DESIGN AND INVESTIGATION OF TWO-PARAMETER SPACE CLASSIFICATION CIRCUITS USING FPAA

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The paper presents the results from the design and investigation of two-parameter space classification neural circuits by using Field Programmable Analog Array (FPAA) of Anadigm Inc. To this aim, the functional model of the artificial neuron is discussed and the results from implementation of FPAA variants of it structure are described. The use of the FPAA ensures possibilities for simple programming and dynamic reconfiguration of different values of the weights on the inputs as well as a flexible realization of the arbitrary output transfer functions. The application of the artificial neuron in different two-parameter space classification circuits is presented. The results could find wide application for implementation of hardware neural modules with possibilities for flexible real-time programming and reconfiguration of the parameters and functions.

Keywords: Parameter space, Classification circuits, Reconfigurable hardware, Field Programmable Analog Array, FPAA, Artificial neural circuit

1. INTRODUCTION

The parameter space classification is frequently solved task in contemporary test and control circuits. Fig.1 demonstrates the simplest two-parameter space classification. In this case the parameter space is divided in two regions - the separator between them is a straight line. Fig.2 depicts another more complex two-parameter space classification - the target region is closed with three borderlines.
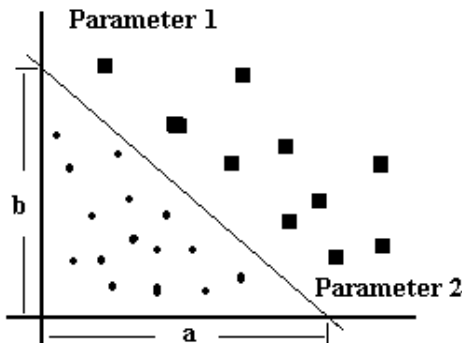

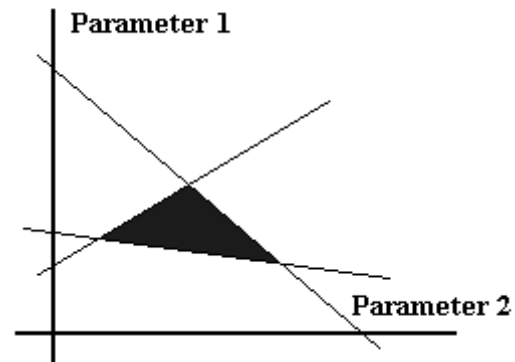Fig.1. The simplest two-parameter space classification task

Fig.2. More complex two-parameter space classification task

Different software or hardware approaches can be used to solve the specified tasks [1,2]. The main advantage of the hardware implementation is the shorter processing time. For instance, the methods based on the neural networks and threshold logic are exceptionally effective [3].

The paper presents the results from the design and investigation of neural circuits for two-parameter space classification by using Field Programmable Analog Array (FPAA).

To this aim, the functional model of the artificial neuron is discussed and the results from implementation of FPAA variant of it structure are described. After, the application of the artificial neuron in different two-parameter space classification circuits is presented.

2. FIELD PROGRAMMABLE ANALOG ARRAY OVERVIEW

The Field Programmable Analog Arrays (FPAAs) are one of the most contemporary and perspective products for fast and flexible implementation of different circuits and devices. Essentially, FPAAs are analog equivalent of well-known digital Field Programmable Gate Arrays (FPGAs). They combine the possibilities for programming and dynamic reconfiguration of different analog and mixed-mode functions in one chip. In this way, repeatable and reliable analog sub-circuits can be configured via standard digital interface.

The most popular of FPAAs are the circuits of Anadigm Inc. [4]. One of them is AN221E04 chip. It consists of four Configurable Analog Blocks and a flexible digital Configuration Interface. It is designed to work with a serial EPROM or with a host microprocessor. Multiple devices can be easily connected together to build up larger analog processing systems. The automation of the design is supported by specially developed CAD software tool- AnadigmDesigner2. It contains different Configurable Analog Modules as library components. All of them have user-programmable and re-programmable attributes. The standard library includes the analog design know-how, which ensures an optimal physical implementation of a circuit function and its high-level parametric setting. In order to facilitate the circuits' experimentation without any lab equipment, a functional simulator is included in AnadigmDesigner2 program. The simulator features intuitive user interface and displays time domain results graphically. By using specially developed Evaluation Board, the designer can fulfill the practical verification of the projects. This board allows AN221E04 FPAA to be programmed via the serial port of the personal computer under control of the AnadigmDesigner2 software. The configuration data for the designed circuit is sent automatically to a programmable chip.

Currently, different complex analog circuits are implemented by using FPAAs. The simplicity and compactness of these solutions stimulate designers to synthesize and examine various new FPAA applications.

3. FPAA IMPLEMENTATION OF AN ARTIFICIAL NEURON

Fig.3 presents functional model of an artificial neuron. The input analog signals (In_i) are multiplied by weights (W_i). After that, the weighted inputs are added to produce a single number at output of SUM block. This number is passed through a nonlinear mathematical function (Transfer Function block). The applied functions can be sigmoid, simple threshold, etc.

Fig.4 presents the FPAA implementation of 4-input analog neuron. The weighting and summing functions are realized by using standard SumDiff block (Half Cycle Sum/Difference Stage) from the library of the AnadigmDesigner2 software. The arbitrary transfer function can be implemented by using User Defined Voltage

Transfer Function Module from the same library. Sample&Hold circuits transform discrete-time signals at the outputs of the SumDiff and Transfer Function blocks to continuous-time.
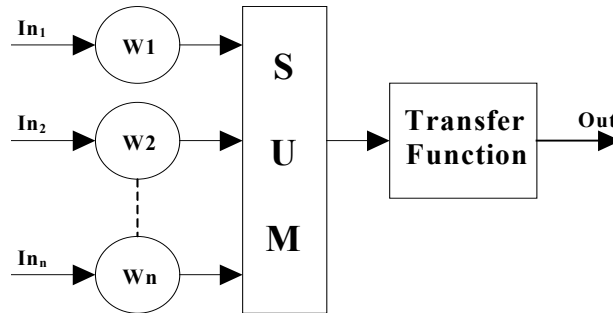

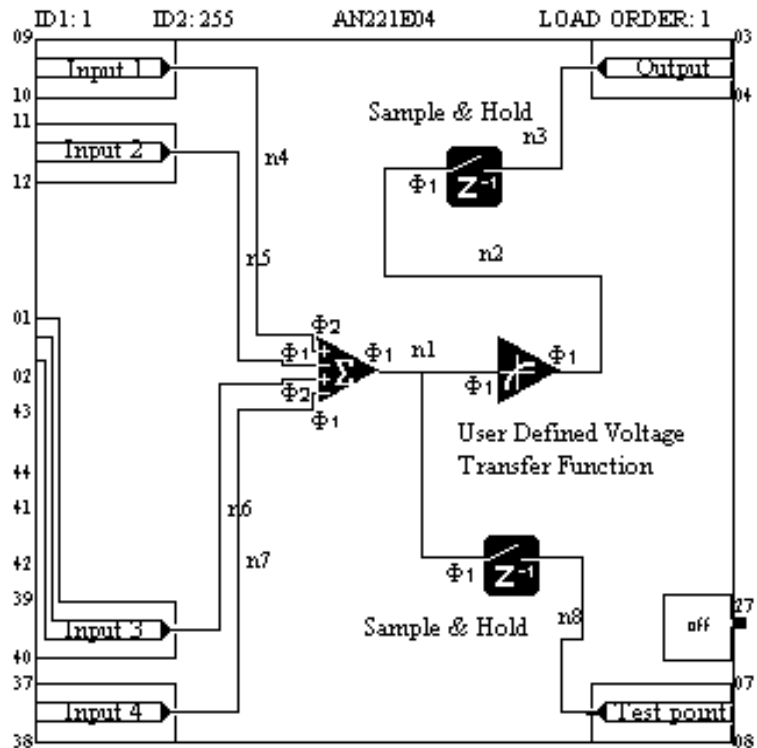Fig.3. Functional model of an artificial neuron.

Fig.4. FPAA implementation of 4-input analog neuron

4. DESIGN OF TWO-PARAMETER SPACE CLASSIFICATION CIRCUITS

When User Defined Voltage Transfer Function block is replaced with Comparator (i.e. standard threshold function is applied), the circuit is named Perceptron. It can be used to solve different classification tasks. For example, the circuit with only one perceptron on Fig.5 can perform 2-parameter space classification shown on Fig.1.

To this aim, the Inverting Sum Amplifier Stage ($-\Sigma$) computes the function

$$f = X2 + \frac{b}{a}X1 - b \qquad (1)$$

The obtained result is applied to the input of Comparator. If the value of f is higher than zero ($f{>}0$) the estimated point is situated above the dividing line from Fig.1; otherwise ($f{<}0$) – the point is under this line.

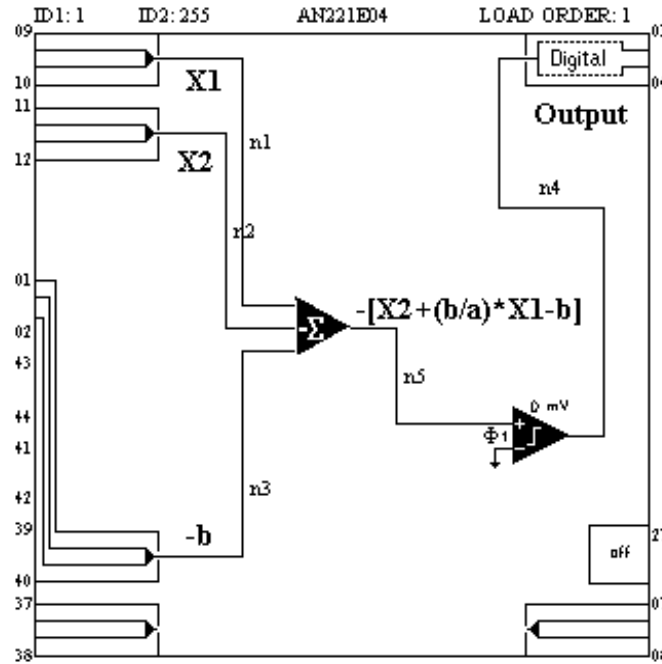
Fig.5. Two-parameter space classification circuit

FPAA circuits, which solve more complex classification tasks, can be developed by using appropriate combinations of simple artificial neurons and threshold logic circuits. For example, to solve the task from Fig.2, we can use two FPAA chips (Fig.6).

The first one realizes three perceptrons (one for each borderline) similar to this that is shown on Fig.5. Each of them consists of Inverting Sum Amplifier Stage ($-\Sigma$) and Comparator. The Inverting Sum Amplifier Stages ($-\Sigma$) compute the equations

$$f_i = -(X2 + \frac{b_i}{a_i} X1) \qquad \text{(for i=1,2,3)} \qquad (2)$$

The comparators estimate the obtained results. They compare the values of the f_i function and the corresponding value of b_i. Theirs outputs generate logical "0" or logical "1" depending on the coordinates X1 and X2 of the examined point. These signals are signed as Y1, Y2 and Y3.

The second chip (FPAA 2) implements threshold logic AND circuit. The Gain Stages with Polarity Control ($\pm G$) are used for signal conditioning. They are controlled by comparators. Depending on the value of Y1, Y2 and Y3 inputs, the outputs (Z1, Z2, Z3) of the Gain Stage with Polarity Control ($\pm G$) generate +1V (for logical "1"), or -1V (for logical "0"). The result F of the output of the SumDiff Amplifier Stage is equals to

$$F = P1 + P2 + P3 \qquad (3)$$

It is compared with threshold value UT=+2.5V. If F>UT, the examined point belongs to the target (triangle) area, otherwise - it is outside of it.
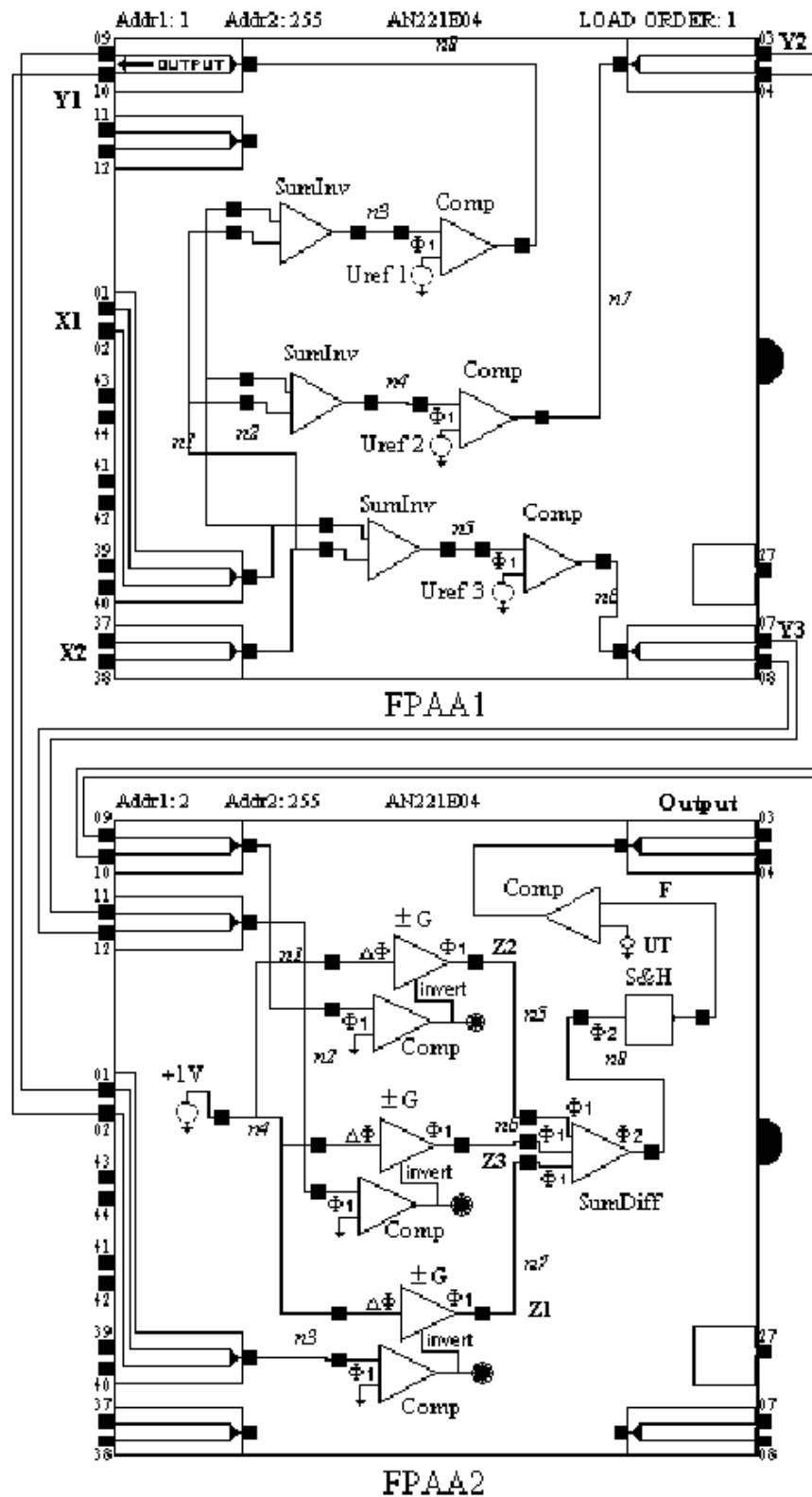
Fig. 6. FPAA implementation of classification task from Fig.2

5. CONCLUSION

The paper proposes an implementation of neural circuits for two-parameter space classification by using FPAA. To this aim, FPAA implementation of an artificial neuron is described. The use of the FPAA ensures possibilities for simple programming and dynamic reconfiguration of different values of the weights on the inputs as well as a flexible realization of the arbitrary output transfer functions (sigmoid, threshold, linear, etc). The application of the artificial neuron in circuits, which solve different simple (Fig.5) and complex (Fig.6) two-parameter space classification tasks, is presented.

The main advantages of the applied approach are:

- simple and effective implementation of different artificial neuron circuits and threshold logic functions;

- possibilities for programming and dynamic reconfiguration;

- fast prototyping and practical examination of developed circuits.

The results could find wide application for implementation of different hardware neural modules with possibilities for flexible real-time programming and reconfiguration of the parameters and functions.

6. REFERENCES

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