ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Development of TMS320F2810 DSP Based Bidirectional buck-boost Chopper

Mr. K.S. Chakradhar*[1], M.Ayesha siddiqa[2], T.Vandhana[3], S.Lavanya[4], K.Jeevitha[5]
chakradharec@gmail.com

Abstract

A DC - DC converter is an electronic circuit which converts a source of direct current (DC) from one voltage level to another. It is a class of power converter. One common application of DC - DC converters is DC motor control. The Buck - Boost Chopper is a type of DC - DC converter. They are static devices which are used to obtain variable DC voltage from the source of constant DC voltage. Besides the saving in power, Buck-Boost choppers offer greater efficiency, faster response, lower maintenance, smooth control and small size. Even though Buck Boost choppers have several advantages, they can't transfer power from either sides. So a unidirectional DC/DC converter is designed to flow energy on both sides by replacing diodes with controllable switch forming a Bidirectional DC/DC converter. The output DC level is controlled by varying the time for which the supply is connected to the circuit. .

Keywords: Buck-Boost Chopper.

Introduction

Introduction to DC - DC Converters

DC - DC converter is a type of electronic circuit which converts a source of direct current (DC) from one voltage level to another. It is a class of power converters. In low power systems, such as in cell phones and laptop computers, frequent level conversion is essential, because each sub - circuit requires different voltage supply levels. It also finds uses in the high power systems, like in DC motor control. By varying the DC level, we can vary the effective power and speed of the DC motor.

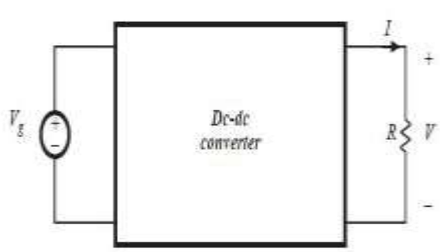

Figure 1.: Basic block diagram of a DC - DC converter

Buck - Boost Chopper

The Buck - Boost converter is a very power efficient, simple, affordable, not-too-bulky solution if one wants to have both step-up and step-down operations on the same setup. The basic topology is as shown in figure 2.

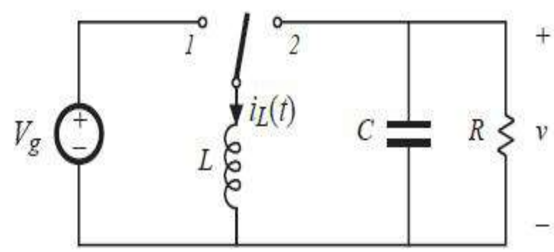

Figure 2: Basic Buck - Boost Circuit Topology

Operation

Figure1.8 shows the implementation of the said circuit using an IGBT and a diode. The gate terminal of the IGBT is used to switch the switch in figure 2 to position 1 or to position 2 (If IGBT is conducting, then switch is in position 1. Else it is in position 2).

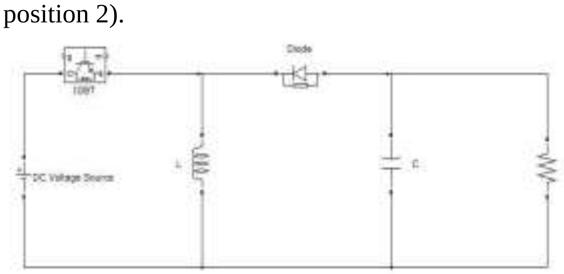

Figure 3: Basic Buck - Boost Circuit Implementation

.

In the below circuit the IGBT is in common emitter configuration, which has two compensation diodes. When power supply is given to the circuit the

IGBT1 is shorted and IGBT2 is activated. By this current flows from V_{in} to inductor. When it is completely charged, the polarity of inductor changes and diode will be in forward bias if the source is removed. Thus the circuit act as boost converter and it will also act as buck converter when it operates in vice versa condition. The IGBT used in unidirectional Buck Boost Converter transfers energy only in one direction as the diodes are in opposite directions. By using the below circuit we can transfer energy in either directions with a combination of step up and step down.

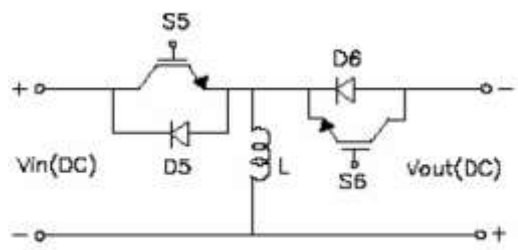

Figure 4:IGBT Circuit with CE Configuration

Bidirectional dc-dc Converter

Buck Boost converters do not have bidirectional power flow capability. Reverse current flow is not possible due to presence of diodes in their structures. Thus, a unidirectional dc-dc converter can be turned into diodes by replacing diodes with controllable switch. When the energy storage is placed on the high voltage side, it is of buck type. And similarly boost type dc-dc converter is to have energy storage on low voltage side. Switch cell should carry the current in both directions to realize the double sided power flow in bidirectional dc-dc converters. Generally IGBT or MOSFET are used in parallel with diode.

Introduction to DSP controllers

DSPs are available from different suppliers like, Texas instruments, Motorola and analog devices etc. The TMS320F2812 device, a member of the TMS320C28x DSP generation, is a highly integrated, high-performance solution for demanding control applications. Further, this DSP has several features for easy implementation of IGBT switching signal generation.

Theoretical Calculations

Analysis for the Buck-Boost converter

Using the principles mentioned in the previous chapter, various relations can be found or the Buck - Boost converter case, between various known and unknown (but desirable) quantities. Throughout this document, the following notations for the various quantities will be observed:

V_g is the input DC voltage given to the converter.
V is the output DC voltage obtained after conversion.
I is the DC component value of the inductor current.
R is the load resistance.
L is the inductance.
C is the filter capacitor.
f_S is the switching frequency.
T_S is the switching time period = $1/f_S$.
D is the duty cycle of switching.
D' is the duty cycle of switching = (1 - D).
i_L is the instantaneous current through the inductor element.
i_R is the instantaneous current through the resistive load element.
i_C is the instantaneous current through the filter capacitor element.
v_L is the instantaneous voltage of the inductor element.
i_L is the instantaneous current through the capacitor.
v_C is the instantaneous voltage across capacitor.
i_L is the inductor current ripple.
v_C is the output voltage ripple.
Δi_L is the inductor current ripple.
Δv_C is the output voltage ripple.

Current Ripple

When the IGBT is ”ON”, the inductor is in charge mode, and the capacitor in the discharge mode, as shown in fig 5.

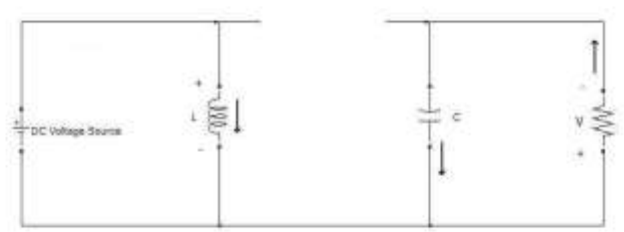

Figure 5: Buck-Boost Circuit when IGBT is ON

Therefore the following equations are valid:

$$V_g = L\frac{di_L}{dt}$$

$$\frac{V_C}{R} = C\frac{dV_C}{dt}$$

Integrating the first equation over the ”ON” time DTs, we get the expression for the inductor current ripple:

$$\Delta I_L = \frac{V_g}{2L}DT_S$$

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

Also, from the small ripple approximation, we can rewrite the second equation as:

$$\frac{V}{R} = C\frac{dV_C}{dt}$$

Therefore, integrating this equation over "ON" time gives:

$$\Delta V_C = \frac{V}{2RC} DT_S$$

Output Voltage Ripple, Transfer Function, Inductor current

When the IGBT is "OFF", the inductor is in discharge mode. The polarity observed is because the current in it is decreasing: $\frac{di_L}{dt} < 0$

Therefore, $V_g < 0$

Now, since the inductor discharges through both the capacitor and the load,

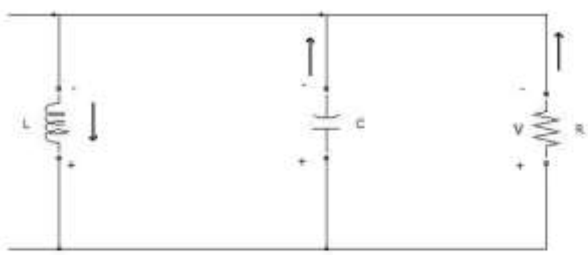

Figure 6: Buck-Boost Circuit when IGBT is OFF

$$i_L = i_C + i_R$$

Applying small ripple approximation to this, we get:

$$I = \frac{V}{R} + \frac{dV_C(t)}{dt}$$

This gives us an expression for the voltage ripple ΔV_C :

$$\Delta V_C = \frac{D'T_S}{2RC} [IR - V]$$

Also,

$$V = L\frac{di_L}{dt}$$

Hence, integrating this over the "OFF" time gives:

$$\Delta i_L = \frac{VD'T_S}{2L}$$

Therefore, equating these two equations with those obtained earlier, we obtain

$$V = \frac{-V_g D}{D'}$$

$$I = \frac{-V_g D}{RD'^2}$$

Relations

Therefore, the following relations are used to calculate values for L, C, and f_S:

$$V = \frac{-V_g D}{D'}$$

$$I = \frac{-V_g D}{RD'^2}$$

$$\Delta i_L = \frac{V_g DT_S}{2L}$$

From these, we can derive relations for L and C:

$$L = \frac{V_g DT_S}{2\Delta i_L}$$

$$C = \frac{V_g D^2 T_S}{2R\Delta v_C D'}$$

Also, we can also define a boundary for the value of Ts and R for which the circuit would operate in continuous conduction mode. The following relation defines that boundary:

$I > \Delta i_L$

Matlab Simulations

This chapter deals with the results of simulations done in Matlab environment. The values for the various components are as per the actual experiment.

Conventional Buck Boost Circuit

Figure 7 shows the circuit setup used to obtain the simulate the controlled Buck-Boost chopper. The components have the same values as those in the actual circuit .The outputs are observed for a 20V input and 10

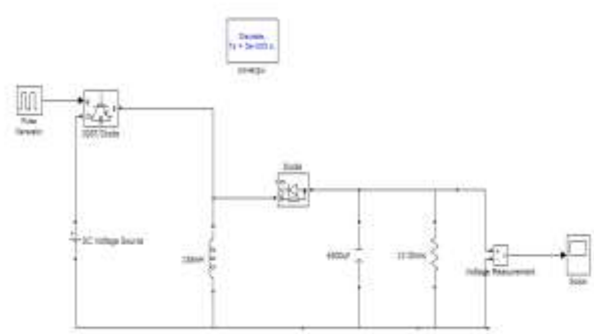

Figure 7: MATLAB-Simulink model of buck-boost chopper

Implementation

This paper deals with how the actual implementation of the DSP controlled Buck -Boost chopper has been done. A block diagram describing various parts of the real system has been provided. The individual blocks have then been explained in

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

larger detail with respect to their need, connections, precautions, and relevant diagrams.

Master Block diagram

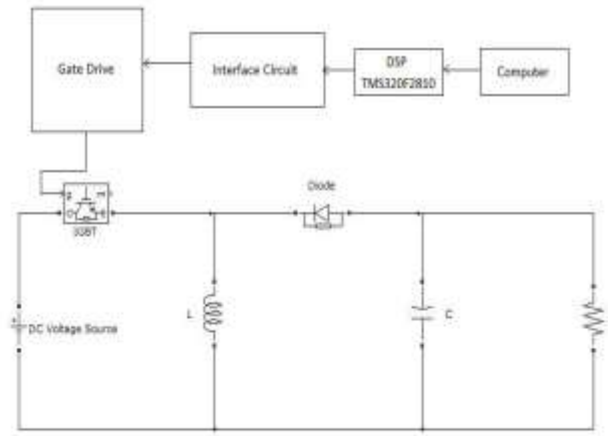

Figure 8: Master Block diagram of the overall system

Fig. 8 . shows how the system has been implemented in the project. The DSP generates a PWM signal whose duty cycle is controlled online via the computer (connected through the JTAG interface) as shown. The control interface circuit boosts the +5V□0V signal obtained from the gate drive to a +15V - 0V signal, also boosting the signal strength in the process.

Results

This chapter shows all the results that have been obtained by experimenting on the real system. The output waveforms have been obtained via a transient recorder, and the output voltage values have been cross checked using a multimeter.

Results for the Bi-directional BUCK BOOST converter:

Table no.1: Bi-directional buck readings at 13 ohms load

Vg	Duty ratio	V practical	V theoretical	Error	% error
20v	0.2	3.5	4	0.5	12.5
20v	0.3	7.2	6	1.2	20
20v	0.4	9.9	8	1.9	23.7
20v	0.5	11.9	10	1.9	19
20v	0.6	13.3	12	1.3	10.8
20v	0.7	14.4	14	0.4	2.85
20v	0.8	15.2	16	0.8	5

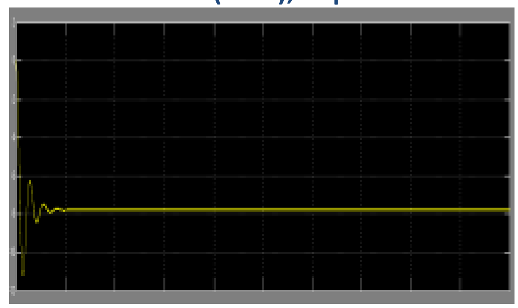

Figure 9: Matlab simulations output for 30 percent duty cycle

Figure 9.1: Observed waveforms for 30 percent duty cycle on CRO

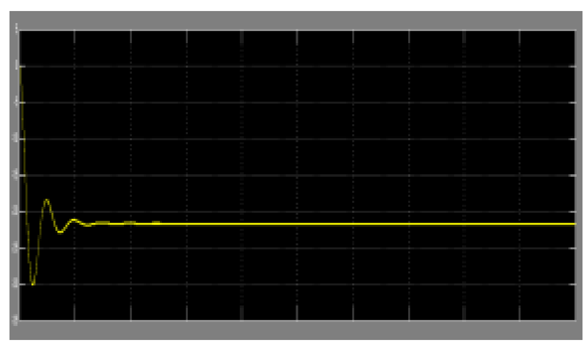

Figure 10: Matlab simulations output for 60 percent duty cycle

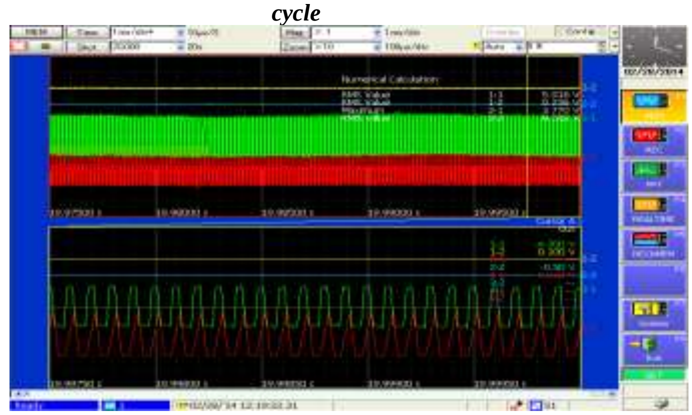

Figure 10.1: Observed waveforms for 60 percent duty cycle

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

Table no.2: Bi-directional boost readings at 56ohms load

Vg	Duty ratio	V practical	V th	Error	% error
20v	0.25	25.6v	26	0.4	1.53
20v	0.3	29.5v	28.5	1	3.50
20v	0.4	37.9v	33.3	4.6	13.81
20v	0.5	46.5v	40	6.5	16.25
16.9v	0.6	46v	42.25	3.75	1.77
12.5v	0.7	38.8v	41.33	2.53	6.12
9.6v	0.8	33.6v	48	14.4	30
7.3v	0.9	29v	73	44	60.27

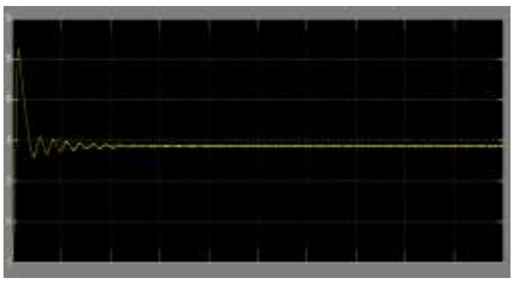

Figure 11: Matlab simulations output for 30 percent duty cycle

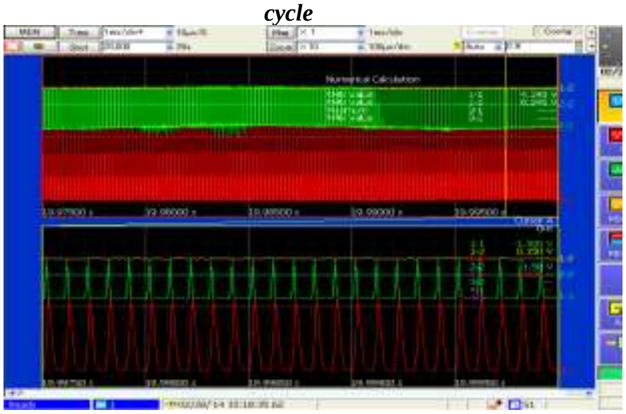

Figure 11.1: Observed waveforms for 30 percent duty cycle on CRO

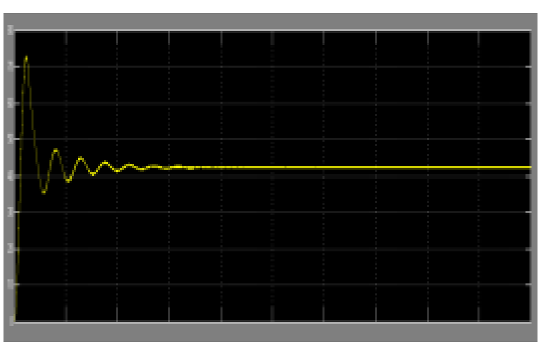

Figure 12: Matlab simulations output for 60 percent duty cycle

Figure 12.1: Observed waveforms for 60 percent duty cycle on CRO.

Conclusions

The project has presented the working model of a DSP controlled bidirectional buck-boost chopper. Simulations results were verified experimentally with the hardware using DSP TMS320F2810 by Texas Instruments. Power circuit was tested with the DSP in Power Electronics Lab in BHEL R and D and is working satisfactorily, with errors described by the table in the previous chapter.

Scope for further work

Closed loop implementation

The system can be implemented to self adjust to a given output voltage by providing a PID controller in closed loop with the converter. The advantage of using feedback is that the system automatically detects any change in the output due to disturbances and corrects it. Thus the system becomes an Automatic Control System. This is a simple modification of the present project.

Hybrid Electric Vehicles (HEV) application

Now a day's more countries vehicles showed interest towards HEV. There is a tremendous effort in past decade to shift from conventional gasoline engines to hybrid electric vehicles. Factor responsible is the improvement in performance, size, cost of power electronics circuits. For hybrid vehicles, the batteries and the DC drive link may be at different voltage. Batteries are at low voltage and dc link may at high voltage levels to have higher efficiency on the motor. Therefore a good interfacing between the batteries and the drive's dc link is essential. This interface handles power flow in between battery to motor, motor to battery, external generator set to battery, and grid to battery. The inverter drives the motor and the DC/DC converter between the battery and the high voltage bus. The designed DC/DC converter should be bidirectional so that energy can

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

flow from the battery to the DC link and from DC link to battery. Designed converters maintains a constant DC link voltage when it is in monitoring mode of operation and energy flow from DC link to battery when it is in generating mode of operation.

References

1. *R.W.Erickson, Fundamentals of Power Electronics, 2nd edition*
2. *TMS320F2810 data manual TMS320F2810 Event managers Data Manual.*