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Guest Editorial

Nowadays, the area of analog integrated circuits is facing some serious challenges due to the ongoing trends to low supply voltages, low power consumption and high frequency operation. The situation is becoming even more complicated by the fact that many transfer functions have to be tunable or controllable.

A promising approach to face these challenges is given by the class of *dynamic translinear circuits*, which are as a consequence receiving increasing interest. Several different names are used in literature: log-domain, exponential state-space, current-mode companding, instantaneous companding, tanh-domain, sinh-domain, polynomial state-space, square-root domain and translinear filters. In fact, all these groups are (overlapping) subclasses of the overall class of dynamic translinear circuits.

Dynamic translinear circuits are based on the dynamic translinear principle, which is a generalization of the conventional, i.e. static, translinear principle, which was treated previously in Vol. 9, No. 2 of *Analog Integrated Circuits and Signal Processing* and can be applied to the structured design of circuits to implement both linear and non-linear differential equations, such as, e.g. filters, oscillators, RMS-DC converters, PLLs and chaotic circuits. In fact, the dynamic translinear principle facilitates a direct mapping of any function, described by a polynomial differential equation, onto silicon.

To address this growing field, which is of both practical and theoretical interest, this Special Issue of *Analog Integrated Circuits and Signal Processing* on *Dynamic Translinear Circuits* has been compiled. It comprises ten contributions, coming from recognized ''dynamic-translinear'' researchers in Europe and North America.

The first paper, by Mulder, Serdijn, van der Woerd and van Roermund, gives an overview of this young, yet rapidly developing, circuit paradigm. Emphasis is placed on methods for analysis and synthesis, rather than on specific circuit implementations. The static and dynamic principles are reviewed and the theoretical relevance, or better, irrelevance, of a generalization of the dynamic translinear principle to strong inversion MOS, resulting in so-called square-root domain filters, is discussed. Finally, state-of-the-art results obtained for both linear and non-linear applications are treated.

The second paper, by Drakakis and Payne, presents a low-level treatment of the non-linear dynamics encountered in log-domain structures, by means of a non-linear circuit element termed a Bernoulli Cell. This cell comprises an NPN BJT and an emitter-connected grounded capacitance, and its dynamic behavior is determined by a differential equation of the Bernoulli form. This results in a system of linear differential equations, which describe the dynamics of the derived log-domain state variables. The approach aids the analysis of log-domain circuits, and allows the internal non-linear currents to be expressed in closed analytical form. A worked example for a specific topology with confirming simulation results is presented.

The third paper, by Leung and Roberts, discusses the analysis of log-domain integrators in the presence of major time-invariant bipolar transistor imperfections, being parasitic emitter and base resistances, finite beta, Early effect and area mismatches. These results are subsequently used to predict the transfer function deviations of biquadratic filters, for both lowpass and bandpass filter responses. Electronic compensations schemes are proposed and their effectiveness verified by computer simulations.

The fourth paper, by Tola and Frey, compares several different class AB translinear filters, of which two are new, in terms of their noise and distortion behavior using analytical and simulation results. The study, although approximate, suggests ways in which both noise and distortion performance may be optimized by appropriate choice of circuit topology. Other practical aspects of the designs, being transistor mismatch and delay, are also discussed.

The fifth paper, by Edwards and Cauwenberghs, describes the synthesis of single-ended, first-order filter circuits, starting from the static and dynamic circuit principle. It is shown how higher-order filters can be easily constructed from these first-order building blocks. Additional issues related to audio-frequency filter design are addressed and measurement results of a 15-channel filter-bank system, fabricated in both a $2\,\mu$ and a $1.2\,\mu$ BiCMOS IC process, are presented.

The sixth paper, by Worapishet, Mahattanakul and Toumazou, presents a transistor-only linear tunable companding integrator, utilizing the non-linear base-emitter diffusion capacitance of the BJT. A first-order approximation of the circuit characteristics is explained, followed by a brief discussion on the departure from ideal characteristics due to transistor non-idealities. Experimental results indicate that the circuit exhibits a low-distortion performance to frequencies approaching the transit frequency of the transistor. The integrator time constant can be simply adjusted over an octave using a current source.

The seventh paper, by Fragnière and Vittoz, presents a CMOS implementation of a log-domain transcapacitor. The circuit integrates a differential input current into an output ''pseudo-voltage'' and is thus compatible with ''pseudo-conductances'' implemented with a single transistor. The circuit is analyzed and a collection of log-domain reactive components and small circuits using it is proposed.

The eighth paper, by Wu and El-Masry, presents a design technique for micro-power continuous-time filters, employing CMOS devices operating in weak inversion, starting from a CMOS log-domain integrator. The effects of the device non-idealities on the integrator performance are investigated and verified by computer simulations. Its application in a fifth-order Chebyshev lowpass ladder filter indicates a proper operation from a 1.5 V supply and a frequency control range of three decades (from 100 Hz to 100 kHz). At 100 kHz, its power dissipation equals 1.27 μW.

The ninth paper, by Masmoudi, Serdijn, Mulder, van der Woerd, Tomas and Dom, proposes a current-mode synthesis method for dynamic translinear filters. A second-order audio filter for hearing instruments, employing subthreshold MOS transistors, is presented. It operates from a supply voltage down to 1 V and consumes 5 μA. The filter cut-off frequency and its quality factor can be tuned from 600 Hz to 13 kHz and from 0.6 to 1.1, respectively. Mismatch problems are investigated on the circuit level and an on-chip compensation method is proposed.

Finally, the tenth paper, by Payne and Eskiyerli, discusses the implementation and performance of square-root domain filters that are based on the large signal square law characteristic of MOS transistors in strong inversion. The design of two non-linear subcircuits, being a geometric mean circuit and a squarer/divider, is described and various performance issues, such as mobility reduction, channel length modulation, velocity saturation and threshold voltage mismatch, are addressed. Finally, simulation and measurement results are presented to validate the approach.

The editors would like to thank all the authors who submitted papers, all the reviewers who participated in the final selection of the papers, and the Kluwer Editorial Staff for their efforts in creating this special issue. We hope that this issue will provide you, the reader, new insights into the potential of dynamic translinear integrated circuits.

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Wouter Serdijn was born in Zoetermeer (''Sweet Lake City''), The Netherlands, in 1966. He started his course at the Faculty of Electrical Engineering at the Delft University of Technology in 1984, and received his ''ingenieurs'' (M.Sc.) degree in 1989.

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