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DSPIC based Low Cost and Efficient Digitized Feedback Loop for DC-DC Converter

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Abstract:

This paper describes and verifies a low cost but efficient digitized feedback alternative for buck converter operating at high frequency. Modern power system uses digital control to allow the inclusion of more functionality, control schemes and flexibility in design for quick modifications. The designed buck converter closed loop stability is assured using PID compensation. The results of the proposed switching converter structure have been presented based on comparison of simulated and experimental results.

Keywords: dsPIC

1. Introduction:

Modern power supplies are becoming more efficient, more flexible, less expensive and smaller. Their enhancement has been achieved by incorporating digital signal controllers into Switch Mode Power Supply (SMPS) based designs shown by figure 1. Buck converters are used when the desired output voltage is stepped down than the input voltage. SMPS using dsPIC devices are specifically designed to provide economical and efficient control for a wide range of power supply topologies. The closed-loop feedback control of switch mode power supplies are facilitated using specialized peripherals, providing communication for remote monitoring and supervisory control. [2]

Synchronous buck converters have received great attention in low voltage DC/DC converter applications because they can offer high efficiency; provide more precise output voltage and also meet the size requirement constraints. A proportional-integral-derivative (PID) type of compensator can stabilize a buck converter with voltage-mode control and voltage-mode error amplifier

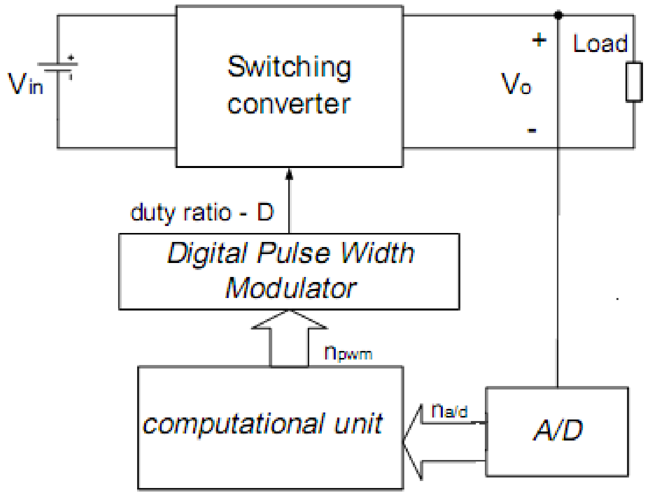


Figure1: Digitized feedback loop for switching converter [1]

2. Design of Synchronous buck converter:
The proposed synchronous buck converter system accepts 9V, 2A and provides 2V output. The digital PWM signals provided to the switching MOSFETs are operated around 400kHz frequency. The part of system's output is feed to the dsPIC based computational unit compromising of ADC where the digital voltage output obtained is compared with the reference voltage to produce an error signal. The error signal is further processed to modify the pulse width of DPWM to stabilise the output.

The source code further stabilises the DC output to around ± 2% of the desired output by incooperating the PID compensation. The digital computation unit used is using dsPIC33FJ16GS502 instead of using DSP processor for obtaining economical but effficient solution over analog feedback system, which sufferes variation due to environmental factors, ageing [3, 7].

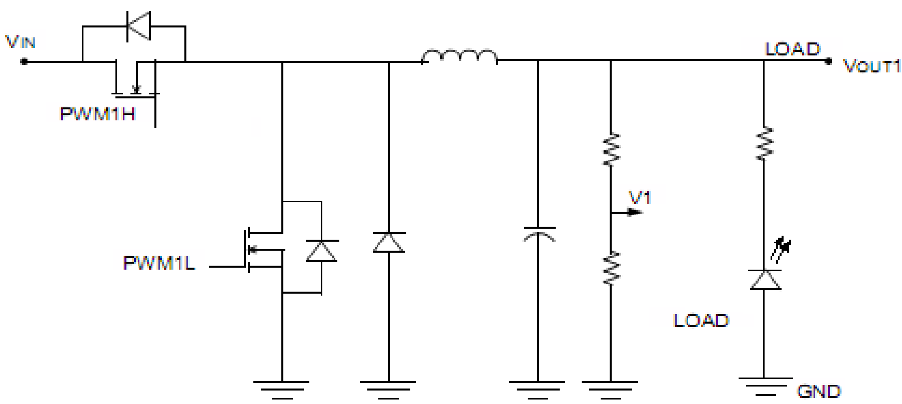


Figure 2: Synchronous buck converter

3. Steady State analysis of buck converter:

Power electronics converter are system having periodic time variation, because of their switching operation. In general, state space averaging method models the converter as time independent system, defined by a unique set of differential equations, capable of representing circuit waveforms. Therefore, it proves be a convenient approach for designing controllers to be applied to switched converters [2].

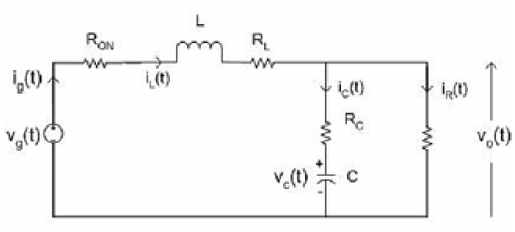


Figure 3 : Buck converter in ON state

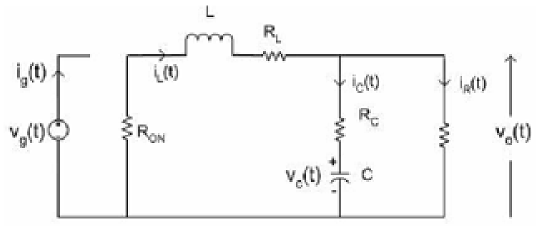


Figure 4 : Buck converter in OFF state

The mathematical model of the buck converter is designed using the above figure 3 and 4. The system analysis is done to obtained the state equation. The state space analysis helps to develop the simulink model for the above system. The designed system model considers the working of the buck converter during ON state and OFF state. As the circuit operates at high frequency the effect of parasatic resistance due to inductor and capacitor is also taken into consideration. The simulink model of the buck converter is shown in figure 5.

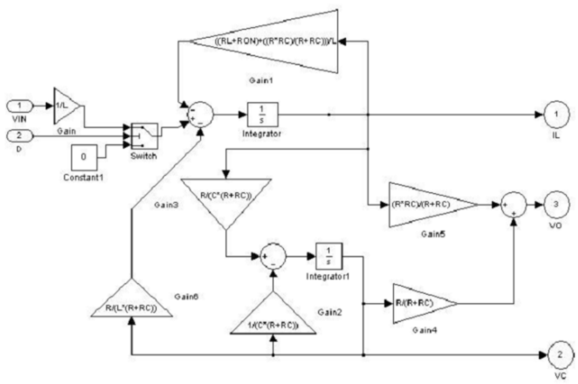


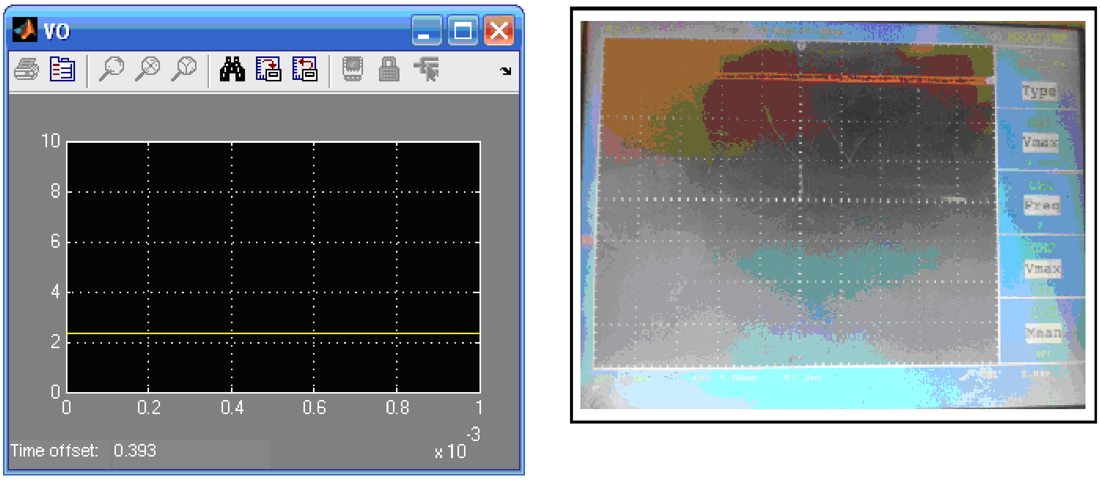
Figure 5: simulink model of buck converter

The dsPIC33FJ16GS502 digital computation unit used in this paper has 10 bit ADC and the frequency resolution of PWM is 1. 04ns. These dsPIC ICs have features like DSP processors. Hence a comparatively efficient but low cost and lesser complex switching sytem is achieved using dsPIC IC[1]. The source code incoperates the calculation of PID coefficient to assure close loop stability of the system. This controller has one pole at the origin and two zeros. The equation PID controller, shown in Equation (3)

$$G_{c\,(s)} = K_p + \frac{K_i}{s} + K_d\,(s)\ldots\ldots\ldots \quad (3)$$

5. Experimental Results:

The DC output obtained for the buck converter for simulation and practical analysis is shown in figure 6. a and 6. b.



a)Simulated output voltage=2. 1v b)Practical Output voltage: 2. 080v

Figure 6: DC output for buck converter

The high frequency PWM signals obtained for required switching MOSFETs obtained are shown in figure 7 and figure 8.

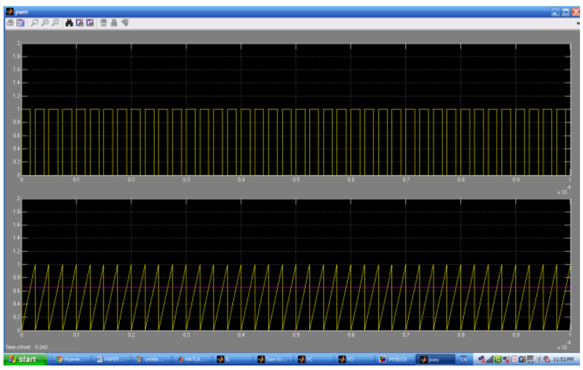
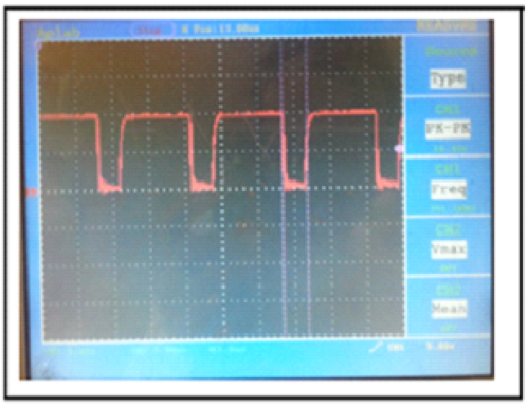
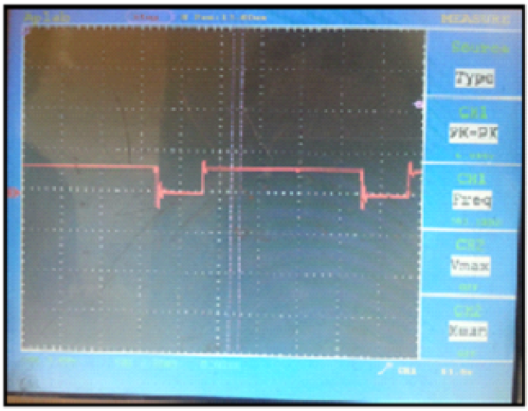


Figure 7. Simulated PWM signal :400 KHz



a) Practical pwm_h=391. 1khz



b) Practical pwm_l=391. 1khz

Figure 8: PWM Signals for main MOSFET and MOSFET used for freewheeling

6. Conclusion:

This paper explores digital controlled power supply systems with objective of the achieving improvements in converter control schemes, system performance over conventional analog control approaches and cost effectiveness lesser complex system over most popular and efficient DSP processor. Digital controllers, provides a favorable position to provide basic feedback control as well as power management functions with lower cost and great flexibility. The design and implementation 400 Khz high frequency buck converter system using dsPIC controller is described.

7. References

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