A Switched Current Mirror based VLSI Architecture of 1-D DCT for Compressed ECG Signal Acquisition

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***Abstract*—The discrete cosine transform (DCT) has been identified as a potential basis for compressed sensing (CS) due to its spectral compaction property. In real-time biomedical applications, a discrete-time analog architecture of the DCT processor has been proposed as a low-energy alternative to digital realization. Some compression applications in image and video processing have reported analog 2-D DCT architectures in either charge mode or current mode. Here, a switched current mode circuit realized 1-D DCT in a biomedical CS system, outperforming charge mode with a simpler design and no capacitor issues. Using a current mode matrix vector multiplier (MVM), power consumption was reduced to 9.2μW with 41dB PSNR accuracy in SPICE simulations (PTM 65nm CMOS). MATLAB-SPICE co-simulation validated performance with ECG signals at compression ratios (CR) of 0.75 and 0.875.**

***Keywords*—discrete cosine transform, compressed sensing, switched current mirror, matrix vector multiplier, co-simulation**

I. Introduction

Compressed sensing [1] has recently gained attention among the researchers due to its popularity in applications such as image acquisition in complex image sensors and multi-channel sensors in wide body area networks (WBAN) [2], [3]. It involves acquiring a sparse signal either in the time or frequency domain and then reconstructing the original signal using an appropriate algorithm. The primary advantage of CS lies in its significantly lower energy requirement compared to traditional signal sensing at the Nyquist sampling rate.

In compressed sensing (CS) based systems [4], it is assumed that a signal vector x of length N can be reconstructed from M measured samples, where $M < N$. These measured samples, denoted by $\hat{x}$, represent a sparse version of x in a particular transform domain. Mathematically, the sensed signal y of length M is obtained by applying an $M \times N$ random measurement matrix ϕ to $\hat{x}$, as shown in (1) [5],

$$y = \phi \cdot \hat{x} \tag{1}$$

Again the signal $\hat{x}$ is transform domain vector of x with basis ψ.

$$\hat{x} = \psi \cdot x \tag{2}$$

The DCT is a widely used transform technique for its ability to condense most of the signal's energy into a few low-frequency components. This property makes the signal sparse in the frequency domain, which is advantageous for compressed sensing.

A. Overview of 1-D DCT

The type-II DCT [6] based sparsifier in compressed sensing uses 1-D/2-D DCT technique. Mathematical equation for DCT of a signal x of length N is given by,

$$\hat{x}(k) = \sum_{n=0}^{N} x(n) \cdot Cos\left[\frac{\pi}{2N}(2n+1)k\right] \tag{3}$$

The hardware realization of DCT in CS applications consists of key components such as analog-to-digital converter (ADC), multiplier & accumulator unit (MAC), memory unit, and fast DCT algorithm [7], [8]. Applications where the precision burden is not there it is possible to get rid of ADC and complex MAC operations with the introduction of analog architecture. This makes it possible to realize the DCT at very low energy and area requirement.