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A VLSI DESIGN FOR HIGH–QUALITY CODEC

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RÉSUMÉ

Les nouveaux projets parrainés par le Ministère des Communications et le Conseil National de la Science sont décrits dans cet article. Le nouveau Codec peut avoir un bas taux de bits. Comme LPC Codec, il peut avoir une meilleure performance qu'un DC, avec un taux de bits de 90K bps.

Ce Codec est un cas particulier de la "Forme d'onde " dont le codage est basé sur la "Forme d'onde abstraite" . D'autre part, la nouvelle théorie du "Temps inversé" est plus bénéfique pour la conception du VLSI. Le VLSI nouveau–né est une puce de CMOS de 1.2 um/n–puits. La puce sera fabriquée par un projet commun appelé "MPC", comme MOSIS aux Etats–Unis. Ce projet est maintenant mené dans cinq universités locales.

D'après la théorie du temps inversé, les formes d'onde généralisées décrites dans cet article sont modifiées pour une nouvelle catégorie. Elles sont de formes triangulaires et triangulaires carrées au lieu des formes de dents de scie et de dents de scie carrés. Celles–ci sont des formes d'onde regénérées de la première génération de la "théorie de la forme d'onde abstraite". L'avantage de cette modification est qu'il n'y a pas de changement brutal dans le processus de regénération.

La structure du VLSI du circuit regénéré est réprésentée dans la figure 2. Il y a au moins quatre multiplicateurs dans le chàssis. Mais il n'est pas très convenable de concevoir un circuit logique avec un tel lot de multiplicateurs, parceque la vitesse, le coùt et la précision seront sacrifiés par une implantation directe. La nouvelle méthode décrite dans cet article montrera une nouvelle orientation pour implanter la plupart des processeurs de signal sans multiplicateur.

Dans cetarticle, deux méthodes de l'élimination des multiplicateurs sont développées. Elles sont appelées "Fonction abstraite" et "enregistrement de nombre flotant". Dans la section 1, la théorie de la "forme d'onde absraite" sera brièvement introduite. La théorie du temps inversé sera présentée dans la section suivante. Dans la section 3, les méthodes de suppression des multiplicateurs seront expliquées. La dernière partie de cet article sera consacrée à la conception des puces de VLSI et quelques applications de la "forme d'onde abstraite" seront décrites et prédites.

ABSTRACT

The newly sponsored projects by Ministry of Communications and National Science Council (ROC) are disclosed in this paper. This new Codec can have a low bit–rate as LPC Codec can have and have a performance better than CD quality with a bit–rate as low as 90k bps.

This Codec is a special kind of waveform coding based on **Waveform Abstract (WA)**. Besides, the new time reversal theorem is much beneficial to the VLSI design. The new born VLSI is a 1.2 um/n–well CMOS chip. The chip will be fabricated by a joint project called MPC, the same as MOSIS of USA. This project is now only for five universities domestically.

According to the new time reversal theorem, the generalized Waveforms used in this paper are modified to a new category. They are triangle and squared triangle wave shapes instead of sawtooth and squared sawtooth wave shapes, which are the regenerating waveforms of the first generation design of the **Waveform Abstract Theory**. The advantage of this modification is that there are no abrupt changes in the regenerating procession.

The basic VLSI structure of the regenerating circuit is shown in Fig. 2. There are at least four multipliers in the framework. However it is so inconvenient to design Boolean logic with lots of multipliers since the speed, simplicity, cost and accuracy will be sacrificed by direct implementation. The new method disclosed in this paper will show a new orientation to implement most of the signal processors without multipliers.

In this paper two methods of eliminating multipliers are developed. They are called **Abstracted Functionals** and **Floating Number Registration** respectively. In Section 1, the theory of wave-form abstract is briefly introduced. The time reversal theorem will be presented in the next. In Section 3, the methods of removing the multipliers are demonstrated. The last part of paper is the design of the VLSI Chip and some further applications of waveform abstract are depicted.

1. INTRODUCTION

The Waveform Abstract Theory has been developed for about ten years. The first paper was published in 1985 at this conference at NICE [1]. The fundamental theory can refer to a paper entitled " Two–Dimensional Abstracting Theory and Its Properties [2]. For a normalized version [3] , a convex waveform from t_1 to t_2 can precisely approximated by the followings.

$$f(t) \cong f(t_1) + w_1(t-t_1) + w_2(t-t_1)^2 \quad , t_1 \le t \le t_2 \qquad (1)$$

$$w_1 = -2f(t_2) - 4f(t_1) + 6m_0 \qquad (2)$$

$$w_2 = 3f(t_0) + 3f(t_1) - 6m_0 \qquad (3)$$

and

$$t_2 - t_1 = 1 \qquad (4)$$

In the case of the least square error, another set of equation of the similar form is shown as follows.

$$f(t) \cong f(t_1) + k_1(t-t_1) + k_2(t-t_1)^2 \quad , t_1 \le t \le t_2 \qquad (5)$$

where

$$k_1 = -1.5f(t_2) - 3.5f(t_1) + 30(m_1 - m_2) \qquad (6)$$

$$k_2 = 2.5f(t_2) + 2.5f(t_1) - 30(m_1 - m_2) \qquad (7)$$

The parameter m_n is the nth moment of the convex waveform such that

$$m_n = \int_{t_1}^{t_2} (t - t_1)^n f(t)dt \tag{8}$$

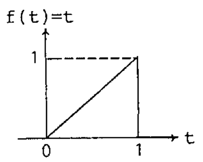
Since two sets of the solutions are convex, the combination of the two is also a convex solution [4]. For example

$$f(t) \cong f(\lambda) = f(t_1) + [\lambda w_1 + (1-\lambda)k_1](t-t_1) + [\lambda w_2 + (1-\lambda)k_2](t-t_1)^2 \quad , 0 \le \lambda \le 1 \tag{9}$$

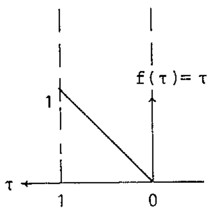
If the specification of the coding is of eliminating zero–mean noise, the parameter λ is 1. On the other hand if minimum squared error is required the parameter λ is then of zero value. The high–quality CODEC of this paper is based on the principle for removing zero–mean noise.

2. Time Reversal Theorem

In order to solve the discontinuity problems of waveform regeneration, a new theorem is developed as follows.



(a) A function of t



(b) A function of τ

Fig. 1 : A Comparison Between Positive–going Time and Negative–going Time.

Any function of t can be perfectly represented by negative–going time τ. The special case of τ is equal to 1–t.

If

$$f(t) = g[f^n(0), t, f^n(1)] \tag{10}$$

the alternate form can be mapped directly by the following formula.

$$f(t) = g[(-1)^n f^n(1), 1-t, (-1)^n f^n(0)] \tag{11}$$

Example I: Taylor Series

$$f(t) = \sum_{n=0}^{\infty} f^n(0)\frac{t^n}{n!} \quad , t \text{ around } 0 \tag{12}$$

$$f(t) = \sum_{n=0}^{\infty} f^n(1)(-1)^n \frac{(1-t)^n}{n!} = \sum_{n=0}^{\infty} f^n(1)\frac{(t-1)^n}{n!} \quad , t \text{ around } 1 \tag{13}$$

Example II : Waveform Abstract

$$f(t) \cong f(0) + [-4f(0) - 2f(1) + 6m_0]t + [\,3f(0) + 3f(1) - 6m_0]t^2 \,, \quad \text{of the positive–going time} \tag{14}$$

When Eq. (14) is mapped onto the τ domain and make the substitution of τ = 1–t, the new approximation has a similar appearance of Eq. (14) as follows.

$$f(t) \cong f(1) + [-4f(1) - 2f(0) + 6m_0](1-t) + [3f(1) + 3f(0) - 6m_0](1-t)^2 \,, \quad \text{of the negative–going time} \tag{15}$$

The reason why m_0 will not be changed can be realized by the following example.

Example III : The moment

By the second theorem of waveform abstract that the m_0 can be approximated by the end samples and end derivatives, such that

$$m_0 = \int_0^1 f(t)dt \tag{16}$$

If f(t) is convex between t = 0 and t = 1, the zero moment can be further approximated by the next equation, such that

$$m_0 \cong \frac{1}{2}[f(0) + f(1)] + \frac{1}{12}[f'(0) - f'(1)] \tag{17}$$

from time reversal theorem Eq. (17) can interchange the roles from Eq. (10) and Eq. (11) such that

$$m_0 = \frac{1}{2}[f(1) + f(0)] + \frac{1}{12}[-f'(1) + f'(0)] \tag{18}$$

It is clear by now that the m_0 in the formulas of waveform abstract will keep the same for the mapped function. From Eq. (1) to Eq. (3) it is observed that the basic waveforms are of sawtooth and squared sawtooth waveforms. If the second convex region is mapped to the form of Eq. (15), the basis waveforms of the two convex regions are tuned into triangles and squared triangles. After some manipulations, the digital form of the regenerator is shown in Fig. 2.

3. Methods of ELIMINATING MULTIPLIERS

Two methods of eliminating multipliers are developed next immediately. The first is called ABSTRACTED FUNCTIONALS, which has no typical structures. However, no matter how complicated the operation is, the operation can be carried on by simple additions for certain. For example, the A or B multiplier with a U/D counter can be implemented by an adder and a buffer as shown in Fig. 3.

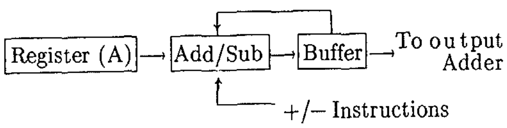


Fig. 3 : A Method For Eliminating A Multiplier For The Functional t and (1–t).

If the operation involved functional t^2 as C, D multipliers do, the operation is first simplified and illustrated in Fig. 4.

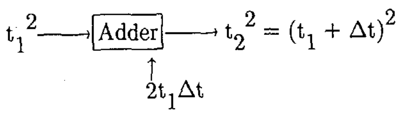


Fig. 4 : A Partial Solution to Eliminate C, D Multipliers, where $\Delta t \rightarrow 0$

Since the operation in Fig. 4 still contains a product of t_1 and $2\Delta t$, the second method, FLOATING REGISTERS, can be utilized. The t_1^2 in Fig. 4 is just the last output of the operation and it is zero at beginning time slot. The method is just load t_1 in a register. This register is namely called floating register When it makes addition with t_1^2, the position is always right–shifted n bits, where

$$n = \log_2 2\Delta t \qquad (19)$$

After the multiplier removing process the digital decoder is redesigned as shown in Fig. 5.

4. The VLSI Design

Based on the block diagram in Fig. 5, the gate level design is shown in Fig. 6. In this paper only the decoder is shown. The reason is that the encoder can be a PCM encoder or a sampler plus an area sampler as hinted is Eq.2 and Eq.3 The analog version of this CODEC was also published in this conference [5]. A testing waveform was compared with regenerating waveform in that paper.

5. Conclusion :

The theory of Waveform Abstract has too many applications. They are designs for the future. If the Abstractor (encoder) and the Regenerator (decoder) interchanged each other, a new channel CODEC is thus formed. The new project sponsored by NSC is the one and called Pulse Shape Modulation (PSM).

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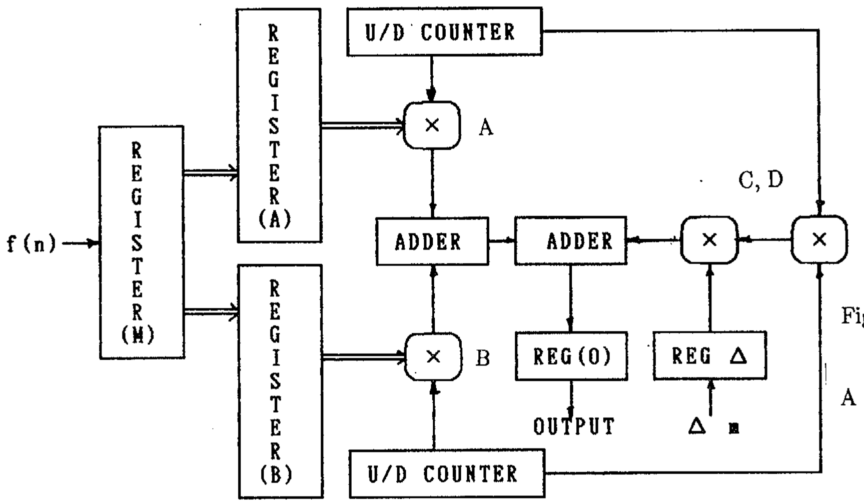

Fig. 2 : A Digital Decoder Based on Waveform Abstract.

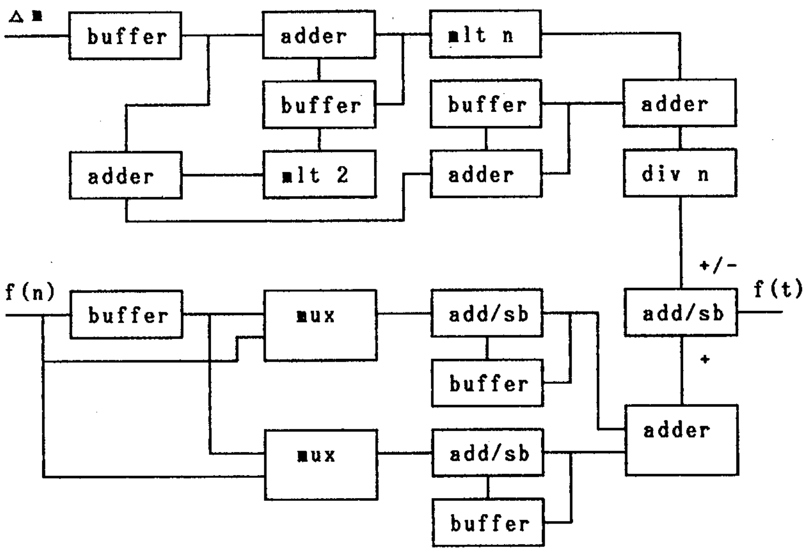

Fig. 5 : The Block Diagram of Decoder

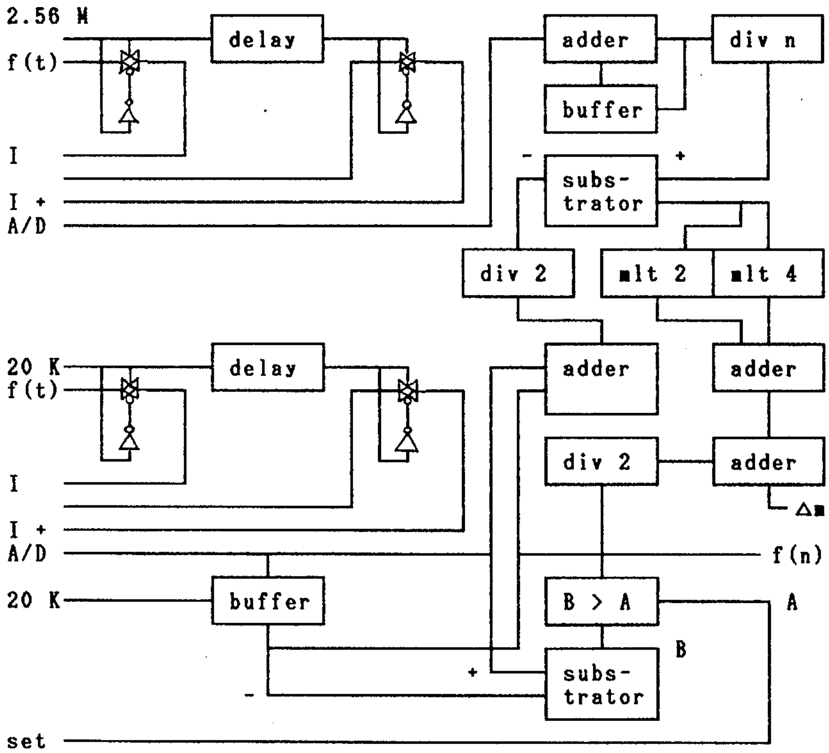

Fig. 6 : A VLSI Design of the Regenerator (Decoder)