The Multi-Valued Logic Elements Synthesis Using the Fuzzy Approach

Olena Semenova, Andriy Semenov, Evgen Lutskiy, Olexander Zubarev, Roman Beznosjuk

Abstract – **In the work developing the ternary and quaternary logic elements with high quick-action and noise stability using the fuzzy-logic approach were proposed. The block-diagrams of the developed logical elements are proposed. In the elements the pulse-frequency coding is used.**

Keywords - **Fuzzy, Ternary, Quaternary, Logic.**

I. INTRODUCTION

Nowadays the systems of automatics and computing are being developed using logic algebra, not only binary one, but also multi-valued and fuzzy those. It is necessary to define the most convenient type of logic for a system. Fuzzy logic is much more alike human mind and works in uncertain cases providing very accurate results. Multi-valued logic has some advantages then using in complex systems. The more logic values a system has, the higher quick-action it has. But the less logic values a system has the higher noise stability it has. So, the compromise between quick-action and noise stability can be achieved by using ternary and quaternary logic [1].

II. THE FUZZY APPROACH

The presented in literature [2, 3] multi-valued logic devices have either low quick-action because of a great amount of blocks or low noise-stability because of pulse-amplitude signals. So, there is a problem of developing the multi-valued logic elements of high quick-action and noise-stability.

In order to provide high noise-stability we propose to use not pulse-amplitude signals but pulse-frequency ones.

In order to provide high quick-action we propose to use the fuzzy-logic approach. The point is, that multi-valued logic operation of inversion, conjunction and disjunction are alike the fuzzy-logic operation of complement, minimum and maximum accordingly; the fuzzy-logic elements performing these operations have less blocks than the well-known ternary and quaternary logic elements [4].

The ternary logic operation of inversion is:
$$\overline{x} = 2 - x.$$

The quaternary logic operation of inversion is:
$$\overline{x} = 3 - x.$$

Olena Semenova, Andriy Semenov, Evgen Lutskiy, Olexander Zubarev, Roman Beznosjuk – Vinnytsya National Technical University, Khmelnytske shosse, 95, Vinnytsya, 21021, UKRAINE,
E-mail: Helene_S@ukr.net, Semenov79@ukr.net.

The fuzzy logic operation of complement is performed so:
$$\overline{\mu_x} = 1 - \mu_x.$$

The ternary and quaternary logic operation of conjunction is performed so
$$x_a \wedge x_b = \min(x_a, x_b).$$

The fuzzy logic operation of minimum is performed so
$$\mu_{a \wedge b} = \min(\mu_a, \mu_b).$$

The ternary and quaternary logic operation of disjunction is performed so
$$x_a \vee x_b = \max(x_a, x_b).$$

The fuzzy logic operation of maximum is performed so
$$\mu_{a \vee b} = \max(\mu_a, \mu_b).$$

III. THE TERNARY LOGIC ELEMENTS

In the proposed elements the pulse-frequency coding of logical values is used. According to it, every frequency is defined so $f = nf_x$. So, when designing the ternary logic elements we have:

Let the 0-level responds to frequency of $f_0 = 4f_x$;

Let the 1-level responds to frequency of $f_1 = 5f_x$;

Let the 2-level responds to frequency of $f_2 = 6f_x$.

The auxiliary frequency equals $f_{aux} = 10f_x$.

The inversion element is a frequency mixer (fig. 1). The input pulse-frequency signal comes on its first input terminal. The auxiliary signal comes on its second input terminal. The output pulse-frequency signal comes from the output terminal.

Thus, we get:

if $f_{in} = f_0$,

then $f_{out} = f_{aux} - f_0 = 10f_x - 4f_x = 6f_x = f_2$;

if $f_{in} = f_1$,

then $f_{out} = f_{aux} - f_1 = 10f_x - 5f_x = 5f_x = f_1$;

if $f_{in} = f_2$,

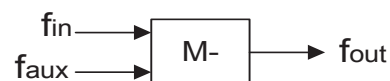then $f_{out} = f_{aux} - f_2 = 10f_x - 6f_x = 4f_x = f_0$.

Fig. 1. The inversion element

The conjunction element consists of three frequency mixers and a frequency divider (fig. 2).

The input pulse-frequency signal f_a comes on the first input terminal of the first mixer and on the first input terminal of the second mixer. The input pulse-frequency signal f_b comes on the second input terminal of the first mixer and on the second input terminal of the second mixer. On the output terminal of the first mixer one gets the $(f_a + f_b)$ signal, it comes on the first input terminal of the third mixer. On the output terminal of the second mixer one gets the $|f_a - f_b|$ signal, it comes on the second input terminal of the third mixer. On the output terminal of the third mixer one gets either the $2f_{con} = (f_a + f_b) - (f_a - f_b) = 2f_b$ signal if $f_a \geq f_b$ or the $2f_{con} = (f_a + f_b) - (f_b - f_a) = 2f_a$ signal if $f_a < f_b$. The signal goes from the output terminal of the third mixer to the input terminal of the frequency divider; on its output terminal one gets the $f_{out} = f_{con}$ signal.

The disjunction element consists of three frequency mixers and a frequency divider (fig. 3).

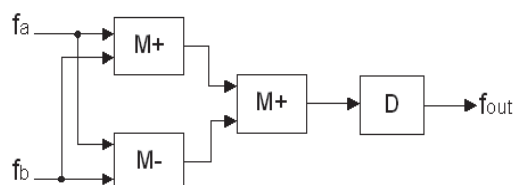The input pulse-frequency signal f_a comes on the

Fig. 3. The disjunction element

first input terminal of the first mixer and on the first input terminal of the second mixer. The input pulse-frequency signal f_b comes on the second input terminal of the first mixer and on the second input terminal of the second mixer. On the output terminal of the first mixer one gets the $(f_a + f_b)$ signal, it comes on the first input terminal of the third mixer. On the output terminal of the second mixer one gets the $|f_a - f_b|$ signal, it comes on the second input terminal of the third mixer. On the output terminal of the third mixer one gets either the $2f_{dis} = (f_a + f_b) + (f_a - f_b) = 2f_a$ signal if $f_a \geq f_b$ or the $2f_{dis} = (f_a + f_b) + (f_b - f_a) = 2f_b$ signal if $f_a < f_b$. The signal goes from the output terminal of the third mixer to the input terminal of the frequency divider; on its output terminal one gets the $f_{out} = f_{dis}$ signal.

IV. THE QUATERNARY LOGIC ELEMENTS

When designing the ternary logic elements:
Let the 0-level responds to frequency of $f_0 = 2f_x$;
Let 1-level responds to frequency of $f_1 = 4f_x$;
Let 2-level responds to frequency of $f_2 = 6f_x$;
Let 3-level responds to frequency of $f_3 = 8f_x/$
The auxiliary frequency equals $f_{aux} = 10f_x$.
The block-diagrams of the quaternary logic elements correspond to those of the ternary logic.

For the inversion element:
if $f_{in} = f_0$,
then $f_{out} = f_{aux} - f_0 = 10f_x - 2f_x = 8f_x = f_3$;
if $f_{in} = f_1$,
then $f_{out} = f_{aux} - f_1 = 10f_x - 4f_x = 6f_x = f_2$;
if $f_{in} = f_2$,
then $f_{out} = f_{aux} - f_2 = 10f_x - 6f_x = 4f_x = f_1$;
if $f_{in} = f_3$,
then $f_{out} = f_{aux} - f_3 = 10f_x - 8f_x = 2f_x = f_0$.
The conjunction quaternary element acts the same ways the conjunction ternary element does. At the output terminal one gets either the $f_{con} = (f_a + f_b) - (f_a - f_b) = f_b$ signal if $f_a \geq f_b$ or the $f_{con} = (f_a + f_b) - (f_b - f_a) = f_a$ signal if $f_a < f_b$.
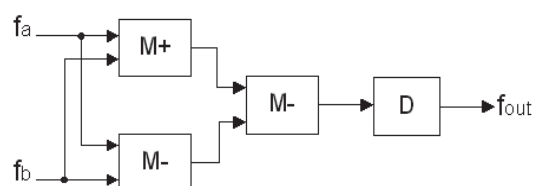

Fig. 2. The conjunction element

At the output terminal of the disjunction quaternary element one gets either the $f_{dis} = (f_a + f_b) + (f_a - f_b) = 2f_a$ signal if $f_a \geq f_b$ or the $f_{dis} = (f_a + f_b) + (f_b - f_a) = f_b$ signal if $f_a < f_b$.

V. CONCLUSION

Thus, using the fuzzy-logic principles it is possible to develop the multi-valued logic elements with high quick-action and noise stability. So, the operations of ternary and quaternary inversion, conjunction and disjunction are performed.

REFERENCES

[1] Lysikov B.G. Arithmetic and logical bases ETsVM [Arifmeticheskie i logicheskie osnovy ETsVM]. – Minsk: Vysheyshaya shkola, 1974. – p. 264 [in Russian].
[2] Kychak V.M. Synthesis frequency pulse Elements digital technology.– Vinnytsya: UNIVERSUM-Vinnytsya, 2005. – 266 p. [in Ukrainian]
[3] Kmet A.V. Four-valued logic. implementation of an operation [Chetyrechznachnaya logica. Realizatsyaya operazyy]. – M.: «Radio i svyaz». – 1991. – 96 p. [in Russian].
[4] Semenova O.O. Structural synthesis of phase-tech Components with impulse frequency presentation / Semenova O.O., Voytsehovska O.O. // *Materials of III-rd and International scientific - technical conference "Modern problems microelectronics, radio, telecommunications and instrument engineering " SPRTP-2007.* – Vinnytsya – 2007. – p.185. [in Ukrainian].