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PULSE CODING OF FUZZY LOGIC VALUES

In this article methods of pulse-frequency, pulse-width and pulse-phase encoding of fuzzy logic values have been proposed. Their difference is that fuzzy logic zero values are encoded not as an absence of pulses, but as pulses with a minimum value of frequency, width or phase. That allows the methods to be used in fuzzy logic elements synthesis.

***Keywords**: fuzzy logic, pulse signal, encoding.*

Nowadays fuzzy logic devices are widely spread in modern industry. That is because using such devices instead of traditional ones permits to increase accuracy and reliability of control.

Many works are dedicated to the fuzzy logic theory and its appliance [1–4].

In articles [5–7] diagrams of fuzzy control system's elements are presented [5]. In the elements an input and an output are presented by analog signals of an alternating current or voltage. A drawback of the elements is their low accuracy and noise stability. Meantime digital fuzzy devices implementing fuzzy logic functions are characterized by low quick-action because of great delay time.

In articles [8–10] using of pulse modulated signals in fuzzy systems and neural nets is considered.

So, in literature diagrams of fuzzy elements are presented, but information in them is presented by analog signals of an alternating current or a voltage, that leads to increasing of devices' quick-action.

It is proposed to increase accuracy of fuzzy logic systems by using not analog but pulse signals, because encoding fuzzy values by pulse parameters taking into account possible errors and noises will permit to reach a higher accuracy, than forming of an analog signal with a form corresponding to a membership function, because it is almost impossible to form a signal with a mathematically ideal form.

Also, the pulse-signals devices have some advantages comparing with the analog or digital-signals devices, these are [8]:

– pulse-signal systems have a higher noise stability comparing to analog-signals systems;
– pulse-signal systems have a higher quick-action comparing to digital-signals systems;
– supply less power;
– have greater design flexibility.

The aim of this work is increasing of the fuzzy-control systems accuracy.

In order to reach the aim one should solve such tasks:

– develop a method of pulse-frequency fuzzy-values coding;
– develop a method of pulse-width fuzzy-values coding;
– develop a method of pulse-phase fuzzy-values coding.

The methods of pulse fuzzy-values coding have been developed on a base of the already existing ones and described in [9]. The main equations and formulae of the developed methods are presented in table.

Pulse-frequency coding: device's input and output are pulses with frequency f_μ proportional to a fuzzy value μ. In this method a zero fuzzy value corresponds to a frequency f_α, a one fuzzy value corresponds to a frequency f_β; a frequency range for fuzzy values from 0 to 1 is defined using pulse frequency f_γ. So, we get:

$$f_\mu \to \mu,$$

$$f_\mu \rightarrow "0" + \mu \cdot "1"$$

$$f_\mu \rightarrow "0" + \mu \cdot ("1" - "0")$$

$$f_\mu = f_\alpha + \mu \cdot f_\gamma .$$

Table

Pulse coding of fuzzy logic values

Type of coding	Fuzzy logic zero	Fuzzy logic one	Supplementary value	Auxiliary conditions	Fuzzy values coding
Pulse-frequency	f_α	f_β	f_γ	$f_\beta > f_\alpha$, $f_\gamma = f_\beta - f_\alpha$	$f_\mu = f_\alpha + \mu \cdot f_\gamma$
Pulse-width	t_α	t_β	t_β^n , t_α^n	$t_\beta > t_\alpha$, $t_\beta^n < t_\alpha^n$	$t_\mu = \mu \cdot t_\beta + (1-\mu) \cdot t_\alpha$
Pulse-phase	φ_α	φ_β	2π	$\varphi_\alpha = 0 , \varphi_\beta = 2\pi$	$\varphi_\mu = \mu \cdot 2\pi$

This method is illustrated by time diagrams in fig. 1. In this case the frequency f_α equals $1MHz$ (A-diagram), the frequency f_β equals $5MHz$ (B-diagram), the frequency f_γ equals $4MHz$ (C-diagram), and the frequency f_μ equals approximately $2,2MHz$ (D-diagram) and corresponds to the fuzzy value $\mu \ 0,3$.

Pulse-width coding: a fuzzy value μ corresponds to a pulse duration t_μ. The pulse duration t_α corresponds to a zero fuzzy value, and t_β corresponds to a one fuzzy value. So, we get:

$$t_\mu \rightarrow \mu ,$$

$$t_\mu \rightarrow "0" + \mu \cdot "1" ,$$

$$t_\mu \rightarrow "0" + \mu \cdot ("1" - "0") ,$$

$$t_\mu \rightarrow \mu \cdot "1" + (1-\mu) \cdot "0" ,$$

$$t_\mu = \mu \cdot t_\beta + (1-\mu) \cdot t_\alpha .$$

This method is illustrated by time diagrams in fig. 2. In this case the pulse duration t_α equals $0,1\mu s$ (A-diagram), the pulse duration t_β equals $1,1\mu s$ (B-diagram), and the pulse duration t_μ equals $0,4\mu s$ (C-diagram) and corresponds to the fuzzy value $\mu \ 0,3$. Pulse-phase coding: a fuzzy value μ corresponds to the phase between an input and a reference signals φ_μ. The phase between an input and a reference signals $\varphi_\alpha = 0$ corresponds to a zero membership function value, and the phase between an input and a reference signals $\varphi_\beta = 2\pi$ corresponds to a one membership function value. So, we get:

$$\varphi_\mu \rightarrow \mu ,$$

$$\varphi_\mu \rightarrow "0" + \mu \cdot "1" ,$$

$$\varphi_\mu \rightarrow "0" + \mu \cdot ("1" - "0") ,$$

$$\varphi_{\mu} = 0 + \mu \cdot (2\pi - 0),$$

$$\varphi_{\mu} = \mu \cdot 2\pi .$$

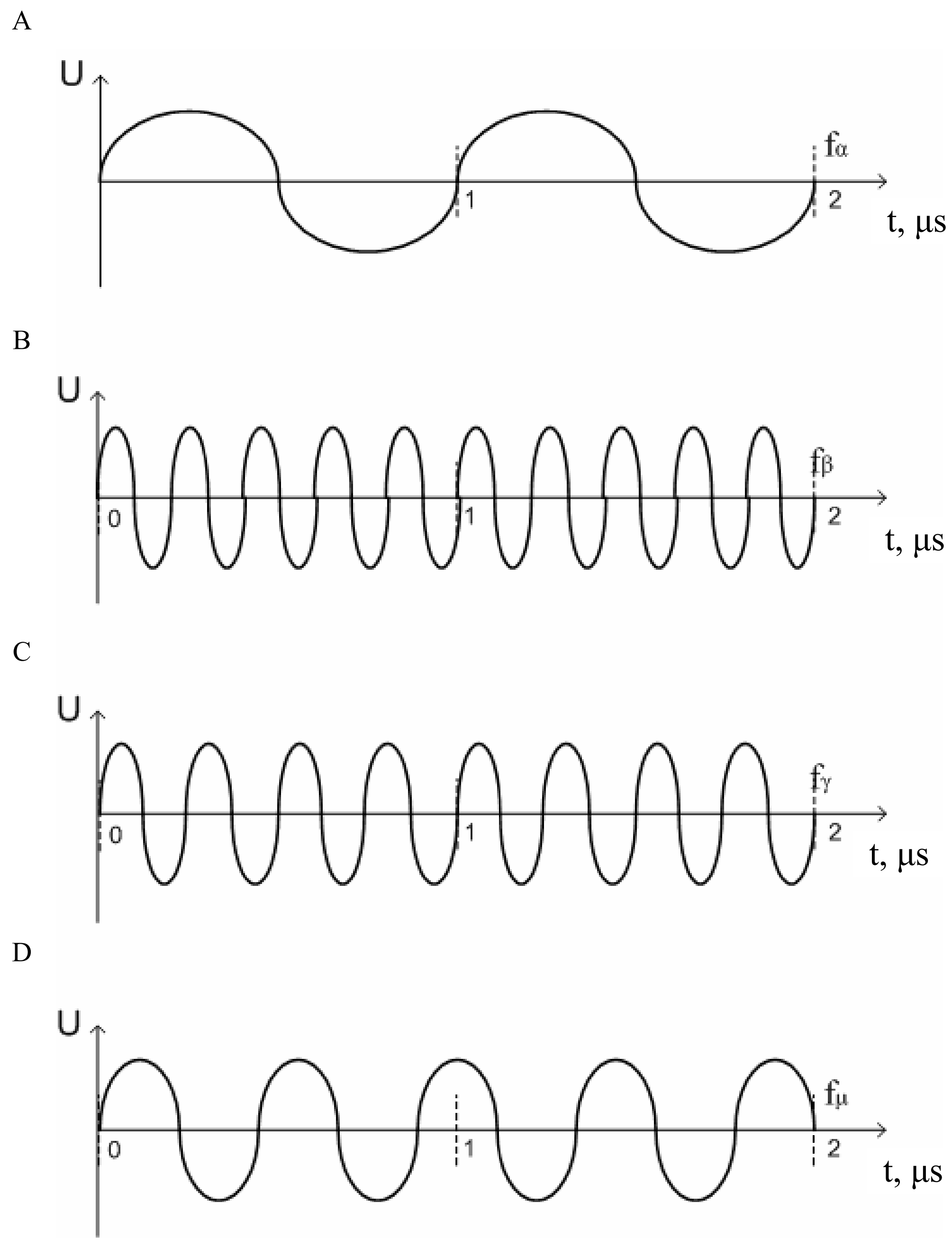

Fig.1. The time diagrams of the pulse-frequency encoding

This method is illustrated by time diagrams in fig. 3. In this case the phase between the reference signal φ_{on} (A-diagram) and the zero signal φ_{α} (B-diagram) equals 0°, the phase between the reference signal φ_{on} and the one signal φ_{β} (C-diagram) equals 2π, and the phase φ_{μ} (D-diagram) equals $\frac{3\pi}{5}$ and corresponds to the fuzzy value $\mu\ 0{,}3$.

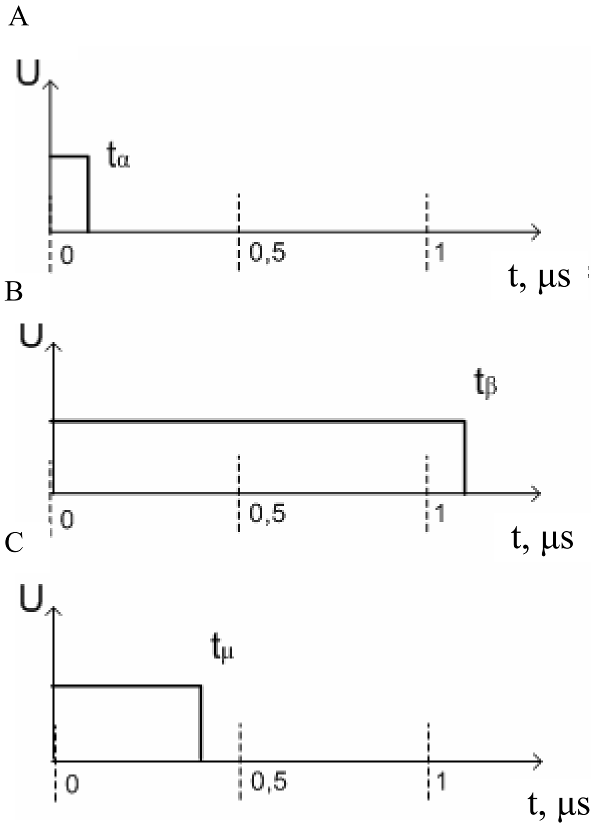

Fig. 2. The time diagrams of the pulse-width encoding

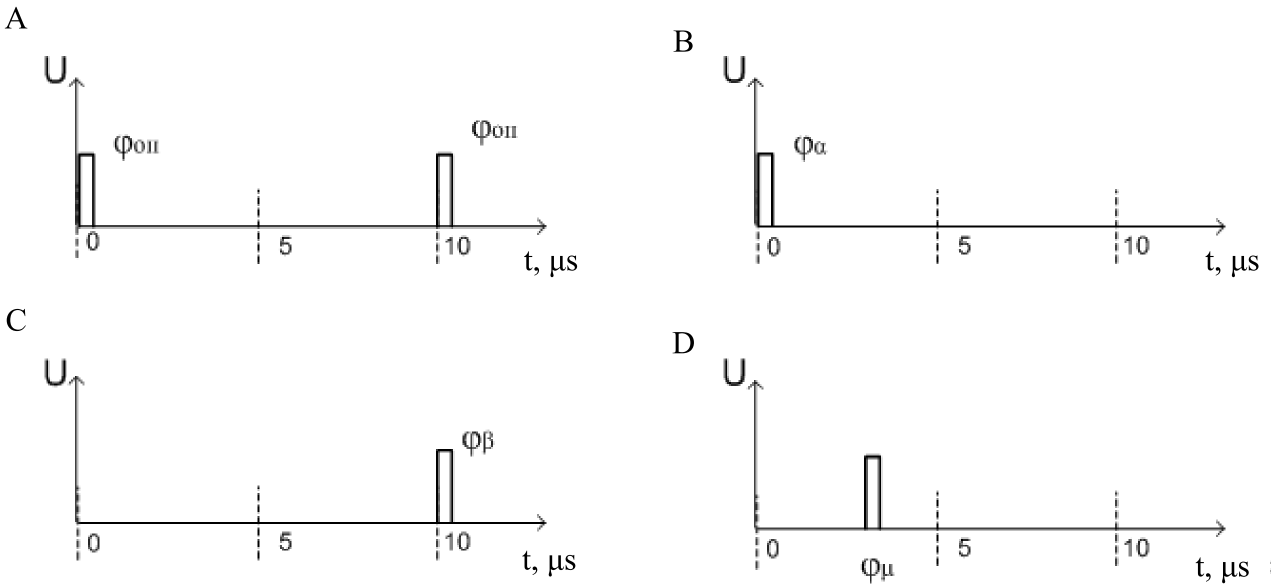

Fig.3. The time diagrams of the pulse-phase encoding

Summary

The methods of pulse-frequency, pulse-width and pulse-phase encoding of fuzzy logic values have been proposed. They permit to present quite precisely values of membership functions in fuzzy logic devices. Here, a value of a membership functions corresponds to a frequency, a width or a phase of the pulse. Their difference is that fuzzy logic zero values are encoded not as an absence of pulses, but as pulses with a minimum value of frequency, width or phase. That allows the methods to be used not only in max-min fuzzy logic elements synthesis, but also in product fuzzy logic elements synthesis. The developed pulse encoding methods are proposed to be used in the design of fuzzy logic elements and devices for control systems with pulse-frequency, pulse-width and pulse-phase inputs and outputs.

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