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Software and Hardware Implementation of DC-DC Buck Converter using Feasible Automatic Control

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Abstract *– In this paper a control technique is presented with a software and hardware implementation. A PWM based feasible control strategy is implemented in designing of DC-DC Buck Converter. Experiments demonstrate that switching converters with this Control reject input-voltage perturbations in only one switching cycle and follow the control reference very quickly. This PWM control method is very general and directly applicable to switching converters in either pulse-width-modulated or quasi-resonant modes.*

1. INTRODUCTION

Step-down choppers find most of their applications in high performance dc drive systems, for example, electric traction, electric vehicles, and machine tools. The dc motors with their winding inductances and mechanical inertia act as filters resulting in high-quality armature currents. The average output voltage of step-down choppers is a linear function of the switch duty ratio.

The different step-down chopper control strategies has been develop yet [1-5]. The step-down dc-dc converter, commonly known as a buck converter, is shown in Fig.1. It consists of dc input voltage source V_S, controlled switch S, diode D, filter inductor L, filter capacitor C, and load resistance R.

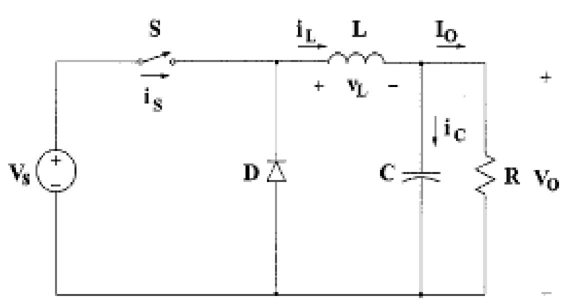

Fig. 1: Basic Buck Converter

Typical waveforms in the converter are shown in Fig. 2. The waveform shows the voltage across inductor, analysis of this voltage can easily provide the relation between input and output voltage. The waveform also shows the current through inductor, capacitor and switch.

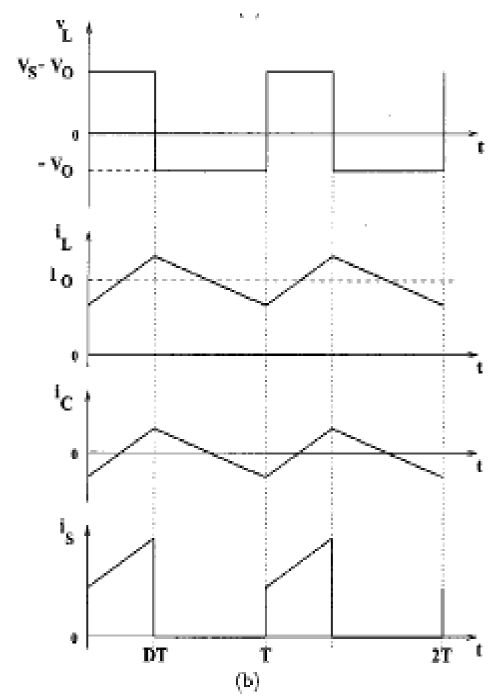

Fig. 2: Waveform of Buck Converter

A dc-dc converter must provide a regulated dc output voltage under varying load and input voltage conditions. The converter component values are also changing with time, temperature, pressure, and so forth. Hence, the control of the output voltage should be performed in a closed-loop manner using principles of negative feedback.

2. CONTROL METHODS

The two most common closed-loop control methods for PWM dc-dc converters, namely, the voltage-mode control and the current-mode control, are presented schematically in Fig. 3 and fig. 5 respectively.

Voltage mode control scheme:

In the voltage-mode control scheme, the converter output voltage is sensed and subtracted from an external reference voltage in an error amplifier. The error amplifier produces a control voltage that is compared to a constant-amplitude saw-tooth waveform. The comparator produces a PWM signal that is fed to drivers of controllable switches in the dc-dc converter. The duty ratio of the PWM signal depends on the value of the control voltage. The frequency of the PWM signal is the same as the frequency of the saw-tooth waveform. An important advantage of the voltage-mode control is its simple hardware implementation and flexibility.

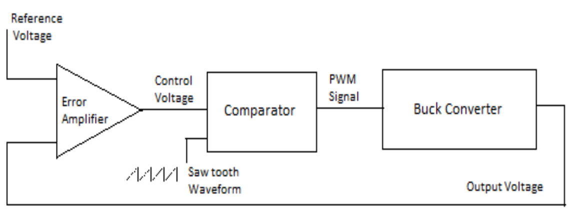

Fig. 3: Voltage mode control Scheme

The error amplifier in Fig. 3 reacts fast to changes in the converter output voltage. Thus, the voltage-mode control provides good load regulation, that is, regulation against variations in the load. Line regulation (regulation against variations in the input voltage) is, however, delayed because changes in the input voltage must first manifest themselves in the converter output before they can be corrected. To alleviate this problem, the voltage-mode control scheme is sometimes augmented by a so-called voltage feed forward path. The feed forward path affects directly the PWM duty ratio according to variations in the input voltage.

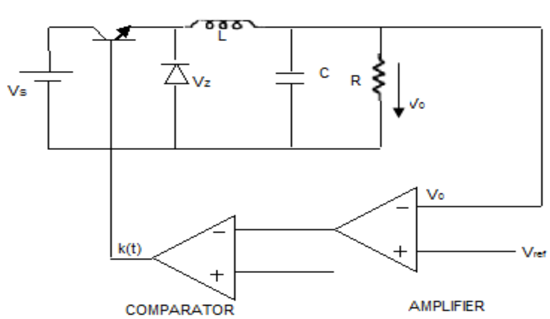

Fig. 4: Implementation of voltage mode control

In voltage control method, the control reference signal with a saw-tooth signal. As a result, the control reference signal is linearly modulated into the duty-ratio signal:

$$D = \alpha . V_{ref} \quad (1)$$

where α is a constant. With feedback, the above equation becomes

$$D = \alpha .(V_{ref} - V_0) \quad (2)$$

Current mode control scheme:

The current-mode control scheme is presented in Fig. 5. An additional inner control loop feeds back an inductor current signal, and this current signal, converted into its voltage analog, is compared to the control voltage. This modification of replacing the saw-tooth waveform of the voltage-mode control scheme by a converter current signal significantly alters the dynamic behaviour of the converter, which then takes on some characteristics of a current source.

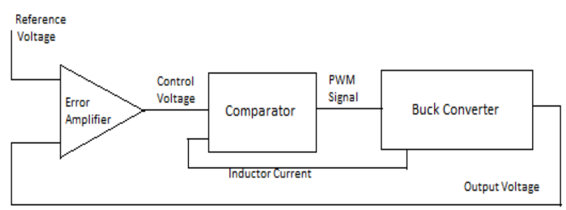

Fig. 5: Current mode Control Scheme

The output current in PWM dc-dc converters is either equal to the average value of the output inductor current or is a product of an average inductor current and a function of the duty ratio. In practical implementations of the current-mode control, it is feasible to sense the peak inductor current instead of the average value. As the peak inductor current is equal to the peak switch current, the latter can be used in the inner loop, which often simplifies the current sensor. Note that the peak inductor (switch) current is proportional to the input voltage. Hence, the inner loop of the current-mode control naturally accomplishes the input voltage-feed forward technique. Among several current-mode control versions, the most popular is the constant-frequency one that requires a clock signal. Advantages of the current mode control are the input voltage feed forward, the limit on the peak switch current, the equal current sharing in modular converters, and the reduction in the converter dynamic order. The main disadvantage of the current-mode control is its complicated hardware, which includes a need to compensate the control voltage by ramp signals.

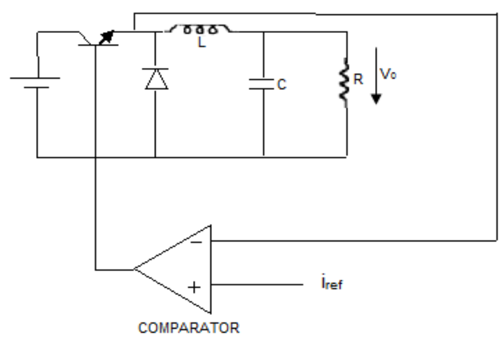

Fig. 6: Implementation of current mode control

Feasible controlling Method:

Experimentation of the above method proves that this method is very feasible. The control method gives the same voltage across diode as reference voltage given.The hardware used for the above experiment is given in Fig. 7.The operating condition for the experiment is Vs=12V, Fs=10MHz, L=10mH, C=100 μF, R=100Ω. The experiment is done at different reference voltages by using potential divider circuit. The output voltage is fed back to the real-time integrator. The integration value is then compared with the control reference in real time. When the output voltage of the integrator reaches the control reference, the switch is turned off and the integration is immediately reset to zero to prepare for the next cycle.

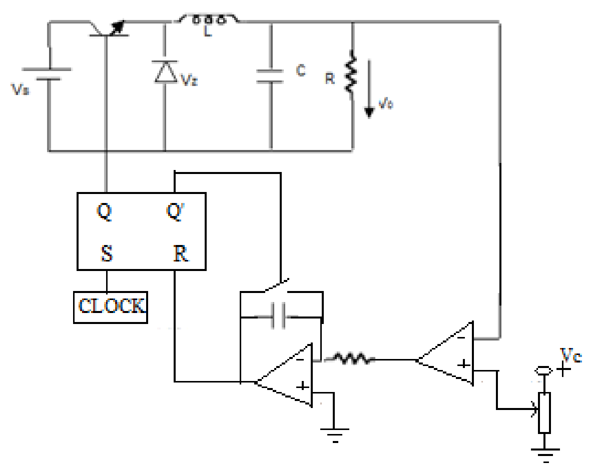

Fig. 7 Hardware implementation of using feasible Control

The output voltage waveform can be different as the reference voltage changes. For different reference voltage, output voltage follows the reference voltage.

3. EXPERIMENTAL RESULT FOR DIFFERENT PERTURBATION:

Case 1: When reference voltage changes from 05Volt to 10volt in case of voltage mode control.

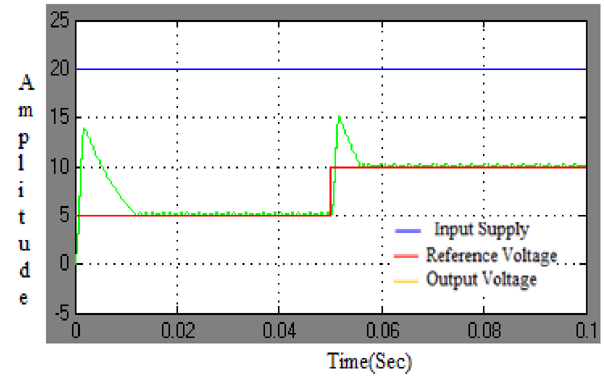

Fig. 8: Waveforms in case of voltage mode control

Fig. 8 shows the waveform of output voltage follows the reference voltage with constant input voltage. Experiments proved the feasibility of One-Cycle Control of the buck converter. This feasible control technique is also feasible for Boost, Buck-Boost Converter and Cuk Converters.

Fig. 9 shows the implementation cuk converter using this control technique.

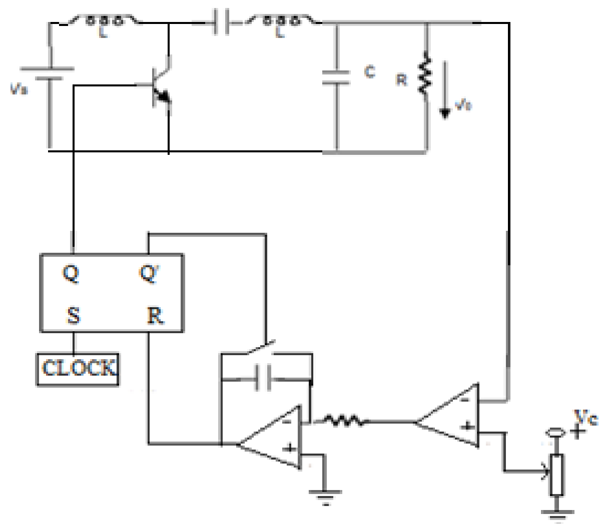

Fig. 9: Hardware implementation of Cuk Converter

Case 2: When reference voltage changes from 10Volt to 15volt in case of current mode control.

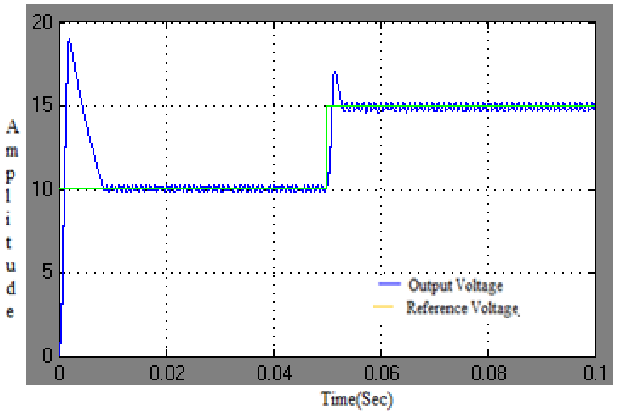

Fig. 10Waveforms in case of current mode control

The above waveform of current mode control also shows the feasible result that the output is following the reference voltage. The settling time of current mode control is lesser than voltage mode control method. The current mode control method is also feasible for all other DC-DC controller.

4. CONCLUSION

Experimental result of the method gives the output voltage similar to reference voltage at different perturbation in reference voltages. Result of two case studies is given in figure 8 and figure 10. The results also show that the output voltage in case of voltage control method is giving lesser disturbances but more settling time in comparison to current mode control. But both methods are simple and very feasible to control as reference voltage changes.

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