A DSP based Controller Design for Noninverting Buck-Boost Converter

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Abstract— In normal Buck-Boost converters, the output voltage is negative with respect to input. The gate drive circuit or microcontroller is required to trigger the MOSFET switch in the converter. In the new proposed topology, a non inverting or positive output buck-boost converter is implemented for PV system of stepper motor application. The pulse width modulation (PWM) signals for two MOSFET switches in the converter circuit are generated from DSP TMS 320F28335. Depending on the solar panel input, the non inverted buck-boost converter charges the battery. The DC load like stepper motor run from the battery. The load voltage and load current are sensed and compared with the reference voltage. The microcontroller is less accurate and by using microcontroller the solar energy cannot be fully converted into electrical energy. In industrial operation for the accurate system working is and commercial application DSP is used and for same DSP is used for generation of PWM signals. For that only the accuracy is more in closed loop operation and this works in real time. In the proposed study the PWM signals are generated from DSP using load voltage and load current, and as compared to existing system the proposed study is better in terms of load & line regulation, efficiency as tabulated by experimental results. MATLAB will used to simulate the circuit.

Keywords— Buck-Boost converter, PWM generation, stepper motor, DSP algorithm

I. INTRODUCTION

Now a day's DC-DC converter places very important role in residential, commercial and industrial applications. In that a buck-boost converter is one of the type of DC-DC converter from that converter getting the output of both stepped up and stepped down voltage depending on duty cycle ratio of PWM signal. In normal buck-boost converter, use of only one switch (MOSFET), a diode and the output voltage is negative, either buck or boost condition. In the new proposed study, the output voltage is positive by combining a normal Buck converter and normal Boost converter. From this combined structure of converter the solar energy output voltage is not inverted. A DSP based controller for dc-dc converter is designed, simulated and implemented in [1]. The implementation of DSP controller is by using the DSP TMS320F2812. The PID controller [1] is designed, simulated and implemented for buck converter only. The paper [2] discusses with the design of PI controller for sliding mode controller of buck-boost converter (PISMC). The control algorithm PISMC is implemented on DSP TMS320F2808. This DSP is used for generating the PWM signals for triggering the MOSFET of conventional Buck –Boost converter. The input from the solar panel is converted into electrical energy through the buck-boost and that output is stored in a battery to drive the DC electrical loads. DSP processor gives the controlling action ,but in this step the converter used is normal buck-boost converter; the output is inverted, so before connecting to output of the converter to battery the output terminal of the converter must be interchanged. In paper [3] the MPPT techniques are discussed for PV application, the above paper discus about the merits and demerits of MPPT techniques the paper [3] gives intelligent methods for reducing oscillations. A microcontroller based PWM generation is implemented in paper [4]. The amplitude of PWM signal is less in microcontroller implementation so that for triggering or turning on of the MOSFET switch requires extra driver circuit (gate drive circuit for MOSFET). Due to this, the gate drive circuit requires extra power and circuit is to be complex and cost is also more. And in microcontroller operating system gives less efficiency and accuracy and solar energy cannot be converted in to electrical energy fully by using microcontroller. The application of DC controllers and DC motors are discussed in [5]. For controlling these, use of DSP TMS320LF2407, but in these they is not discussed about solar PV application. In paper [6] discus with application of PV system and converter with interfacing the DSP TMS320C2808for small DC LED light application. But in this paper does not explain the implementation of DSP with PV system for controlling action of DC motor. From the above literature the application of DSP, non inverting buck-boost converter with solar PV system reduce the complexity of operation of DC motor and increase the efficiency. By using DSP it doesn't require any extra circuit for triggering the MOSFET hence DSP can be implemented for non inverting buck-boost converter in PV system. In commercial and industrial purpose the DSP used for automation and controlling action of drives etc. and that same DSP is used to generate PWM signals so as to get more electrical energy. DSP is more accurate than microcontroller and it works on the real time function. And from DSP the sources are used efficiently. In the proposed study, non inverting buck-boost converter is designed and simulated in MATLAB and then implemented in solar PV application for controlling operation of dc motor.

II. ANALYSIS OF DSP BASED NON INVERTING BUCK BOOST CONVERTER WITH EQUAVELENT CIRCUIT TOPOLOGY

The conventional buck-boost shown in Fig.2. In conventional buck-boost converter a switch and power diode is used. The output voltage is negative and while connecting to load terminals, polarity should be interchanged

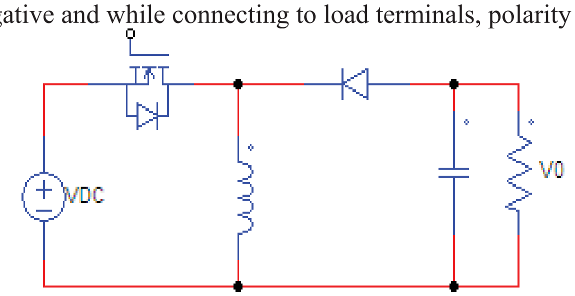


Fig. 2 Conventional Buck-Boost converter

In the proposed study, this problem is addressed with non inverting buck-boost converter as shown in Fig.3.In the proposed structure, two MOSFET switches and two diodes used. This is the combination of buck and boost converter.

Mode of Analysis of Non Inverting Buck-Boost converter

Mode-1: Switches are closed

The switches S1 and S2 are simultaneously on during on time as shown in Fig. 4

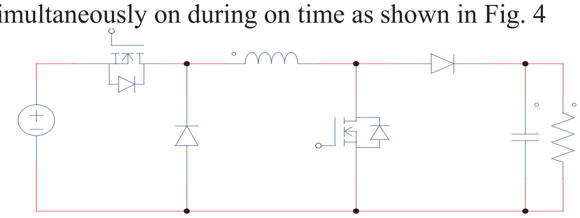


Fig. 3 Non Inverting Buck-Boost converter

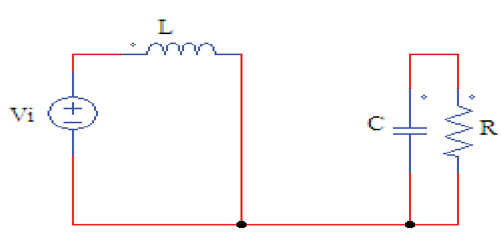


Fig. 4 Two switches are closed

When two switches are closed diodes D1 and D2 are reversing biased during on time. And expression is given by

$$(\Delta i_L)_{\text{closed}} = \frac{V_s DT}{L} \quad (1)$$

Mode-2: Switches are opened

The switches S1 and S2 are simultaneously off during off time as shown in Fig. 5

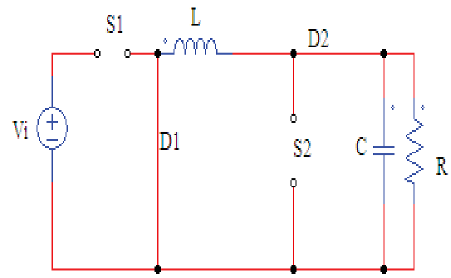


Fig. 5 Two switches are opened

When two switches are opened diodes D1 and D2 are forward biased during off time. The energy stored in the inductor is discharged to the load capacitor. And expression is given by

$$(\Delta i_L)_{\text{open}} = -\left(\frac{V_o}{L}\right)(1-D)T \quad (2)$$

The non inverted Buck-Boost converter is designed as follows. The total load current of 2.5A. The output voltage is given by

$$V_o = V_i \frac{D}{1-D} \quad (3)$$

The ripple voltage has been taken as 2% of the load current. ΔiL= 2%IL where

$$I_L = \frac{I_o}{1-D} \quad (4)$$

The swtching frequency of the switch is f=50kHz. The Inductor value is calculated using Eqn. (5)

$$L_{cr} = \frac{V_g.D}{f * \Delta i_L} \quad (5)$$

From Eqn.(5), the inductor value L=1.15mH is obtained. The output voltage ripple has been taken as 1% of the output voltage. The capacitor value is calculated using Eqn. (6).

$$C_{cr} = \frac{i_o * D}{f * \Delta V_o} \quad (6)$$

From Eqn. (6) the capacitor value C=220μF obtained. The efficiency of the buck-boost converter is given by

Where $$\eta = \left[1 - \frac{dV_{sn}}{V_g} - \frac{V_{sf}(1-d)}{V_g}\right]\left[\frac{1}{1+\frac{\alpha}{(1-d)^2}}\right] \quad (7)$$

$$\alpha = (R_l + R_g) / R$$

Where Vsn, Vsf are the ON state and OFF state voltage drops.R*l* & R*g* are the parasitic resistances of inductor and source and d is the duty ratio. The regulation is given by

$$reg = (Vnl - Vfl)/Vfl \quad (8)$$

Where V*nl*= no load voltage and V*fl*= full load voltage.

IV. TMS320F28335 DSP ARCHITECTURE

The TMS320F28335 Digital Signal Controller (DSC) is capable of executing six basic operations in a single instruction cycle. The TMS320F28335 block diagram is shown in figure 6 . It can be divided into many functional units:Internal and external Bus System, Central Processing Unit (CPU), Internal Memory Sections, Control Peripherals, Communication Channels, Direct Memory Access Controller (DMA), Interrupt Management Unit (PIE) and Core Time Unit, Real - Time Emulation Interface

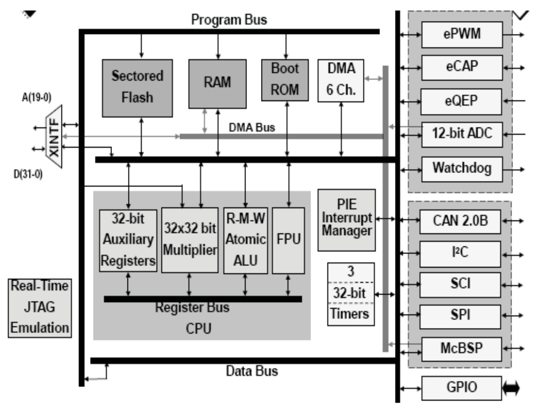


Fig. 6 TMS320F28335 Block diagram

V. DIGITAL INPUT OUTPUT UNIT

All digital I/O's are grouped together into "Ports", called GPIO-A, B and C. Here GPIO means "general purpose input output". The F28335 features a total of 88 I/O-pins, called GPIO 0 to GPIO 87. The device comes with so many additional internal units, that not all features could be connected to dedicated pins of the device package at any one time. The solution is multiplex. This means, one single physical pin of the device can be used for up to 4 different functions and it is up to the programmer to decide which function is selected. The block diagram of one physical pin of the device is shown below in figure 7.The term "Input Qualification" refers to an additional option for digital input signals at GPIO0-63. When this feature is used, an input pulse must be longer than the specified number of clock cycles to be recognized as a valid input signal. This is useful for removing input noise. Register Group "GPxPUD" can be used to disable internal pull-up resistors to leave the voltage level floating or high impedance. When a digital I/O function is selected, then register group GPxDIR defines the direction of the Input or Output. Clearing a bit position to zero configures the line as an input, setting the bit position to 1 configures the line as an output. A data read from an input line is performed with a set of GPxDAT registers. A data write to an output line can also be performed with registers GPxDAT. Additionally, there are 3 more groups of registers:GPxSET ,GPxTOGGLE ,GPxCLEAR

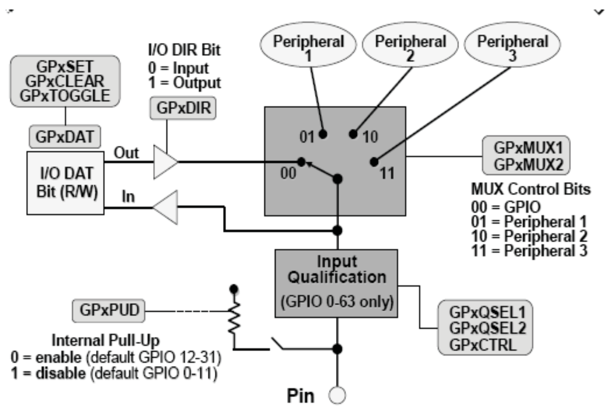


Fig. 7 Block diagram of TMS230F28335 GPIO Pin

VI. ENHANCED PULSE WIDTH MODULATION

Enhanced Pulse Width Modulation (ePWM) unit is controlled by its own logic block, as shown in figure 8. This logic is able to automatically generate signals on different time events and also to request various interrupt services from the F28335 PIE interrupt system, to support its operational modes.Main feature of an ePWM is its ability to start the Analogue to Digital Converter (ADC) without software interaction, directly from an internal hardware event. There are two basic operating modes of the ePWM system: (1) standard ePWM 16-bit mode and (2) 24-bit High Resolution PWM mode (HRPWM).The purpose of an ePWM unit is to generate a single ended signal or a pair of output signals, called EPWMxA and EPWMxB, which are related to each other. The lower case letter x is a placeholder for the number of the ePWM unit.The load voltage and current are sensed. The voltage sensed is compared with a reference voltage of 12V using an error amplifier. The output of error amplifier is given to a comparator. This comparator is also fed with a current sensor output. The comparator output is fed to DSP TMS320 F 28335 which has built in Analog to Digital Converter (ADC).The PWM signal generated from DSP depends on comparator output value. If the comparator output is more, then this corresponds to more load voltage accordingly DSP will produce a PWM signal of less width. If the comparator output is less then this corresponds to less load voltage accordingly DSP will produce a PWM signal of more width. [10][11][12]. In the proposed study, ePWM compare module is used and PWM signals are generated. The DSP is programmed to generate PWM signals. The different sourceand header files are developed to sense the ADC output available in order to generate PWM signals.

VII.PROGRAM DESIGN OF DSP

The system adopts the DSP TMS320F28335 chip as the control core, the main language of whole software programming is C language and assembly language, under the environment of CCS5.0 debugging, and the whole program is running good, to reach the expected aim. Program flow chart is shown in figure 9. The working process

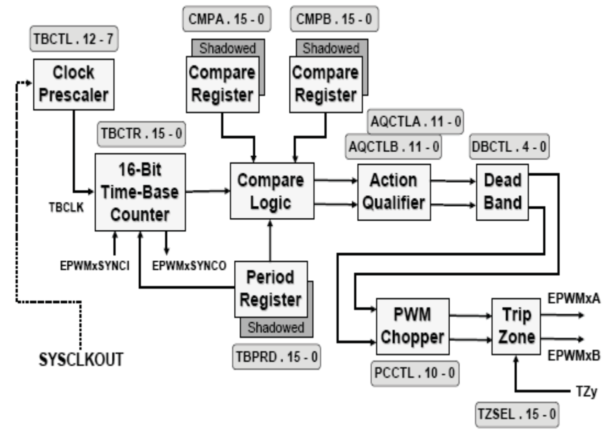


Fig. 8 Block diagram of ePWM

of the main program is: system initialization, read the A/D sampling to get the current value of the converter output voltage current, run the digital PID control algorithm, according to the controller output value calculated based on the algorithm to adjust the duty ratio of PWM signal, A new PWM signal control the state of the MOSFET switch to keep the converter output voltage stability.

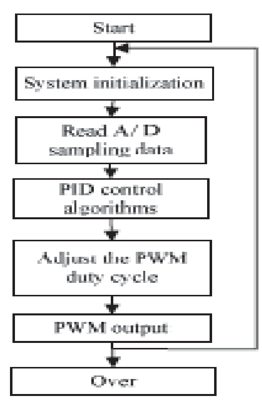


Fig. 9 Main Program Flowchart

VIII. SIMULATION RESULTS

The non inverting Buck-Boost converter is simulated using MATLAB Simulink and simulink diagram and waveforms are shown in Fig.10

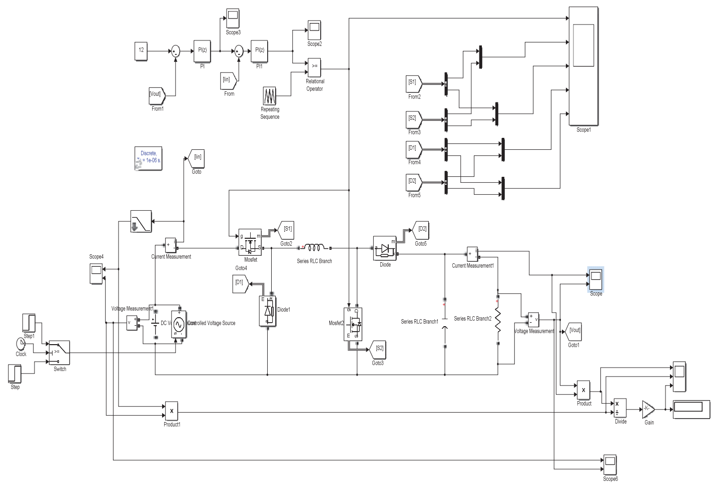


Fig. 10 MATLAB-Simulink Diagram of Non-inverting Buck-Boost converter

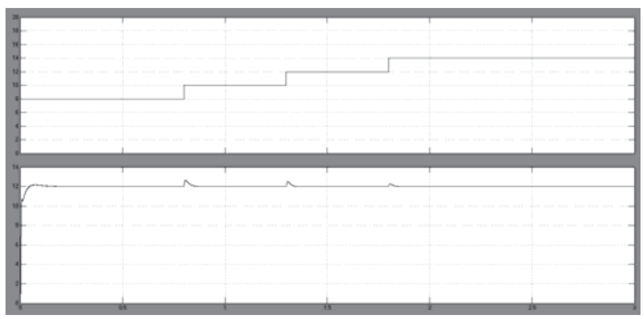


Fig. 11 MATLAB-Simulink Line regulation wave forms of Non-Inverting Buck-Boost converter

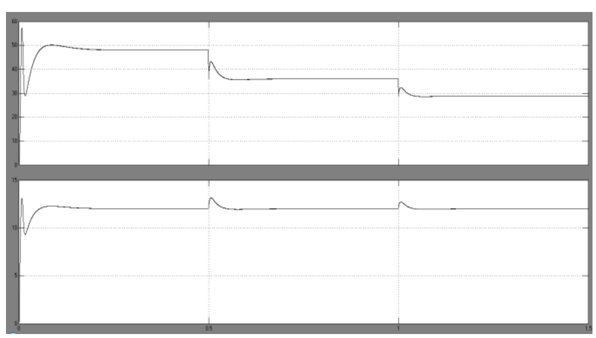
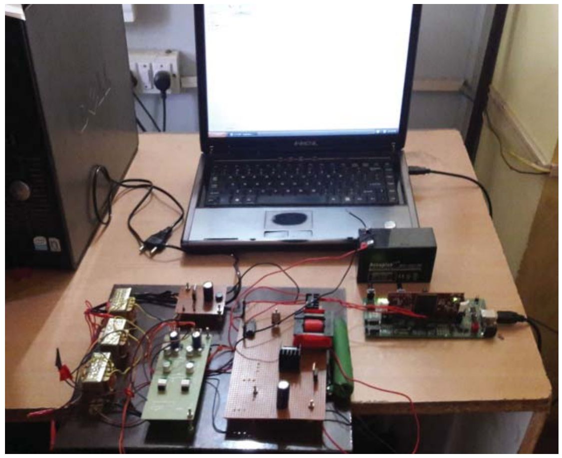


Fig. 12 MATLAB-Simulink load regulation wave forms of Non-Inverting Buck-Boost converte

IX. EXPERIMENTAL RESULTS AND DISCUSSION

The study is found to be better as compared existing systems in terms of both line and load regulation. The simulation results are shown in the Fig.. The efficiency of the proposed study is 92%. The converter is designed for PV system, simulated in MATLAB and then implemented using DSP.. In proposed work, DSP TMS320F28335 is interfaced to non inverting buck-boost converter. For the proposed study inverters can be designed as a future work and for the control of inverters the same DSP can be used.



X. CONCLUSSION

In industries and commercial applications involving automation process with DSP, the resources such as DSP is underutilized. In rural areas, with other forms of electricity are unavailable, solar energy is the most promising alternative. The cost of DSP is getting reduced and computational power of the same is getting increased during the last decade. Hence DSP processor can be used to generate PWM signals as compared to microcontroller or hardware circuitry. To address the above issues, a reliable DSP based non inverting buck-boost converter is developed in the proposed study. In the proposed study, a non inverting buck-boost converter for PV system with DC motor application is designed, simulated and implemented. The proposed work is better in terms of speed, accuracy, regulation and cost as compared to hardware circuit based or microcontroller based PV systems.

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