

Preface

Signal processing represents an important domain of electronics, in the last years many efforts being directed for improving the performances of these structures.

The approach of the signal processing from an analog perspective presents the advantage of allowing an important reduction of the circuits' power consumption. The compact implemented structures are compatible with ultimate low-power designs and find a lot of applications such as portable equipments, wireless nano-sensors or medical implantable devices. Even the power consumption is continuous for analog circuits comparing with digital structures that consume only in the switching intervals, the possibility of an important reduction of designs' complexities and of the number of their constitutive active devices strongly decrease the medium power consumption per unity of time for analog designs. Moreover, low-power analog signal processing circuits are often implemented using subthreshold-operated MOS transistors, having extremely low values of drain currents, this fact producing an additionally lowering of the total power requested by the analog computational structures. The original approach of designing analog signal processing circuits using multifunctional structures also contributes to the decreasing of power consumption per implemented function.

Another important advantage of analog signal processing is that the speed of circuits is usually greater than the speed of digital computational circuits, allowing a real time signal processing.

Two important classes of analog signal processing circuits can be identified. The first class corresponds to linear structures, such as differential amplifier structures, multiplier circuits or active resistor structures, being necessary to develop particular linearization techniques in order to improve their general performances. The second class of analog signal processing circuits covers the area of nonlinear structures: squaring or square-rooting circuits, exponential structures or vector summation and Euclidean distance circuits. In this case, the most important goal is to minimize the approximation error of the implemented function. In order to improve the circuits' frequency response, a part of analog signal processing circuits are implemented

using exclusively MOS transistors biased in saturation region. In cases in which the low-power operation is crucial, the subthreshold operation of MOS active devices represents the single choice for the designer.

In order to obtain an important reduction of design costs and of power consumption for the designed circuits, multifunctional computational structures can be implemented. Their principle of operation is based on the possibility of a multiple use of the same functional cell that is named multifunctional circuit core. As the design effort is mostly focused on the improving of the core performances and because the most important silicon area is consumed by the multifunctional core, the reutilization of this part of the multifunctional structure for all circuit functions will strongly decrease the complexity and power consumption per implemented function. The multifunctional structures present the important advantage of a relatively simple reconfiguration, small changing of the design allowing to obtain all necessary linear or nonlinear circuit functions.

The first chapter is dedicated to the presentation of linearization techniques for improving the performances of CMOS differential structures, fundamental circuits in VLSI analog and mixed-signal designs. The mathematical fundamentals are structured in eight different elementary mathematical principles, each of them being illustrated by concrete implementations in CMOS technology of their functional relations.

As it exists a relative limited number of mathematical principles that are used for implementing the multiplier circuits, the first part of Chap. 2 is dedicated to the analysis of the mathematical relations that represent the functional core of the designed circuits. In the second part of the chapter, starting from these elementary principles, there are analyzed and designed concrete multiplier circuits, grouped according to their constitutive mathematical principles. Both current and voltage multiplier circuits are presented, their operation being extensively described in Chap. 2.

The squaring function can be relatively easily obtained considering the intrinsic squaring characteristic of the MOS transistor biased in saturation region. Referring to the input variable, the squaring circuits can be clustered in two important classes: voltage squarers and current squarers, for both of them, the output variable being, usually, a current. The first part of Chap. 3 is dedicated to the analysis of the mathematical relations that represent the functional core of the designed circuits, while, in the second part of the chapter, starting from these elementary principles, there are analyzed and designed concrete squaring circuits, clustered according to their constitutive mathematical principles.

An important class of VLSI computational structures is represented by the square-root circuits. Frequently implemented using a translinear loop, they exploit the squaring characteristic of MOS transistors biased in saturation region. The presented design techniques are based on five different elementary mathematical principles, each of them being illustrated in Chap. 4 by concrete implementations in CMOS technology.

Exponential circuits represent important building blocks with many applications in VLSI designs. In CMOS technology, the exponential law is available only for

the weak inversion operation of MOS transistor, the circuits designed using subthreshold-operated MOS active devices having the disadvantage of a poor frequency response. Thus, circuits realized in CMOS technology that require a good frequency response can be designed using exclusively MOS transistors biased in saturation region. The first part of Chap. 5 is dedicated to the analysis of the mathematical relations that represent the functional core of the designed circuits. In the second part of the chapter, using these elementary principles, there are analyzed and designed concrete exponential circuits, grouped according to the mathematical principles they are based on.

Chap. 6 is dedicated to the analysis and design of Euclidean distance circuits, classified (depending on their input variable), in computational structures having current-input or voltage-input vectors.

Functionally equivalent with a classical resistor, but presenting many important advantages in comparison with them, active resistor structures are extensively analyzed in Chap. 7. The goal of designing this class of active structures is mainly related to the possibility of an important reduction of the silicon area, especially for large values of the simulated resistances. The techniques presented for designing active resistor structures are based on six different elementary mathematical principles, each of them being illustrated by concrete implementations in CMOS technology.

A multitude of fundamental linear or nonlinear analog signal processing blocks can be realized starting from the same core, the optimization techniques implemented for the core being efficient for all derived circuits. The structures that can be realized starting from an improved performance multifunctional core are: differential amplifiers, multiplier circuits, active resistors (having both positive and negative controllable equivalent resistance), squaring, square-rooting or exponential circuits. Additionally, developing proper approximation functions, multifunctional structures are able to generate any continuous mathematical function. The circuits shown in Chap. 8 are based on four different elementary mathematical principles, being also presented concrete implementations in CMOS technology of these complex computational structures.

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