

Novel Duty-Cycle – to – Code Conversion Method

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Abstract – New duty-cycle – to – code conversion method is described in the Paper. It is based on the determination of average pulse width and average period during the conversion time T_q . The last one is determined by the beforehand given quantization error δ and equals to the integer number of periods. Due to this, the component error by reason of non-multiplicity of conversion time T_q and period T_x is eliminated. The method allows to measure the duty-cycle in a wide range of frequencies of input signals. The quantization error does not depend on the frequency of converted signal f_x and is determined basically by the pulse width τ_x . The proposed method can be used in different duty-cycle output smart sensors and transducers, as well as in DAQ boards for frequency-time parameters of electric signals.

Keywords – duty-cycle; method of dependent count, quasi-digital sensor

I. INTRODUCTION

A duty-cycle output signal is widely used as informative output signal for different quasi-digital sensors (Figure 1).

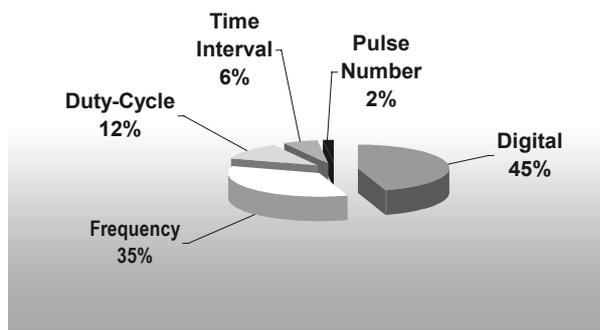


Fig. 1. Classification of sensors from discrete group in terms of output signals (studied by IFSA).

For example, there are the temperature sensors SMT160-30 from *Smartec* [1], TMP04 from *Analog Devices* [2] and MAX6666/67 from *MAXIM* [3] accelerometer ADXL202E [4] and KXG20-L20 accelerometer inclinometer [5], optical sensor [6], humidity sensor from *Humirel* [7], etc. All these sensors produce an output that is a duty-cycle modulated quasi-digital signal. Such kind of signal can be easily interfaced with modern microcontrollers. In comparison

with a frequency output signal the duty-cycle is rather immune to interfering signals, such as spikes [8], and the ratio does not depend on the absolute value of any component [9].

Various methods exist to measure duty-cycle of an impulse signal. For example, some simple PWM A/D converter can use the classical approach: to measure the pulse width and period of signal, then calculate the ratio:

$$\text{D.C.} = \frac{\tau_x}{T_x}, \quad (1)$$

where τ_x is the pulse width, T_x is the period of pulse signal. Main error's components are quantization errors for pulse width and period. Both components can be big enough. If a high accuracy is needed, a very high clock frequency should be used. The result also depends on the frequency $f_x = 1/T_x$.

Another approach to measure a duty-cycle is to take random samples of a digital signal (random-sampling method) [10]. The method can be realized very easy by program-oriented way. But this method is suitable only for low-resolution conversions for which the necessary resolution is a maximum of 9 bits.

A new method of reading the time-domain sensor signals is described in [11]. It can eliminate the part of quantization error without increase of clock frequency. The method uses the internal clock frequency as 2^N times of the signal frequency. So, it means that T_x doesn't change with the sensor output signal. However, very often, the frequency (period) of signal is changing. In this case this method cannot be used.

II. NOVEL CONVERSION METHOD IN ESSENCE

The novel proposed method is based on the determination of average pulse width and average period during the conversion time T_q . The last one is determined by the beforehand given quantization error δ and equals to the integer number of periods. Due to this, the component error by reason of non-multiplicity of conversion time T_q and period T_x is eliminated. The time diagrams of the method are shown in Figure 2.

At the beginning of conversion the given relative error $\delta_{T_x} = 1/N_\delta$ is set up. The beginning of T_q is coincided always with the wavefront of first pulse with τ_{x1} duration, and the wavetail – with the τ_{N_x+1} pulse. Hence,

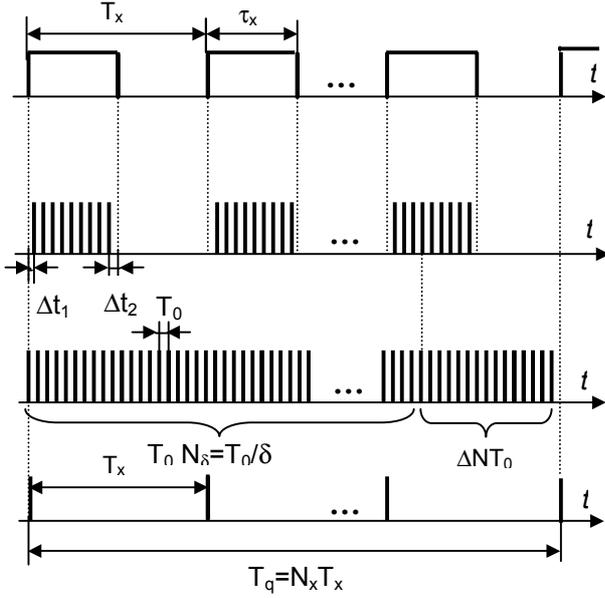


Fig. 2. Time diagrams of novel method for duty cycle – to – code conversion.

the requirement of the method of the dependent count [12] - the multiplicity of number of periods T_x to the conversion time T_q is fulfilled. The numbers $N_{\tau_x} = N_{\delta} \tau_x / T_0$ and $N_{T_x} = N_{\delta} T_x / T_0$ are counted by two counters during the conversion time T_q . The duty-cycle is calculated according to the following equation:

$$N_{D.C.} = \frac{N_{\tau_x}}{N_{T_x}} = \frac{\bar{\tau}_x}{\bar{T}_x} = \overline{D.C.} \quad (2)$$

With the purpose to determine the relative quantization error, having calculated the full differential of the equation (1), proceeded to the final increments and relative units, we shall receive the following equation:

$$\begin{aligned} \delta_{D.C.} &= \frac{\Delta \tau_x}{\tau_x} = \frac{\Delta N_{\tau_x}}{N_{\delta} \cdot \tau_x} \cdot T_0 + \frac{\Delta N_{T_x}}{N_{\delta} \cdot T_x} \cdot T_0 = \\ &= \frac{1}{N_{\delta} \cdot f_0} \left(\frac{\Delta N_{\tau_x}}{\tau_x} + \frac{\Delta N_{T_x}}{T_x} \right) \end{aligned} \quad (3)$$

Without the usage of any advanced conversion methods, the ΔN_{τ_x} and ΔN_{T_x} are equal to ± 1 . However, using the principle incorporated in the method of the dependent count [12-14], the conversion interval can be chosen by multiple to the period of input signals. Hence, in this case the $\Delta N_{T_x} = 0$. Then the quantization error will be calculated according to the following equation:

$$\delta_{D.C.} = \frac{1}{N_{\delta} \cdot f_0 \cdot \tau_x} \cdot 100, \% \quad (4)$$

As it is visible from the equation (4), the quantization error does not depend on the converted frequency of signal and is determined basically by the pulse width τ_x .

III. MODELLING RESULTS

The converter modeling has been realized with the help of system of analytical calculations Maple 6.0. The following size of variables changing were used for the modelling according to formula (4): $f_0 = 1$ MHz; $N_{\delta} = 20$, $\tau_x \in [0.271 \times 10^{-4} \dots 9.31 \times 10^{-4}]$, $f_x \in [1 \dots 25]$ kHz. It is correspondent to the output parameters of modern sensors with duty-cycle output. In comparison to the quantization error for the proposed method, the quantization error of classical duty-cycle – to – code conversion method also has been modelled according to the following equation:

$$\delta_{D.C.} = \frac{\tau_x + T_x}{f_0 \cdot \tau_x \cdot T_x \cdot n} \cdot 100, \% \quad (5)$$

where n is the number of periods T_x during the averaging. The modelling results are shown in Figure 3 and Figure 4, accordingly.

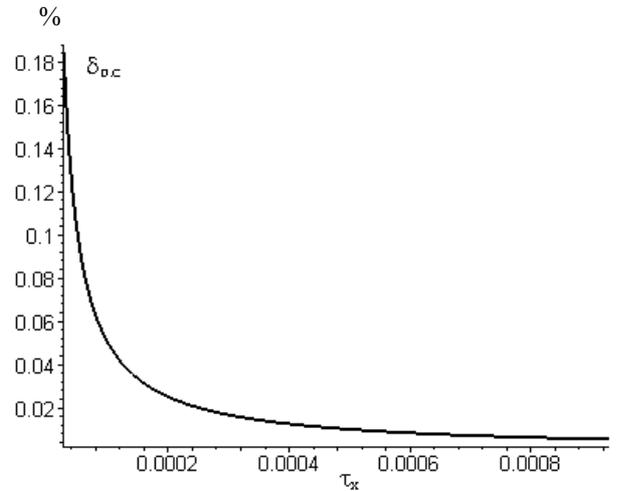


Fig. 3. Dependence of $\delta_{D.C.} = f(\tau_x)$ for proposed conversion method.

IV. CONCLUSIONS

The proposed duty-cycle – to – code conversion method allows to measure the duty-cycle in a wide range of frequencies of input signals. The quantization error does not depend on the frequency of converted signal f_x and is determined basically by the pulse width τ_x . The quantization error's component due to the period quantization is fully eliminated.

The proposed method for duty-cycle - to - code conversion can be used in different duty-cycle output smart sensors and transducers, as well as in data

acquisition (DAQ) boards for frequency-time parameters of electric signals.

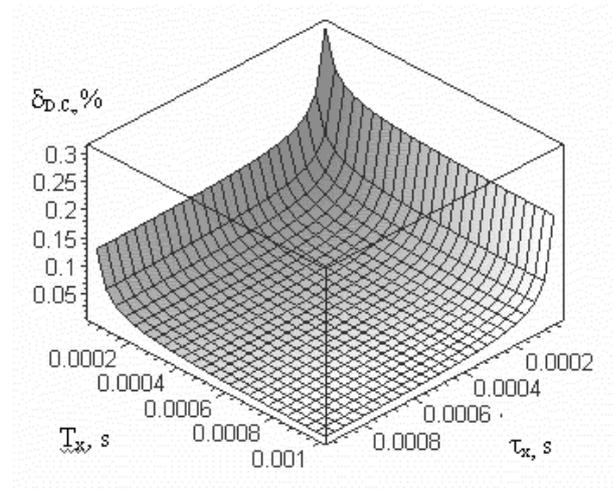


Fig. 4. Dependence of $\delta_{D.C} = f(T_x, \tau_x)$ for classical conversion method.

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