MIXED-SIGNAL DESIGN OF BIOPOTENTIAL FRONT-ENDS

E. M. SPINELLI† and M. A. MAYOSKY‡

† LEICI, Dto Electrotecnia UNLP and CONICET, CC 91 (1900) La Plata. ARGENTINA
spinelli@ing.unlp.edu.ar
‡ LEICI, Dto Electrotecnia UNLP and CICPBA, CC 91 (1900) La Plata. ARGENTINA
mayosky@ing.unlp.edu.ar

***Abstract*— High resolution Sigma-Delta Analog-to-Digital Converters (SDADC) have drastically changed traditional analog signal processing stages. However, as the boundary between analog and digital worlds becomes diffuse, a "mixed-signal processing" approach arises. For instance, analog filters, traditionally implemented as independent processing stages can be easily incorporated in the design of the Sigma-Delta converter, resulting in a more compact approach, with important advantages regarding size and power consumption. In this context, a design technique for mixed-signals front-ends intended for biomedical signals is presented here.**

As an example, the design of an ECG front-end is presented. It accepts DC offsets of ±300mV, presents an AC input range of ±10mV, a -3 dB bandwidth of 100Hz and a total noise less than 10μVp-p, operating at a clock frequency of 57kHz. The front-end provides "fast baseline recovery" features and its transient response fulfills the AAMI standard. A functional prototype was built and tested, validating the design procedure.

***Keywords*— Biopotential Amplifier, AAMI Standard, Sigma Delta Converter, Mixed Signal Processing.**

I. INTRODUCTION

Few decades ago, electrocardiograph recorders were entirely analog, from the electrodes to the graph printer. Nowadays, the tendency is toward fully digital equipment, leading to more flexible systems, which can be easily configured by software, without any hardware change. In order to achieve this, a direct analog-to-digital conversion is required, which implies null or minimum analog signal processing. Two approaches for this technique are shown in Fig.1. In the first one, depicted in Fig. 1(a), the raw analog signal is converted to digital and all the processing is made digitally. Only a small amount of analog circuitry is included at the input stage (input range and impedance adaptation networks). In the second alternative, shown in Fig. 1(b), the boundary between analog and digital domains is diffuse; signals are processed in a mixed signal domain, finally providing a digital output signal.

The latter technique allows adaptation of the frequency response between the input analog signal and the digital output data to a particular application. This is based on sigma delta converters specifically matched to each situation, for example band pass ADC converters for RF receivers (Philips *et al.*, 2004).

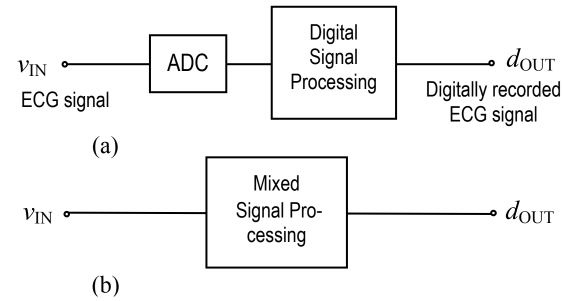

Fig. 1. Direct Analog-to-Digital conversion alternatives. (a) The raw signal is converted to digital and then digitally processed. (b) The ecg signal is processed in a mixed signal domain providing a shaping transfer function between the analog input and the final digital signal.

The scheme of Fig. 1(a) has been successfully used for ECG signal acquisition (Aksenov *et al.*, 2001; McKee *et al.*, 1996) and also in commercial EEG equipments by companies as BIOSEMI™ and NEUROSCAN™. In these cases, the raw electrode signal is converted to digital data and all operations, as gain adjust or dc removal, are made digitally, resulting in very flexible systems. This approach requires using ADCs with dynamic ranges of 20 bits or more to properly represent a small biopotential signal immersed in a high DC electrode offset. Although general-purpose sigma delta ADCs with these resolutions are commercially available, a high clock frequency is needed in order to achieve the required resolution. This in turn increases power consumption, which is always a limited resource in battery powered circuits.

This work proposes a mixed-signal technique for biomedical front-ends that allows design of the SDADC transfer function, thus resulting in an efficient use of the available dynamic range. As an example, the design of an ECG front-end fulfilling the AAMI standard is also presented.

II. BASIS OF THE SIGMA DELTA CONVERTER

A simplified scheme of SDADC is shown in Fig. 2. It consists of a negative feedback loop that minimizes the difference between the integral of the input (v_{IN}) and the integral of the digital output y_D. So, the low frequency components of y_D will correspond to v_{IN}. The digital signal y_D also contains quantization noise, which presents components up to one-half the sampling frequency