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The influence of optimal programmed PWM waveforms on the static and dynamic output behaviour of a digital controlled DC/DC-converter

Abstract

Optimal programmed PWM waveforms (pPWM) are useful to minimize conducted EMI at discrete frequencies. The method of pPWM is based on a variation of the switching period. The bandwidth and the repetition rate of this variation influence the static and dynamic output behaviour of the converter. These influences are investigated. Both, simulation results and practical results are shown.

Summary

Introduction: The suppression of electromagnetic interferences (EMI) becomes more and more important with the values of switching frequency getting higher. At this the reduction of conducted EMI is of greater interest than the reduction of radiated EMI being several orders lower than the conducted [4]. Possibilities to minimize the conducted EMI in DC/DC -converters are described in several recent papers, e.g. [1],[2]. In [1] the application of programmed PWM waveforms spreads out the spectral energy from discrete frequencies to a wider spectral range. So the peak amplitude of the input current at a given frequency is effectively reduced. Side effects of this pPWM method, like its influence on the output voltage ripple and on the control quality, are investigated.

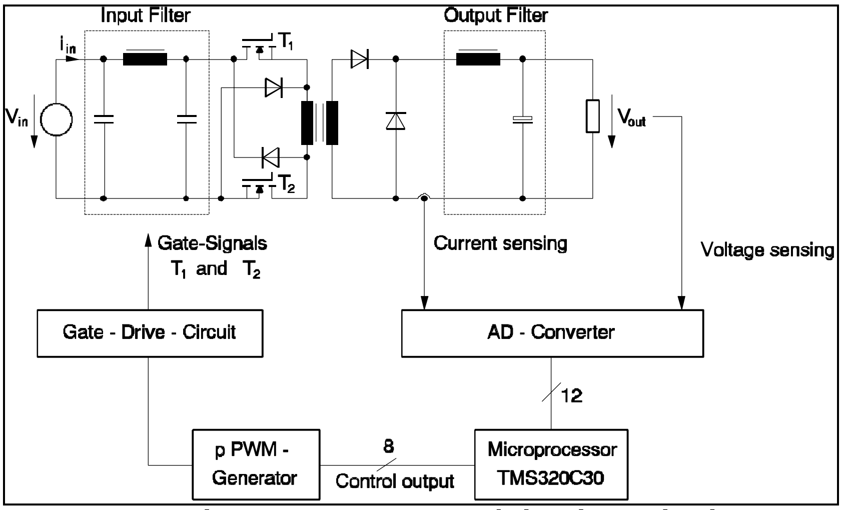

Figure 1: Forward converter power stage with digital control and programmed pulse width modulation

For practical implementation of pPWM a digital control unit [3] as shown in figure 1 seems to be well suited. This figure shows the power stage of the two transistor forward converter [4] with the microprocessor based control unit. This control unit is devided in two parts. Computing the control algorithms and converting the measured signals into digital values is executed by the first part, the AD-converter, the microprocessor and its peripheral cards. The second part consists of the pPWM generator and the gate drive circuits. They are located close to the power stage. The structure of the pPWM generator will be described in detail by the paper.

Programmed PWM: The programmed pulse-width-modulation (pPWM) [1] is derived from the well known PWM method with triangle modulation signal. Instead of a constant switching frequency $f_s = 1/T_s$ the pPWM method (see figure 2) works with a number (n) of different subperiods T_i (i = 1..n). The average time interval of these subperiods is defined to be of same magnitude as T_s. This procedure of varying the switching frequency f_s leads to a flowing out of the spectral energy away from the switching frequency and its harmonics to their side bands and hence it leads to a considerable reduction of conducted EMI.

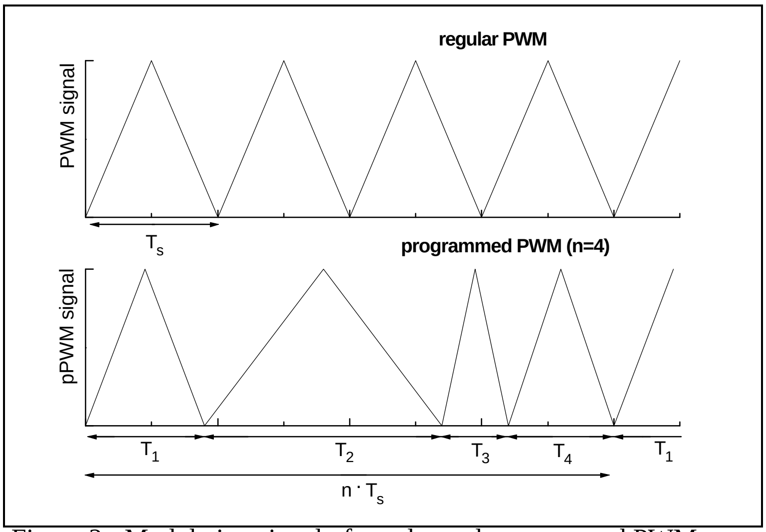

Figure 2: Modulation signal of regular and programmed PWM with 4 subperiods

Investigations: It was found out that the rate of EMI reduction depends on

- the number of subperiods and
- the maximum deviation of the subperiods from the average period.

Figure 3 shows the EMI reduction refering to the regular PWM (100%) in dependence on the number n of subperiods. It does not seem to be very useful to choose a higher number of subperiods than about 15 or 20, because then the further reduction is neglectable.

Moreover the number of subperiods influences the dynamic output behaviour. The lowest harmonic occuring at pPWM is n times lower than at regular PWM. To avoid instabilities the crossover frequency of the open loop transfer-function which has to be well below the lowest harmonic must be about n times lower than the crossover frequency of a regular PWM converter. Hence, if the number of subperiods is chosen to high, the dynamic response of the closed control loop is

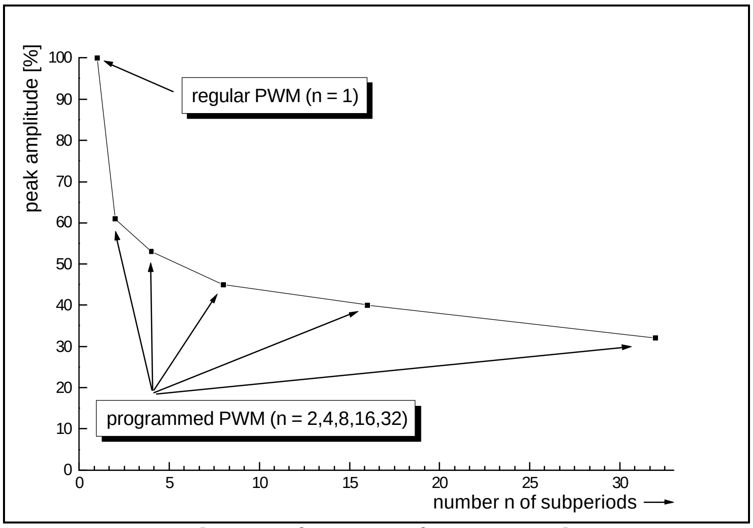

Figure 3: EMI reduction of pPWM refering to regular PWM in dependence on the number n of subperiods.

poor. To find an acceptable compromise between significant reduction of EMI and good dynamic response is a main subject of this paper.

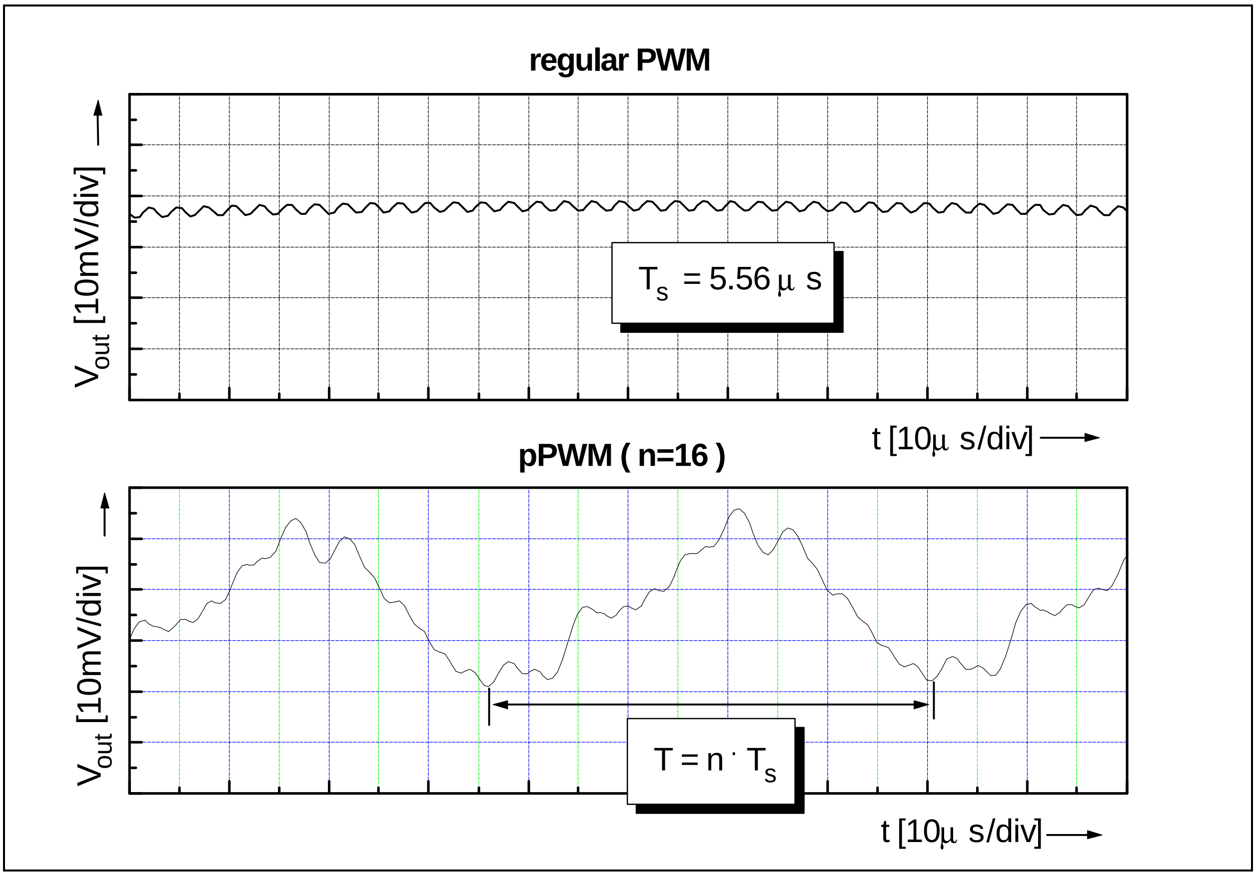

Figure 4: Simulated static output behaviour of the converter with regular PWM (above) and programmed PWM (below).

Another important aspect discussed here is the influence of the subperiods deviation with regard to the average period on the output voltage ripple. It is obvious that longer subperiods cause longer increasing and decreasing of the filter inductor current. This leads to a higher ripple content of the inductor current and therefore to a higher output voltage ripple with lower frequency (see figure 4).

To smooth this voltage ripple filters with lower corner frequencies are necessary. This extends the output filter in volume, weight and costs. These negative effects of pPWM on the output filter are investigated and compared with its economizing effects on the input filter.

References

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