The FPAA Realization of Analog Robust Electronic Circuit

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***Abstract*—We call an electronic robust one then, if it the stress-like electronic change without a breakdown, possibly beside a minimal damage, not disturbing the normal function possibly, tolerates it. Not really definable the extreme changes quantity and his qualitative parameter, and the measure of the robustness. It was thawing out in robust electronics applications electronic circuit redundancy, the safe, in this manner advantageously can be used the programmable analogous electronic circuits (field programmable analog array, FPAA). Using of these FPAA circuits can be developed such robust architectures which are redundant, adaptive and reconfigurable. Additional benefit, it is you that the analogous system may be attached to an embedded controller or a computer through a digital surface to, that the adequately chosen feedbacks intervene in the function of the electronic circuit.**

I. INTRODUCTION

The "robust system" or "robustness" used to be an accepted term regarding mechanical applications, which is widely used in several disciplines. "Robustness" as a term is often associated with reliability, adaptability, error tolerance, reconfigurability sometimes with certain overlaps [13] [14] [16]. The term itself has no exact definition; generally, the measure of its quality cannot be defined. The literature uses versatile expressions such as systems of high reliability, error tolerance, readiness to serve changed circumstances and cost effectiveness. The "proper operation in uncertain conditions" is the most frequent definition [10] [8]. A little more concrete definition is: "operation within the error limit in unpredictable conditions" [14] [9] [5]. The quantity and quality parameters of the "conditions" and the measure of "robustness" are also difficult to define [12]. According to the system approach robust equipment can be constructed from units of lower performance depending on the quality of their connection. In this case if we can change the quality of the connection of the parts, we can further increase the quality of system robustness [19]. On the basis of the above mentioned, an electronic circuit is robust when it tolerates the stress like changes without a breakdown and, possibly, without disturbing the normal operation.

II. ROBUST ANALOG CIRCUIT SYSTEMS

An electronic system is such a multi-unit parts system where each functional unit can operate independently. This system is robust if the operation of the whole system, through the art of connecting the part units, is provided under the changed circumstances too. Figure 1 shows the external and internal factors influencing the robust electronic system. The operation has to be maintained either only one or several factors exist.

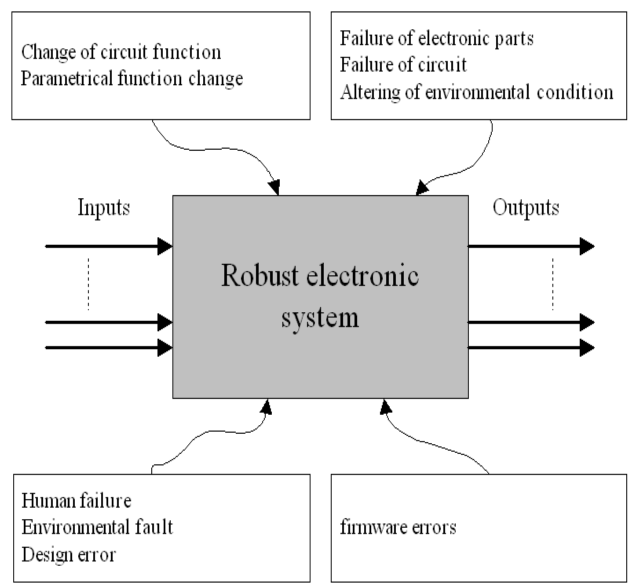

Fig. 1. Classification of robust system.

The internal factors, originate from the circuit which creates the system, are component errors, circuit errors, design errors, firmware errors. Over heatedness, increased internal noise, component parameter changes also fall into this category. The external errors are usually human errors and environmental errors; they are improper operation, high environmental temperature, radio frequency radiation etc. The adaptivity of a system is the synonym of robustness if it means tolerating the changed environmental conditions, the need of a circuit function change and the parametric function change.

This above needs can be satisfied partly by circuit redundancy, by over safety or by the adaptivity of the system and the scalable formation of the components. Thus the operation of the whole system can be modified by switching the part units on and off, or by changing the operation parameters of the part units. If a robust system is broken down into an appropriate number of part units, and those part units are configurable, the adaptivity and reliability of the electronic devices and equipment will significantly grow [1] [2].

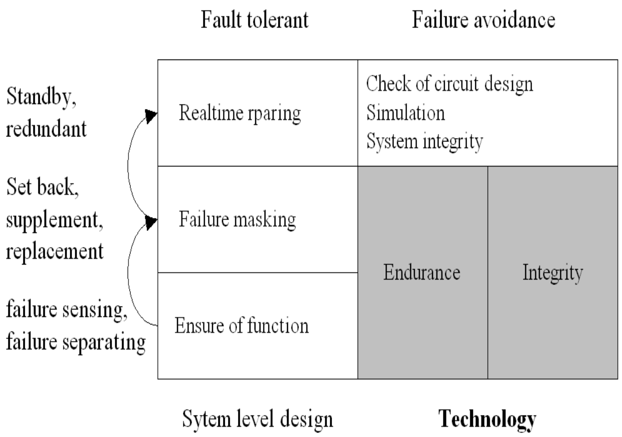

Fig. 2. The technical aspect of the robust system.

Table of figure 2 shows the components of the robust electronic system and their interplay [11]. An analogous circuit is robust if it responds to the changed external conditions with error tolerance. The aim is to maintain the operation either through masking the error or by the real-time repair of errors. The maintenance of circuit operation is provided by detecting and eliminating the errors. Error mask-ing means restoring the faulty part units and replacing them. Real-time repair means the activation of the replacements which are permanently present via maintenance as well. The proper interaction, operation-differently from the traditional methods-can be realized by a system-level design

The avoidance of the circuit and part unit malfunctioning is mostly a technological question, including circuit simulation-aided planning, state-of-art automated production and monitoring (CAT) and selecting the appropriate system design technology [14].

III. REALIZATION OF ROBUST ANALOG CIRCUIT SYSTEMS

There is no single solution of the robust analog circuit system formation. According to figures 1, 2 it is realized by system-level planning. The latter depends on the actual component and production technology, whose development results in the reliability of circuit systems. The toleration of circuit redundancies will increase the robustness of the system just as well. To reach such system-level planning is needed where the in-operation error detection, diagnosis, self-repair, self-correction, automatic system self-management are solved. The system realization process shown in figure 3 is offered to such planning.

Each circuit of the system is marked with the system-level input signal (I_s). The control unit collects information about the correct operation of each circuit via γ_n output signal. γ_n is a mapping of input signs/signals (I_s), which is interpretable

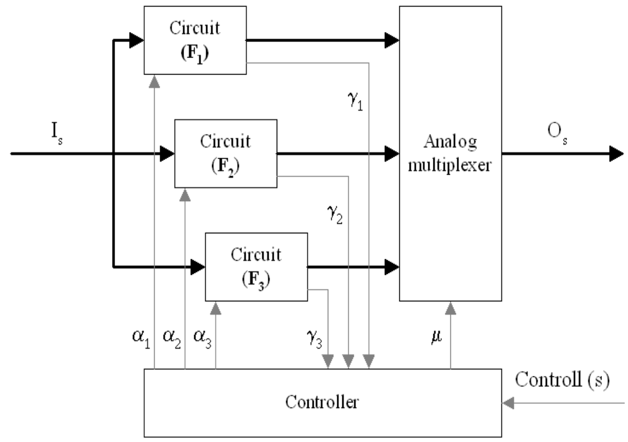

Fig. 3. The robust analog system in parallel art.

for the control unit. In certain cases it can be the output signal of the circuit as well.

From a control unit output we can change the circuit functions (**F**) of each circuit by means of the (α_n) signal. The selection of the proper circuit (μ) occurs with the help of the analog multiplexer. The output of the selected circuit will be the system output. (O_s). The control can be external (s) too, which supports further system integration [7] [6]. By increasing the number of circuits ($\mathbf{F}_n$) the robustness of the system will grow.

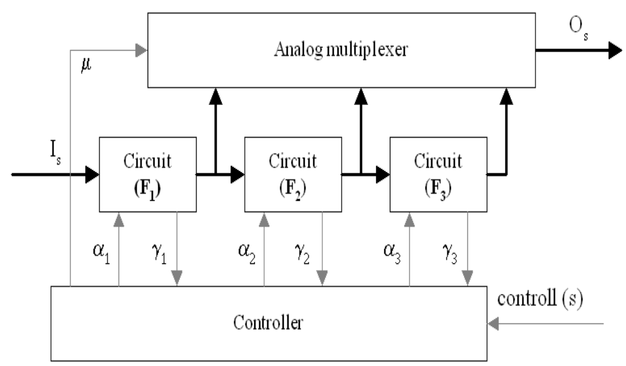

Fig. 4. The robust analog system in serial art.

On the figure 4 the signals and the functions are same than the figure 3. The architect of figure 4 serves the quality of the analog functions, and the arrange of the figure 3 useful in case of the quantity of the different analog abilities. This layout sup-ports the increased quantity circuit functions. If we include the non-variant transfer functions in the single circuit functions too, we can see, that the circuit replacements are present in this case as well, which can be increased by raising the number of circuits.

The figure 5 shows the above both solution. The architecture contains the parallel, and the serial arrangements. In these case we get a flexible useful analog circuit arrangement. By the help

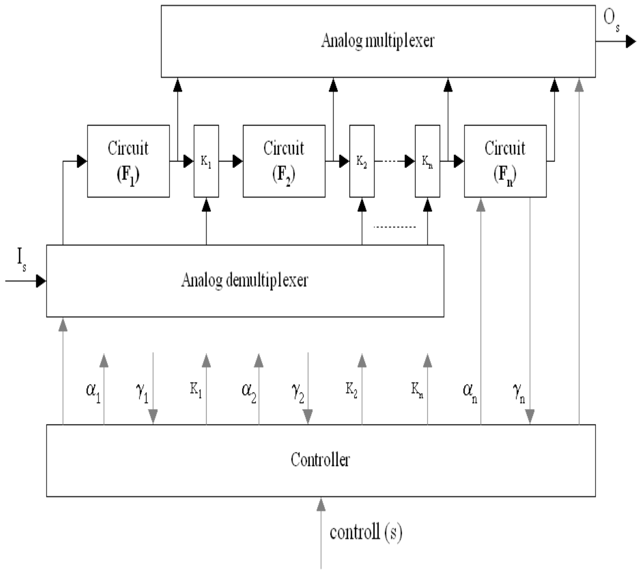

Fig. 5. Realization of robust analog system in combined architecture.

of two multiplexer-demultiplexer able to configuring one part of architecture as a parallel-, and other part as a serial robust circuit. Using of the above proposed architecture follow two real example. On the figure 6 shows a serial in parallel art two different signal paths and the figure 7 shows three parallel signal paths.

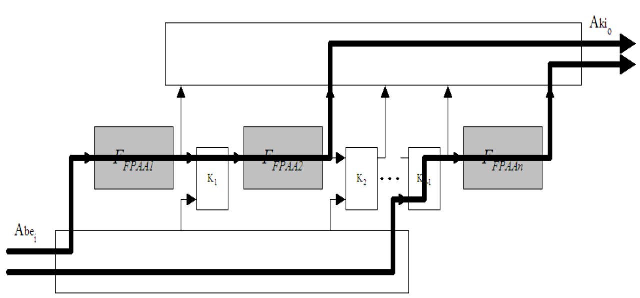

Fig. 6. Example 1 of combined architecture.

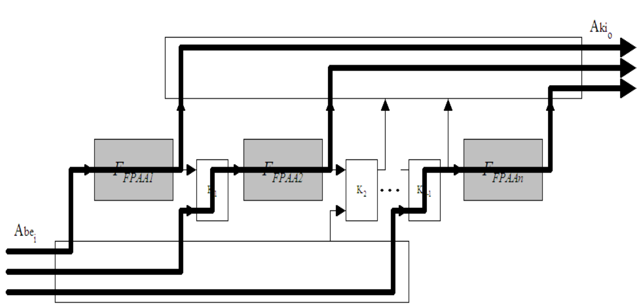

Fig. 7. Example 2 of combined architecture.

IV. Using of proposed robust arrangements

As an decomposition in the above chapter proposed solutions, and use the reconfigurable analog circuits (FPAA) in cooperation of embedded microcontroller, follow here two real examples. First of all the majority voter circuit (figure 8). As shows the figure this is a typical parallel application of the redundant robust circuit [18] [20]. Their consists of three parallel circuit (F_n), and output of theirs is a vote circuit. The last one choices the properly value of the output signals. At least two value (inner in the failure range) are equal, the voter gives one of these to the system output (U_{out}).

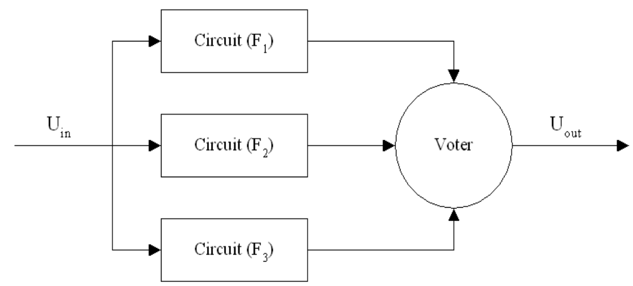

Fig. 8. The voter circuit in a robust application.

The equation 1 gives one useful functions of the voter circuit. In this case the part unit with a faulty output value is switched out of the system operation [22] [23]. The voting unit will result in good operation in case of different and several similarly good relations.

$$U_{out} = \begin{cases} \mathbb{F}_1(U_{in}) & \text{if} \quad \mathbb{F}_1(U_{in}) = \mathbb{F}_2(U_{in}) = \mathbb{F}_3(U_{in}) \\ \mathbb{F}_1(U_{in}) & \text{if} \quad \mathbb{F}_1(U_{in}) = \mathbb{F}_2(U_{in}) \neq \mathbb{F}_3(U_{in}) \\ \mathbb{F}_1(U_{in}) & \text{if} \quad \mathbb{F}_1(U_{in}) = \mathbb{F}_3(U_{in}) \neq \mathbb{F}_2(U_{in}) \\ \mathbb{F}_2(U_{in}) & \text{if} \quad \mathbb{F}_2(U_{in}) = \mathbb{F}_3(U_{in}) \neq \mathbb{F}_1(U_{in}) \end{cases} \tag{1}$$

On the figure 9 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.

$$U_f = \begin{cases} U_f & \text{ha} \quad U_{cl} > (f(U_{in}) - \mathbb{F}(U_{in})) \geq U_{co} \\ 0 & \text{ha} \quad U_{cl} \leq (f(U_{in}) - \mathbb{F}(U_{in})) < U_{co} \end{cases} \tag{2}$$

where: U_{cl}, lower threshold voltage of comparator, U_{co} upper threshold voltage of comparator, what calculated of

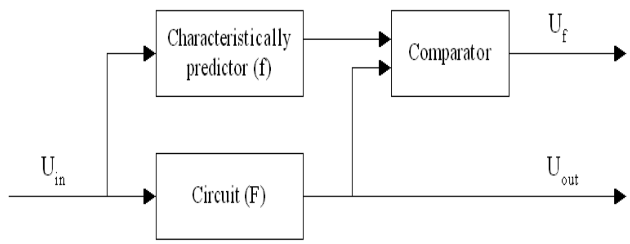

Fig. 9. Realization of a characteristic predictor circuit in a robust system.

the output of f circuit, and the hysteresis (h) according of equations 3, 4.

$$U_{cl} = f(U_{in}) - \frac{h}{2}, \quad (3)$$

and,

$$U_{co} = f(U_{in}) + \frac{h}{2}. \quad (4)$$

.

Figure 10 demonstrates typical signals of characteristic predictor circuit.

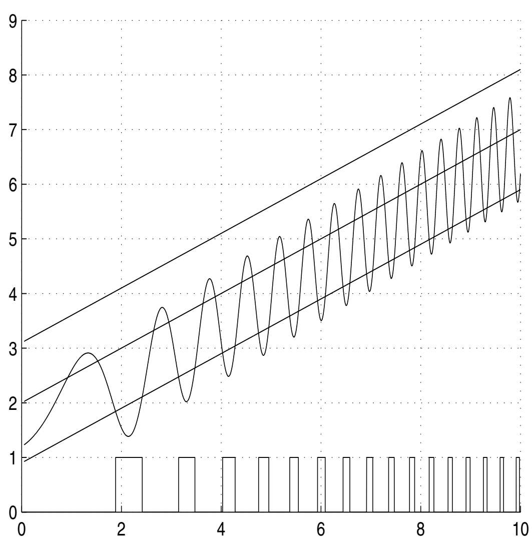

Fig. 10. Typical signals of the characteristic predictor circuit.

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 [15] [17] [24] .

V. Conclusions

The robust analog circuit solutions provide a consistent, high-level operation, which is field programmable analog arrays and changeable. The safety and effectiveness of the analog systems can be increased, the performance uptake, the maintenance and repair costs can be reduced. We can carry out an in-operation testing and can eliminate incorrect signal levels. The significance of noise as an error source can be reduced, the over-control errors can be eliminated. The different control processes and system topologies give solution in case of predictable and unpredictable errors too. There are further secondary benefits if the analog system is attached to the embedded controllers via a digital surface. The above discussed solutions offer the use of the programmable analog circuits in the robust analog systems. [21] [25]

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