Low Power VLSI Architecture for Image Compression System using Discrete Wavelet Transform

Jamuna.M, A.M.Vijaya Prakash, J.Pushpanjali

Abstract*— Image compression has got applications in many fields like digital video, video conferencing and video over wireless networks and internet etc. This paper deals with the implementation of VLSI Architecture of image compression system using low power DWT (Discrete Wavelet Transform). DWT is the most widely used image compression technique and it is the most efficient algorithm used in JPEG image compression. This paper presents implementation of 2 methods of DWT, one is conventional method and the other one is lifting scheme. Since conventional method requires more memory, area and power, lifting scheme is used as an enhanced method. Architecture of the DWT which is a powerful image compression algorithm is implemented using lifting based approach. This architecture enjoys reduced memory referencing¸ related low power consumption¸ low latency and high throughput. The Inverse Discrete Wavelet Transform (IDWT) is also obtained in a similar way to get back the image matrix. The design is implemented in verilog HDL. ISIM is used for the simulation of the design. MATLAB is used as a support for the design for obtaining the input pixels and comparison of the results. CADENCE RTL compiler is used to synthesize and obtain the detailed power and area of the design.

***Keywords*—Discrete Wavelet Transform (DWT), Inverse Discrete Wavelet Transform (IDWT), Digital filters.**

I. INTRODUCTION

DWT is one of the fastest computation of wavelet transform. It is easy to implement and reduces the computation time and resources required. In the case of DWT, a time-scale representation of the digital signal is obtained using digital filtering techniques. The signal to be analyzed is passed through filters with different cut off frequencies at different scales. Discrete Wavelet Transform (DWT) is a very useful tool in time-frequency analysis because of its excellent localization both in time and frequency. It has been very successful in several areas such as image compression, communication and de-noising. DWT is a good alternate to FFT (Fast Furier Transform) in most applications. DWT is more efficient because of its perfect reconstruction property. The DWT can be used in several medical applications, such as finding cancer in mammogram images , monitoring of fetal heartbeats, ultrasounds, and analyzing electrocardiograms.

Manuscript Received on June 22, 2012.
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DWT is used to compress the sequence of images and we can obtain best results DWT can be implemented in many ways because of its simplicity. This paper introduces two architectures for DWT.

II. ARCHITECTURES FOR DWT

A. Conventional Method Dwt

Filters are one of the most widely used signal processing functions. Wavelets can be realized by iteration of filters with rescaling. The resolution of the signal, which is a measure of the amount of detail information in the signal, is determined by the filtering operations, and the scale is determined by up sampling and down sampling (sub sampling) operations. The DWT algorithm consists of Forward DWT (FDWT) and Inverse DWT (IDWT). The FDWT is computed by successive low pass and high pass filtering of the discrete time-domain signal as shown in fig.1.

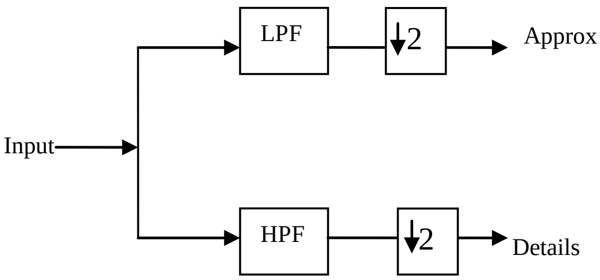

Fig.1 Block diagram for conventional FDWT

The preliminary work in convolution DWT is to build 1D-DWT modules which are composed of high pass filter (HPF) and low pass filter (LPF) that performs convolution of filter co-efficient and input pixels. Most natural images have smooth colour variations, with the fine details being represented as sharp edges in between the smooth variations. Technically, the smooth variations in colour can be termed as low frequency components and the sharp variations as high frequency components.

In wavelet analysis, A signal can be separated into approximations (Approx) or averages and detail coefficients. Averages are the high-scale, low frequency components of the signal. The details are the low scale, high frequency components. If we perform forward transform on a real digital signal, we wind up with twice as much data as we started with. That's why after filtering down sampling has to be done.

Similarly we can perform Inverse DWT to get the reconstructed image by matrix multiply method. Figure for IDWT is shown fig.2.

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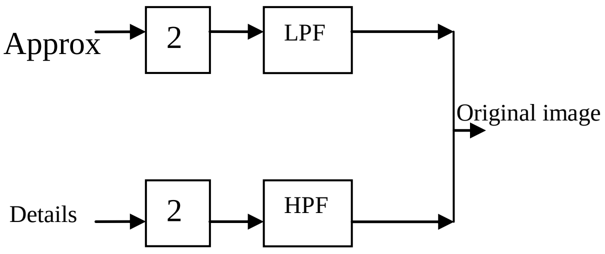

Fig.2 Block diagram for Inverse DWT (IDWT)

Since conventional method requires more computations, area and power, an enhanced method which is known as lifting scheme is implemented and it is used as Low Power Technique.

B. Lifting Scheme Dwt

The lifting scheme is a well known method for constructing bi-orthogonal wavelets. The main difference with the classical construction is that it does not rely on the Fourier transform. The lifting scheme is a technique for both, designing wavelets and performing the discrete wavelet transform.

The lifting scheme is an efficient implementation of a wavelet transform algorithm. It was primarily developed as a method to improve wavelet transform, and then it was extended to a generic method to create so-called second-generation wavelets
i.e. wavelets which do not necessarily use the same function prototype at different levels). Second-generation wavelets are much more flexible and powerful than the first generation wavelets. The lifting scheme is an implementation of the filtering operations at each level.

Lifting scheme consists of three steps:
1. SPLIT 2. PREDICT 3.UPDATE

1. SPLIT: In this step, the data is divided into ODD and EVEN elements.

2. PREDICT: The PREDICT step uses a function that approximates the data set. The differences between the approximation and the actual data replace the odd elements of the data set. The even elements are left unchanged and become the input for the next step in the transform. The PREDICT step, where the odd value is "predicted" from the even value is described by the equation:

$$odd_{j+1,i} = odd_{j,i} - P(even_{j,i}) \qquad (1)$$

3. UPDATE: The UPDATE step replaces the even elements with an average. These results in a smoother input for the next step of the wavelet transform. The odd elements also represent an approximation of the original data set, which allows filters to be constructed. The UPDATE phase follows the PREDICT phase. The original values of the odd elements have been overwritten by the difference between the odd element and its even "predictor". So in calculating an average the UPDATE phase must operate on the differences that are stored in the odd elements:

$$even_{j+1,i} = even_{j,i} + U(odd_{j+1,i}) \qquad (2)$$

A simple lifting scheme forward transform is shown in fig.3

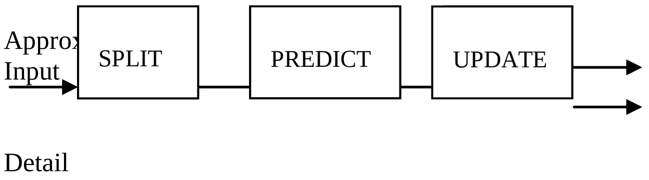

Fig.3 Block diagram for Forward lifting scheme

One of the elegant features of the lifting scheme is that the Inverse transform is a mirror of the forward transform.
Inverse Lifting Scheme block schematic is shown in fig.4.

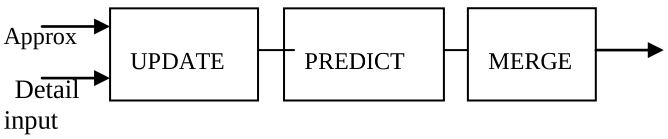

Fig.4 Block diagram for Inverse lifting scheme

Here in inverse lifting scheme all the steps are similar to forward lifting scheme except split step is replaced by merge step.

III. IMPLEMENTATION OF DWT ALGORITHM

In this section first we will discuss how to implement FDWT and IDWT in MATLAB. In the FDWT part the input data will be transferred from time domain to scale domain and in the IDWT part the coefficients will be transferred back into time domain.

While implementing the algorithm in MATLAB the matrix multiplication method has been used. After we have achieved satisfactory result in MATLAB we proceed to the next stage where we translate the code into VERILOG. The development of algorithm in VERILOG is different in some aspects. The main difference is unlike MATLAB, VERILOG does not support many built in functions such as convolution, max, mod and many more. So while implementing the algorithm in VERILOG, linear equations of FDWT and IDWT is used. The VERILOG code is compiled and simulated in MODELSIM by Mentor Graphics. Next, the VERILOG codes are synthesized in CADENCE RTL Compiler. The simulation results and synthesis results are presented in following section IV and V.

IV. SIMULATION RESULTS

Here **"cat.jpg"** is used as an input image for MATLAB simulation. The MATLAB and HDLsimulation results for both conventional DWT and Lifting scheme DWT are shown in below.

Fig.5Original Image

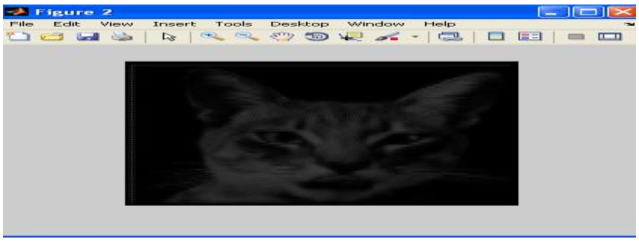

Fig.6 Recovered Image

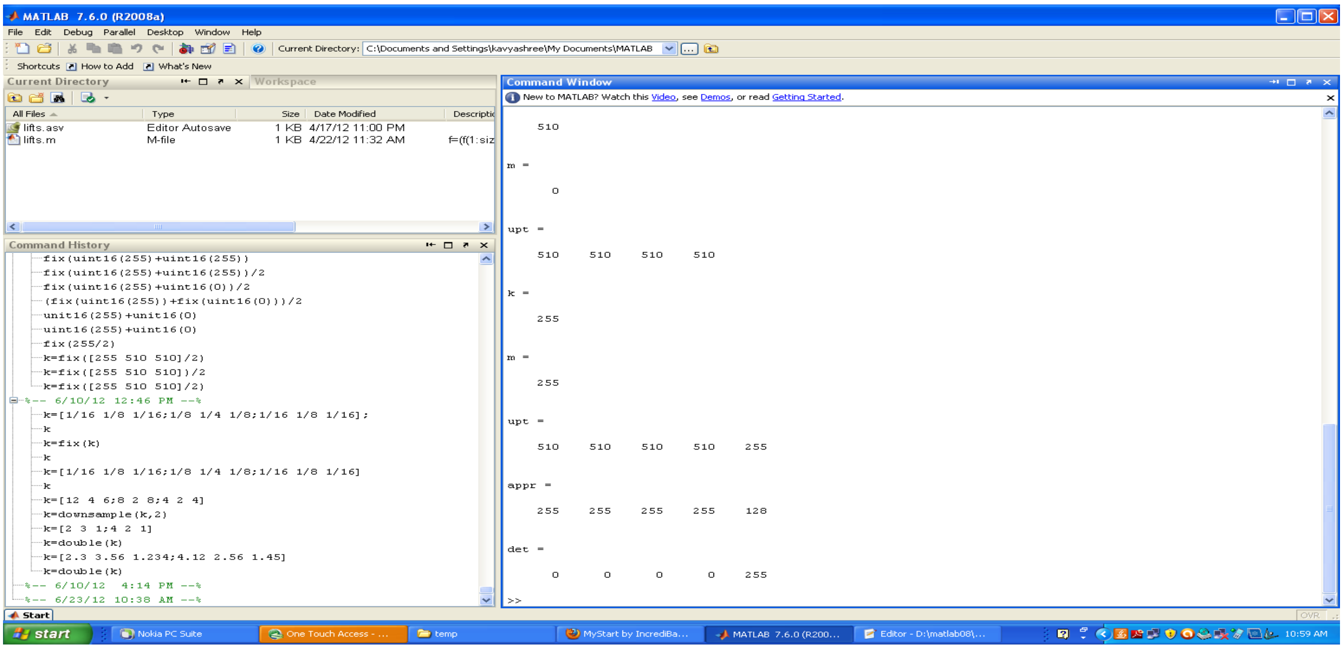

Fig.7 Conventional DWT MATLAB result

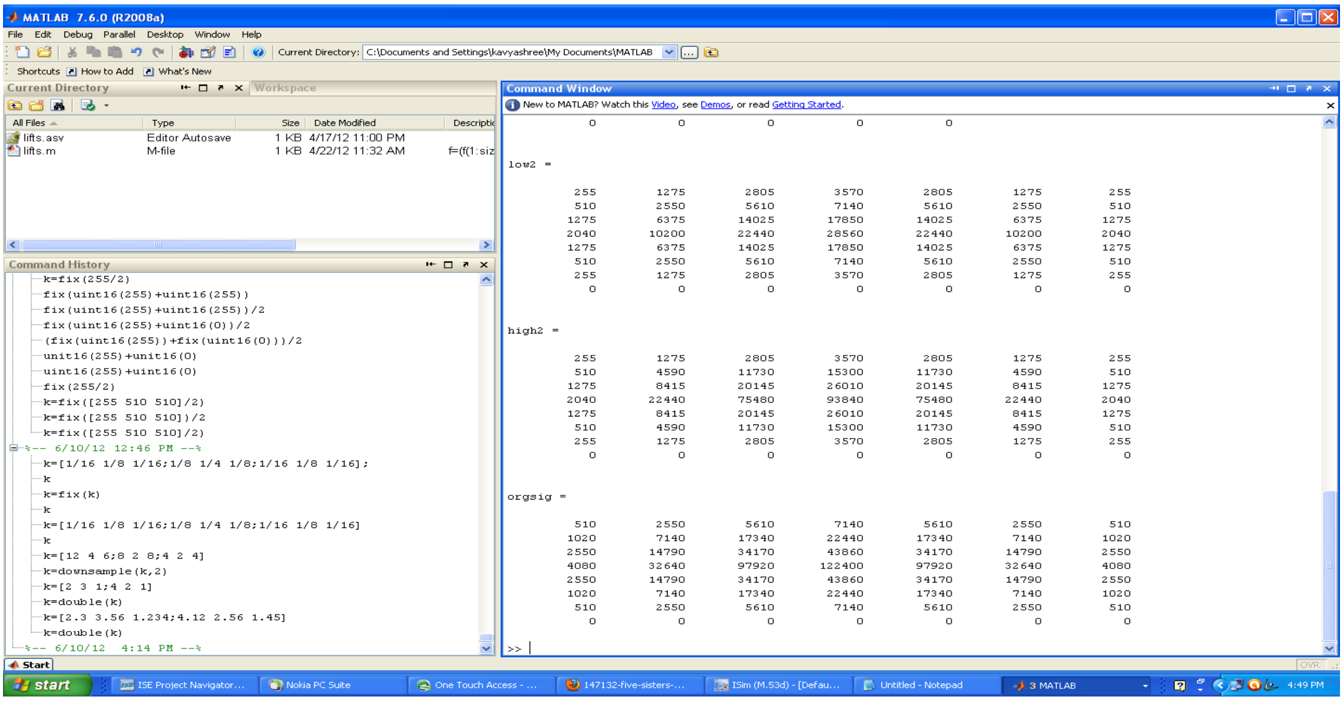

Fig.8 Conventional IDWT MATLAB result

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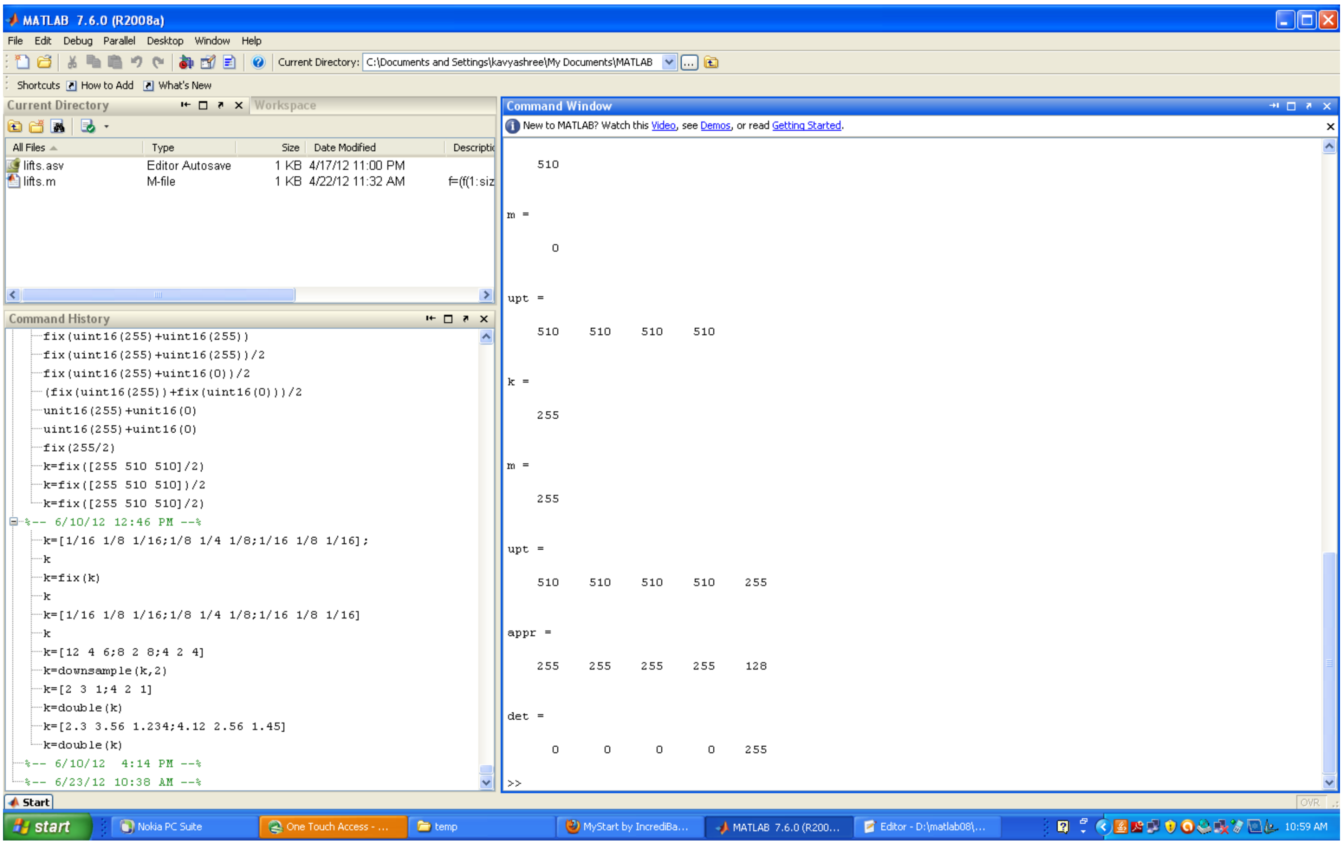

Fig.9 Lifting DWT MATLAB result

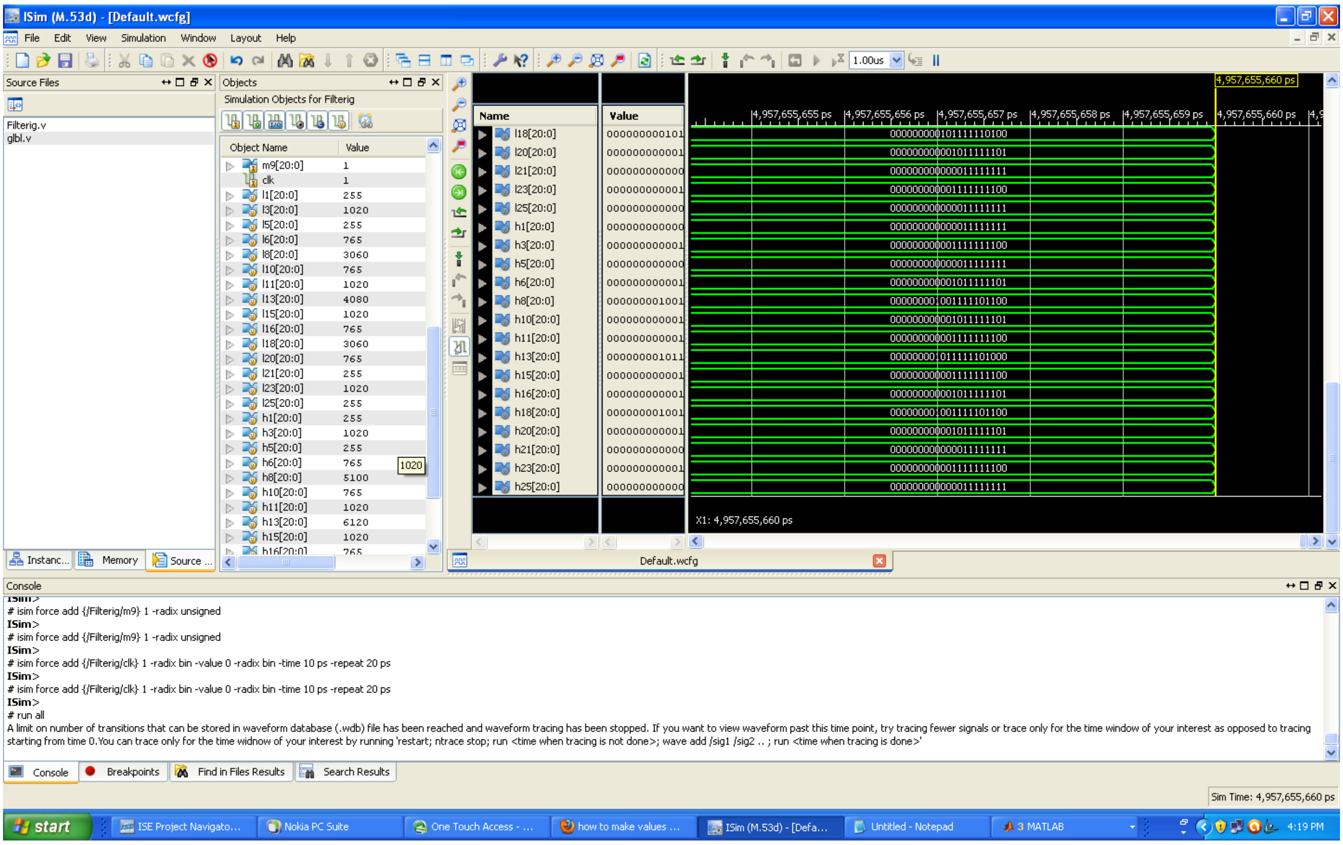

Fig .10 Conventional DWT HDL Simulation result

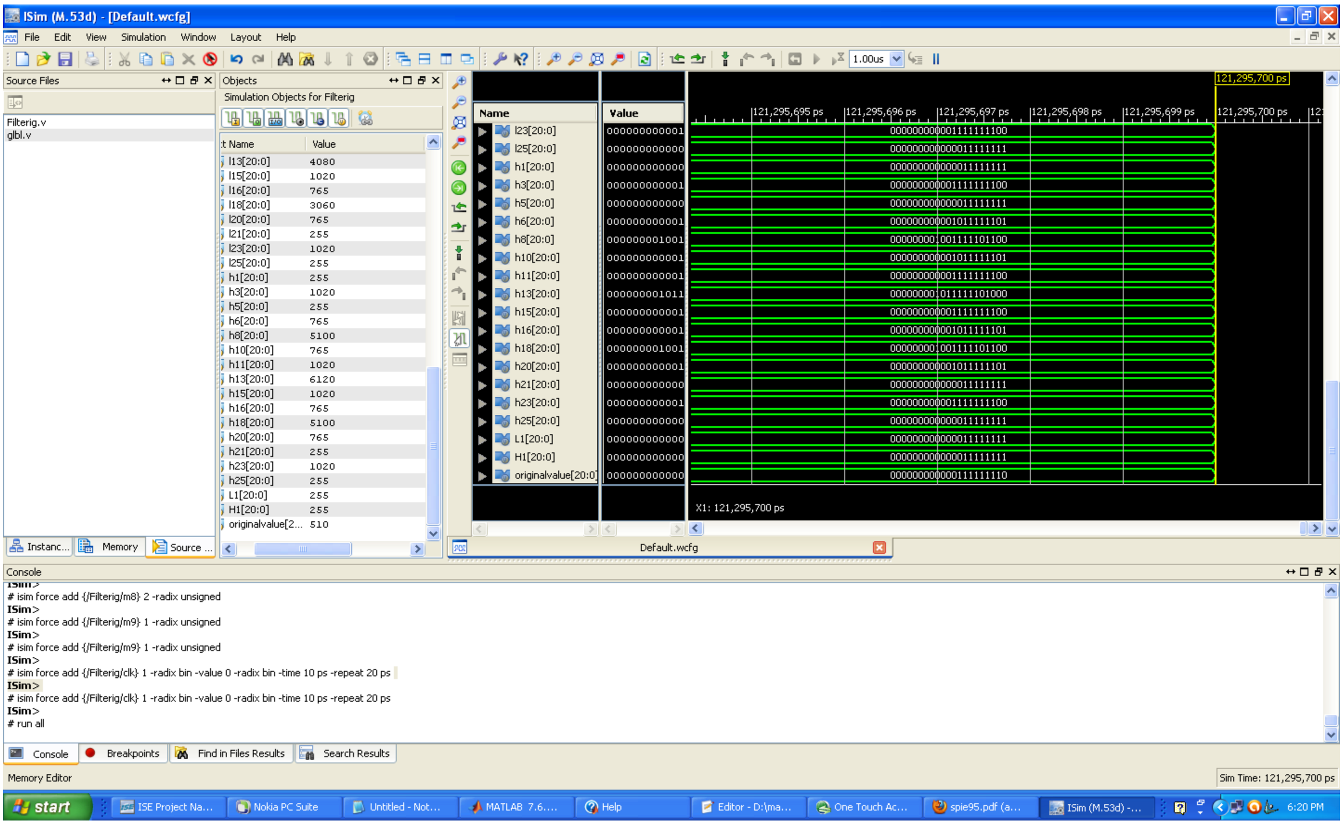

Fig.11 Conventional IDWT HDL Simulation result

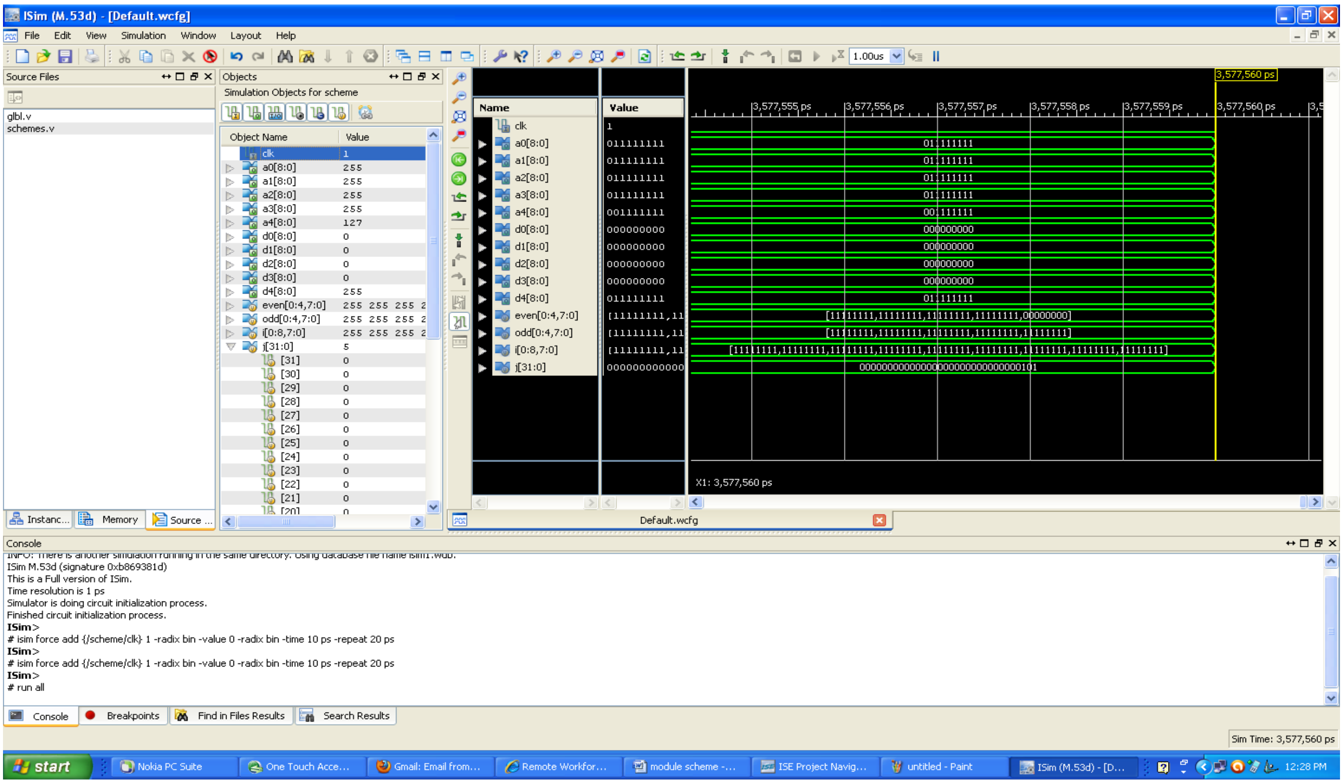

Fig.12 HDL Simulation result for Lifting

V. SYNTHESIS RESULTS

RTL Compiler was used to synthesis the Verilog code. Cadence RTL compiler was used to synthesis and generate schematic. After synthesis, area and power analysis was performed.

A. Power Analysis

CADENCE tool is used to Synthesis the Verilog HDL code written. After synthesis, power and area analysis is done by mapping on to 180nm TSMC technology. The characteristics of Conventional DWT and Lifting DWT are tabulated in Table 1.

TABLE 1: Charactertics of DWT

Features	Conventional DWT	Lifting DWT
Power	84.32mW	0.016Mw
Area	6268μm^2	2309μm^2
Block size	3x3	3x3
No. of cells	90764	375

VI. CONCLUSION

In this paper an improved and efficient Discrete Wavelet Transform algorithm has been developed and tested. An ASIC implementation of DWT was designed to meet low power constraints. DWT and IDWT algorithm was written using VERILOG HDL, then simulated and synthesized successfully. From the MATLAB we obtain the image coefficients and it is compared with HDL simulation results. Power and Area analysis is done using CADENCE RTL Compiler with 180nm TSMC library and low power is achieved.

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