ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 1, January 2014

Fast DCT Based image compression Using FPGA

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Abstract-Image and video compression is one of the major components used in video –telephony, videoconferencing and multimedia –related applications. In this paper we describe the design and implementation of a fully pipelined architecture for implementing the JPEG image compression standard. The architecture exploits the principles of pipelining and parallelism in order to obtain high speed and throughput. This design aimed to be implemented in Spartan-3E X C3S500E FPGA.

Index terms- Compression, discrete cosine transforms (DCT), FPGA, Huffman Encoding, JPEG, Quantization

I. INTRODUCTION

One of the most popular lossy compression methods is JPEG.JPEG stands for joint photographic Expert Group. The JPEG compression can be divided in to five main steps as shown in Fig.1 color space conversion, down-sampling, 2-D DCT, quantization and entropy coding .the first two operations are used only for color images .for gray scale image we use only last three steps .In this present paper we concentrated on hardware architecture of 2D-DCT, and entropy coding . To achieve high throughput, this paper uses pipelined architecture, rather than single clock architecture.The process of the JPEG starts with color space conversion this process is not applicable to gray scale image, where there is only one luminance component for gray scale image. Color image data in computers is usually represented in RGB format. Each color component uses 8bits to store ,thus ,a full color pixel would require 24 bits .From the fact that human eyes are more sensitive to intensity change rather than color change, the JPEG algorithm exploits this by converting the RGB format to another color space called YCbCr.Y is luminance component ,Cb and Cr are chrominance components After converting the color space, the encoder stores the luminance Y in more detail than the other two chrominance components. The Y components represents the brightness of a pixel, the Cb and Cr components represent the chrominance .this is the same color space as used by digital color television as well as digital video including video DVDs, and is similar to the way color is represented in analog PAL video space. The YCbCr color space conversion allows greater compression without significant effect on perceptual image quality. The compression is more efficient as the brightness information, which is more important to the eventual perceptual quality of the image,is confined to a single channel ,more closely representing the human visual system.

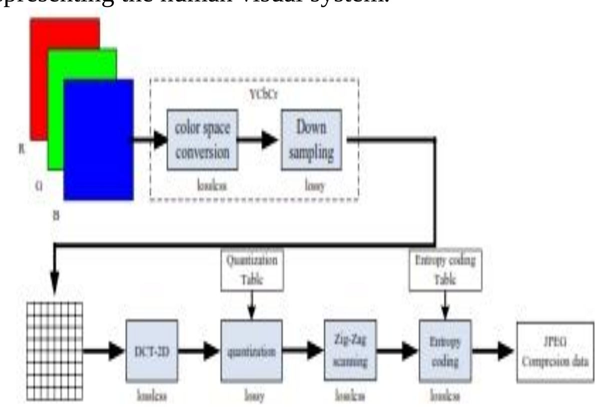

Fig 1- Steps of a JPEG Base Line Compression

The RGB image is converted to YCbCr by using the following equations

Y=0.299R+0.587G+0.114B
Cb=0.564B-0.564Y
Cr=0.713R-0.713Y

The down sampling operation consists in reducing the number of samples of the chrominance components .these are less important to the human eye than the luminance components .the architecture uses a 4:1:1 sampling rate ratio for the Y,Cb,Cr data. Such down sampling results in a 50% reduction in the image data.

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II. OVERVIEW OF DCT

The DCT in two dimensions is the core of the JPEG compression .this is the most critical module to be designed in hardware JPEG compressor because of its high algorithm complexity. There are many algorithms to solve the 2-D DCT with a small number of operations. This algorithm calculates the DCT in one dimension (1D DCT) and uses 29 additions and 5 multiplications. The 2-D DCT has the separability property. Thus using two1-D DCT calculations it is possible to generate the 2-D DCT results. In an 8x8 input matrix, the first 1-D DCT is applied on the matrix lines then the second 1-D DCT is applied on the columns of the first 1-D DCT results matrix. This separation reduces the complexity of the calculation.

The two-dimensional DCT for a square N x N matrix is defined in Figure 2

$$t(i,j) = c(i,j) \sum_{n=0}^{N-1} \sum_{m=0}^{N-1} s(m,n) \cos\frac{\pi(2m+1)i}{2N} \cos\frac{\pi(2n+1)j}{2N},$$

Fig 2 Definition of DCT

c(i,j) is given by c (0,j) = 1/N, c (i,0) = 1/N, and c (i,j) = 2/N for both i and j $\neq$ 0. The input matrix is s, and t is the output matrix. Like the Fourier transform, the DCT maps the signal to the frequency domain. In fact, the DCT is often computed indirectly by first computing a Fast Fourier Transform (FFT). The output matrix, t, represents the different frequency Components of the image. The upper left-hand corner of the DCT matrix provides the Coefficients for the low frequency components while the lower right-hand corresponds to high frequencies. Once the DCT has been computed, the next step in compression is quantization. This is basically discarding less-important information. The human eye is much less responsive to very high-frequency components, so a quantization matrix is derived which rounds the entries in the DCT matrix giving more attention to the lower frequencies while often virtually disregarding the higher frequencies.

Quantization is the part of the process that actually allows for compression. The quantization matrix can be altered to create an acceptable balance between image quality and compression ratio. Once quantization has occurred, the data are encoded to a bit-stream in which form they are stored or transported.

III. QUANTIZATION

The quantization operation is an integer division of the 2D DCT coefficients by pre-defined values. These pre-defined values are stored in tables called quantization tables. In JPEG base line mode there are two quantization tables. one for luminance components (Y)and another foe chrominance components(Cb and Cr).the optimum values of the components in quantization tables are dependent on the application ,but the JPEG standard suggests typical tables that have a good efficiency for any application. This operation eliminates the 2-D DCT coefficients that are less perceptible to the human eye. The result of this operation in an 8x8 matrix of 2-D coefficients is a sparse matrix.

IV. HUFFMAN ENCODER

Huffman block performs Huffman encoding operation. It converts parallel data into serial bit stream. Serial bit stream output is packed in to bytes which are stored in output FIFO .Huffman encoded data are stored to output FIFO.Two FOFOs with size 2x64x8 bits each 2x64x8 for assumption that JPEG encoded stream is no more size than 2xof input uuencoded stream.

Double FIFO block is simply double buffer using two FIFOs.The idea is that while Huffman writes data for next block byte stuffer can read encoded data for previous block.

FIFOs is used instead of RAM because Huffman encoder can write variable number of encoded words to FIFO thus FIFO implementation is easier than using RAM.

V. SIMULATION RESULTS

Logic units	2-D DCT +Entropy coding
Number of slices	2876
Number of slice flip-flops	495
Number of Multiplier	04
Number of bounded IOs	77
Number of 4input LUT	5358
Number of GCLK	01

Table 1-Device Utilization Using Xilinx Spartan- 3E

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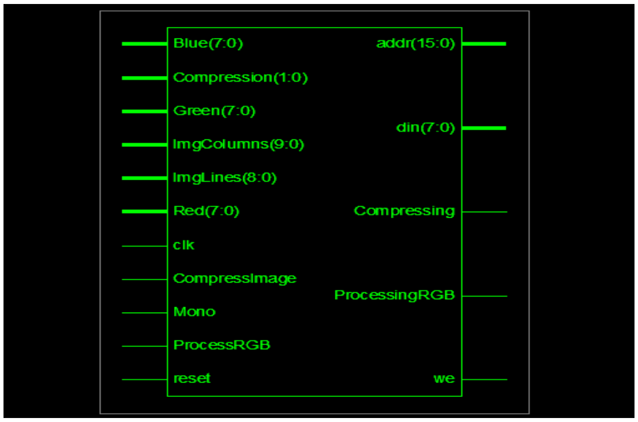

Fig 3-symbol of image coder

The 2D-DCT, entropy coding was described in VHDL.This VHDL was synthesized into a Xilinx Spartan 3E family. System is tested with color image. The complete synthesis results to Spartan-3E FPGA are presented in table 1, whose hardware was fit in an XCS500E device.

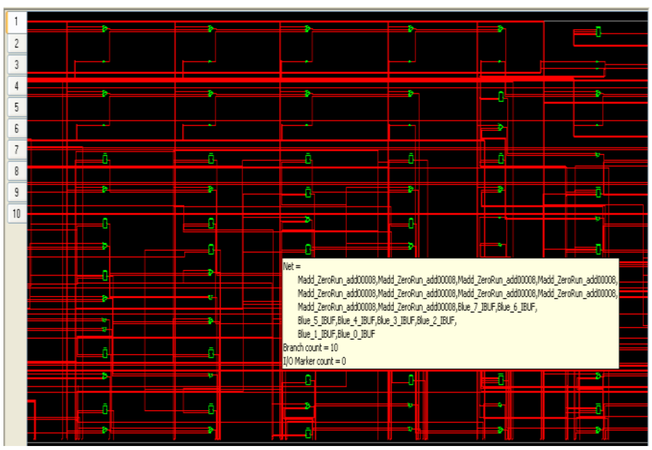

Fig 4-RTL schematic of JPEG image coder

VI.CONCLUSION

This paper presented the architecture of the 2D-DCT combined with the entropy coding is designed using VHDL.system is tested with color image. In this paper ,a new fully parallel architecture based on row –column decomposition has been proposed for the computation of the 2D DCT.The system is highly modular and utilizes a highly parallel structure to achieve high speed performance. Due to its widely identical units, it will be relatively easy to implement and very suited to VLSI implementation.

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