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Linear Convolution and Deconvolution Algorithm Based on Cell Processing Using IVM 4x4multiplication

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ABSTRACT:-In Digital Signal Processing, the convolution and de-convolution with a very long sequence is ubiquitous in many application areas. The basic blocks in convolution and de-convolution implementation are multiplier and divider. They consume much of time. This paper presents a direct method of computing the discrete linear convolution, circular convolution and de-convolution. The approach is easy to learn because of the similarities to computing the multiplication of two numbers. The most significant aspect of the proposed method is the development of a multiplier and divider architecture based on Ancient Indian Vedic Mathematics sutras Urdhvatriyagbhyam and Nikhilam algorithm. The results show that the implementation of linear convolution and circular convolution using vedic mathematics is efficient in terms of area and speed compared to their implementation using conventional multiplier & divider architectures. The coding is done in Verilog HDL. Simulation and Synthesis are performed using Xilinx ISE design suit 14.2. Simulated results for proposed 4x4 bit Vedic convolution circuit shows a reduction in delay of 88% than the conventional method and 41% than the OLA method.

Keywords: Linear Convolution, Circular Convolution, De-convolution, Vedic Mathematics, Urdhva Triyagbhyam, Paryavartha, VerilogHDL.

I. INTRODUCTION

The Vedic Mathematics is the name given to the old arrangement of Indian Mathematics. There are nearly 16 sutras in vedic multiplying technique. For instance, 'Vertically and Crosswise` or 'Urdhva Tiryagbhyam (UT)' is one of these Sutras. All these antiquated Vedic duplications influences our brain to work normally to and it is an extraordinary help for everybody keeping in mind the end goal to get arrangement in a fitting strategy. Maybe cognizance is the most striking component of the Vedic framework. Rather than a hotch-potch of random strategies the entire framework is incredibly interrelated and brought together augmentation. For instance, it is anything but difficult to make one line divisions and squaring the techniques should likewise be possible in one line. What's more, these are for the most part straightforward. This extraordinary nature is exceptionally fulfilling, it makes figuring's simple and it empowers development. In the Vedic arithmetic the most troublesome issues can be understood quickly by the Vedic duplication calculations. These striking strategies are only a piece of a total arrangement of Arithmetic which is significantly more efficient than the cutting edge framework Vedic Multiplication calculations shows the intelligible and its one of a kind structure. All these strategies are reciprocal, immediate and simple. The straightforwardness of antiquated Vedic Mathematics is that the computations can be completed rationally (however the strategies can likewise be composed down). There are numerous geniuses in utilizing an adaptable, mental framework. Understudies can utilize their own particular strategies they are not restricted to a solitary strategy. This prompts more inventive, fascinating and clever musings. Mischances happening can be definitely decreased, bringing about a significantly more secure driving background. Enthusiasm for the antiquated Vedic framework is developing broadly in instruction where arithmetic instructors are longing for better arrangements. Examination is being done in numerous regions including the impacts of learning Vedic Mathematics on kids, growing new, effective are looking however simple uses of the Vedic Sutras in geometry, analytics, figuring and so on. But the truly excellence and viability of vedic arithmetic can't be completely appreciated without really practicing the system. One would then be able to see that it is maybe the most refined and proficient scientific framework conceivable.

II. RELATED WORK OF CONVOLUTION:

Convolution is a mathematical way of combining two signals to form a third signal. It is the single most important technique in Digital Signal Processing. Using the strategy of impulse decomposition, systems are described by a signal called the impulse response . Convolution is important because it relates the three signals of interest: the input signal, the output signal, and the impulse response. This chapter presents convolution from two different viewpoints, called the input side algorithm and the output side algorithm. Convolution provides the mathematical framework for DSP.

Let's summarize this way of understanding how a system changes an input signal into an output signal. First, the input signal can be decomposed into a set of impulses, each of which can be viewed as a scaled and shifted delta function. Second, the output resulting from each impulse is a scaled and shifted version of the impulse response. Third, the overall output signal can be found by adding these scaled and shifted impulse responses. In other words, if we know a system's impulse response, then we can calculate what the output will be for any possible input signal.

Convolution is a formal mathematical operation, just as multiplication, addition, and integration. Addition takes two numbers and produces a third number, while convolution takes two signals and produces a third signal.

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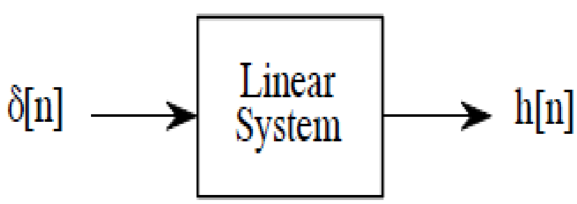
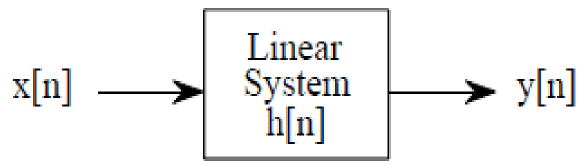
Convolution is used in the mathematics of many fields, such as probability and statistics. In linear systems, convolution is used to describe the relationship between three signals of interest: the input signal, the impulse response, and the output signal.

The notation when convolution is used with linear systems. An input signal, x[n] , enters a linear system with an impulse response, h[n], resulting in an output signal, y[n] . In equation form: x[n]*h[n]=y[n] Expressed in words, the input signal convolved with the impulse response is equal to the output signal. Just as addition is represented by the plus, +, and multiplication by the cross, ×, convolution is represented by the star, *. It is unfortunate that most programming languages also use the star to indicate multiplication. A star in a computer program means multiplication, while a star in an equation means convolution.

A. Linear convolution:



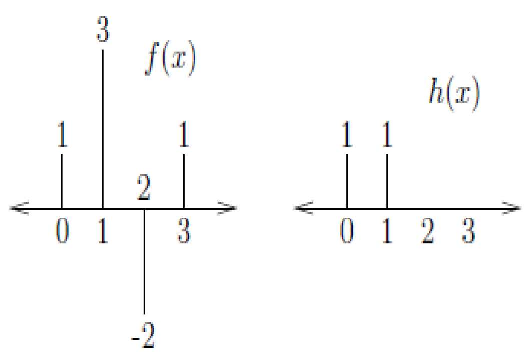


$$x[n] * h[n] = y[n]$$

One dimensional linear discrete convolution is defined as:

$$g(x) = \sum_{s=-\infty}^{\infty} f(s)\, h(x-s) = f(x) * h(x)$$

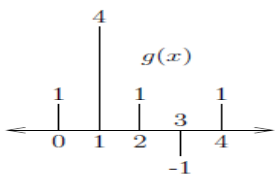
For example, consider the convolution of the following two functions:



This convolution can be performed graphically by rejecting and shifting h(x), as shown in Figure 1. The samples of f(s) and h(s - x) that line up vertical are multiplied and summed:

$$g(0) = f(-1)h(1) + f(0)h(0) = 0 + 1 = 1$$
$$g(1) = f(0)h(1) + f(1)h(0) = 1 + 3 = 4$$
$$g(2) = f(1)h(1) + f(2)h(0) = 3 + -2 = 1$$
$$g(3) = f(2)h(1) + f(3)h(0) = -2 + 1 = -1$$
$$g(4) = f(3)h(1) + f(4)h(0) = 1 + 0 = 1$$

The result of the convolution is as shown below:



Notice that when f(x) is of length 4, and h(x) is of length 2, the linear Convolution is of length 4 + 2 - 1 = 5.

Convolution is the mathematical process that relates the output, y(t), of a linear, time-invariant system [4] to its input, x(t), and impulse response, h(t).

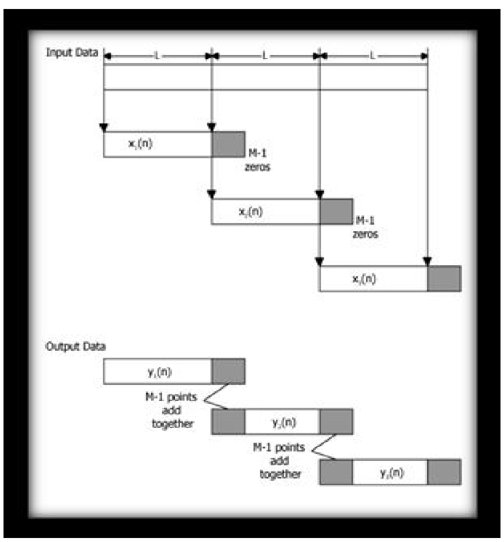


Fig.1: Overlap add method

The overlap-add method (OLA) is an efficient way to evaluate the discrete convolution between a very long signal x[n] with a finite impulse response h[n]**.** The Fig. shows the concept of overlap add method by Zero-pad length-*L* blocks by *M*−1 samples. Add successive blocks, overlapped by *M*−1 samples, so that the tails sum to produce the complete linear convolution.

B. Circular convolution:

x[n] and h[n] are two finite sequences of length N with DFTs denoted by X[k] and H[k], respectively. Let us form the product.

$$W[k] = X[k]H[k],$$

and determine the sequence w[n] of length N for which the DFT is W[k].

First, extend x[n] and h[n] to periodic sequences with period N, x˜[n] and h~[n],respectively. Then, the periodic convolution of $\tilde{x}[n]$ and $\tilde{h}[n]$ corresponds to multiplication of the corresponding periodic sequences of Fourier series coefficients.

$$\tilde{w}[n] = \sum_{m=0}^{N-1} \tilde{x}[n]\tilde{h}[n-m] \quad \leftrightarrow \quad \tilde{W}[k] = \tilde{X}[k]\tilde{H}[k]$$

The periodic sequence $\tilde{w}[n]$ for which the DFS coefficients are $\tilde{W}[k]$ corresponds to the periodic extension of the finite length sequence w[n] with period N. We can recover w[n] by extracting w one period of w ˜[n]:

$$\begin{aligned} w[n] &= \tilde{w}[n]\mathbb{R}_N[n] \\ &= \sum_{m=0}^{N-1} \tilde{x}[m]\tilde{h}[n-m] \\ &= \sum_{m=0}^{N-1} x[m]h[((n-m))_N] \end{aligned}$$

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This operation is called circular convolution and denoted

$$w[n] = x[n] \;Ⓝ\; h[n].$$

Example:

Consider two constant sequences of length N, x1[n] = x2[n], depicted

The N-point DFT of $x_1[n]$ is,

$$X_1[k] = \sum_{0}^{N-1} x_1[n] W_N^{kn} = \sum_{0}^{N-1} W_N^{kn} = \frac{1 - W_N^{NK}}{1 - W_N^{k}} \quad = 0 \quad k \neq 0$$
$$= N \quad k = 0$$

where $W_N = e^{-j(2\pi/N)}$. Since $x_1[n] = x_2[n]$,

$$X_3[k] = X_1[k]X_2[k] = N^2\delta[k] = NX_1[k]$$

Using linearity, we can see that

$$x_3[n] = x_1[n] \;Ⓝ\; x_2[n] = Nx_1[n] \quad = N \quad 0 \leq n \leq N-1$$
$$= 0 \quad \textit{otherwise.}$$

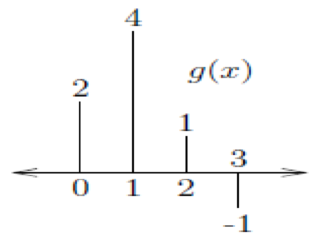
One dimensional circular discrete convolution is defined as:

$$g(x) = \sum_{s=0}^{M-1} f(s)\, h((x - s) \bmod M) = f(x) \circledast h(x)$$

For M = 4, the convolution can be performed using circular reflection and shifts
of h(x), as shown in Figure 2. The samples of f(s) and h((s - x) mod M) that line up vertically are multiplied and summed:

$$g(0) = f(3)h(1) + f(0)h(0) = 1 + 1 = 2$$
$$g(1) = f(0)h(1) + f(1)h(0) = 1 + 3 = 4$$
$$g(2) = f(1)h(1) + f(2)h(0) = 3 + -2 = 1$$
$$g(3) = f(2)h(1) + f(3)h(0) = -2 + 1 = -1$$

The result of the convolution is as shown below:



Notice that f(x) and h(x) are both treated as if they are of length 4, and the circular convolution is also of length 4.

C. Linear Convolution as Circular Convolution:

If f(x) and g(x) are both treated as if they are of length 4+2 - 1 = 5, then the following circular convolution is calculated:

$$g(0) = f(4)h(1) + f(0)h(0) = 0 + 1 = 1$$
$$g(1) = f(0)h(1) + f(1)h(0) = 1 + 3 = 4$$
$$g(2) = f(1)h(1) + f(2)h(0) = 3 + -2 = 1$$
$$g(3) = f(2)h(1) + f(3)h(0) = -2 + 1 = -1$$
$$g(4) = f(3)h(1) + f(4)h(0) = 1 + 0 = 1$$

This procedure is called zero padding." Notice that this circular convolution matches the linear convolution.In general, if f(x) has length A, and h(x) has length B, and both f(x) and h(x) are zero padded out to length C, where C ¸ A + B - 1, then the C-point circular convolution matches the linear convolution.

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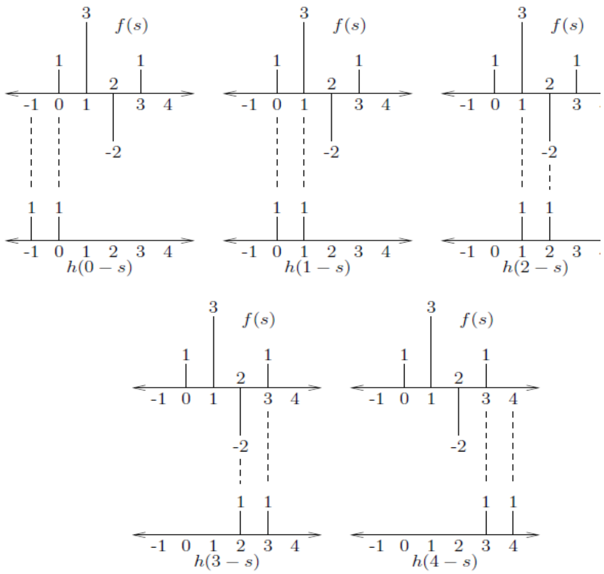


Fig2: Linear convolution by the graphical method.

D. Multiplication

We have already observed the application of Vedic sutras in multiplication. Let us recall them. It enables us to have a comparative study of the applicability of these methods, to assess advantage of one method over the other method and so-on.

Example (i) : Find the square of 195. The Conventional method :

195^2 = 195
x 195

975
1755
195

~~38025~~

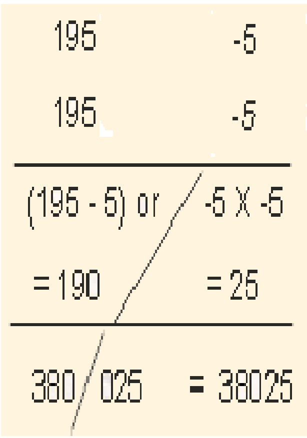
(ii) By Ekadhikena purvena, since the number ends up in 5 we write the answer split up into two parts.

The right side part is 5^2 where as the left side part 19 X (19+1) (Ekhadhikena) Thus 195^2 = 19 X 20/5^2 = 380/25 = 38025

(iii) By Nikhilam Navatascaramam Dasatah; as the number is far from base 100, we combine the sutra with the upa-sutra 'anurupyena' and proceed by taking working base 200.

a) Working Base = 200 = 2 X 100.

Now 195^2 = 195 X 195



iv) By the sutras "yavadunam tavadunikritya vargamca yojayet" and "anurupyena"

195^2, base 200 treated as 2 X 100 deficit is 5.

ii) urdhava-tiryak sutra

98 x 92
106
891

9016

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III. PROPOSED SYSTEM:

A. Convolution:

In this section novel multiplier architecture [5] based on Urdhva Triyagbhyam Sutra of Ancient Indian Vedic Mathematics is embedded into proposed method of convolution to improve its efficiency in terms of speed and area. This method for discrete convolution using vedic multiplication algorithm is best introduced by a basic example. For this example, let f(n) equal the finite length sequence (4 2 3) and g(n) equal the finite length sequence (4 5 3 4). The linear convolution of f(n) and g(n) is given by [1]:

$$y(n) = f(n) * g(n) \qquad (1)$$

$$y(n) = \sum_{k=-\infty}^{\infty} f(k)g(n-k) \qquad (2)$$

This can be solved by several methods, resulting in the sequence y(n) = (16 28 34 37 17 12). This new approach for calculating the convolution sum is set up like multiplication where the convolution of f(n) and g(n) is performed as follows:

g(n):			4	5	3	4
f(n):			*	4	2	3
			12	15	9	12
		08	10	6	8	
	16	20	12	16		
y(n):	16	28	34	37	17	12

As seen in the Fig. 2 computation of the convolution sum, the approach is similar to multiplication calculation, except carries are not performed out of a column. This first example shows the simplicity of this method and how easily the calculation can be performed. As shown below, this method can be used to check intermediate values in graphical convolution, as well as the final answer. In Fig. 1, the convolution sum is computed using graphical convolution. Fig. 1(a) shows the sequences f(n) and g(n). For each value of n, the convolution sum consists of a folding, translation, multiplication, and summation. For a given value of n, the summation is a product of the sequence f(k) and the folded and translated sequence g(n-k). The left-hand column of Fig. 1(b) shows both sequences f(k) and g(n-k) for each value of n, and the right-hand column shows the product of the two sequences vn(k) which is given by

$$v_n(k) = f(k)g(n-k) \qquad (3)$$

The value of the convolution sum for each value of n is

$$f(n) * g(n) = \sum_{k} v_n(k) \qquad (4)$$

The final answer for the graphical convolution method is shown in Fig. 1(c). This answer was verified above using the new method. The sequence vn(k), which is an intermediate answer in computing the convolution sum, may also be checked as

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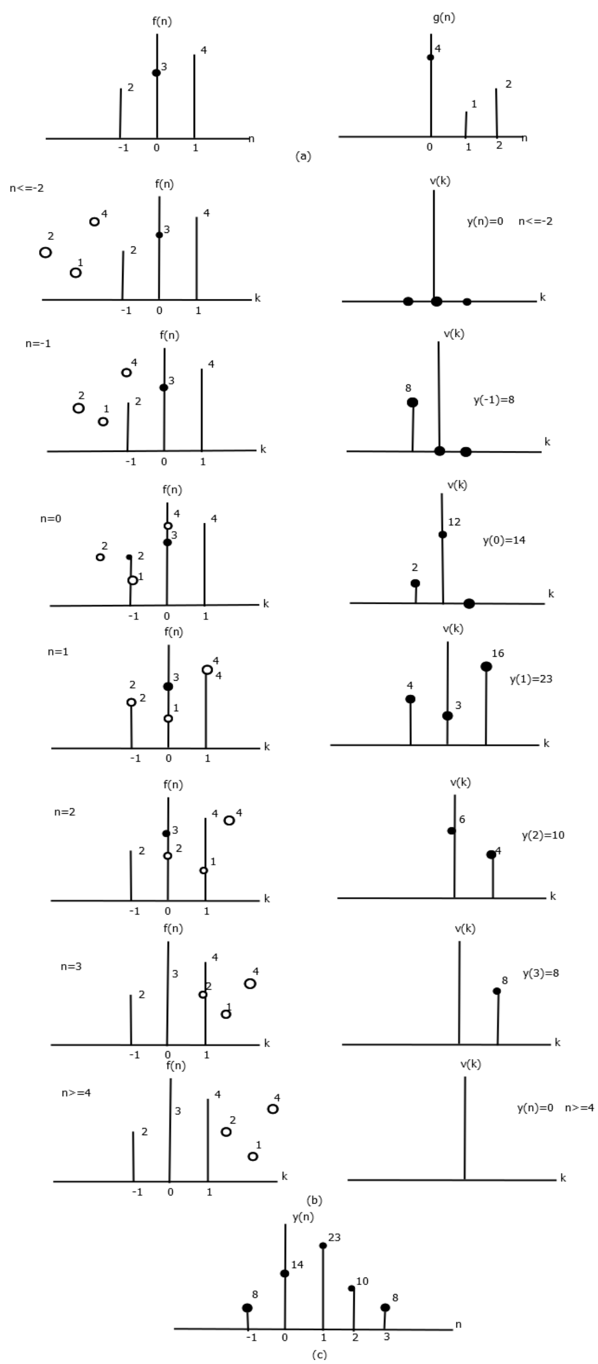
shown below using the method presented in this paper.



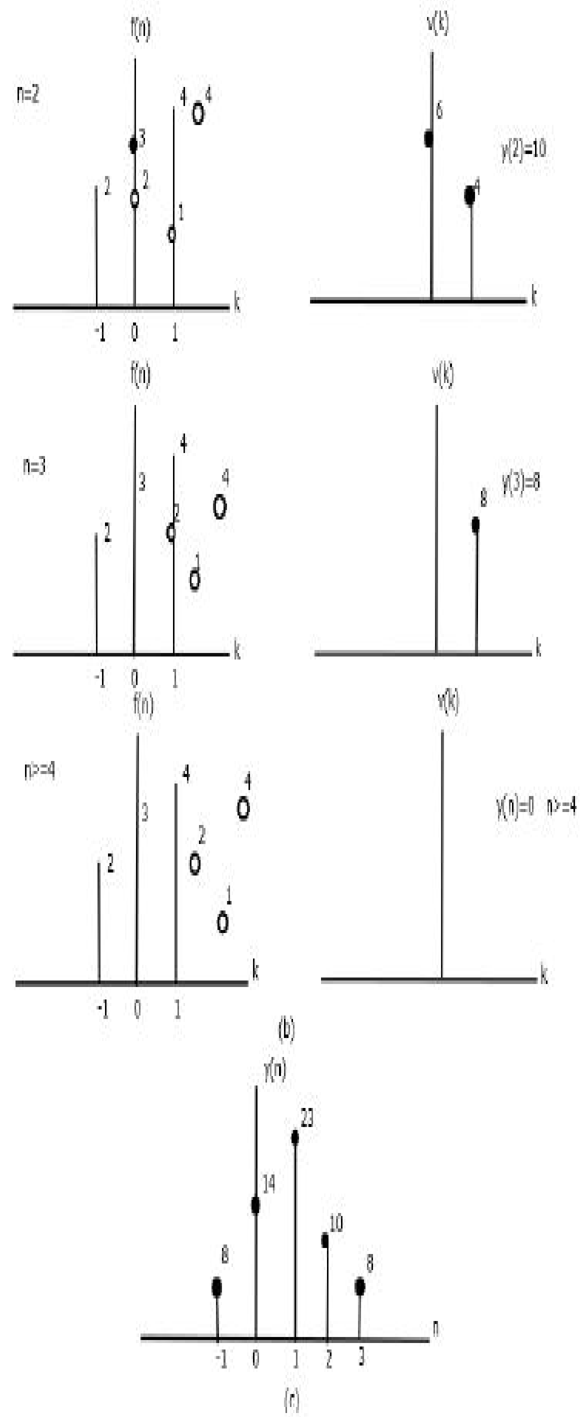


Fig.3.1: The sequences f(n) and g(n), shown in (a), are graphically convolved

in (b), resulting in the sequence y(n), shown in (c).

g(n):			4	1	2	
f(n):		*	2	3	4	k
v(1):			16	04	08	1
v(0):		12	03	06		0
v(-1):	08	02	04			-1
y(n):	08	14	23	10	08	
n:	-1	0	1	2	3	

Fig.3: Verification of intermediate terms using proposed method

Above example illustrates the ease in computing the convolution sum for finite sequences using this new method.

B. Vedic Mutiplier: Urdhva Triyagbhyam:

Among all available multipliers, this paper proposes a systematic design methodology for fast and area efficient digit multiplier based on Vedic Mathematics. In the proposed convolution method the multiplier architecture is based on an algorithm Urdhva Triyagbhyam (Vertical and Crosswise) of Ancient Indian Vedic Mathematics [5]. The use of Vedic Mathematics lies in the fact that it reduces the typical calculations in conventional mathematics to very simple ones. Urdhva Tiryagbhyam Sutra is a general multiplication formula applicable to all cases of multiplication [6]. Because of parallelism in generation of partial products and their summation obtained, speed is improved. In this algorithm the small block can be wisely utilized for designing bigger NxN multiplier. For higher no. of bits in input, little modification is required. Divide the no. of bit in the inputs equally in two parts. Let's analyse 4x4 multiplications, say A3A2A1A0 and B3B2B1B0. Following are the output line for the multiplication result,S7S6S5S4S3S2S1S0. Let's divide A and B into two parts, say A3A2&A1A0 for A and B3B2&B1B0 for B. Using the fundamental of Vedic multiplication, taking two bit at a time and using 2 bit multiplier block, we can have the following structure for multiplication.

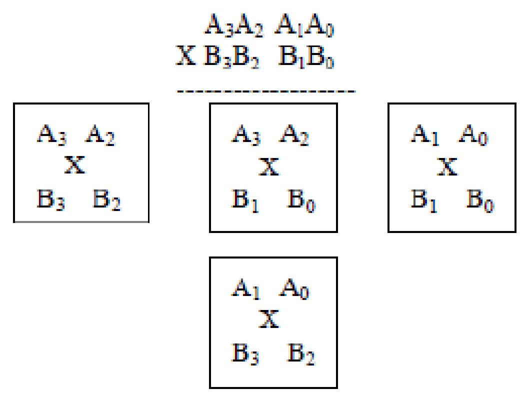


Fig.4:Block diagram presentation for 4x4 multiplications

Each block as shown above is 2x2 multiplier. First 2x2 multiplier inputs are A1A0 and B1B0. The last block is 2x2 multiplier with inputs A3A2 and B3B2. The middle one shows two, 2x2 multiplier with inputs A3A2 and B1B0 and A1A0 and B3B2. So the final result of multiplication, which is of 8 bit, S7S6S5S4S3S2S1S0, can be interpreted as givenbelow.

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$$\begin{array}{cccc} A_3A_2 & A_3A_2 & A_1A_0 & A_1A_0 \\ B_3B_2 & B_1B_0 & B_3B_2 & B_1B_0 \\ \hline S_{33}S_{32}S_{31}S_{30} & S_{23}S_{22}S_{21}S_{20} & S_{13}S_{12}S_{11}S_{10} & S_{03}S_{02}S_{01}S_{00} \end{array}$$

Assuming the output of each multiplication is as given above. For the final result, add the middle product term along with the term shown below.

$$\begin{array}{cccccc} S_{33}S_{32} & S_{31} & S_{30} & 0 & 0 & S_{01}S_{00} \\ & S_{23} & S_{22} & S_{21} & S_{20} & \\ & S_{13} & S_{12} & S_{11} & S_{10} & \\ & 0 & 0 & S_{03} & S_{02} & \end{array}$$

The first two outputs S0 and S1 are same as that of S00 and S01. Result of addition of the middle terms by using two, 4 bit full adders will forms output line from S5S4S3S2. One of the full adder will be used to add (S23S22S21S20) and (S13S12S11S10) and then the second full adder is required to add the result of 1st full adder with (S31S30S03S02). The respective sum bit of the 2nd full adder will be S5S4S3S2. Now the carry generated during 1st full adder operation and that during 2nd full adder operation should be added using half adder so that the final carry and sum to be added with next stage i.e. with S33S32 to get S7S6. The same can be extended for input bits 8, 16, 32.

C. Methodology followed:

In this proposed paper we have made a convolution with x(n) and h(n) both having 256 samples.And as we are performing block convolution using overlap add method this sample is divided into 16 input data block for OLA method, each having 16 elements. The methedology followed in this proposed work is explained using the flow diagrams below.

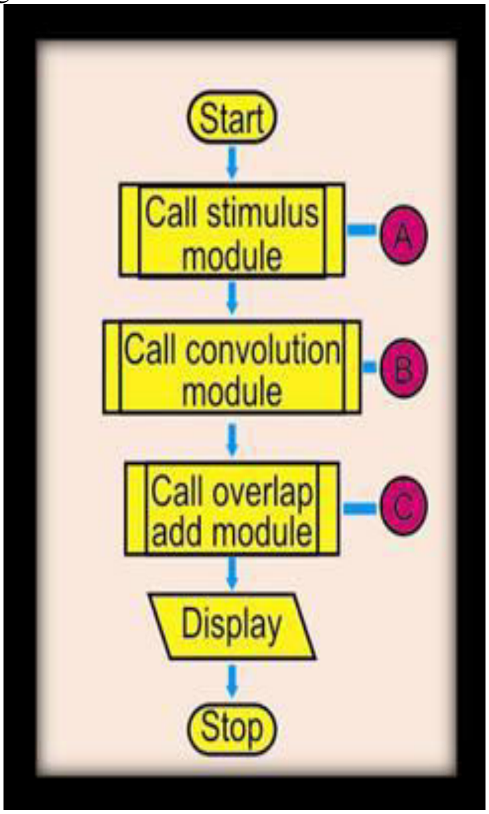

Fig.5: flow chat of proposed method

This flow "A" is the stimulus module which is dividing the input sequence of length 256 into 16 input blocks of length 16.

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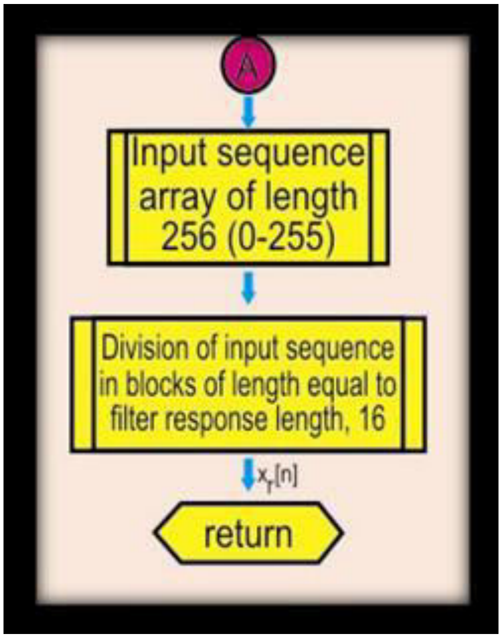


Fig.6:flowchart diagram of 256 input arraylength

This flow "B" is the convolution module which is performing the convolution of individual block with 16 elements.

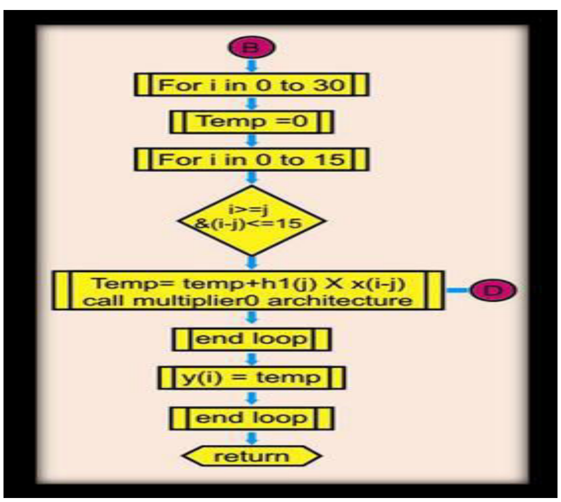
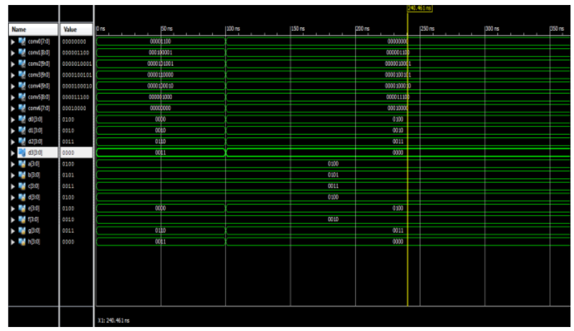


Fig.7: flow Chart Diagram Overlap add module

The flow "C" is overlap add module which helps in providing efficient area and speed of the proposed architechture as it reduces the complexity of the calculation.

IV. SIMULATION RESULTS:



Paravartya Sutra help to minimize computation and maintain accuracy even as the number of iteration is reduced. It provides easier and logically simple implementation. According to paravartya sutra, all the digit of the divisor is complemented except the most significant digit. This complemented digit is initially multiplied with the most significant digit of the dividend and this multiplication result is added with columns of dividend. The result of addition is again multiplied with complemented digits of Divisor and added with the remaining column of the dividend, followed successive multiplication and addition of consecutive column.

V. CONCLUSION:

This work generally connected with to display a system for figuring the immediate convolution using Vedic counts which is simple to learn and apply. This system is showed up as a strategy for fast handling convolution total and simulating both their last and widely appealing solutions from pictorial convolution.

Fastness of the linear convolution extended by using Vedic UT multiplier. From the fundamental mix examination unmistakably the expansion delay of convolution utilizing UT multiplier has reduced to 23% than convolution with normal multiplier. Using Vertical and Crosswise multiplier gives an unrivaled output when compared to convolution with normal multiplier. Mean number of concede segments used for convolution utilizing UT multiplier is 78.53% less when compared to convolution using normal multiplier.

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