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Generation of New Random PWM Pulse for Buck Boost Converter Using LabVIEW

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ABSTRACT: This paper addresses random pulse width modulation (RPWM) and its applications to the power electronic converters. RPWM differentiate from conventional PWM, which produces switching functions that have non deterministic variables. This paper presents new RPWM scheme developed with the help of virtual Instrumentation (VI) software. The comparative investigations of proposed RPWM scheme against the normal PWM for the buck boost converter is presented. The effectiveness of randomization on spreading the dominating frequencies that normally exist in constant frequency PWM schemes is evaluated by the power spectral density (PSD) estimations in the low-frequency range.

KEYWORDS: Power converters, random switching techniques, Virtual Instrumentation, Power Spectral Density.

I.INTRODUCTION

Power electronic converters are used to convert electrical energy from one level to another level using power semiconductor based electronic switches. The essential characteristics of these types of circuits is that the switches are operated only in one of two states either fully ON or fully OFF. The process of switching the electronic devices in power electronic converter from one state to another is called modulation. A fast switching operation generates signals with high voltage-rate (dv/dt) and high current rate (di/dt) and, consequently, disturbances over wider frequency bandwidths. These high switching frequency harmonics can have adverse effects, such as acoustic noise, mechanical vibration and electromagnetic interference. Standard pulse width modulation (PWM) schemes cause the power converter to switch in a “deterministic” manner, which results in a PWM waveform with a large fundamental voltage component with low-order harmonics suppressed. However, the harmonic power is usually concentrated at a few predictable frequencies. The use of PWM technique for the control of power converters allows adjusting the useful component of the voltage and eliminating some unwanted harmonics. Thus, it is required for power converters to provide the desired electrical functionality and to meet international standards of Electro-Magnetic Compatibility (EMC) by reducing conducted emissions. Using filtering technique to meet the better EMC standards for conducted EMI. RPWM technique is one of the effective method to spread the power spectrum over a wide frequency range while reducing its amplitudes and it constitutes a significant EMC advantages. Several RPWM techniques have been proposed recently: Randomized Carrier Frequency Modulation (RCFM) and Randomized Pulse Position Modulation (RPPM).

The RCFM technique can be mainly categorized into The Random Carrier-Frequency Modulation with Fixed Duty cycle (RCFMFD), and with variable duty cycle (RCFMVD) respectively. In the conventional randomized PWM techniques, certain switching signal parameters are randomized. The followings are the possibilities of switching signal parameters duration of the k^{th}cycle (T_k), the duration of the on-state within the cycle (α_k), duty ratio is $d_k=\alpha_k/T_k$ and the delay from the start of the switching cycle to the turn-on within the cycle (ε_{ks}), Trailing edge of the switching cycle (ε_{kt}). In the proposed random modulation scheme trailing edge of the switching cycle (ε_{kt}) is fixed constant and delay from the start of the switching cycle (ε_{ks}) and duty ratio d_k is randomized. Analytical model of power spectral density (PSD) of proposed modulation scheme is developed and validated in buck-boost converter. The PSD analysis of proposed RPWM allows a better spread shape of PSD com-pared to the simple randomization scheme that is the desired EMC advantage.

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II. RANDOMIZED SWITCHING SIGNAL

The fundamental difference between classic PWM and RPWM method is, that the power carried by the PWM signal is no longer limited to a few leading frequency that are normally controlled by the switching frequency and the modulated signal. The probability laws govern the dithering of nominal switching patterns. If the probabilistic structure is constant from one cycle to cycle, it is called stationary. If it is constant only over a block cycles, it is called as block-stationary. RPPM is similar to the classical PWM scheme with constant switching frequency. However, the position of the gate pulse is randomized within each switching period, instead of commencing at the start of each cycle. RPWM allows the pulse width to vary, but the average pulse width is equal to the required duty cycle. RCFMFD exhibits randomized switching period and constant duty cycle, while RCFMVD exhibits randomized switching period and constant pulse width. As the pulse width in RCFMVD is fixed and the switching period is randomized, the resultant duty cycle is also randomized.

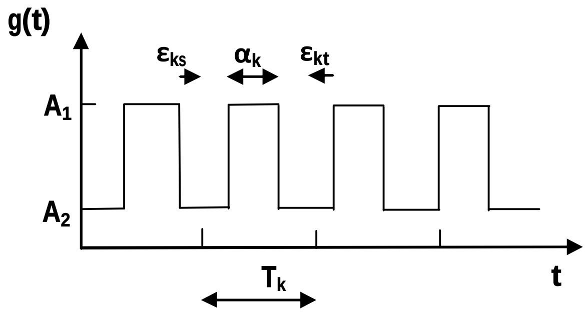

Fig. 1.Switching Signal of Proposed RPWM Technique

The switching parameters shown in Fig.1 such as the duration of the k^{th} cycle (T_k), the duration of the on-state within this cycle (α_k), duty ratio is ($d_k=\alpha_k/ T_k$) and the delay from the start of the switching cycle to the turn-on within the cycle (ε_{ks}), Trailing edge of the switching cycle (ε_{kt}). Randomness level and the average duty cycle for all the random modulation schemes were kept constant to maintain the desired output voltage. A_1 and A_2 are the magnitudes of the switching pulses. The characteristics of the switching pulse in each modulation scheme are summarized in Table 1, with the aid of Fig. 1. The switching function g(t) has two discrete levels (namely A1 and A2), which are applicable for describing the behavior of classical DC-DC converters.

III. GENERATION OF PROPOSED RPWM

Electronic circuit requires accurate methods for evaluating circuit performance. Because of enormous complexity of modern integrated circuits, computer aided analysis of the circuits is essential and can provide information about circuit performance that is most impossible to obtain with laboratory prototype measurements. LabVIEW is a general purpose circuit program that simulates electronic circuits. LabVIEW contains model for common circuit elements, active as well as passive, and it is capable of simulating most electronic circuits. Fig.2 shows the simulation block diagram for generation of constant trailing edge random PWM signal.

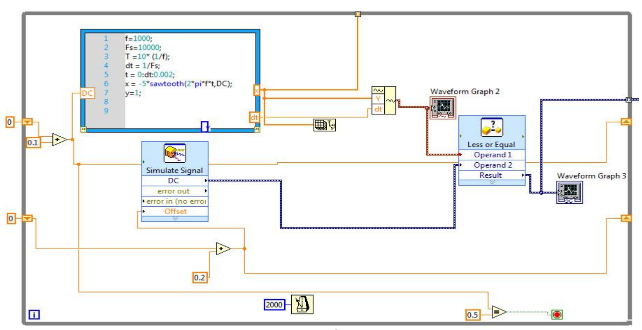

Fig. 2. Simulation circuit for CTERPWM scheme

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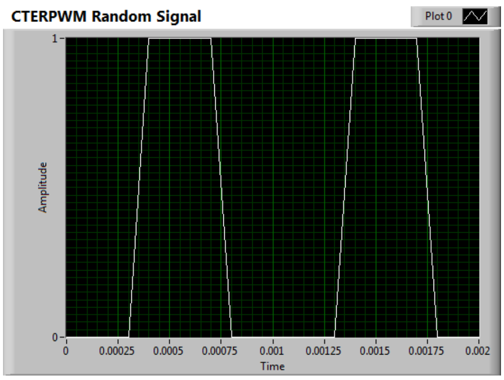
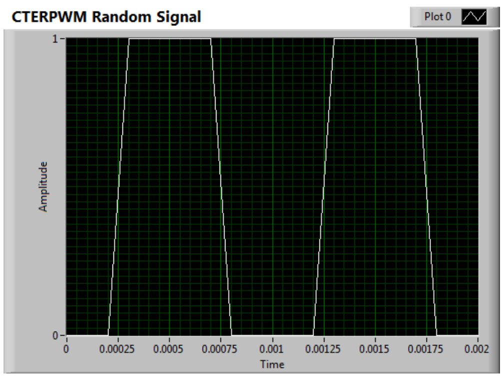
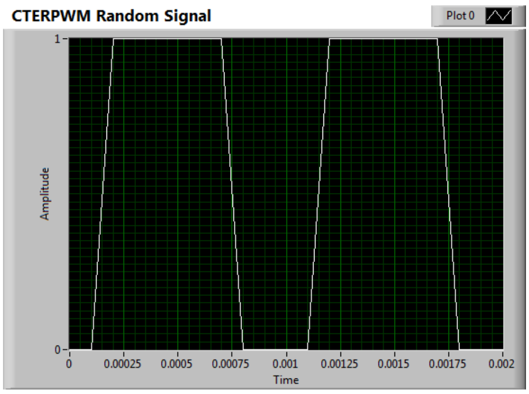
The simulation block diagram consists of triangular carrier wave with variable duty cycle and dc reference voltage. Here the falling edge of the switching cycle is randomized. Fig. 3 shows the different random PWM pulses of constant trailing edges with different duty ratio is presented.



(a)



(b)



(c)

Fig.3. CTERPWM signals with different duty ratio

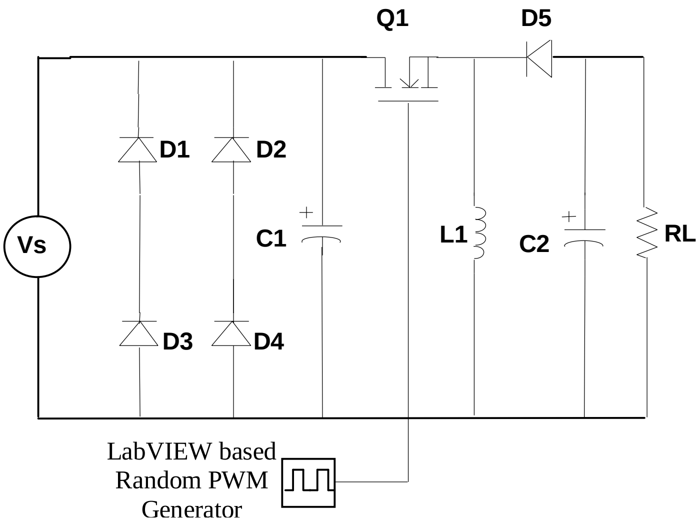


Fig.4 Simulation circuit for Buck-Boost Converter

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The simulated RPWM signal is fed to the buck boost converter circuit. The simulation circuit for buck boost converter is shown in fig.4. The simulation circuit was developed by Multisim electronic circuit simulation software and switching pulse for MOSFET is fed from labVIEW software.

IV. RANDOMNESS LEVEL

In order to investigate the effectiveness of the stochastic variable randomness level on spreading harmonic power, a randomness level for each scheme is defined. For RPPM,

$$\Re_{RPPM} = \frac{\varepsilon_2 - \varepsilon_1}{T_S}, \tag{1}$$

where ε_k [ε_1, ε_2]. ε_1 and ε_2 are the minimum and maximum limits of the pulse positions within each cycle. ε_1 is obviously equal to zero. T_S is the nominal switching period.
For RPWM,

$$\Re_{RPWM} = \frac{\alpha_2 - \alpha_1}{T_S} = d_2 - d_1, \tag{2}$$

Where α_k [α_1, α_2]. Thus, the duty cycle d_k varies between the minimum possible value d_1 and the maximum possible value d_2 around the nominal duty cycle within the classical PWM scheme.
For proposed RPWM,

$$\Re_{CTERPWM} = \frac{(\varepsilon_{ks2} - \varepsilon_{ks1})}{T_k} = \frac{(\alpha_2 - \alpha_1)}{T_k} = d_2 - d_1 \tag{3}$$

where ε_{ks} [ε_{ks1}, ε_{ks2}]. ε_{ks1}, ε_{ks2} are the minimum and maximum limits of delay for start of pulse positions within each cycle. Thus, the duty cycle d_k varies between the minimum possible value d_1 and the maximum possible value d_2 around the nominal duty cycle within the classical PWM scheme.

V. VALIDATION OF PROPOSED METHOD

In the randomized modulation switching scheme the harmonic spectrum is random and it varies with respect to time. Therefore, it must be evaluated by an appropriate mathematical tool, Power spectrum (the Fourier transform– FT of the autocorrelation function of a signal) and not the harmonic spectrum (i.e. the FT of the signal itself). In particular, the autocorrelation function of a random process is the appropriate statistical average concerning the characterizations of random signals within the time-domain. The FT of the autocorrelation function gives the PSD and provides transformation from the time domain to the frequency-domain.

$$R(\tau) = \lim_{T_0 \to \infty} \frac{1}{2T_0} \int_{-T_0}^{T_0} x(t)x(t-\tau)\, d\tau \tag{4}$$

Where the expectation operator E[.] take over the whole ensemble. The well known Welch's estimation method for PSD is also implemented within Matlab software package as the "psd" function:

$$\text{PSD} = \text{psd}(X, \text{NFFT}, \text{Fs}, \text{Window}, \text{NOverlap}, \text{DTrend}) \tag{5}$$

According to the significant characteristics of each particular window - the best asymptotic side lobe decay rate and a sufficient low side lobe level as well - Hanning window was chosen and used in all estimations, and the results were experimentally verified. The validation of the mathematical model of the PSD for the conventional sinusoidal PWM and proposed CTERPWM method is performed by comparing the PSD calculated analytically with that estimated by the Welch method which can be obtained after simulation of the converter. LabVIEW and its analysis VI library provide a complete set of tools to perform Fourier and Spectral Analysis. The Power Spectrum VI calculates the harmonic power in discrete-time, real-valued sequences. The Power Spectrum VI executes faster than the FFT VI because the computation is done in place and there is no need to allocate memory to accommodate complex results.

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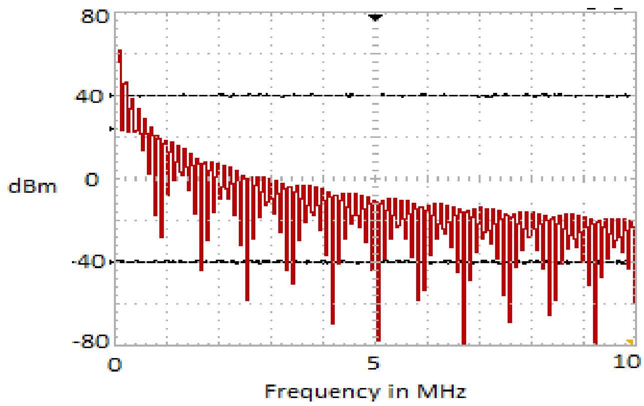

Fig.5 PSD Spectrum for Conventional PWM with buck boost converter

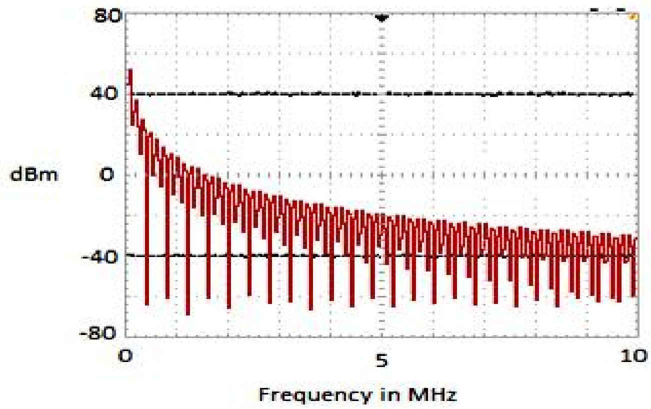

Fig.6 PSD Spectrum for proposed CTERPWM with buck boost converter

Simulated PSD results for conventional PWM scheme is shown in fig.5. In this figure it shows that in the frequency range 5MHz to 10MHz frequency spectrum crosses the 80dB/Hz. Fig.6 shows the spectrum of PSD for proposed RPWM scheme. In this figure it is clearly shows that spectrum of power density is distributed over the whole frequency range. The maximum peak of the spectrum is also limited with the range when compared with the conventional PWM method. Thus the proposed method gives limited PSD spectrum over the all frequency range.

VI. CONCLUSION

This paper has given comparative investigations of conventional PWM and proposed CTERPWM modulation schemes on the PSD estimation. It has been clearly demonstrated that all RPWM can gradually spread the discrete frequency harmonic power over the whole frequency spectrum. However, this investigation shows that proposed RPWM method gives the minimum low-frequency harmonic spectrum and, therefore, can be considered as the best choice for DC-DC converter applications. Future work is focused on implementing the proposed work in hardware working model and verify the experimental PSD and EMI measurements.

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