Special Hybrid Control Application of Field Programmable Analog Arrays

György Györök

Alba Regia University Center
Óbuda University
Budai út 45, H-8000 Székesfehérvár, Hungary
Email: gyorok.gyorgy@arek.uni-obuda.hu

***Abstract**: Most of embedded control tasks is often necessary to ask an analog or digital solutions should appropriately. Other hand, the use of Field Programmable Analog Arrays (FPAA) suggests on a great opportunity to give additional advantages. More great opportunity is the co-operation of the FPAAs and microcontrollers. It is very important to develop such an architecture that allows maximum flexibility and circuit-freedom to. After that we get a new arrangement, which has a special function, and usable as an "embedded hybrid controller".*

***Keywords**: FPAA; embedded microcontroller; cooperation; circuit-flexibility*

1 Introduction

An electronic device or subsystem (Fig. 1) inputs ($S_{in1}, S_{in2}, S_{in3}... S_{inm}$.) and outputs ($S_{out1}, S_{out2}, S_{out3}... S_{outn}$) are connected the environment and each other. The conventional embedded controllers are mostly connected a digital interface in an electronic environment. Microcontroller gets digital signals as: $i_1, i_2, i_3... i_r$, and gives digital signal out as: $o_1, o_2, o_3... o_p$. The microcontroller connected via the input/output (IC) of another controller or an external informatics device. The electronic environment does not necessarily require the exchange of digital information. The analog signals trough analog–digital converters enter the embedded control input, while the digital signals trough a digital–analog converters, if necessary, granted to the environment (Fig. 2). These converters in the microcontroller can be located either in the electronic environment. [10]

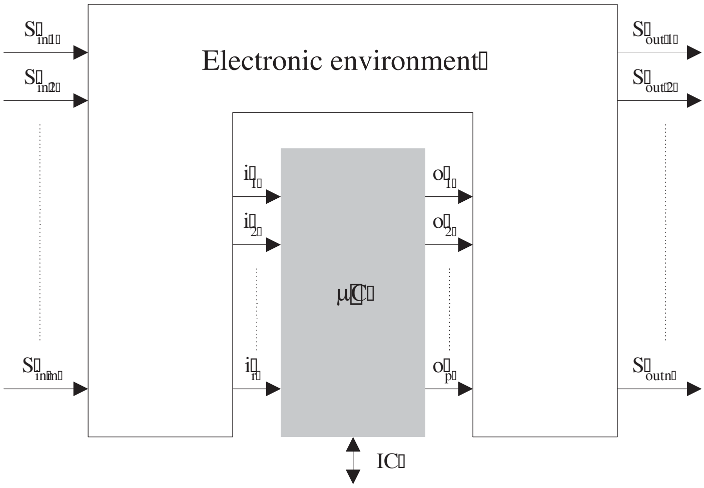

Figure 1
Classification of traditional embedded microcontroller system

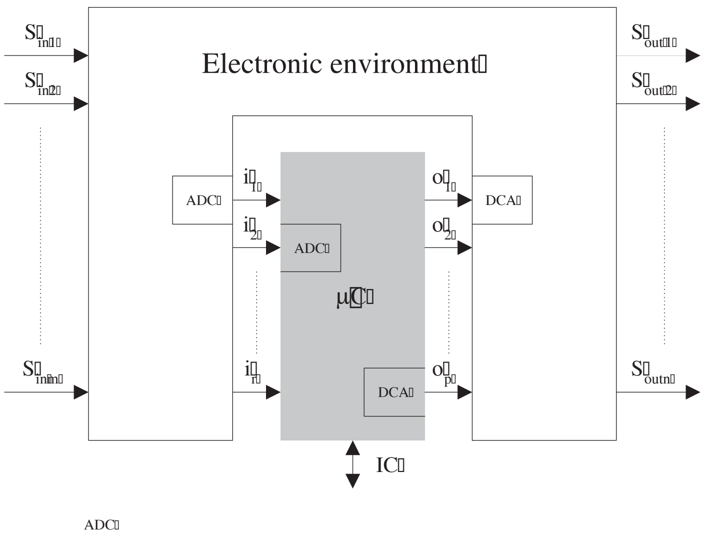

Figure 2
Embedded microcontroller system with analog servicing

The signal converting a variety of hardware solutions, and-, or algorithmically procedures are used. They are either component, or time wasteful. In addition, this procedure will of course distortion and conversion errors. [11] [12] [13] [14]

2 Field Programmable Analog Array

The programmable analog circuit (Field-Programmable Analog Array), as a new component and relatively new technology appeared some twenty-five years ago (Fig. 3). As a result of the continuous development, these devices programmed on a digital surface make an analog circuit topology with component parameters also given as programmable. FPAAs can be used for the realization of different functional units, circuits, circuit elements. These circuits can be used effectively in applications where the low electric power, the lower development and component cost, the effective electronic CAD possibility are important.

The advantage of FPAAs in the field of faster and more economical circuit planning is significant. It is beneficial in self-developing circuit applications, in neural networks, in signal conditioning, in filters, in fuzzy controls and high frequency applications. According to other approaches FPAAs serve the linear and non-linear implementation of the analog system and the scalability of the application to be realized. Yet the above mentioned advantages are not obvious since it is very difficult to make a user-friendly FPAA and environment.

In multi-value logics, in neural networks, in mixed-signal processor digital and analog circuits in which the traditional microprocessor is integrated onto a silicon chip with low performance analog circuit elements, further applications are offered. The smaller geometrical size, the fewer outputs, the cheaper mounting, the specifically smaller dissipation falling on of one volume unit are among the advantages.

Developments to be realized in the field of programmable analog circuits are as follows: speed, accuracy, digital noise, analog noise, performance, resource allocation possibility (capacity of FPAAs, component-level configurability), source usability, effective architectures, development environment services, macros, simulation, dynamic reprogramming.

There are further advantages of the programmable analog circuit applications; more compact, more reliable, more flexible systems can be produced with better performance. It is especially beneficial if for programming we modify the function of a programmable analog circuit either giving a new topology or a new component parameter using the flexibility of the microcontroller.

Research into the applications of programmable analog circuits, the spread of their application possibilities are to be solved.

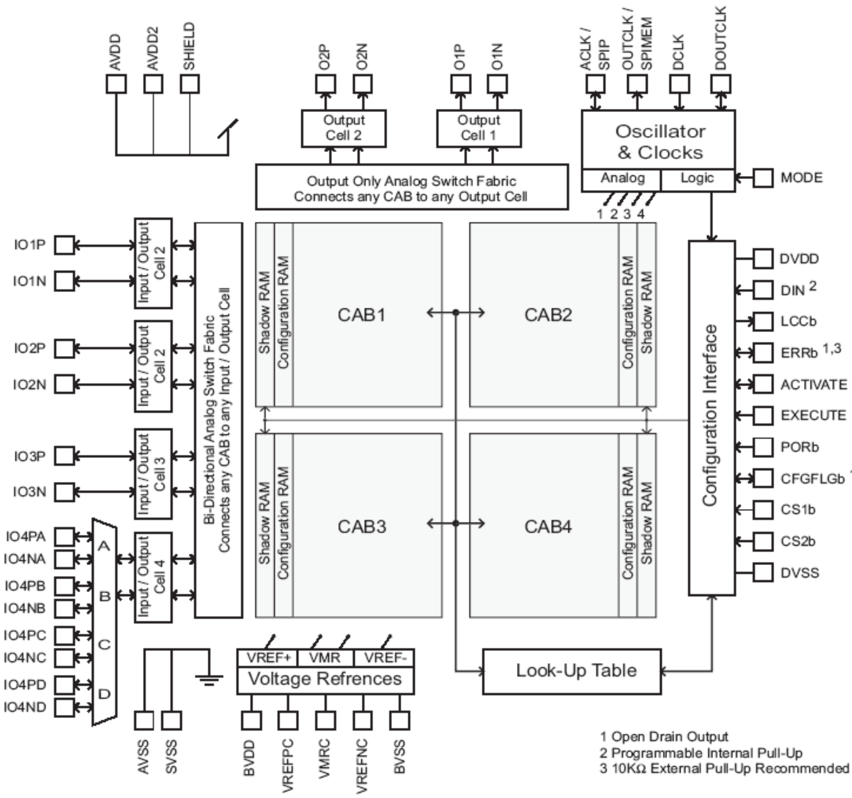

Figure 3
Inner structure of Anadigm Programmable Analog Arrays

The vast majority of FPAA applications allow the user to use the analog circuit in accordance with the required function taking advantage of the reconfiguration possibility. A further advantage of FPAAs is the simple embedding in bigger hybrid and digital systems.

The cooperation of the analog and digital circuits and the embedded controllers as well as their industrial use and technical application has always been in the focus of this article. [4] [5] [6] [7] [8]

3 Hybrid Controller with FPAA Circuit

Fig. 4 shows the arrangement of proposed hybrid controller. In the topology of the digital and analog signals are physically handled separately. The first connected to the inputs ($\alpha_1, \alpha_2, \alpha_3. . .\alpha_s$) and outputs ($\beta_1, \beta_2, \beta_3. . . \beta_z$) of FPAA, the latter conventional digital inputs (i_1, i_2, i_3... i_g) and outputs (o_1, o_2, o_3...o_z) of the microcontroller. The circuit function (FPAA) means a topology of the feature described by defining the network-function (***n***), which in the parts of the legs, the external linkages of the combined type, and setting the parameter-vector (*P*), which contains the exact values (p_0, p_1, p_2,... p_n) of of each component (1).

$$F_{FPAA} = \mathbf{b}(\mathbf{n}(P)). \tag{1}$$

where **b** is a binary string.

The required configuration parameters the microcontroller produces, by its algorithm (**A**), alias; firmware. The FPAA Circuit by its transfer function generates outputs (β_s) from input signals (α_s) by its transfer function (F_{FPAA}) as write it formal equal 2;

$$\beta_z = F_{FPAA}(i_1, i_2, i_3 \ldots i_g). \tag{2}$$

The appropriate digital inputs i_g) deciding the function of microcontroller function depends of algorithm (**A**) in equal (3).

$$\mathbf{A} = f(i_1, i_2, i_3 \ldots i_g) \tag{3}$$

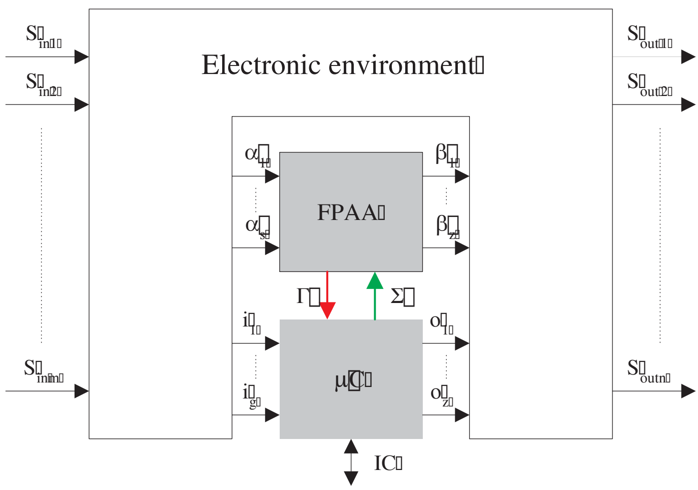

Figure 4

Proposed embedded hybrid controller system with programmable analog circuit

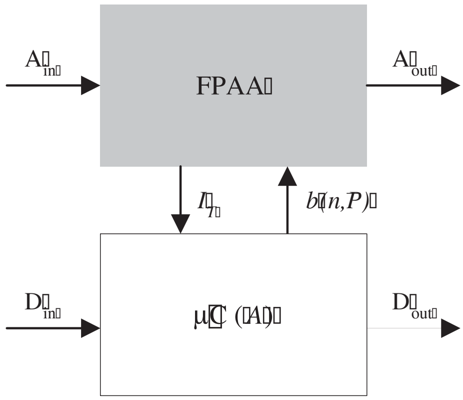

Figure 5
Connecting the microcontroller and the analog circuit trough interrupt

Equals 1-4 give equal (4):

$(i_g, \alpha_s) => \mathbf{A} => b(\mathbf{n}, P) => F_{FPAA} => (o_s, \beta_z),$ (4)

thus completes the whole of analog and digital control functions.

A very interesting aspect is of the analyzing of interaction of microprocessor and the analog circuit. These various physical and logical linking (Fig. 4 Σ and Γ connections) more and more options may be granted.

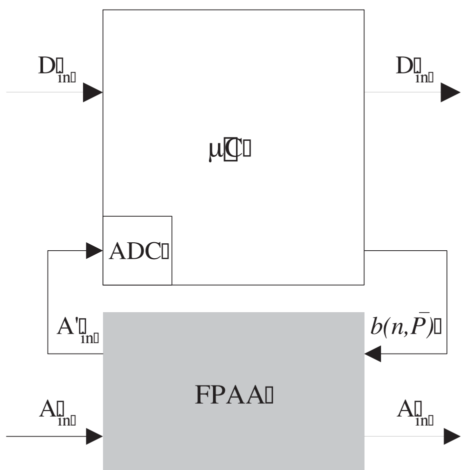

Figure 6
Feedback cooperation of the programmable analog circuit and the microcontroller

4 Microcontroller and FPAA in Hybrid Systems

The microcontroller not only the static function (equal 1) my be solves. Various claims on the basis of the configuration can be constructed rapidly alternating, this is called reconfiguration. The reconfiguration of the various signals from the analog circuit (Γ) can perform a function.

On Fig. 5 shows a connection of the microcontroller and the analog circuit in which the change of the parameters of the circuit point assignable in a configurable way is able to generate the termination of the program requiring reconfiguration. [1] [2] [11] [12]

Figure 6 shows a specific connection of μC and FPAA circuit. On the first one can be seen a virtual combination network constructed in the microcontroller where the feedback can be realized by changing and reconfiguring the circuit function of the programmable analog circuit using the configuration input, the analog output, the analog-digital transfer signal route. The circuit function are described by equals

$$D_{out} = \mathbf{A}(D_{in}, A'_{in}), \tag{5}$$

where: ($\mathbf{A}$) is the microcontroller's algorithm predestinate function;

$$A'_{in} = \mathrm{F}_{FPAA}(A_{in}), \tag{6}$$

where: F_{FPAA}) is circuit function. The FPAA transfer function depends of digital inputs (D_{in}) and feedback branch of FPAA, formal: b($\mathbf{n}$, P) => F_{FPAA}, and b($\mathbf{n}$, P) = $f(\mathbf{A})$, so $\mathbf{A}$ => F_{FPAA}

On (5, 6), we have (7):

$$\mathrm{D}_{out} = \mathrm{A}(\mathrm{D}_{in}, \mathrm{A}_{in}). \tag{7}$$

According (6) the output value of FPAA is:

$A_{out} = \mathrm{F}_{FPAA}(A_{in})$so we get the output of FPAA (8):

$$\mathrm{A}_{out} = \mathrm{F}_{FPAA}\{\mathrm{A}_{in}, [\mathrm{P}((\mathrm{A'}_{in}), \mathrm{D}_{in})]\}. \tag{8}$$

Because A => F_{FPAA}, so the (8) simpler form (9):

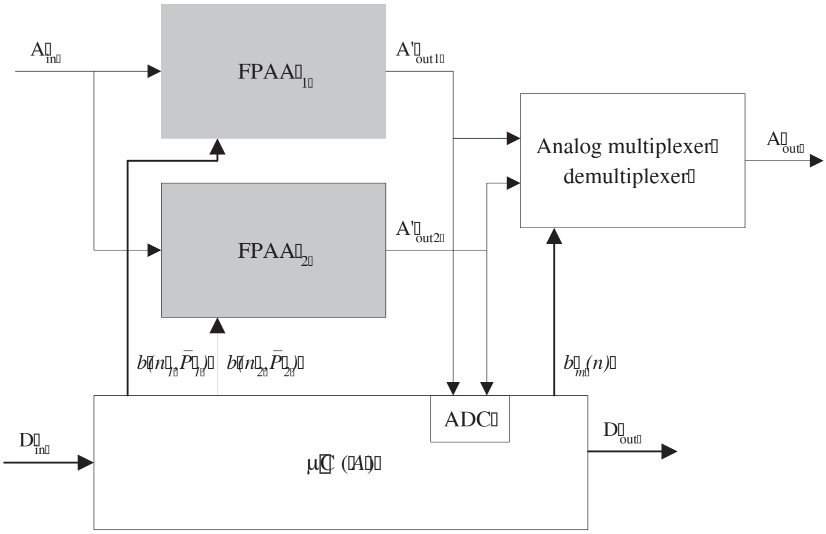

Figure 7
Circuit function change with microcontroller and duplicate programmable analog circuits

$$A_{out} = \mathbf{A}(D_{in}, A_{in}) \tag{9}$$

Such a microcontroller and programmable analog circuit arrangement reached where both the digital and the analog output values of the program, the analog and digital input values are determined. In this case we have abilities of construction in which the programmable analog circuit, as a coprocessor, according to its actually configurable configuration, can overtake analog signal processing tasks, which results in speed increase. [3] [14]

In applications where the reconfiguration time-critical, it is possible to establish redundant structure is shown in Fig. 6. In this case is an analog multiplexer circuit of the currently active output of the hybrid controller analog output. Thus, the microcontroller has enough time, not only in the loading circuit structure, but even with a new circuit topology to develop by an algorithmic procedure. [1] [2] [3]

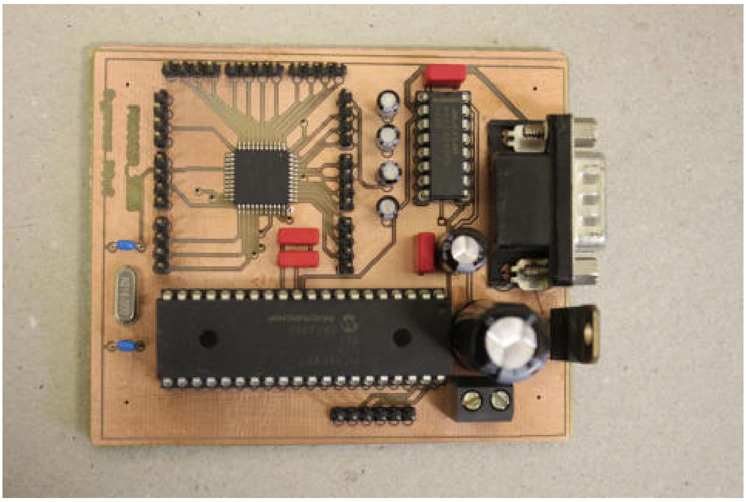

Figure 8
Test board of hybrid controller with PIC16F788 microcontroller and a programmable analog circuit

Conclusions

The built board in Fig. 7 can be seen. This is a flexible configurable layout, its function depending on the microcontroller program (algorithm) and the current status of configuration jumpers.

The proposed layout, some hybrid applications, is used more effectively than conventional digital controllers. Released processor resources can be used for other tasks.

Further research is needed to develop the appropriate algorithms.

References

[1] J. Vásárhelyi, M. Imecs. Dynamically Reconfigurable Drive Control Systems. The First International Conference on Energetics, Electrotechnics ENELKO 2000, October 6-8, 2000, Kolozsvár, Romania, pp. 56-61

[2] M. Imecs, J. Vásárhelyi, P. Bikfalvi, S. Nedevschi. Re-Configurable Controller Implementation for AC Drive. Micro-Cad 2000, International Conference, February 23-24 ISBN: 963 661 418 Helysg: Miskolc, Hungary, pp. 81-86

[3] R. Kastner, A. Kaplan, M. Sarrafzadeh. Synthesis Techniques and Optimizations for Reconfigurable Systems. Kluwer Academic Pub, 2003

[4] C. Reiser. Optimization of Performance of Dynamically Reconfigurable Mixed-Signal Hardware Using Field Programmable Analog Array (FPAA) Technology. PhD thesis, (1998)

[5] F. Scott, L. Kemper, S. Afreen, O. L. Weck. Flexible and Reconfigurable Systems: Nomenclature and Review. In Proceedings of the ASME 2007 International Design Engineering Technical Conferences Computers and Information in Engineering Conference, volume IDETC/CIE, 2007, Las Vegas, Nevada, USA

[6] S. Zebulum, R, A. Stice, K. Didier. The Design Process of an Evolutionary-oriented Reconfigurable Architecture. www.coe.uncc.edu/ kdatta/-papers/The/20Design/20Process/20o...urable/20Architecture.pdf

[7] N. Ádám: *Single Input Operators of the DF KPI System*. Acta Polytechnica Hungarica 2010 7(1)

[8] Labun, J., Adamcik, F., Pilá, J., Madarász, L.: *Effect of the Measured Pulses Counton the Methodical Error of the Air Radio Altimeter*. Acta Polytechnica Hungarica 2010 7(1)

[9] B. Reskó, P. T. Szemes, P. Korondi, P. Baranyi: *Artificial Neural Network-based Object Tracking*. Transaction on Automatic Control and Comof Timisoara, 4:125-130, May 25-26, 2004

[10] Gy. Györök. Embedded Hybrid Controller with Programmable Analog Circuit In: IEEE 14th International Conference on Intelligent Systems. Gran Canaria, Spain, May 5-7, 2010, pp. 1-4, Paper 59 (ISBN:978-4244-7651-0)

[11] Gy. Györök. Functional and Parametrical Self Adjustment in Analog Circuit. 5th International Symposium on Intelligent Systems and Informatics (SISY 2007) August 24-25, 2007, Subotica, Serbia, ISBN 1-4244-1443-1, IEEE Catalog Number 07EX1865C, Library of Congress 2007930059, pp. 67-70

[12] Gy. Györök. Programmable Analog Circuit in Reconfigurable Systems. 5th Slovakien-Hungarien Joint Symposium on Applied Machine Intelligence, January 25-26, 2007, Poprad, Slovakia, ISBN 978-963-7154-56-0, pp. 151-156

[13] Gy. Györök. Self Configuration Analog Circuit by FPAA. 4th Slovakien-Hungarien Joint Symposium on Applied Machine Intelligence, January 20-21, 2006, Herlany, Slovakia, ISBN 963 7154 44 4, pp. 34-37

[14] Gy. Györök, M. Makó. Configuration of EEG Input-Unit by Electric Circuit Evolution. In 9th International Conference on Intelligent Engineering Systems (INES 2005) September 16-19, 2005, Cruising on Mediterranean Sea, ISBN 0-7803-9474-7, IEEE 05EX1202C