NIRMA UNIVERSITY
INSTITUTE OF TECHNOLOGY
NAAC ACCREDITED 'A' GRADE

REPORT

DLD PROJECT

Convolution

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Introduction

- Convolution is a fundamental mathematical operation that plays a crucial role in various fields, including signal processing, image analysis, and machine learning.
- At its core, convolution is a mathematical operation that combines two functions to produce a third, representing the way one function influences the shape of the other.
- In the context of digital signal processing and image analysis, convolution provides a powerful tool for filtering and extracting essential features.

Features of Convolution

- Convolution has applications that include probability, statistics, acoustics, spectroscopy, signal processing and image processing, geophysics, engineering, physics, computer vision and differential equations.

Motivation and Objective

Choosing a convolution-related project can be a highly motivating and rewarding endeavor for several reasons.

Real-world Applications:

- Image Processing: Convolution is widely used in image processing for tasks such as edge detection, blurring, and feature extraction.
- Signal Processing: Convolution plays a crucial role in signal processing applications, like audio and speech processing.

Deep Learning and Computer Vision:

- Convolutional Neural Networks (CNNs): If you're interested in deep learning, understanding convolution is essential.
- Object Recognition: Build a project around object recognition using convolutional techniques.

Open Source Contribution:

- Many open-source projects related to convolution exist

Learning and Skill Development:

- Programming Skills
- Understanding Algorithms

Creativity and Problem-Solving:

- Convolution can be applied in various creative ways

Visualization and Interpretability:

- Convolutional operations can be visualized to better understand how they process data.

Literature Survey

For gathering knowledge a few research paper were studied including

- INVESTIGATION AND VLSI IMPLEMENTATION OF LINEAR CONVOLUTION ARCHITECTURE FOR FPGA BASED SIGNAL PROCESSING APPLICATIONS

In this paper a detailed analysis and implementation has been carried out for linear convolution in which the architecture of Vedic multiplication is used to enhance the computational speed of convolution operation.The architecture was simulated using ISim andsynthesized using Xilinx synthesis technology.

- The Wallace Tree Simulator
  John D. Carpinelli, Michael Dokachev
  New Jersey Institute of Technology

- FPGA Implementation of Convolution using
  Wallace Tree Multiplier

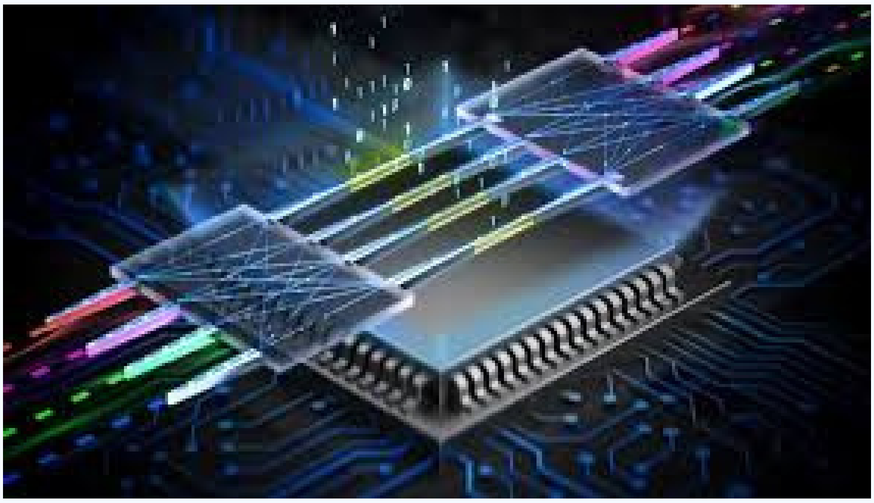
This paper is presenting a method to reduce the convolution processing time using hardware computing and implementations of discrete linear convolution of two finite length sequences (NXN).

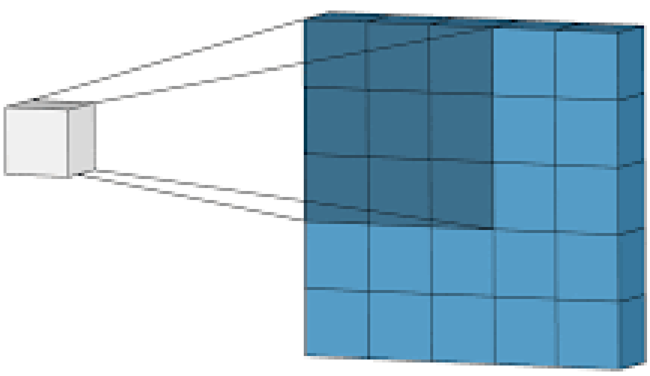
https://acadpubl.eu/hub/2018-119-16/2/480.pdf

https://research.ijcaonline.org/icettas2015/number1/icettas2565.pdf

Introduction to Linear Convolution

- **In this Verilog and ModelSim project, we delve into the realm of linear convolution, a fundamental operation in signal processing. Focusing on 4-bit numbers, our goal is to implement a robust convolution algorithm using Verilog for hardware description and ModelSim for simulation. This venture combines digital design and simulation tools to achieve the convolution of two sets of 4-bit numbers, paving the way for a deeper understanding of signal processing in a hardware context.**



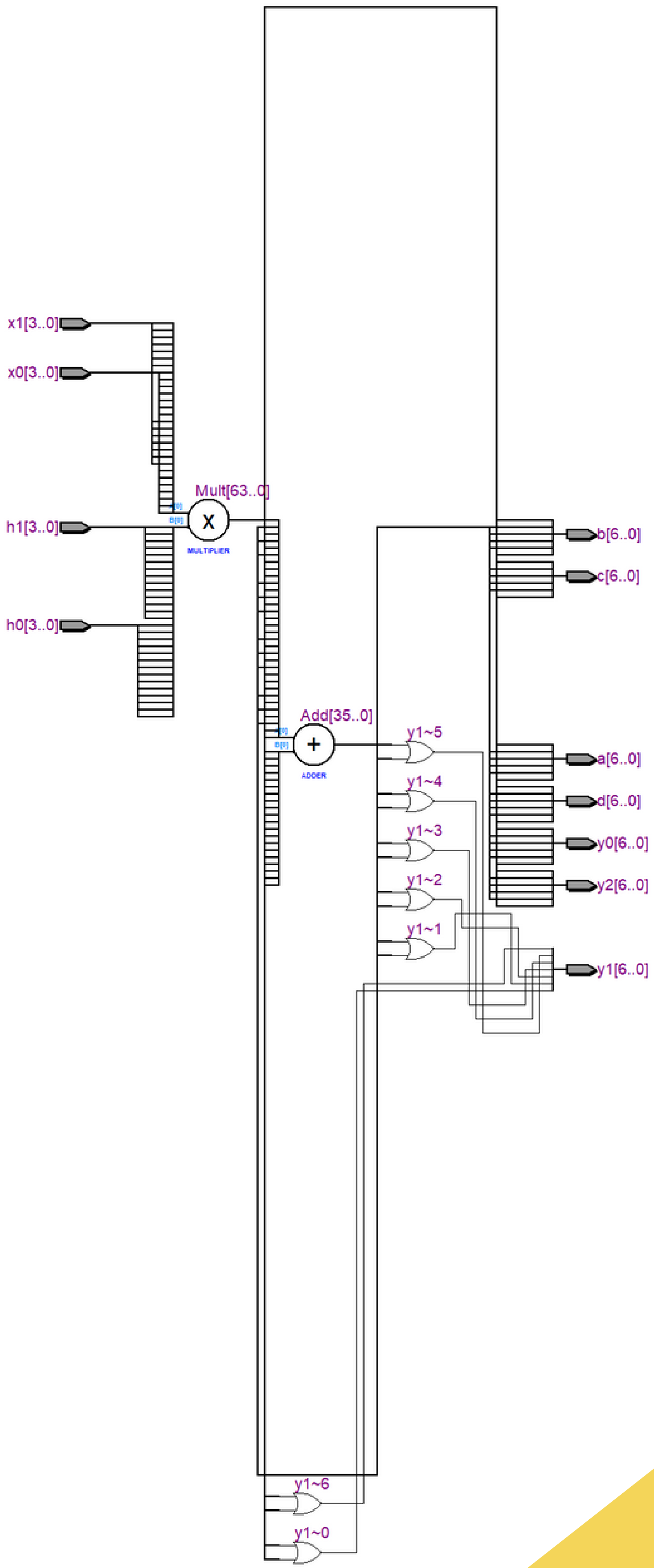


Block Diagram of Linear Convolution

Verilog Code

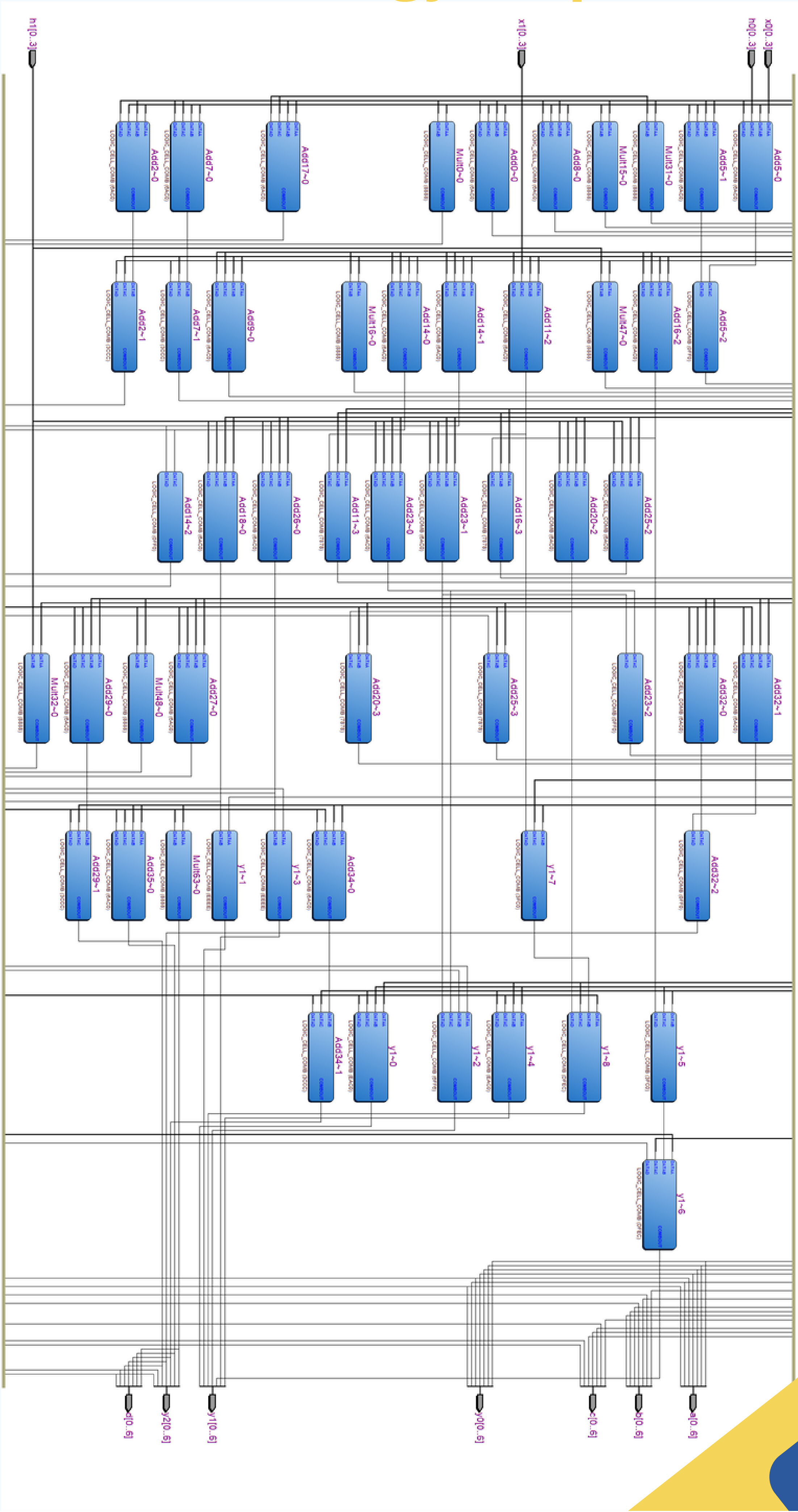
```
module Project7 (
 input [3:0] x0 ,
 input [3:0] h0 ,
 input [3:0] x1 ,
 input [3:0] h1 ,
 output [6:0] a ,
 output [6:0] b ,
 output [6:0] c ,
 output [6:0] d ,
 output [6:0] y0 ,
 output [6:0] y1 ,
 output [6:0] y2
 );

 assign a[0] = x0[0] * h0[0];
 assign a[1] = x0[0] * h0[1] + x0[1] * h0[0];
 assign a[2] = x0[0] * h0[2] + x0[1] * h0[1] + x0[2] * h0[0];
 assign a[3] = x0[0] * h0[3] + x0[1] * h0[2] + x0[2] * h0[1] + x0[3] * h0[0];
 assign a[4] = x0[1] * h0[3] + x0[2] * h0[2] + x0[3] * h0[1];
 assign a[5] = x0[2] * h0[3] + x0[3] * h0[2];
 assign a[6] = x0[3] * h0[3];

 assign b[0] = x1[0] * h0[0];
 assign b[1] = x1[0] * h0[1] + x1[1] * h0[0];
 assign b[2] = x1[0] * h0[2] + x1[1] * h0[1] + x1[2] * h0[0];
 assign b[3] = x1[0] * h0[3] + x1[1] * h0[2] + x1[2] * h0[1] + x1[3] * h0[0];
 assign b[4] = x1[1] * h0[3] + x1[2] * h0[2] + x1[3] * h0[1];
 assign b[5] = x1[2] * h0[3] + x1[3] * h0[2];
 assign b[6] = x1[3] * h0[3];

 assign c[0] = x0[0] * h1[0];
 assign c[1] = x0[0] * h1[1] + x0[1] * h1[0];
 assign c[2] = x0[0] * h1[2] + x0[1] * h1[1] + x0[2] * h1[0];
 assign c[3] = x0[0] * h1[3] + x0[1] * h1[2] + x0[2] * h1[1] + x0[3] * h1[0];
 assign c[4] = x0[1] * h1[3] + x0[2] * h1[2] + x0[3] * h1[1];
 assign c[5] = x0[2] * h1[3] + x0[3] * h1[2];
 assign c[6] = x0[3] * h1[3];

 assign d[0] = x1[0] * h1[0];
 assign d[1] = x1[0] * h1[1] + x1[1] * h1[0];
 assign d[2] = x1[0] * h1[2] + x1[1] * h1[1] + x1[2] * h1[0];
 assign d[3] = x1[0] * h1[3] + x1[1] * h1[2] + x1[2] * h1[1] + x1[3] * h1[0];
 assign d[4] = x1[1] * h1[3] + x1[2] * h1[2] + x1[3] * h1[1];
 assign d[5] = x1[2] * h1[3] + x1[3] * h1[2];
 assign d[6] = x1[3] * h1[3];

 assign y0 = a ;
 assign y1 = b | c ;
 assign y2 = d ;

 endmodule
```

RTL View

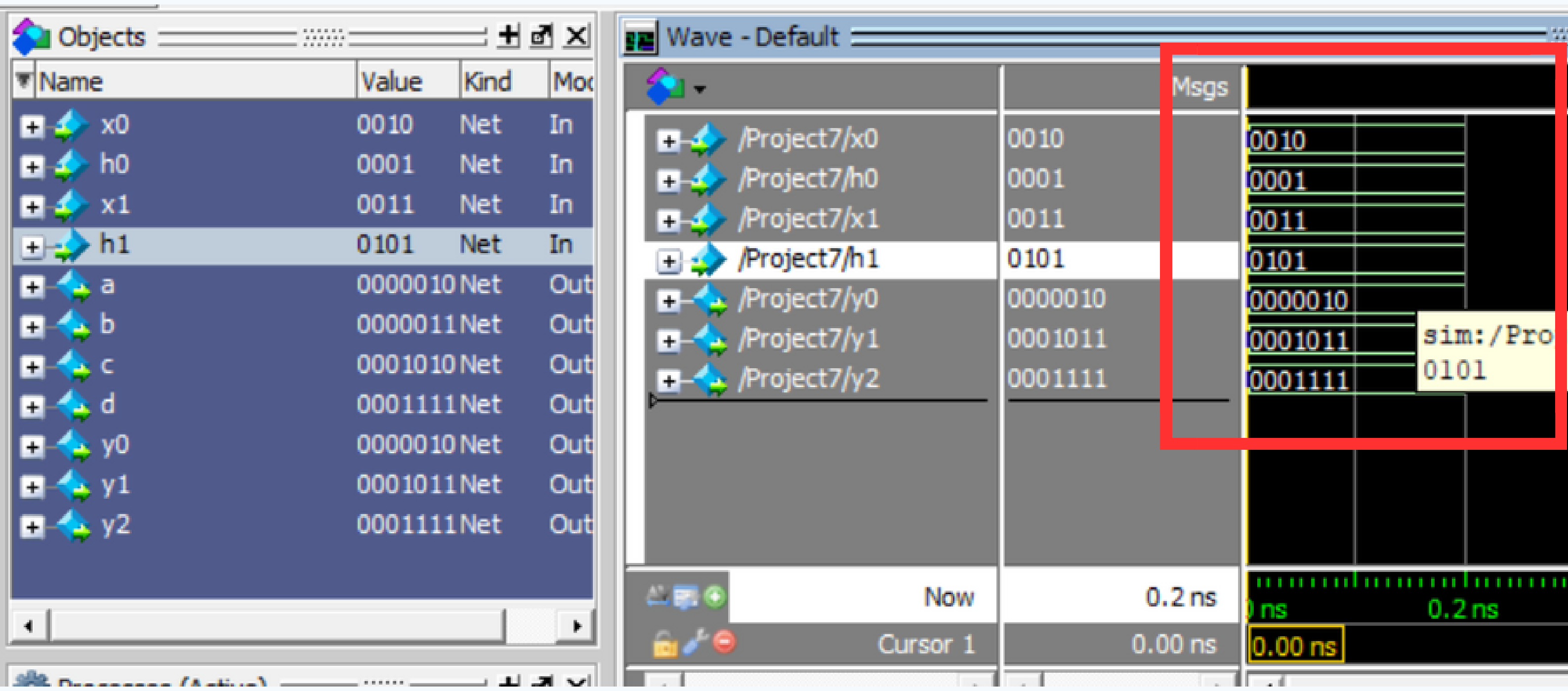


x1[3..0]
x0[3..0]
h1[3..0]
h0[3..0]
Mult[63..0]
MULTIPLIER
Add[35..0]
ADDER
y1~5
y1~4
y1~3
y1~2
y1~1
y1~6
y1~0
b[6..0]
c[6..0]
a[6..0]
d[6..0]
y0[6..0]
y2[6..0]
y1[6..0]

Technology Map View



Simulation Results



Here ,

- **X0 was forced to 0010 (2)**
- **X1 was forced to 0011 (3)**
- **H0 was forced to 0001 (1)**
- **H1 was forced to 0101 (5)**

- **The Output as calculated manually is**
  Y[0] = 0010 (2)
  Y[1] = 1011 (13)
  Y[2] = 1111 (15)

- **The Output waveform as obtained by Simulation matches the result . Output waveform is marked with a box.**

Conclusion

In conclusion, the project on linear convolution has provided valuable insights into the fundamental concept of signal processing and its practical applications. Through a comprehensive exploration of the convolution operation, we have gained a deeper understanding of its mathematical underpinnings and its significance in various fields such as image processing, audio analysis, and communication systems. The project not only delved into the theoretical aspects of linear convolution but also included hands-on implementation and experimentation, fostering a more practical grasp of the subject.

Moreover, by examining real-world scenarios and utilizing digital signal processing tools, we have showcased the versatility and applicability of linear convolution in solving complex problems. The project has not only reinforced theoretical knowledge but has also encouraged critical thinking and problem-solving skills. As we conclude, it is evident that linear convolution serves as a crucial tool in signal processing, enabling us to analyze, filter, and manipulate signals for a wide range of applications. This project has laid a solid foundation for further exploration and application of convolution in the ever-evolving landscape of signal processing.

Future Scope and References

1. Advanced Signal Processing Techniques
2. Deep Learning Integration
3. Applications in Emerging Technologies
4. Multi-dimensional Convolution
5. Real-time Processing
6. Hardware Acceleration
7. Collaboration with Other Domains

References

https://acadpubl.eu/hub/2018-119-16/2/480.pdf

https://research.ijcaonline.org/icettas2015/number1/icettas2565.pdf

Wikipedia , etc.

Thank You