Reconfigurable Architecture for Efficient and Scalable Orthogonal Approximation of DCT in FPGA Technology

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Abstract: - **Approximation of discrete cosine transform (DCT) is useful for reducing its computational complexity without significant impact on its coding performance. Most of the existing algorithms for approximation of the DCT target only DCT of smaller lengths and some of them are nonorthogonal. This paper presents a generalized recursive algorithm to obtain orthogonal approximation of DCT where an approximate DCT of length could be derived from a pair of DCTs of length at the cost of additions for input preprocessing. We perform recursive sparse matrix decomposition and make use of the symmetries of DCT basis vectors for deriving the proposed approximation algorithm. Proposed algorithm is highly scalable for hardware as well as software implementation of DCT of higher lengths, and it can make use of the existing approximation of8-point DCT to obtain approximate DCT of any power of two length,. We demonstrate that the proposed approximation of DCT provides comparable or better image and video compression performance than the existing approximation methods. It is shown that proposed algorithm involves lower arithmetic complexity compared with the other existing approximation algorithms. We have presented a fully scalable reconfigurable parallel architecture for the computation of approximate DCT based on the proposed algorithm. One uniquely interesting feature of the proposed design is that it could be con figured for the computation of a 32-point DCT or for parallel computation of two 16-pointDCTs or four 8-point DCTs with a marginal control overhead. The proposed architecture is found to offer many advantages in terms of hardware complexity, regularity and modularity. Experimental results obtained from FPGA implementation show the advantage of the proposed method.**

Index Terms—**Algorithm-architecture code sign, DCT approximation, discrete cosine transform (DCT), high efficiency video coding (HEVC)**

I. INTRODUCTION

The discrete cosine transform (DCT) is popularly used in image and video compression. Since the DCT is computationally intensive, several algorithms have been proposed in the literature to compute it efficiently]. Recently, significant work has been done to derive approximate of 8-point DCT for reducing the computational complexity .The main objective of the approximation algorithms is to get rid of multiplications which consume most of the power and computation-time, and to obtain meaningful estimation of DCT as well.Haweel [8] has proposed the signed DCT (SDCT) for 8 blocks where the basis vector elements are replaced by their sign, i.e., 1. Bouguezel-Ahmad-Swamy (BAS) have proposed a series of methods. They have provided a good estimation of the DCT by replacing the basis vector elements by 0, 1/2, 1.In the same vein, Bayer and Cintra] have proposed two transforms derived from 0 and 1 as elements of transform kernel, and have shown that their methods perform better than the method in , particularly for low- and highcompression ratio scenarios. The need of approximation is more important for higher-size DCT since the computational complexity of the DCT grows nonlinearly. On the other hand, modern video coding standards such as high efficiency video coding (HEVC) uses DCT of larger block sizes (up to 32 32) in order to achieve higher compression ratio. Wehave proposed a new 16 16 matrix also for approximation of 16-point DCT, and have validated it experimentally. Recently, two new transforms have been proposed for 8-point DCT approximation: Cintra *et al*. have proposed a low-complexity 8- point proximate DCT based on integer functions and Potluri *et al*. have proposed a novel 8-point DCT approximation that requires only 14 addition.

A scheme of approximation of DCT should have the following features:

- It should have low computational complexity.
- It should have low error energy in order to
- provide compression performance close to the exact
- DCT, and preferably should be orthogonal.
- It should work for higher lengths of DCT to
- support modern video coding standards, and other
- applications like tracking, surveillance, and
- simultaneous compression and encryption

II. PROPOSED DCT APPROXIMATION

The elements of -point DCT matrix are given by:

$$c(i,j) = \epsilon_i \sqrt{\frac{2}{N}} \cos \frac{(2j+1)i\pi}{2N}$$

III. SCALABLE AND RECONFIGURABLE

ARCHITECTURE FOR DCT COMPUTATION

We discuss the proposed scalable architecture for the computation of approximate DCT of and 32. We have derived the theoretical estimate of its hardware complexity and discuss the recon figuration scheme.

A. Proposed Scalable Design

The basic computational block of algorithm for the proposed DCT approximation, is given in [6]. The block diagram of the computation of DCT based on is shown in Fig. 1. For a given input sequence $\{x(n)\}, n \in [0, N-1]$, the approximate DCT coefficients are obtained by F=CN ^.Xt

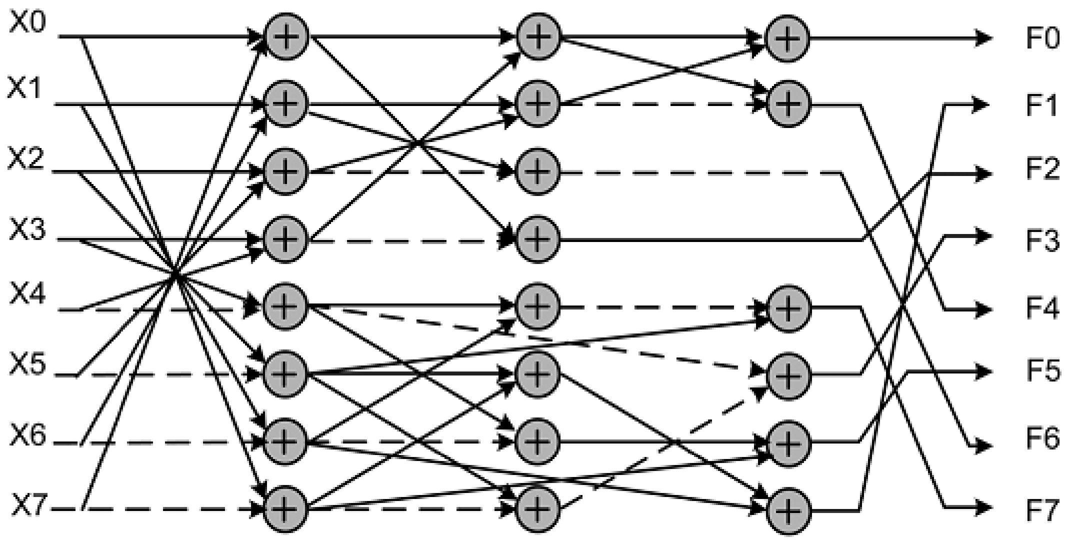

Fig. 1. Signal flow graph (SFG) of (C8). Dashed arrows represent multiplications by 1

An example of the block diagram of is illustrated in Fig. 2, where two units for thecomputation ofareused along with an input adder unit and output permutation unit. The functions of these two blocks are shown respectively in (8) and (6). Note that structures of 16-point DCT of Fig. 2 could be extended to obtain the DCT of higher sizes. For example, the structure for the computation of 32- point DCT could be obtained by combining a pair of 16-point DCTs with an input adder block and output permutation block.

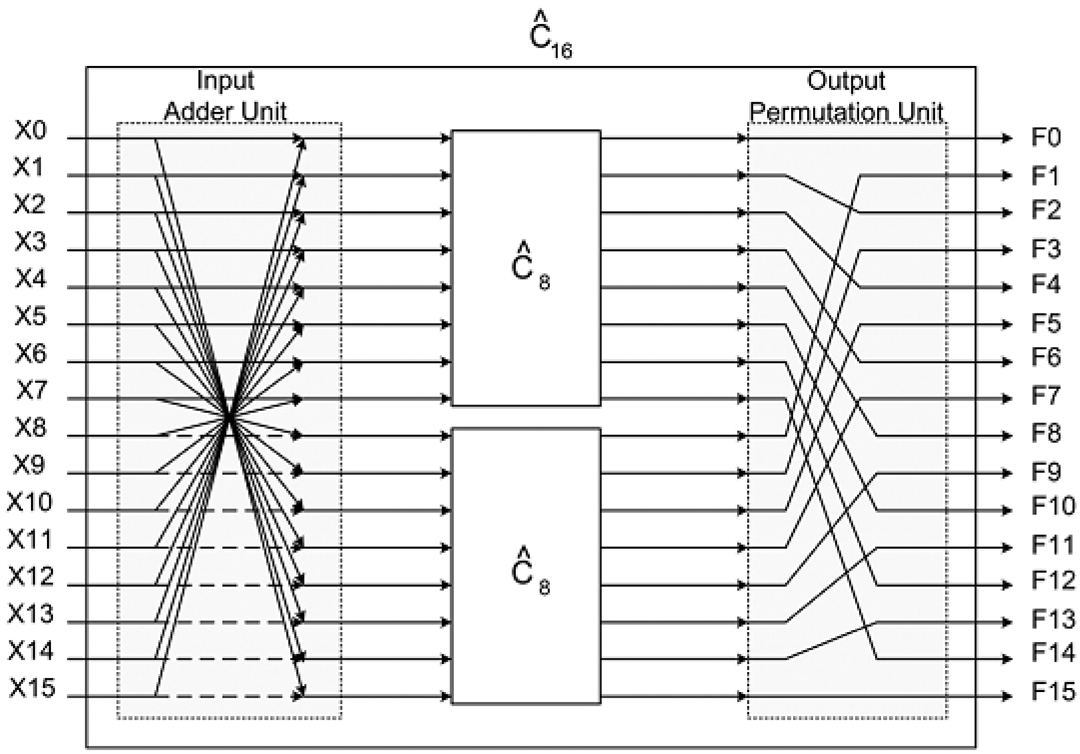

Fig.2.block diagram of proposed DCT for N=16(c^16)

B. Complexity Comparison

To assess the computational complexity of proposed –point approximate DCT, we need to determine the computational cost of matrices quoted in (9). As shown in Fig. 1 the approximate 8-point DCT involves 22 additions. Since has no computational cost and requires additions for –point DCT, the overall arithmetic complexity of 16-point, 32-point, and 64-point DCT approximations are 60, 152, and 368 additions, respectively. More generally, the arithmetic complexity of -point DCT is equal to additions.

C. Proposed reconfiguration scheme

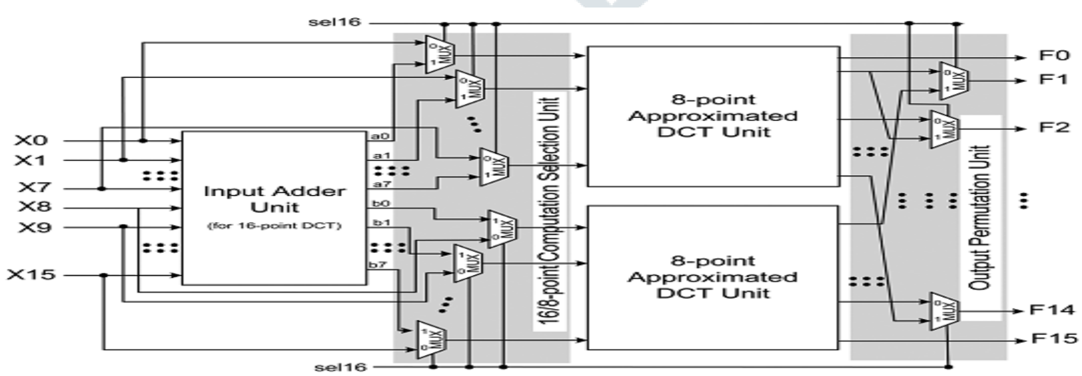

Fig. 3. Proposed reconfigurable architecture for approximate DCT of lengths N=8 and 16

As specified in the recently adopted HEVC [10], DCT of different lengths such as, 16, 32 are required to be used in video coding applications. Therefore, a given DCT architecture should be potentially reused for the DCT of different lengths instead of using separate structures for different lengths. We propose here such reconfigurable DCT structures which could be reused for the computation of DCT of different lengths. There configurable architecture for the implementation of approximated 16-point DCT is shown in Fig. 3. It consists of three computing units, namely two 8- point approximated DCT units and a 16-point input adder unit that generates a(i) and b(i)he input to the first 8-point DCT approximation unit is fed through 8 MUXes that select either [a(0)…a(7)]or ,[x(0)….x(7)] depending on whether it is used for 16-point DCT calculation or 8-point DCT calculation. Similarly, the input to the second 8- point DCT unit (Fig. 3) is fed through 8 MUXes that select either [b(0)…b(7)] or , dependingon whether it is used for 16-point DCT calculation or 8-point DCT calculation. On the other hand, the outputpermutation unit uses 14 MUXes to select and re-order the output depending on the size of the selected DCTis used as control input of the MUXes to select inputs and toperformpermutation according to the size of the DCT to be computed. Specifically sel16=1 enables the computation of 16-point DCT and sel16=0 enables the computation of a pair of 8- point DCTs in parallel. Consequently, the architecture of Fig. 3 allows the calculation of a 16- point DCT or two 8-point DCTs in parallel.

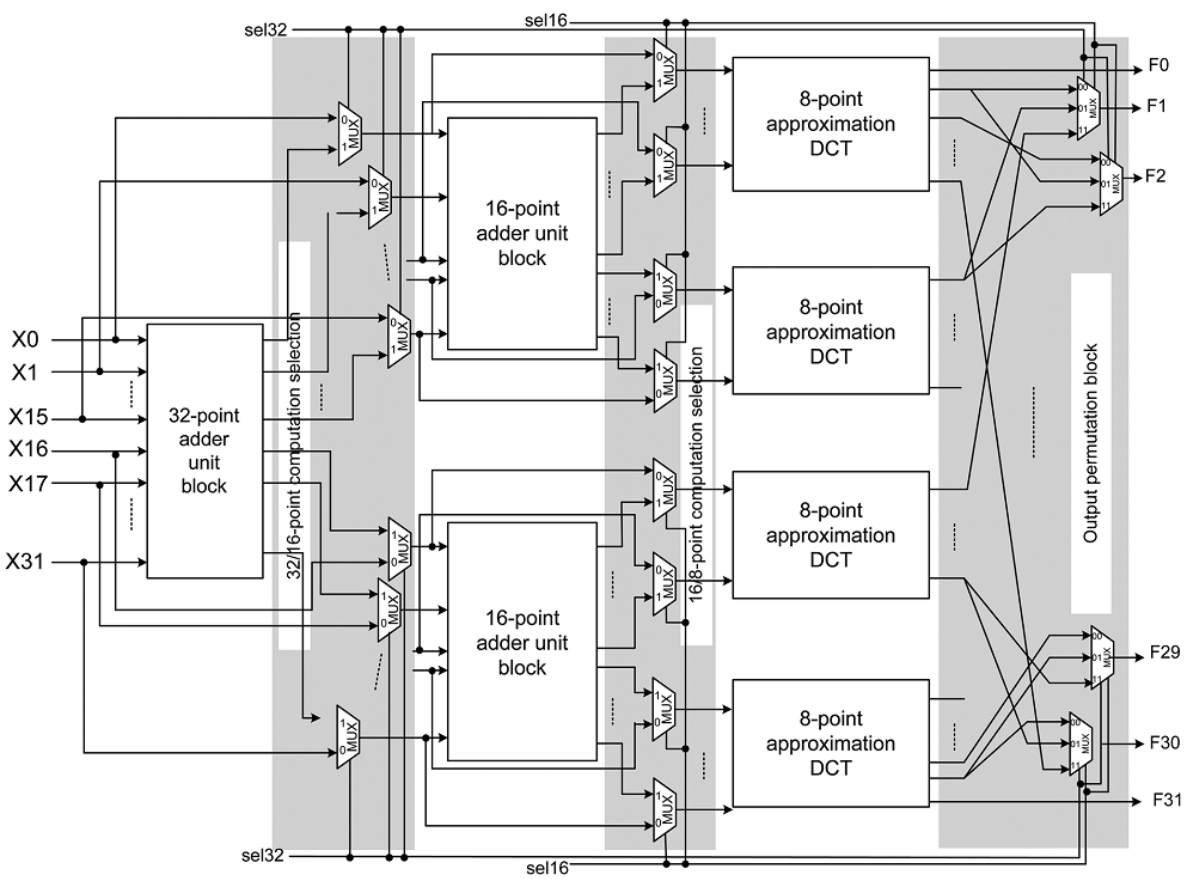

Fig. 4. Proposed reconfigurable architecture for approximate DCT of lengths 8, 16 and 32

A reconfigurable design for the computation of 32-, 16-, and 8-point DCTs is presented in Fig. 4. It performs the calculation of a 32-point DCT or two 16-point DCTs in parallel or four 8-point DCTs in parallel. The architecture is composed of 32-point input adder unit, two 16-point input adder units, and four 8-point DCT units.The reconfigurability is

achieved by three control blocks composed of 64 2:1 MUXes along with 30 3:1 MUXes. The first control decides whether the DCT size is of 32 or lower. If the selection of input data is done for the 32 point DCT, Otherwise for the DCTs of lower lengths.

IV. SIMULATION RESULTS

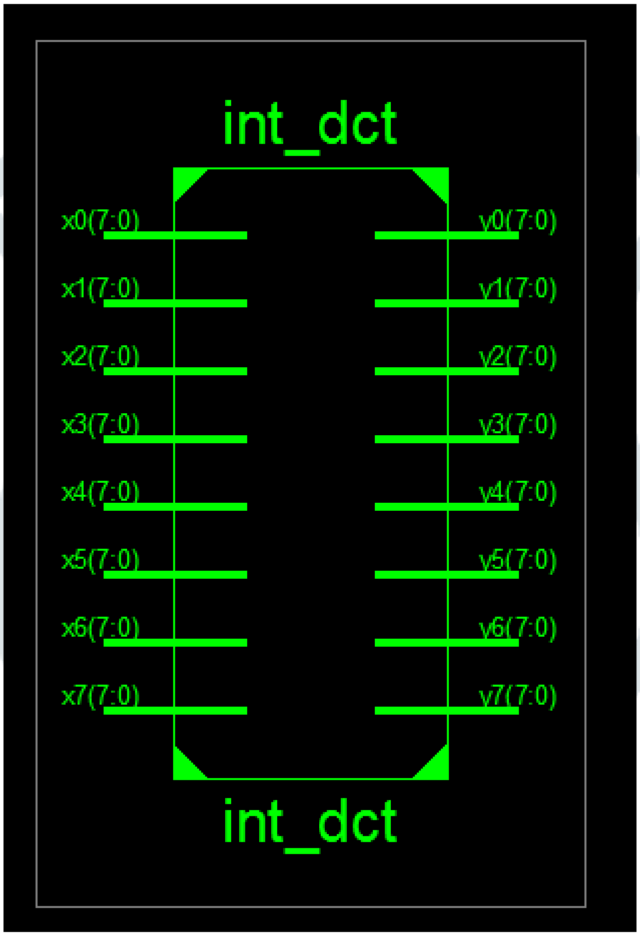

Fig.5.Existing RTL

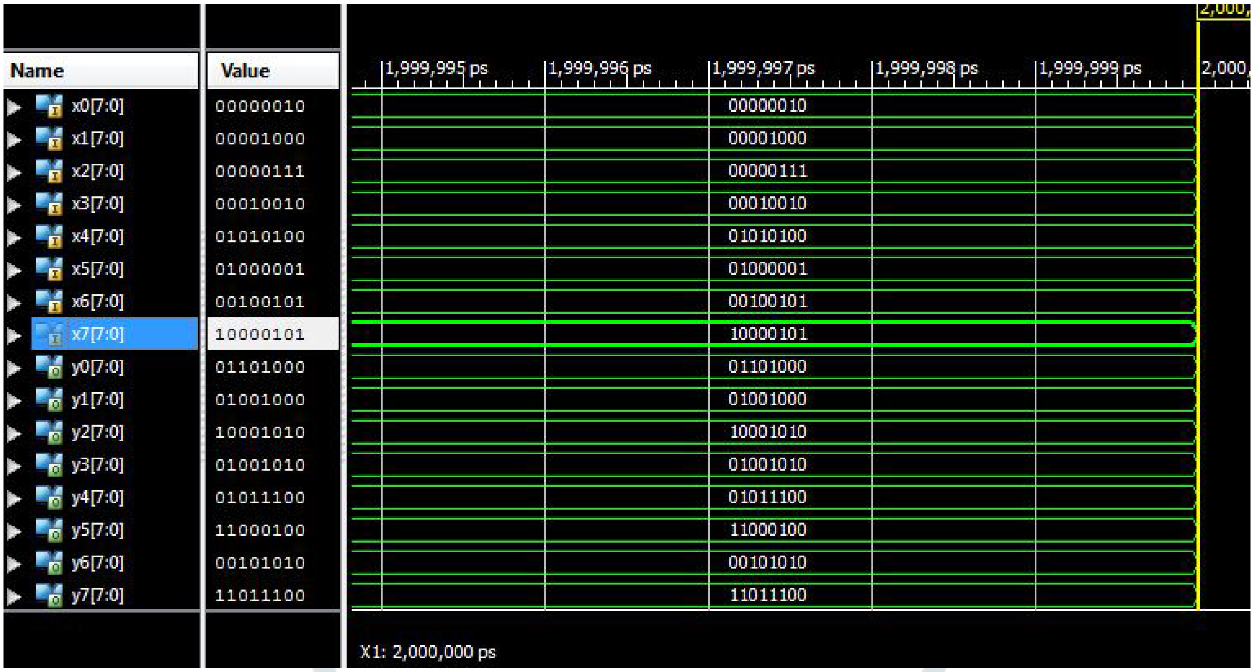

Fig.6.Existing Simulation Output

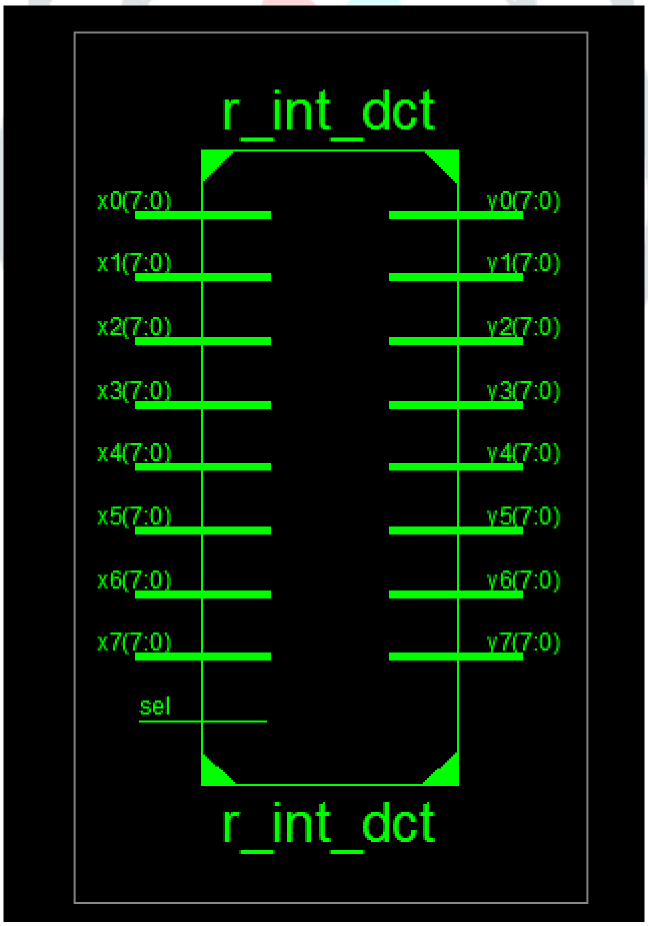

Fig.7 .Proposed RTL

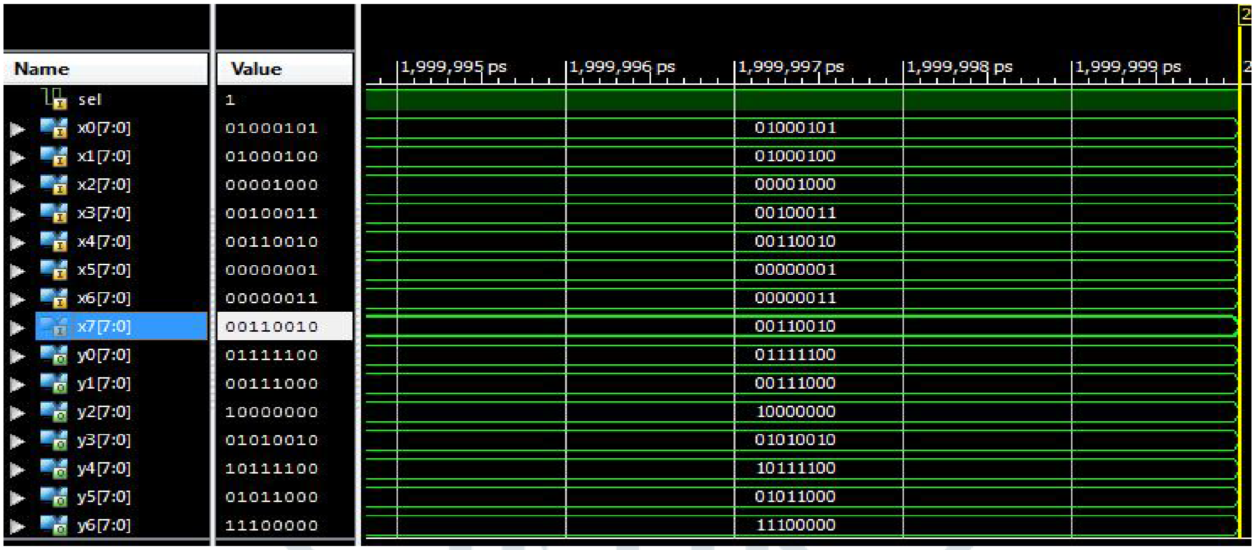

Fig.8.Proposed Simulation Output

V. CONCLUSION

In this paper, we have proposed a recursive algorithm to obtain orthogonal approximation of DCT where approximate DCT of length could be derived from a pair of DCTs of length at the cost of additions for input preprocessing. The proposed approximated DCT has several advantages, such as of regularity, structural simplicity, lower computational complexity, and scalability. Comparison with recently proposed competing methods shows the effectiveness of the proposed approximation in terms of error energy, hardware resources consumption, and compressed image quality. We have also proposed a fully scalable reconfigurable architecture for approximate DCT computation where the computation of 32-point DCT could be con figured for parallel computation of two 16-point DCTs or four 8-point DCTs.

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