

# Audio Signal Processing Using Mixed Hardware-Software Approach

\*A. Romiński, Z. Ciota and A. Napieralski

Department of Microelectronics and Computer Science,  
Technical University of Lodz,  
al. Politechniki 11, 93-590 Lodz - Poland,  
\*rominski@dmcs.p.lodz.pl  
\*\*ciota@dmcs.p.lodz.pl  
\*\*\*napier@dmcs.p.lodz.pl

## ABSTRACT

In this paper the possibilities of modern audio-processing systems have been described. One of the most important tasks is a proper definition of feature vectors. For example, the long-term spectra vector has been chosen as the background for text-independent verification system. In this case it is possible to compare specific features of the current speaker voice with the computer base containing stored vectors of known speakers. As the results, the distances between the vector of unknown person and the vectors of the persons included in the base have been obtained. Afterwards, the possibility of hardware realization of some voice processing components has been discussed.

**Keywords:** DSP, VLSI, switched currents, filter, audio

## 1 INTRODUCTION

One of the important problem is the choice of proper software. In the case of speaker recognition the application of Java software permits to obtain efficient program for relatively small speaker base. Unfortunately, our attempt to use Java in the case of emotion recognition was unsuccessful, because the precision of feature vector calculations was insufficient.

Finally, we applied Matlab environment, where spectrograms have been calculated with high precision in reasonable time. Such spectrogram is the base for calculations of feature vectors.

More efficient systems can be obtained using mixed hardware-software approach. For example, current mode realizations of analog components permit to obtain an efficient tool for audio signal processing. As the most important analog realizations we can mention multiplier, analog-to-digital converter (linear and non-linear) and current mode filters. Low-power, highspeed and low-voltage comparators are more and more needed for market increasing of wireless devices, for instance cellular phones, global system for mobility and wireless local area networks, where verification of speaker emotions and speaker

recognizing plays a significant rule. Comparators are often used in nowadays microelectronics, therefore different structures can be applied according to given requirements.

Comparison of the different design methods permits to choose the best one with regard to the kind of technology in which the system of voice processing should be integrated.

Computer simulations indicate that the proposed blocks have simple structures and have low sensitivity to variations in technological parameters. Switched current (SI) circuits can be easily manufactured in standard CMOS processes because both the first- and the second generation.

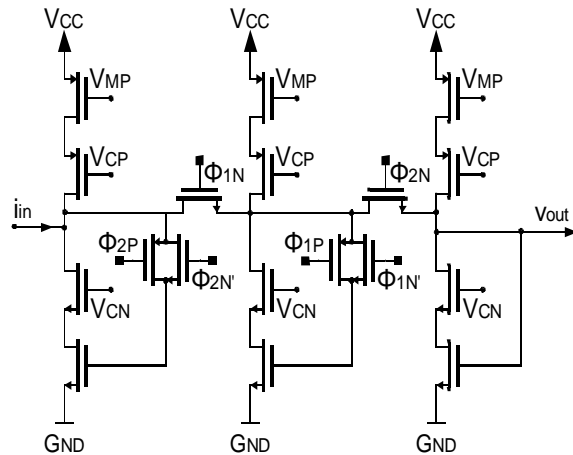


Figure 1: CMOS SI differentiator structure.

SI circuits are composed of only CMOS transistors. The fig. 1 shows relised discrete differentiator built only with usage of MOS transistors. Additional advantage is the simplicity of implementing various mathematical operations, such as summation, comparison, inversion and multiplication. Therefore, current mode techniques are commonly used in discrete-time analog signal processing, neural networks, A/D and D/A conversion [1].

Application of transconductance amplifiers in active filter realization generated on the basis of passive RLC filter permits to obtain high frequency structures. Transconductor possibilities are very high, because its

bandwidth is wide for high output current, i.e. low load impedance [2].

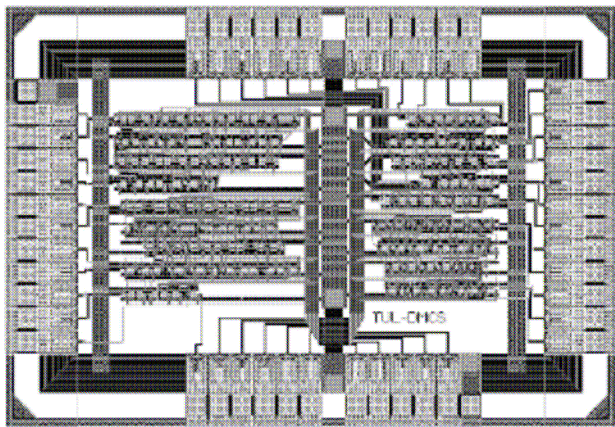


Figure 2: SI filters layout.

Taking into account the above remarks, a system of audio processing has been designed and performed in CMOS technology (fig. 3). The prototypes contain high precision CMOS integrated filters with low sensitivity to technological mismatches. The proposed laboratory stand permits to obtain accurate current measurements for such circuits. The prototype presented in fig 2 contains also digital memory to control all functions of audio signal processing, including software radio capabilities. The implementation of the proposed algorithm as hardware-software system, including mixed analog-digital approach, should improve the speed and also the quality of the system.

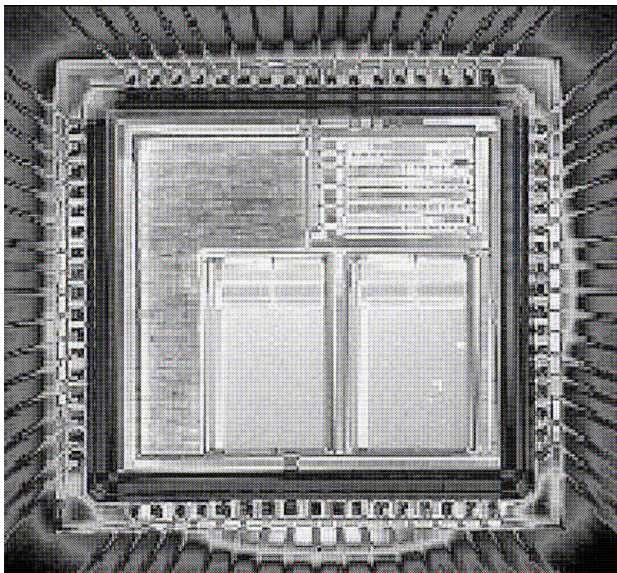


Figure 3: Microphotograph of system on chip for audio processing (0.35µm technology).

## 2 SYSTEM FOR AUDIO SIGNAL PROCESSING

The mentioned mixed signal system for audio signal processing, shown at fig. 4 was built for prototype purposes and preliminary researches over integration of different parts on a monolithic silicon die. The bulk CMOS technology with all advantages (economic) and disadvantages (quality) was used. The future belongs to SOI CMOS technology, especially in area of System-on-Chip integration. Better substrate noise isolation, lower threshold voltages of MOS transistors and lower power dissipation are key aspects in this case.

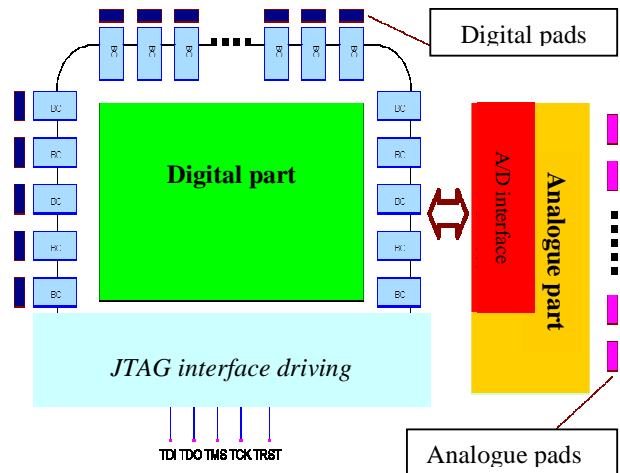


Figure 4: Block diagram of the audio signal processing system.

The digital part has driving purposes (analogue part configuration) and also software radio signal processing. The novel method of FM signal demodulation was introduced based on asynchronous digital circuit, using standard CMOS digital cell from the technology vendor (Austria Microsystems). Direct pulse counting was used for FM detection, the obtained samples were processed by the fixed-point arithmetic circuit. Digital sigma-delta modulator was used as additional output interface.

The analogue part presented on the fig. 4 is designed as 4 SI reprogrammable cells. The coefficients for this part are loaded from the digital part.

## 3 SI REPROGRAMMABLE CELLS

The idea of reprogrammable discrete-analogue cells based on SI technique was introduced in order to obtain better flexibility and wider usage of the prototype circuit. Nowadays solution in switched current area are generally academic, no industrial solution commonly used was

presented. The programmable circuits with discrete-analogue SC (Switched Capacitors) are in the mature phase of development (solutions from Anadigm, Freescale, Cypress etc.).

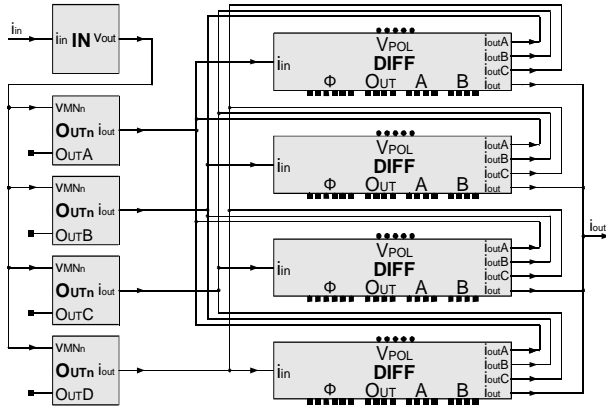


Figure 5: Switched Currents cell outlook

Presented at fig. 5 topology allows to change connections between the cells. The heart of the DIFF cells are differentiator presented at fig. 1, there is possibility of changing clocks for the keys used in the inside and A, B parameters of the differentiator ( $X = A + B \cdot z^{-1}$ ). Additionally cascades bias voltages are regulated outside the integrated circuit.

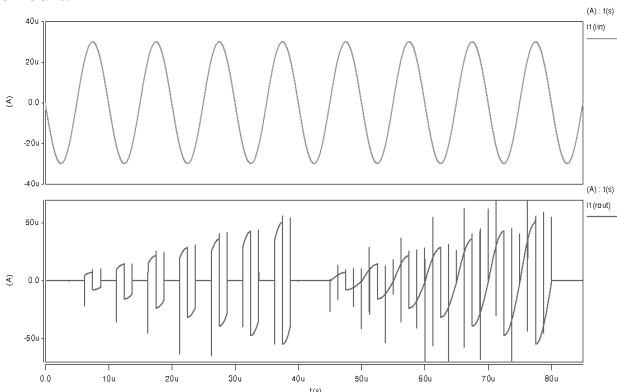


Figure 6: Multiplication coefficients changing while feeding the sinusoidal input.

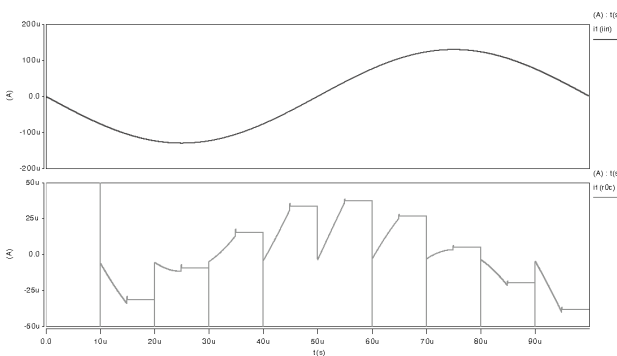


Figure 6: Discrete SI differentiation with sinusoidal input

The simulation of changing the multiplication coefficients (A and B) are presented at the fig. 6, fig. 7 shows differentiator processing sinusoidal signal.

## 4 SUMMARY

The presented results show new possibilities of the system integration level. Combining analogue SI circuits and digital signal processing at the same chip reduces overall costs and gives more robust and flexible circuits.

The System-on-Chip allows to build complete structure for up to date multimedia purposes with low power dissipation and modest costs in high volume production series that is very important for many of the modern portable devices.

The solutions are suitable for sound processing with all novel demands shown enumerated in the introduction.

Presented in this paper reprogrammable SI mini-matrix could be treated as first step in exploration of the very promising technique, often proclaimed as the antecessor of widely used SC discrete-time processing. Lack of the industrial proposals is a gap that potentially could be filled by reprogrammable SI circuits. Higher usage of SI could reveal and improve its negative features which might develop better solution for discrete-time signal processing.

## REFERENCES

- [1] Toumazou C., Lidgey F.J., Haigh D.G. "Analogue IC Design: The Current-Mode Approach" – IEE London 1993
- [2] Handkiewicz A. "Mixed-Signal Systems: A Guide to CMOS Circuit Design" – Wiley 2002