A Low-Cost Architecture Design with Efficient Data Arrangement and Memory Configuration for MPEG-2 Audio Decoder

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ABSTRACT

The paper describes a low-cost MPEG-2 audio decoder with a modified fast algorithm for decoding. In the modified decoding scheme, the computation amount of the bottleneck module can be reduced into one-forths of the original one. Also, the major memory storage only requires half size of the standard synthesis subband filterbank. The decoder is developed for the approaches of simplicity and low-cost architecture design, with the techniques of intelligent data arrangement and memory configuration.

1. Introduction

The ISO MPEG-2 audio standard has developed a world-wide standard audio coding algorithm, which can significant reduce the requirements of transmission bandwidth and data storage with low distortion. With the recent advances in VLSI and ATM networking technology, the low-cost MPEG-2 audio decoder in real-time system becomes more and more essential for multimedia applications. This paper presents a low-cost MPEG-2 audio decoder, which is capable of decoding MPEG-2 standard multichannel audio bitstream for Layer I and II with a modified decoding scheme. The modified decoding scheme takes the advantages of low-cost computation and low memory requirements. This paper is also intended to show an efficient data arrangement and memory configuration for low complexity and high efficiency applications.

2. MPEG-2 Audio Coding

The MPEG-2 audio coding standard is an extension of MPEG-1. Emphasis of the new activity is on multichannel and multilingual audio and on an extension of the existing standard to lower sampling frequencies and lower bit rates. Besides, backward compatibility is the key aspects to ensure the existing two channel decoders will still be able to decode compatible stereo information from five multichannel signals. This implies the provision of compatibility matrices, using adequate inverse matrix coefficients. Figure 1 describes the operation of MPEG-2 audio codec and the coding relationship among the five audio channels (L, R, C, LS, RS), the two basic channels (T0, T1) and the three extended channels (T2, T3, T4).

3. The Modified Fast Algorithm for Decoding

The MPEG-2 decoding flow chart is shown in Figure 2. Also, within the synthesis subband filter, the inverse Modified Discrete Cosine Transform (IMDCT), inverse Pseudo Quadrature Mirror Filter (IPQMF) will be further realized as shown in Figure 3. According to the computation power analysis for MPEG-2 audio decoding in Table 1, the most computation load highly depends on the realization of IMDCT module.

First, the original inverse MDCT of a sequence $S(k)$ is defined as following [1]:

$$V_i = \sum_{k=0}^{31} \cos[\frac{(16+i)(2k+1)\pi}{64}] * S_k \qquad (1)$$

$$i = 0, 1, ...63$$

$$k = 0, 1, ...31$$

Taking the advantage of the symmetric properties, the inverse MDCT standard function of Equation (1) can be leaded into a new formula with a reduction of computation amount as following:

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$$V_i = \sum_{k=0}^{15} \cos[\frac{(32+i)(2k+1)\pi}{64}] * [S_k + (-1)^i * S_{31-k}] \quad (2)$$

$$i = 0, 1, ...31$$

$$k = 0, 1, ...15$$

The proposed modified algorithm requires about 1/4 amount of multiplier-accumulate computation of the ISO suggestion method. Moreover, the required size for the RAM buffer in which the QMF data V stored can be reduced only to 512 words per channel, instead of the original size of 1024 words per channel. Table 2 shows the comparisons between the original and proposed decoding algorithms for the computation complexity and memory requirement

4. Architecture Design

Figure 4 describes the overall architecture diagram of our proposed design. It includes 5 primary modules called: preprocessor, inverse quantization, multichannel processor, IMDCT module and IPQMF module. The preprocessor interprets header information from audio bit-stream (DATAIN), then extracts multichannel processing modes and some control informations to store in control register. Inverse quantization module processes the inverse quantization function to get the quantized samples. These samples are fed into multichannel processor to reconstruct five channel samples. The synthesis subband filterbank, viewed as the most computation load, can be performed in two pipeline stage of IMDCT and IPQMF for high throughput consideration. These two modules mainly contain a multiplier-accumulator (MAC) respectively. Finally the output interface performs the parallel-to-serial operation to get the five PCM audio channel samples with some word select signals (WORDSEL) and the associated PCM clock signal (PCMCLK).

5. Efficient Data Arrangement and Memory Configuration

The synthesis window buffer takes the important role in synthesis subband process. Thus we take the efficient memory configuration for synthesis window buffer as shown in Figure 5. This buffer can be divided into five individual memory banks. Each bank matches an audio channel data. The bank can be decomposed further into 32 blocks. Each block contains 16 audio samples.

According to the proposed algorithm and the memory configuration, only 512 clocks is needed for the computation of the IMDCT transform. Also, the IPQMF takes 512 clocks for a cycle. These make the pipeline processing with IMDCT and IPQMF modules with high efficiency and as shown in Figure 6. In each cycle, the data processed from IMDCT are written into synthesis window buffer with two blocks. In the meantime, the IPQMF module reads the data from buffer with some blocks. The memory data access for IPQMF can be realized by the dedicated address generator and illustrated in Figure 7. These imply two pointers address the starting and ending blocks to realize a circular buffer access for the IPQMF shifting.

6. Conclusions

We have described a low-cost MPEG-2 audio decoder. Based on our modified fast algorithm for decoding and efficient data arrangement and memory configuration, the goal for low-cost and high efficiency design is realized.

References

[1] MPEG, "ISO CD 11172-3: coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mb/s", Nov 1991.

[2] MPEG, "ISO CD 13818-3: coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mb/s", Nov 1994.

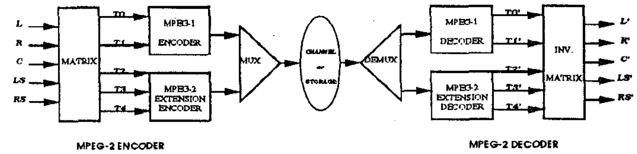

Figure 1: Backward Compatible for MPEG-2 Audio Codec

Table 1: Required Computation Power (MOPS) for MPEG-2 Decoding

Classification	Function	Required Processing Power (MOPS)
IQ	Degrouping	0.88
	Requantization	1.44
	Rescalization	0.96
		3.28
MC	Dematrixing	0.576
	Denormalization	1.44
		2.016
Syn. Subband	IMDCT	61.44
	IPQMF	19.22
		81.36
Total		86.656

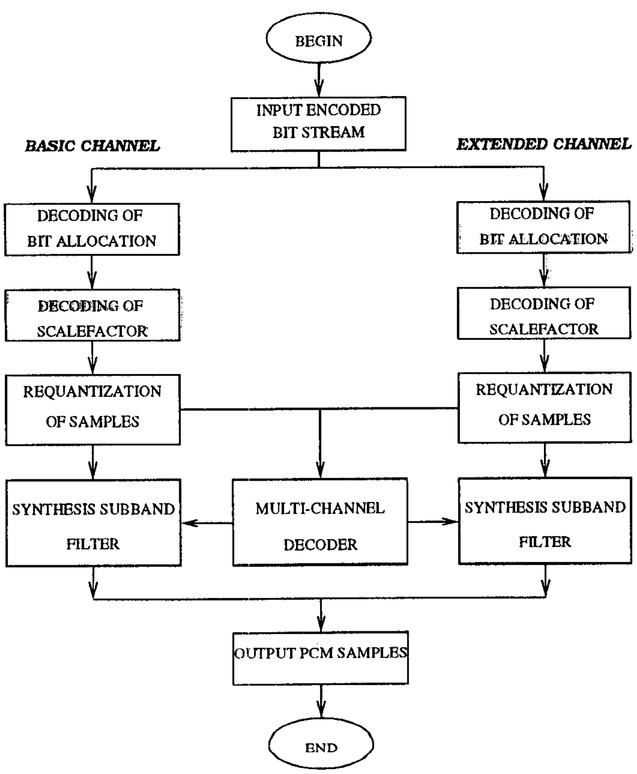

Figure 2: MPEG-2 Decoding Flow Chart

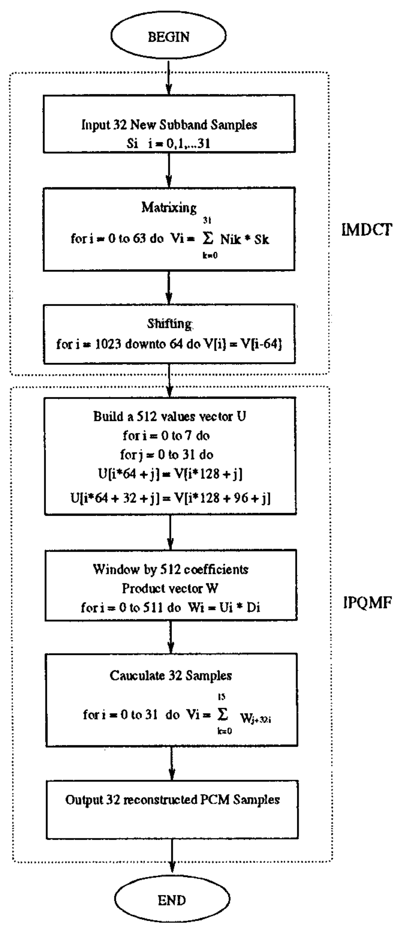

Figure 3: Synthesis Subband Flow Chart

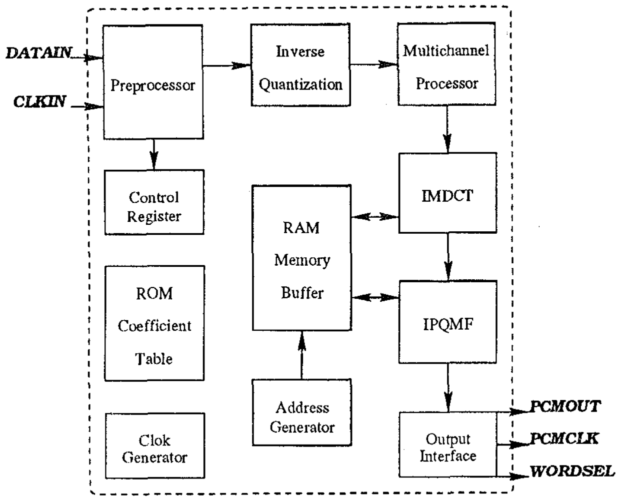

Figure 4: Overall Architecture Diagram

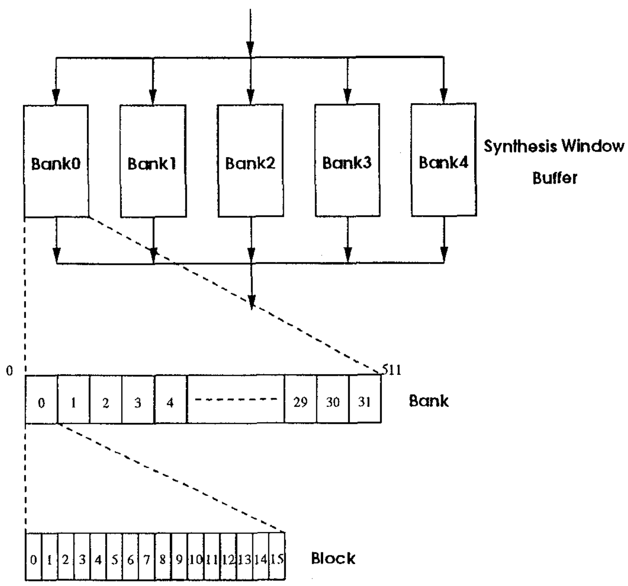

Figure 5: Memory configuration for synthesis window buffer

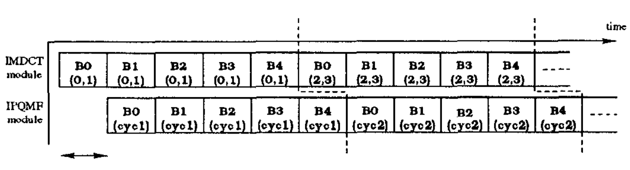

Figure 6: Pipeline processing for IMDCT and IPQMF

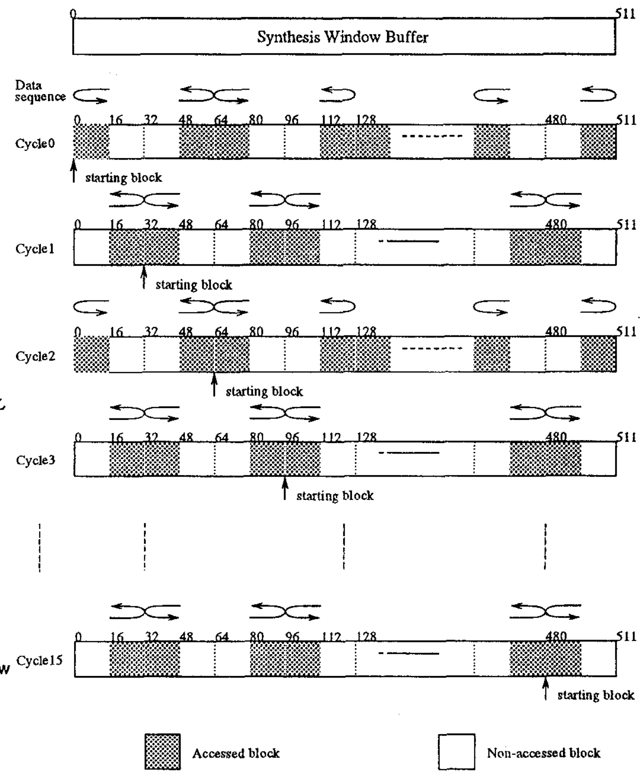

Figure 7: IPQMF Memory Data Access per Audio Channel

Table 2: Comparisons between the Original and Proposed Decoding Algorithms for the Computation Complexity and Memory Requirement

Function	Item	Original	Proposed	Ratio
IMDCT	MAC per transform	2048	512	$\frac{1}{4}$
IPQMF	Buffer Size per channel	1024	512	$\frac{1}{2}$