Analog Predictive Circuit with Field Programmable Analog Arrays

György Györök

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

Abstract: 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 my interes. In reconfigurable systems the effectiveness and quality of the analog circuit system can be maintained and modified by circuit or by changing the single element values. 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. In the microcontroller environment we can use these FPAA circuit in different useful application as a predictive-, and a characteristic prediction circuit solution. We describe a control solution of an industrial machine control asa demonstration of applicability of microcontroller and FPAA circuit cooperation.

Keywords: Field Programmable Analog Array, cooperation with microcontroller, prediction, flexible analog circuit, circuit robustness

1 Introduction

The programmable analog circuit can be used universally understood by the program configured for circuit. (Fig. 1)

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
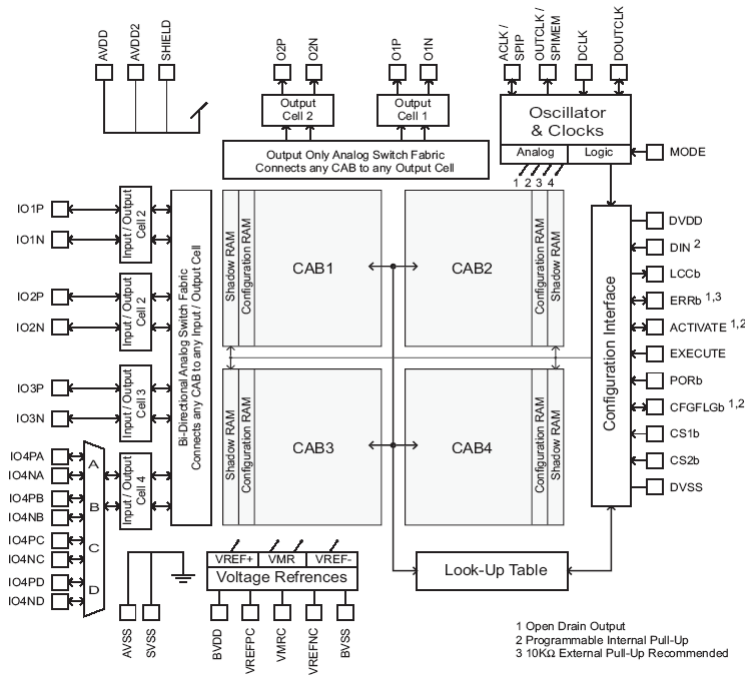
Figure 1

Internal structure of most popular Anadigm's FPAA with the four configurable analog blocks

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.

It has been suggested that the mixed-signaled architecture should be constructed duplicated, thus this circuit will be suitable for the realization of configurable, self-learning processes, algorithms by reprogramming occurring in the background.

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 developments aim at meeting the big analog processing requirements in the field of high integrated FPAA devices in which there are too complex programmable applications: high-order filters (Fourier-processor), adaptive filter systems, vector-multiplier, and matrix-multiplier.

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.

Research into the applications of programmable analog circuits, the spread of their application possibilities are to be solved. [1-8] [11]

2   Characteristic Prediction in Analog Circuit

Programmable analog circuits are an important area of research on the use of analog and hybrid electronic circuit technology. Particularly interesting is the field where, for a device already present in the microcontroller may be any co-operation between the two cardinal devices. The microcontroller and FPAA such co-operation allows the ”embedded hybrid system” tool for using. In this article, beyond the theoretical approach, a practical application being introduced, this realizes the characteristic prediction [9].
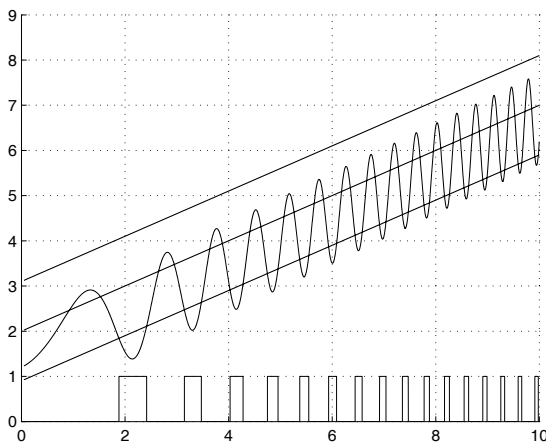

Figure 2

Characteristic prediction with normal range-, and limits, and under the generated error signal

The diagram of Figure 2 explains the characteristic prediction is observed. The predictor determines the analog characteristics of the expected value and the error range. If the analog signal will fall outside the range, the error signal is produced. The error signal, optionally used in the circuit re-configuration or other signals to generate.

On Figure 3 carries out error detection. In this case a predictor circuit (*f*) maps the "good operation" values from the input signal (U_{in}). Thus the output signal of the current circuit (*F*) is compared with the output of the characteristic predictor circuit. The comparator operates as a window-comparator and checks the in-range character of the circuit output value according to (4.3), where (U_{cl}) is the lower comparing threshold voltage, (U_{co}) is the upper comparing thresh-old voltage.

$$U_f = \begin{cases} U_f & \text{if} \quad U_{cl} > (f(U_{in}) - \mathbb{F}(U_{in})) \geq U_{co} \\ 0 & \text{if} \quad U_{cl} \leq (f(U_{in}) - \mathbb{F}(U_{in})) < U_{co} \end{cases}$$

(1)

where: U_{cl}, lower threshold voltage of comparator, U_{co} upper threshold voltage of comparator, what calculated of the output of *f* circuit, and the hysteresis (*h*) according of equations 2, 3.

$$U_{cl} = f(U_{in}) - \frac{h}{2}$$

(2)

and,

$$U_{co} = f(U_{in}) + \frac{h}{2}$$

(3)

In case of an error, the further usage of the output signal, the selection, change and correction of the actual circuit and that of the reference circuit are new, challenging system technological tasks [10] [11].
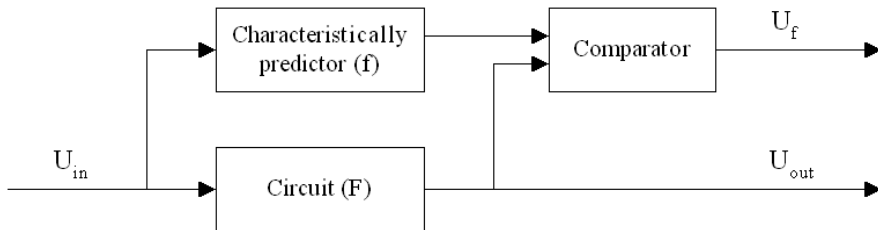

Figure 3

Realization of a charecteristic predictor circuit in an analog system

3   Characteristic Prediction with FPAA

The error detection is one possible solution to the characteristic predictor application. This, a programmable analog circuit and microcontroller implemented decomposition is shown in Figure 4.

The programmable analog circuit (F_{FPAA}) input receives an input signal ($A_{(a)}$), output ($A_{(a)}$) the system output signal to (4) according to the description,

$$A_{out} = F_{FPAA} (A_{in}), \tag{4}$$

where: F_{FPAA} circuit function of programmable analog circuit.

The A_{in} input signal the of (ADC) too, which generate D_{be} signal (5),

$$D_{be} = \mathbf{d}(A_{in}). \tag{5}$$

Here **d** is the transfer characteristic of analog-digital converter
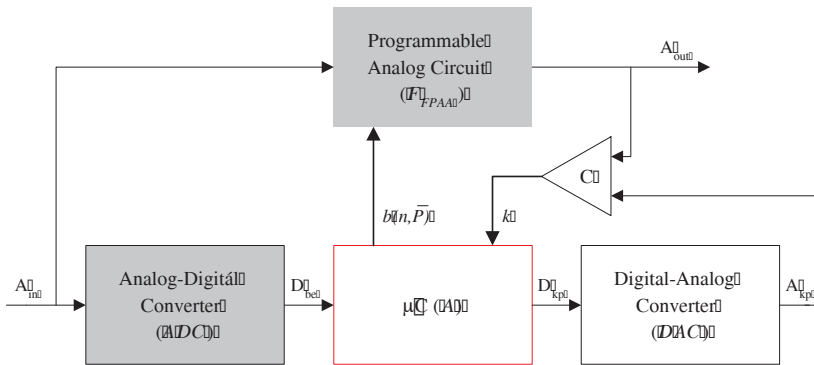

Figure 4

Solution of analog error detection with a characteristic prediction in microcontroller environment.
(The block shown gray in the microcontrollers inside located unit.

The D_{be} signal goes to the input of microcontroller µC which from this value create, by the characteristic prediction, the D_{kp} signal (6),

$$D_{kp} = \alpha_{kp} (D_{be}) \tag{6}$$

where: α_{kp} characteristic prediction part of the the firmware of microcontroller (**A**), in short; $\alpha_{kp} \in \mathbf{A}$.

The digital-analog converter the D_{kp} signal transforms to analog signal, according of (7),

$$A_{kp} = \mathbf{a}(D_{kp}) \tag{7}$$

where: **a** the transfer characteristic of digital-analog converter.

The hysterises comparator cooperates (C) the A_{ki} and A_{kp} signals (8) namely:

$$k = \begin{cases} \mathbf{0} & \text{if} \quad (A_{kp} + \frac{h}{2}) > A_{out} \geq (A_{kp} - \frac{h}{2}) \\ \mathbf{1} & \text{if} \quad (A_{kp} + \frac{h}{2}) \leq A_{out} < (A_{kp} - \frac{h}{2}) \end{cases}$$

(8)

Here h the programmable hysteresis value's of comparator.

If A_{out}, defined by the prediction value $(A_{kp} \pm h)$ is outside the range, the comparator output (k) binary (1), which generates for the microcontroller error value. The error causes the microcontroller to the **A** algorithm re-configure the FPAA circuit $b(\mathbf{n}, P)$ interface, thereby creating the new circuit function (9):

$F_{FPAA} = \mathbf{A}[b(\mathbf{n},P)]$ (9)

The (4)-(9) prediction equations, as described in the operating characteristic function formally layout: $(A_{ki}, A_{kp}) \rightarrow k \rightarrow \mathbf{A} \rightarrow b(\mathbf{n}, P) \rightarrow F_{FPAA}$, and $F_{FPAA} \rightarrow A_{ki}$ over and above $\alpha_{kp} \rightarrow A_{kp}$, so the feedback is established.

The microcontroller characteristic segment of the program (α_{kp}), the complexity of the prediction, depending on the accuracy of the required resources (time) can be demanding.

Thus, this procedure is complicated algorithm, only the analog signal A_{be}) over frequency limit reduction will be achieved.

On Fig. 4 proposed layout of the architecture of reality is much simpler, as indicated in the gray blocks of programmable analog circuit can be formed, the comparator and the digital-analog converter can be found in most of the microcontroller peripherals [2] [3] [5].

Conclusions

The characteristic prediction and it's using of re-configuration of programmable analog circuits, to make robust electronic circuits in which the circuit reliability can be improved greatly. At the same time, or other important aspect, the quality parameter of the analog circuit can be increased.

It is very important that this process lies in the microcontroller's resources are not significant. The microprocessor can only take advantage reconfigure the FPAA when the output of the characteristic predictor gives error signal. In the latter case, even discontinuous relationship can be constructed between the programmable analog circuit and the microcontroller [5].

The proposed solution successfully used the dynamic filter reconfiguration in an EEG unit control [12].

The additional work is for the concrete implementation of circuit applications, the optimal algorithm design processes, self-improving solutions to refine the target.

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