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Real Time Implementation of PI Controller for Triple-Lift Luo Converter

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Abstract: **Positive output Luo converters are a series of new DC-DC step-up (boost) converters, which were developed from prototypes using voltage lift technique. These converters perform positive to positive DC-DC voltage increasing conversion with high power density, high efficiency and cheap topology in simple structure. They are different from other existing DC-DC step-up converters with a high output voltage and small ripples. Triple lift LUO circuit is derived from positive output elementary Luo converter by adding the lift circuit three times. Due to the time varying and switching nature of the Luo converters, their dynamic behavior becomes highly non-linear. Hence in this research work, design and hardware implementation of PI controller have been carried out using TMS320C242 DSP for the Triple-lift Luo converter .The experimental results are presented and analyzed under line and load disturbances.**

Keywords: PI Controller, Triple-lift Luo converter, Digital Signal Processor (DSP).

I. INTRODUCTION

DC to DC step-up converters are widely used in computer hardware and industrial applications such as computer periphery power supplies, car auxiliary power supplies, servo-motor drives and medical equipment. Because of the effect of parasitic elements, the output voltage and power transfer efficiency of all DC-DC converters is restricted. The voltage lift technique is a popular method that is widely applied in electronic circuit design. It can lead to improvement of DC-DC converter characteristics. The elementary circuit which can perform step-down and step-up DC-DC conversion. Other positive output Luo converters are derived from this elementary circuit; they are the self-lift circuit, re-lift circuit and multiple-lift circuits (e.g. triple-lift and quadruple-lift circuits). PI control offer stability, robustness to large line and load variations and good dynamic response. PI control is chosen to ensure fast dynamic response with output voltage regulation. Hence hardware implementation of PI controller for Triple-lift LUO converter has been developed.

II. ANALYSIS OF TRIPLE-LIFT LUO CONVERTER

The Triple- lift LUO circuit is shown in Fig.1 .Switch S is a p-channel power MOSFET device (PMOS), and S_1 is an n-channel power MOSFET device (NMOS). They are driven by a pulse-width-modulated (PWM) switching signal with repeating frequency *f* and conduction duty *k. T*he switch repeating period is $T = 1/f$, so that the switch-on period is kT and switch-off period is $(1-k)$ T.

The load is resistive, i.e. $R = V_0/I_0$; the combined inductor $L = L_1 L_2/ (L_1 + L_2)$; the normalized load is $Z_N = R/fL$. The converter consists of a pump circuit S–L_1–C–D and a low-pass filter L_2-$C_{o,}$ and lift circuit.The pump inductor L_1 transfers the energy from the source to capacitor C during switch-off and then the stored energy on the capacitor C is delivered to load R during switch-on. Therefore, if the voltage V_0 should be correspondingly higher. When the switch S turned off, the current i_D flows through the free-wheeling diode D. This current descends in whole switching-off period (1 –k) T. If current i_D does not become zero before switch S turned on again, this working state is defined as continuous mode. If current i_D becomes zero before switch S turned on again, this working state is defined as discontinuous mode.The triple-lift LUO circuit consist of two static switches S and S_1 , four inductors $L_{1,}$ $L_{2,}$ L_3 and $L_{4,}$ five capacitors C, C1, C2, C_3 and $C_{0,}$ and five diodes. Capacitors C1, C2, and C_3 perform characteristic functions to lift the capacitor voltage V_C by three times of source voltage $V_{1,}$ L_3 and L_4 perform the function as ladder joints to link the three capacitors C1, C2, and C_3 and lift the capacitor voltage V_C up. Current $i_{C1}(t)$, $i_{C2}(t)$, $i_{C3}(t)$ are exponential functions. They have large values at the moment of power on, but they are small because $V_{C1} = V_{C2} = V_{C3} = V_1$ in steady state. The circuit parameters of the chosen Luo converter is listed in Table.1

The output voltage and current are

$$V_0 = \frac{3}{1-k} V_I$$

and $I_0 = \frac{1-k}{3} I_I$

The Voltage transfer gain in continuous mode is

$$M_T = \frac{V_0}{V_I} = \frac{3}{1-K}$$

Other average voltages:

$V_C = V_0$; $V_{C1} = V_{C2} = V_{C3} = V_I$

Other average currents:

$$I_{L2} = I_0 ; \quad I_{L1} = \frac{k}{1-k} I_0$$

$$I_{L3} = I_{L4} = I_{L1} + I_{L2} = \frac{1}{1-k} I_0$$

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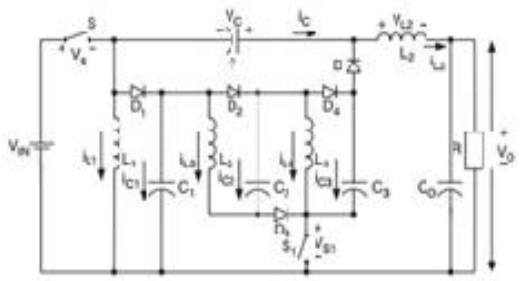

Fig.1 Triple - Lift LUO converter

TABLE 1. CIRCUIT PARAMETERS OF TRIPLE –LIFT LUO CONVERTER

Parameters	Symbol	Values
Input voltage	V_{in}	10 V
Output voltage	V_o	60V
Inductors	L_1-L_2-L_3-L_4	330µH
Capacitors	C_0-C1-C2-C3-C	22µf/60V
Load resistance	R	10Ω
Switching frequency	fs	50KHZ
Duty ratio	D	0.5

III. PI CONTROLLER

The actual output voltage of a converter is compared with reference voltage and error so obtained is processed by PI controller. The main function of PI controller is to reduce the peak overshoot and make steady state error zero. The value for k_p is 0.1 and T_i is 0.9sec.

IV.TMS320C242 DSP CONTROLLER

The TMS320C242 device is a member of the TMS320C2xx DSP family of digital signal processor (DSP) controllers based on the TMS320C2xx generation of 16-bit fixed-point DSPs. This new generation is optimized for digital motor/motion control applications. The DSP controllers combine the enhanced TMS320X DSP family architectural design of the C2xx core CPU for low-cost, high-performance processing capabilities and several advanced peripherals optimized for motor/motion control applications. These peripherals include the event manager module, which provides general-purpose timers and PWM registers to generate PWM outputs, and a single, 10-bit analog-to-digital converter (ADC), which can perform conversion within 1 µs. The instruction cycle time of the processor is 50ns. The architectural view of the TMS320C242 DSP is shown in Fig. 2.

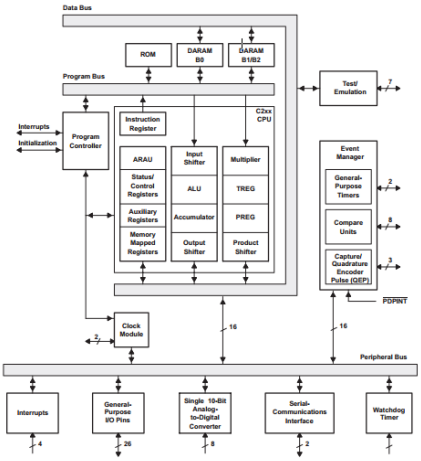

Fig. 2 Functional Block Diagram of TMS320C242 DSP

V. HARDWARE IMPLEMENTATION

The block diagram for the TMS320C242 DSP based implementation of closed loop control of a triple-lift Luo converter is shown in Fig.3 . The output voltage of the converter is scaled down to 0–5volts and read by the 10-bit ADC of DSP. The DSP executes 20 MIPS with 50 ns instruction cycle time. The conversion time of the on-chip ADC is 1µs. The DSP takes an average of 500µs to execute the PI control algorithm, which involves sampling the output voltage, calculating the new duty cycle and updating the PWM output. The switching device S_1 used is a N-channel MOSFET (enhancement type) IRF540N and S is a P-channel MOSFET IRF9630.In order to provide isolation between the power converter circuit and the DSP, the isolation amplifier HCPL7840 is needed in the feedback path. The MCT2E provides the isolation between the DSP and the power converter circuit. The PWM signal from the DSP based controller is not capable of driving MOSFET. In order to strengthen the pulses, driver IC IR2110 is used.

VI.SIMULATION RESULTS AND DISCUSSION

A snapshot of the experimental setup for a LUO converter is displayed in Fig. 4. Fig.5 shows the output voltage for the LUO converter with a step change of ±25% of rated supply voltage at 0.04 sec and at 0.06 sec. The experimental results show that the output voltage is regulated within a maximum of 0.005 sec after line disturbances and the %peak overshoot is 12.5%. Fig. 6 shows the output voltage of the LUO converter with a step change of ±20% of rated load at 0.04 sec and at 0.06 sec. It can be seen that the %peak overshoot is 12.5 and the settling time is 0.01sec for a step change of 10 -12 Ω and 0.003 sec for a step change of 10 – 8 Ω.

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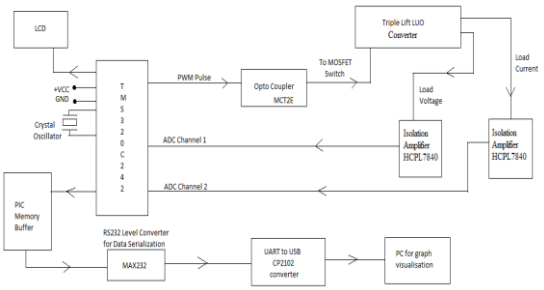

Fig.3 Block Diagram of closed loop control for Triple –Lift LUO converter

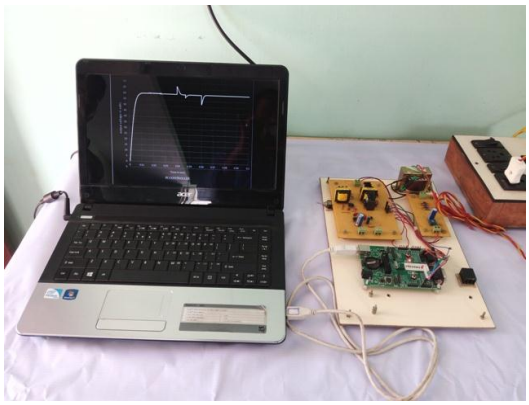

Fig.4 Hardware set up for Triple –Lift LUO converter

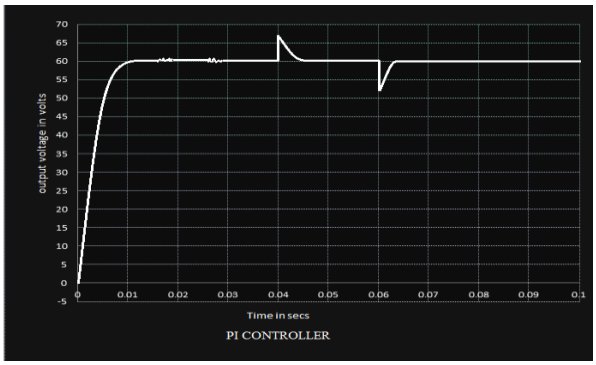

Fig. 5 closed loop response of conventional PI controller with sudden disturbances of ±25% of rated supply voltage at 0.04 sec and 0.06 sec

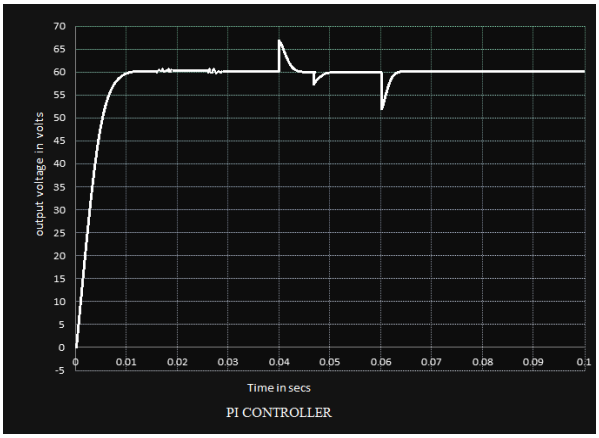

Fig. 6 closed loop response of conventional PI controller with sudden disturbances of ±20% of rated load at 0.04 sec and 0.06 sec

VII. CONCLUSION

The performance of the PI controlled triple-lift LUO converter has been presented. PI control gives output voltage regulation for both line and load disturbances with less settling time and less %peak overshoot. The hardware model of the LUO converter with its control circuit was implemented using TMS320C242 DSP.

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