Preface

Analog signal processing structures represent an important part of analog VLSI designs, a multitude of specific techniques being developed in order to maximize their performances. Comparing with digital structures that respond to the same requirements, the analog approach of signal processing presents the advantages of a real-time operation and of the possibility of their facile integration, especially for portable devices. The development of specific superior-order approximation functions that constitutes the functional cores of the function synthesizer circuits presented in this book increases the flexibility of designs, making them comparable, from this point of view, with latest digital computational structures. The design of analog signal processing computational structures from the perspective of multifunctionality (the utilization of a single functional core for generating a large number of continuous functions) additionally reduces both power consumption and silicon area per implemented function.

The aim of this book is to propose a large diversity of analog function synthesizer structures, based on accurate approximation functions, that are able to implement a multitude of circuit functions, with many applications in analog signal processing: exponential, Gaussian, or hyperbolic functions. Generalizing the methods for obtaining these particular functions, the book analyzes superior-order approximation functions, which represent the core for developing CMOS analog nonlinear function synthesizers.

The method presented for generating continuous functions is based on the utilization of superior-order approximation functions. Comparing with the classical method of designing analog function synthesizer circuits using the limited Taylor series expansion of the generated function, the utilization of high-accuracy approximation functions permits an important reduction of the overall complexity of designed computational circuits. In order to maximize the performance/complexity ratio, some fundamental requirements must be taken into account when developing the general form of an approximation function. First, technical considerations referring to the CMOS implementation of these approximation functions impose a particular structure of primitive mathematical functions that compose them. Because the simplest and most performance basic CMOS computational building blocks are represented by the squaring and multiplying/dividing circuits, the fractional and the squaring functions represent the most convenient primitive mathematical functions for developing any superior-order approximation function. Second, the requirements for an increased accuracy of approximations impose an independence of the output variable on technological parameters, from this point of view the current-mode operation of the basic building blocks representing the best possible choice. Additionally, the current-mode operation contributes to a reduction of the minimal supply voltage and to an important improving of the computational structures' frequency response. In most cases, the general form of the approximation function is represented by a linear combination of a finite number of primitive functions (usually smaller or equal with two) and some additional terms (linear or polynomial terms). The particular forms of these superior-order approximation functions are developed considering the specific type of the approximated function (odd or even functions).

A general tradeoff that must be taken into account is referring to relation between the computational structures' accuracy and complexity and their capability of generating a multitude of continuous functions. The increasing of the number of computed functions increases also the complexity of the function synthesizers and reduces the possible accuracy that can be obtained using a fixed approximation function. On the other hand, the grouping of approximated functions in some specific classes and the development of analog function synthesizer circuits dedicated only to one specific class maximize the performances of computational structures and decrease the complexity of their implementation.

The first chapter presents possible realizations of exponential function synthesizer circuits, developing third-order and fourth-order approximation functions in order to design accurate computational structures. The circuits are structured considering the order of the approximation functions they are based on and illustrating the block diagrams and the concrete implementations of these structures. Exponential function synthesizer circuits are evaluated from the point of view of their accuracy in analytical and graphical manner, for each particular computational structure being evaluated its output dynamic range. A new general method for increasing the exponential function synthesizers' output dynamic range is presented, the reducing of the effective variation range of the input variable using proper variable changing contributing to fulfill this desiderate.

High-accuracy superior-order approximation functions are developed in the second chapter for generating the Gaussian function. The particular form of the approximation functions presented in this chapter represents a consequence of some important particularities of the Gaussian function (which is even function that allows facile variable changing in order to increase the output dynamic range of computational circuits that generate it). The chapter analyzes a multitude of possible realizations of Gaussian function synthesizer circuits, based on superior-order particular approximation functions: fourth-order, sixth-order, and eighth-order approximation functions. In order to improve the area of operation of developed Gaussian circuits, convenient variable changing are considered for each analyzed approximation function. Analytical and graphical analyses are performed for determining the performances of these superior-order approximation functions.

The analysis, design, and performances' optimization of hyperbolic functions represent the goal of the third chapter. The nonlinear function synthesizer circuits, developed for generating the hyperbolic sinusoidal, co-sinusoidal, and tangent functions use specific superior-order approximation functions. The form of these approximation functions is strongly influenced by the particularities of hyperbolic functions, being correlated with the requirements of minimizing the computational circuits' complexity.

The fourth chapter analyzes the possibility to realize general analog function synthesizer structures, designed for implementing a multitude of circuit functions. Comparing with classical designs in which for any particular function it is designed a specific circuit, the re-utilization of the same functional core for generating a large number of circuit functions presents important advantages. As the most important part of the power is consumed by the functional core and because the largest complexity and design efforts are concentrated for designing this part of the circuit, the utilization of a single computational structure for generating a multitude of circuit functions removes all redundant parts of the circuits and, in consequence, strongly reduces the power consumption and the required complexity per implemented function. The second-order approximation is not able to approximate with enough accuracy a continuous function, resulting the necessity of increasing the order of approximation for improving the analog function synthesizer' performances. In the context of the equilibrium that must be considered between the accuracy of computational circuits and the complexity of their CMOS implementation, the third-order of the approximation represents, for most of continuous functions, a convenient choice. Similar technological restrictions like in previous chapters must be considered for the implementation in CMOS technology of these third-order approximation functions.

For applications that require a more accurate approximation of the circuit functions, the fourth-order approximation is usually enough accurate for generating the most important circuit functions, from the perspective of their applications in analog signal processing and of fulfilling the conditions imposed by these applications. Comparing with previously presented computational structures based on third-order approximation functions, the same requirements must be taken into account when designing a high-precision fourth-order analog function synthesizer circuit.

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