start and end of a period T will not change. To get a simple relation between voltages we assume no voltage drop across transistor or diode while ON and a perfect switch change. Thus during the ON time $V_x=V_{in}$ and in the OFF $V_x=0$. Thus

$0 = di = \int_0^{ton}(V_{in}-V_o)dt + \int_{ton}^{ton+toff}(-V_o)dt$

which simplifies to

$(V_{in}-V_o)ton - V_o\, toff = 0$

Or

$(V_o/V_{in}) = (t_{on}/T)$

$D = (t_{on}/T)$

and defining "duty ratio" as the voltage relationship becomes Vo=D Vin Since the circuit is lossless and the input and output powers must match on the average $V_o * I_o = V_{in} * I_{in}$. Thus the average input and output current must satisfy $I_{in} = D\ I_o$ These relations are based on the assumption that the inductor current does not reach zero.

Transition between continuous and discontinuous

When the current in the inductor L remains always positive then either the transistor T1 or the diode D1 must be conducting. For continuous conduction the voltage V_x is either V_{in} or 0. If the inductor current ever goes to zero then the output voltage will not be forced to either of these conditions. At this transition point the current just reaches zero as seen in Figure 5. During the ON time V_{in}-V_{out} is across the inductor thus $I_L(peak) = (V_{in}-V_{out}).(t_{on}/L)$

The average current which must match the output current satisfies

I_L(average at transition)=$(I_L(peak)/2)=(V_{in}-V_{out})dT/2L=I_{out}$

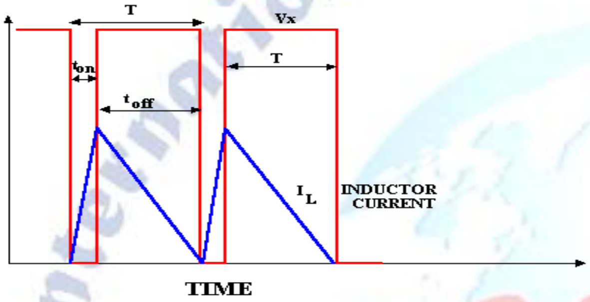


Fig 5.2 Buck converter at boundary

If the input voltage is constant the output current at the transition point satisfies

I_{out}(transition)=$V_{in}(1-d)d\ T/2L$

1.2 Voltage Ratio of Buck Converter (Discontinuous Mode)

As for the continuous conduction analysis we use the fact that the integral of voltage across the inductor is zero over a cycle of switching T. The transistor OFF time is now divided into segments of diode conduction d_dT and zero conduction d_oT. The inductor average voltage thus gives

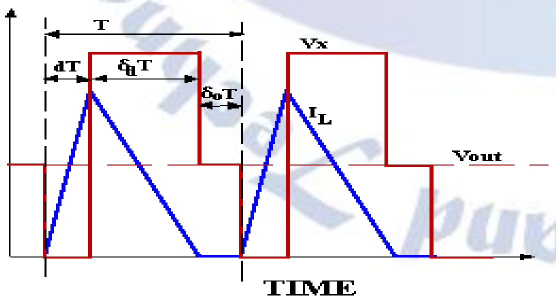


Fig 5.3 .Buck Converter - Discontinuous Conduction

$V_{out}/V_{in} = d/(d+\delta_d)$

for the case. $d+\delta_{d<}1$ To resolve the value of δ_d consider the output current which is half the peak when averaged over the conduction times $d+\delta_d$

$I_{out}=I_L(peak)\ d+\delta_d$

Considering the change of current during the diode conduction time

$I_L(peak)=V_o(\delta\zeta)/L$

Thus from (6) and (7) we can get

$I_{out}V_o\delta\zeta(d+\delta)/(2L)$

using the relationship in (5)

$I_{out}=V_{in}\ d\delta\zeta/2l$

and solving for the diode conduction

$\delta_d=2L\ I_{out}/V_{in}dT$

The output voltage is thus given as

$V_{out}/V_{in}=d^2/d^2+(2L\ I_{out}/V_{in}T)$

defining $k^* = 2L/(V_{in}\ T)$, we can see the effect of discontinuous current on the voltage ratio of the converter.

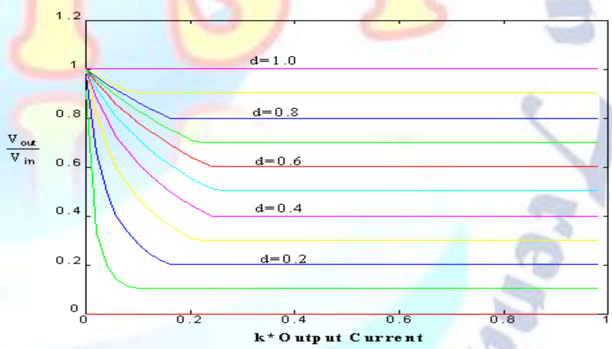


Fig 3.5 Output Voltage vs Current

IV. OPERATING CONTROLLER PIC16877A

The pic 16f877a is one of the most advanced microconroller from microchip.the controller widely used for experimental and model applicatiom because of its low prize, wide range of appication ,high quality, and ease of availability. It is ideal for such as application for machine applocations, measurement devices, study purpose, and so on. The PIC 16877A features all the components which modern microcontrollers normally have. The figure of normally of a PIC 16877A chip is shown below.

PIC 16F877A

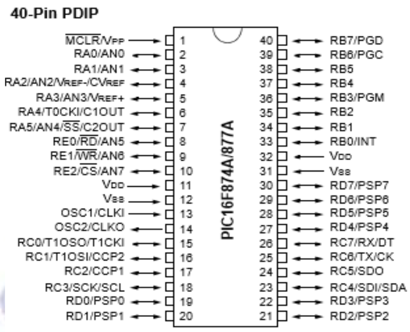


Fig .6.pin diagram

Input And Out Put Ports

PIC16877A has five basic input and outputs. They are usually denoted as ports PORT A, PORT B, PORT C, PORT D, PORT E.

PORT-A	RA-0 to RA-5	6 bit wide
PORT-B	RB-0 to RB-7	8 bit wide
PORT-C	RC-0 to RC-7	8 bit wide
PORT-D	RD-0 to RD-7	8 bit wide
PORT-E	RE-0 to RE-2	3 bit wide

Table .1

Simulation Result

Both simulation and experimental tests are conducted to evaluate the proposed converter topology and control scheme. The system parameters for evaluation are below.

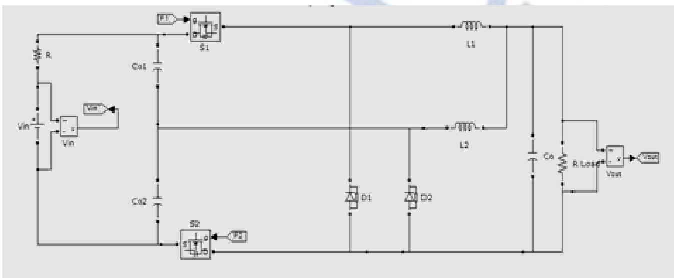


Fig.7. MATLAB/ simulink model for proposed system

Simulation Result

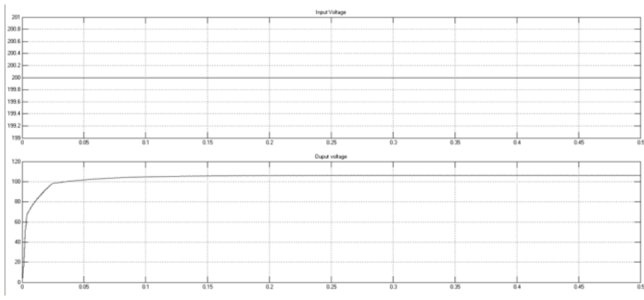


Fig.8.MATLAB/ simulink result

V. CONCLUSION

In this paper, we proposed a novel transformer-les step-down dc-dc converter that offer high step-down conversion ratio, low switch voltage stress, the automatic uniform current sharing. The proposed system design used only few numbers of components to provide better efficiency compare to the conventional system. The proposed converter topology provide low switching loss and conduction losses because we are used less number of active switches. The efficiency of the proposed converter were verified by experimental studies sing a prototype circuit.

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