



# ACCELERATING BINARY MULTIPLICATION: GROUPING AND DECOMPOSITION MULTIPLIER FOR HIGH-SPEED OPERATIONS

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## ABSTRACT:

Binary multipliers are essential components of computational systems used in Digital Signal Processing (DSP) and Fast Fourier transform (FFT) applications. Multipliers are important mathematical units that need more hardware resources and processing time. As a result, significant research has been conducted in order to reduce processing time and hardware needs. The Grouping and Decomposition (GD) multiplier is proposed as a high-speed binary multiplier in this research report to save processing time. The primary goal of the proposed multiplier is to improve algorithm processing efficiency in comparison to existing multiplier architectures. The aforementioned goal is attained by employing two methodologies: parallel grouping of partial products of identical size and decomposition of each partial-product bit within the grouped sets. A 5:2 logic adder, often known as a 5LA, is used to perform the summing. The use of parallel processing and decomposition logic reduces the number of computational steps, improving the efficiency of multiplication operations. The proposed GD multiplier's front-end and physical design implementation was carried out in the 180 nm technology library utilizing the Cadence® Virtuoso and Cadence® Virtuoso Assura tools. In compared to established multiplier architectures, the front-end design of the 8 8 suggested GD multiplier demonstrated a considerable reduction in computing time of roughly 56% and a reduction in power-delay product of 53%. The suggested multiplier's power-delay product is additionally reduced by the physical design implementation, which includes using the shortest-path method for internal subsystem routing. When used for increasingly complex multiplication jobs, the proposed multiplier's efficacy increases, making it ideal for advanced applications.

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**Keywords:** digital signal processing; fast Fourier transform; grouping and decomposition multiplier; 5:2 logic adder

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## 1. INTRODUCTION

Incorporating multimedia, image processing, and the Internet of Things necessitates enormous computational resources, as well as the vital need for quick responsiveness and energy efficiency. Digital logic circuits serve an important part in a variety of computer arithmetic applications, exhibiting a high level of reliability and accuracy. The multiplier is a fundamental mathematical element that is essential in many applications, particularly signal processing. There are numerous rapid multipliers available, each with its own set of perks and downsides. The current

focus in academia is on improving performance measures, including power efficiency, area utilization, and processing speed. For multipliers, there are two basic design options: sequential and parallel architectures. Sequential designs use less electricity, but with a longer delay. The Wallace tree and Dadda architectures, on the other hand, are parallel systems with substantial power usage.

The optimization of power consumption and processing speed is critical in the design of digital circuits, especially when multipliers are involved. A frequent method is to optimize a single parameter



while taking into account a limitation placed on another parameter. The current project provides a tough challenge due to the limited power capacity of portable devices, necessitating careful planning to achieve optimal efficiency. The presence of a specific amount of reliability may impede the system's intended performance level. There are multiple methods available at various levels of design abstraction that can be used to meet the power and speed requirements. The array multiplier is a typical type of multiplier that performs multiplication by shifting and adding. However, because of its increased processing demands, it consumes more energy, takes up more physical space, and takes longer to complete computing tasks. The main focus of current research is on the Vedic multiplier, which has significant advantages over array multipliers. Some of the advantages include increased operating efficiency and reduced geographical needs. The topic of inexact computing seeks to improve computer operations by prioritizing objective aspects over computational precision. The fundamental concept underlying the process of inexact arithmetic calculation is the reduction of circuit complexity inside arithmetic units. The aforementioned methodology can be used in situations when a definitive solution is not possible and/or a collection of approximate outcomes is acceptable.

## 2. REVIEW OF LITERATURE

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Sebastian, Alen, et al. present a 16-bit Dadda multiplier using novel compressor designs. The new compressors have two 4–2 and an enhanced higher-order compressor. Three potential multiplier designs were compared to existing ones. The proposed design matches the ideal state better than earlier designs based on latency and area analyses. It can also be utilized for accurate multipliers. The method above provides 84 slices and 20.612 nanoseconds of latency. The power loss was disregarded.

To reduce multiplier delay time and maintain area efficiency, Devi Ykuntam et al. proposed a Wallace tree multiplier architecture. In the configured setup, parallel prefix adders efficiently add partial products (PPAs). The work introduced Kogge–Stone, Sklansky, Brent–Kung, Ladner–Fischer, and Han–Carlson Wallace tree multiplier architectures. The proposed multiplier designs are compared to the typical one for nanosecond latency and Look-Up Tables. We studied a 16-bit Wallace tree multiplier utilizing the Kogge–

Stone adder. The design had 634 Look-Up Tables and 29.44 nanoseconds.

In high-computation applications, approximation methods reduce device use, battery consumption, and delay. The superfluous proportion and data storage will shrink. Approximation approaches lower arithmetic circuit computational complexity while maintaining coding efficiency. The approximate, practically complete adder-based Dadda multiplier enhances speed, energy usage, and device count. This study evaluates many multipliers using a nearly full adder approximation. An almost-full adder 8-bit Dadda multiplier requires 11.409 W and 0.20 LUTs.

Jaiswal, Kokila Bharti, et al. created a multiplexer-based complete adder to save multiplier power. The Wallace tree multiplier design evaluated the structure's efficiency. The proposed multiplier reduced power consumption by 37.45%, area utilization by 45.75%, and latency by 17.65% compared to a typical topology using ASIC synthesis. The recommended complete adder builds a 16-bit Wallace multiplier in 8.81 nanoseconds and consumes 6.5534 milliwatts.

Wallace and Dadda multiplied using Devnath's hybrid 3–2 counter. The recommended method generates partial products utilizing numerous AND gates with two transistors. The 65 nm PTM transistor architecture made multipliers. A comprehensive assessment and analysis compared both multipliers' system outcomes to other models. The hybrid full adder in the 4-bit Dadda multiplier had a latency of 220.9 ps and used 20.34  $\mu$ W of power.

Ram et al. compared Wallace multiplier delay to array and Dadda multipliers. The suggested 16-bit Wallace multiplier employed CSLA and BEC adders. The Wallace multiplier computes faster with a CSLA than a BEC. Wallace multiplier with 16-bit input converts binary to excess code in 24.948 nanoseconds and 86.48 mW.

Two multiplier 4–2 compressor estimates were established by Momeni et al. Different compression algorithms accommodate computational faults in circuit-based performance measurements in these systems. Researchers examined four Dadda multiplier approximation compressor integration approaches. A 4–2 compressor approximation 8-bit Dadda multiplier has 44.35 picoseconds latency and 1.14 micro-Watts power consumption.

Four 4:2 compressors with accurate and approximation modes were introduced by Akbari, Omid, et al. The approximation mode uses 2D compressors to boost speed and power but reduce

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accuracy. The compressors' latency, power consumption, and accuracy vary between exact and approximate modes. 16-bit Dadda Multiplier with dual-quality 4:2 mixed compressors has 1.19 nanosecond delay and 2339 microWatts power consumption.

Wallace/Dadda/parallel binary multipliers' performance specifications are in Table 1. All architectures increase power-delay product by slowing processing or consuming more power. This study proposed a new binary multiplication design to lower power-delay product and other crucial factors. Decomposing partial goods by size and parallel decomposing each category partial product helped complete this homework. Parallel processing and decomposition logic decrease computing stages and speed up calculation in the revolutionary architecture. The GD multiplier decomposes using a 4x4 Wallace and Dadda binary multiplier.

Table 1. The parameters of numerous literature works will be compared in this study.

Title	Multiplier	Computational Time	Power Consumption/ Area Consumption	Implementation Tool/ Technological Node
1. Design and Implementation of an Efficient Dadda Multiplier Using Novel Compressors and Fast Adder	16-bit Dadda multiplier with 4-2	20.612 ns	84 slices	Xilinx ISE
2. Design and Analysis of High speed Wallace Tree Multiplier Using Parallel Prefix Adders for VLSI Circuit Designs	16-bit Wallace tree multiplier using Kogge-Stone adder compressors	29.44 ns	634 LUT	Xilinx ISE
3. An Efficient Dadda Multiplier using Approximate Adder	8-bit Dadda multiplier using almost full adder	NA	11.409 Watt / 0.20 LUT	Xilinx ISE
4. Low-Power Wallace Tree Multiplier Using Modified Full Adder	16-bit Wallace tree multiplier using full adder	8.81 ns	6.5584 mW / 12,627.71 $\mu\text{m}^2$	Synopsys design compiler using SAED 90 nm CMOS technology
5. 4-bit Wallace and Dadda Multiplier Design Using Novel Hybrid 3-2 Counter	4-bit Dadda multiplier with hybrid full adder	220.9 ps	20.34 $\mu\text{W}$	65 nm technology
6. Design of Delay Efficient Modified 16-bit Wallace Multiplier	16 x 16-bit Wallace multiplier binary to excess code converter	24.948 ns	86.48 mW / 1019 LUT	Xilinx
7. Design and Analysis of Approximate Compressors for Multiplication	8-bit Dadda multiplier with approximate 4-2 compressor	44.35 ps	1.14 $\mu\text{W}$	32 nm HSPICE simulation
8. Dual-Quality 4:2 Compressors for Utilizing in Dynamic Accuracy Configurable Multipliers	8-bit Dadda multiplier with dual-quality 4:2 compressors mixed	0.25 ns	424 $\mu\text{W}$ / 423 $\mu\text{m}^2$	45 nm technology node

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  5. 4\*4 MULTIPLIER
  - 6.
- Conventional Wallace Multiplier (4\*4)**  
**Wallace's method binary multiplier.**

The attainment of the ultimate outcome is accomplished by diminishing the generator of partial products [22,23] (as depicted in Figure 1) via the utilization of a single-bit full adder and a half adder (as illustrated in Figure 2a,b).

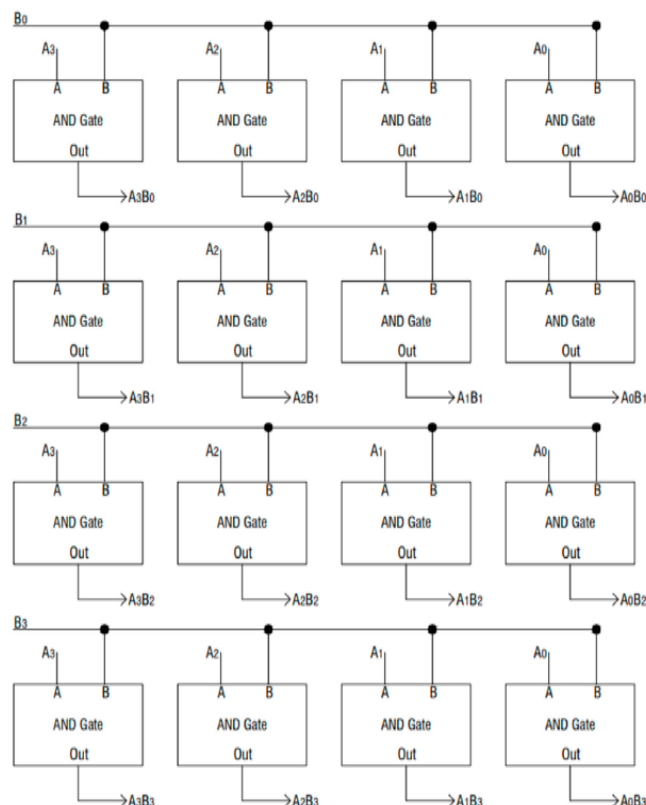
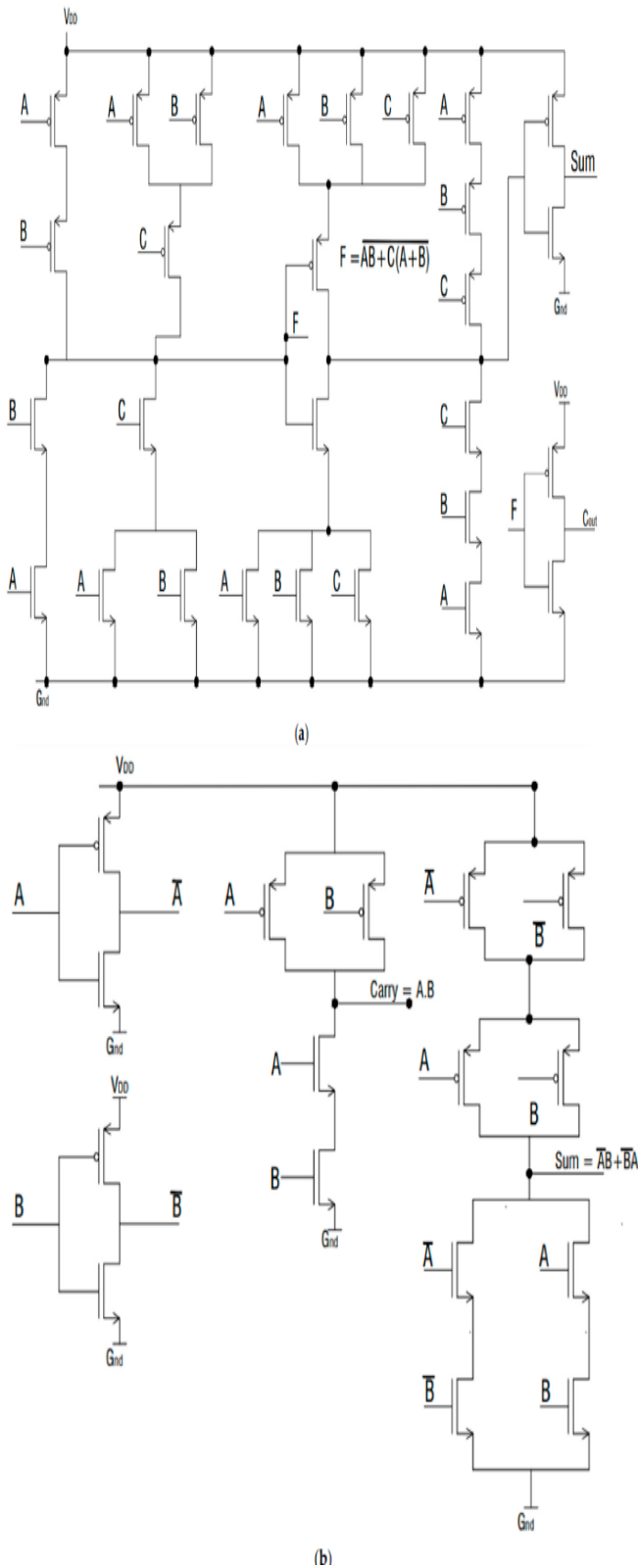


Figure 1. Schematic design of 4\*4 partial product generator.

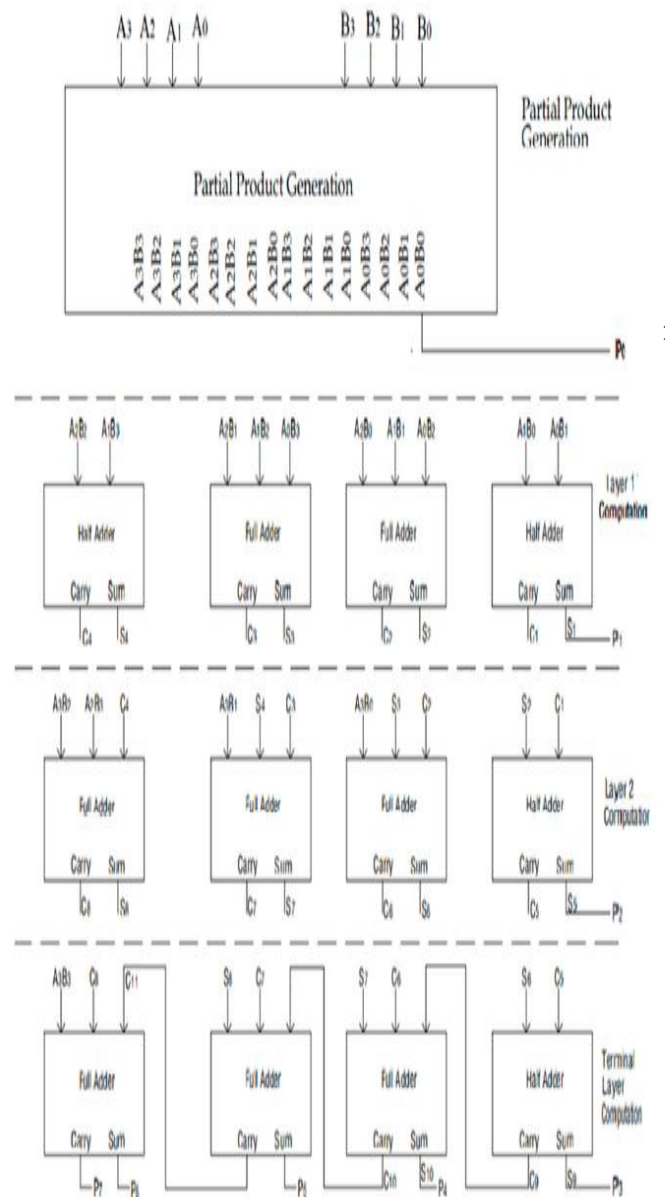
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**Figure 2. (a)** This paper presents the schematic design of a static CMOS single-bit full adder.  
**(b)** This paper presents the schematic design of a static CMOS single-bit half adder.  
 After the partial products have been generated, an analysis is conducted on each column, which has a maximum height of  $h = 3$ . The subsequent step

involves the reduction of layers. The schematic construction of a conventional 4x4 Wallace multiplier is illustrated in Figure 3. The processing of layers in the provided system is contingent upon the number of items present in the column. Single-bit half adders are utilized in situations when there exists a singular bit that needs to be carried over to the subsequent layer. In contrast, when there are two or three partial products listed in the column, the computational task is carried out using full adders. The sum of all previous values and the remainder are passed on to the next set of entries. The technique described above is repeated until it reaches the final layer, which is defined by only one pair of entries in each column.



**Figure 3.** The current investigation is on the schematic design of a 4x4 Wallace multiplier.  
 The computing time is reduced by the Wallace multiplier by the implementation of parallel bit



reduction in layers, which involves the utilization of single-bit half adders and full adders. Nevertheless, it is conceivable to further diminish the quantity of logical levels required for executing the summing, hence decreasing the intricacy of the process. The complicated nature of the physical construction of the Wallace multiplier becomes particularly apparent when contemplating higher order multiplication.

7. PROPOSED GD MULTIPLIER (8\*8)

The GD multiplier, as seen in Figure 4, is a high-speed multiplier that employs a parallel multiplication and grouping process. The GD multiplier technique is implemented as follows for binary multiplications of size 8\*8.

- This analysis concludes the Five-Level Alphabet (5LA) bit examination.
- After generation, imperfect goods are separated into equal-sized groups.

The decomposition method sequentially processes each group through the Dadda and Wallace multipliers. The concurrent implementation of Wallace and Dadda multipliers reduces partial product accumulation computing time. The half adders and byproducts from each group are transferred to the 5LA, as shown in Figure 5, to yield the final findings. The 5LA is a composite architecture with two fully working adders designed to improve carry propagation reduction. An unusual hybrid multiplier, the GD multiplier combines Wallace and Dadda features. Its goal is to synergistically use each multiplier architecture's advantages. Figure 6 illustrates the operating concept of the GD multiplier using an 8\*8 input test case.

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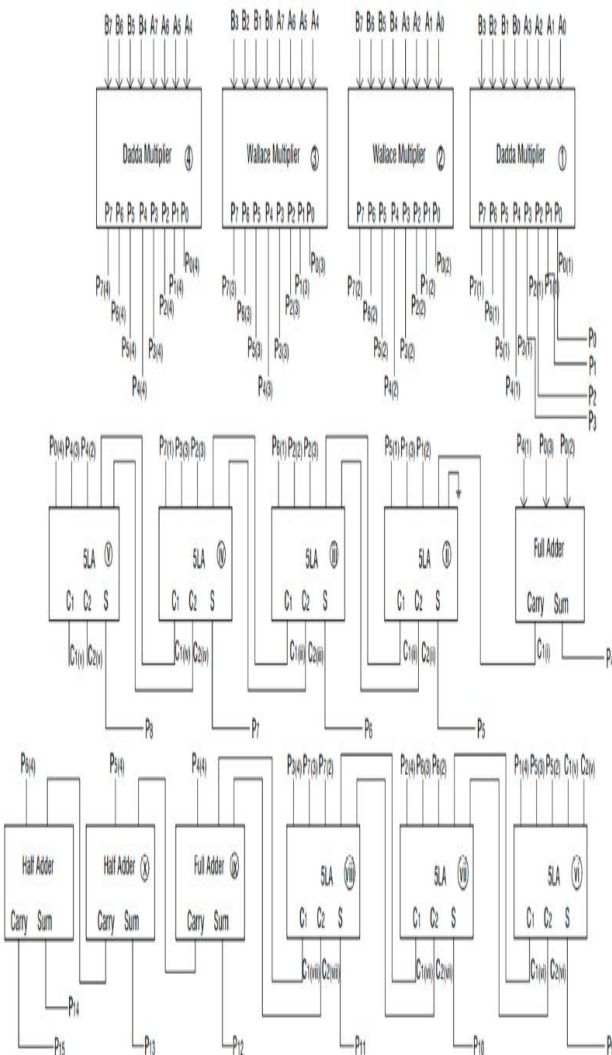


Figure 4. This is a schematic diagram of an 8x8 gate diffusion (GD) multiplier.

- Decomposing grouped bits and obtaining partial products via parallel grouping is the study's main goal. This study will use a 4x4 Wallace multiplier and a 4x4 Dadda multiplier.

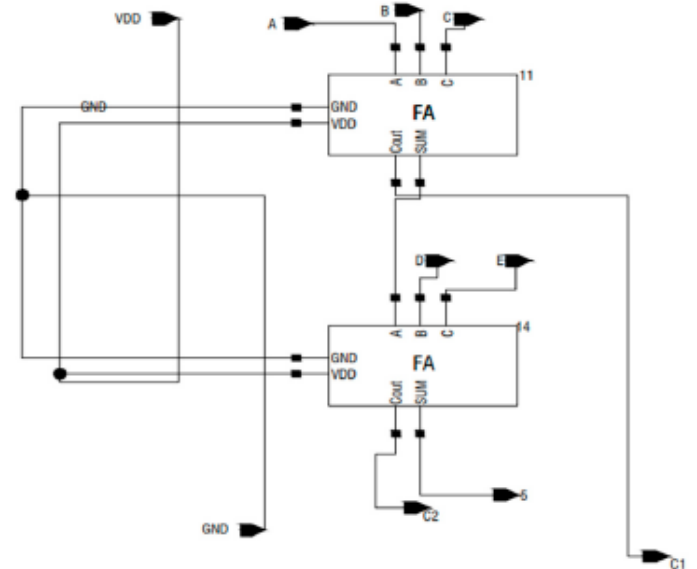
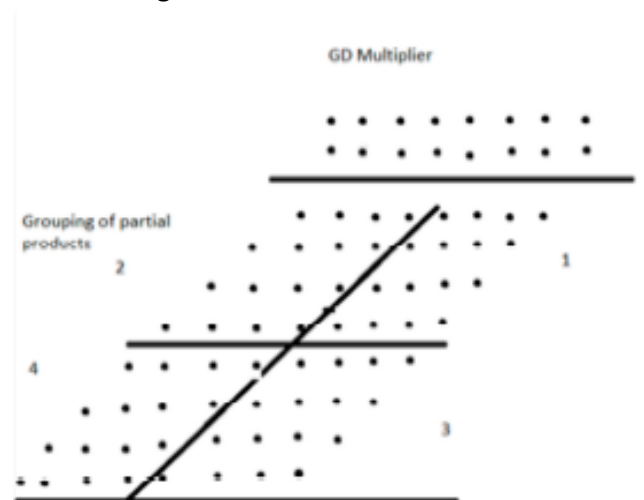
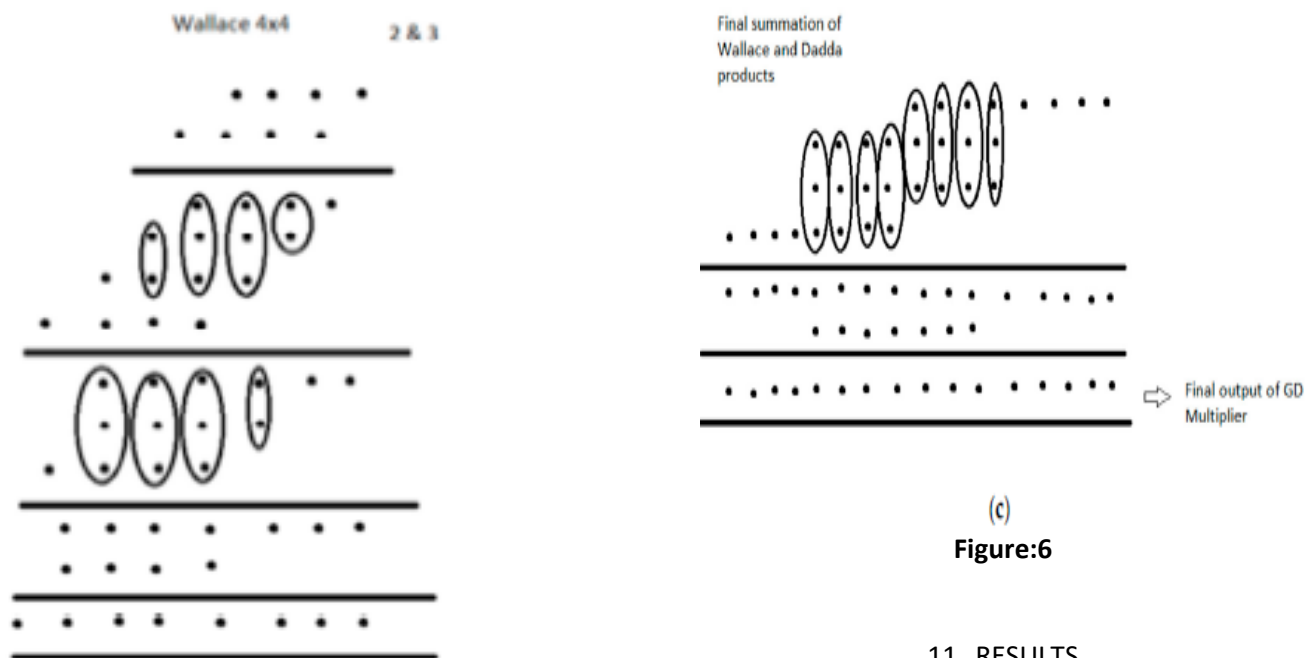


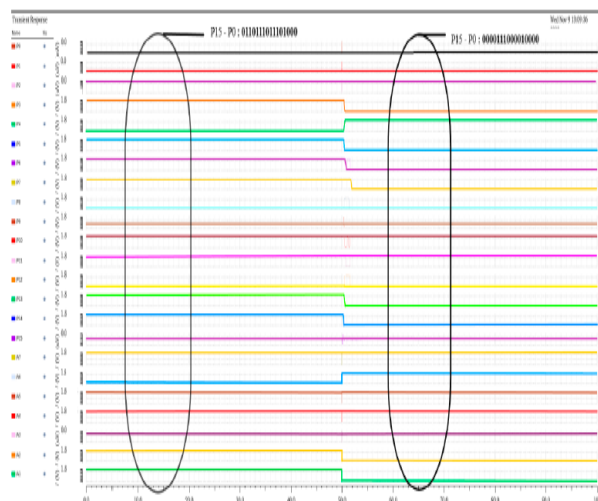
Figure 5. Schematic of 5LA.



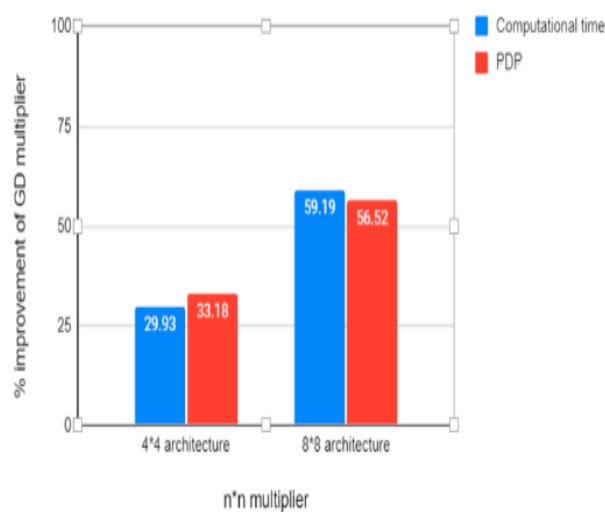


(c)  
**Figure:6**

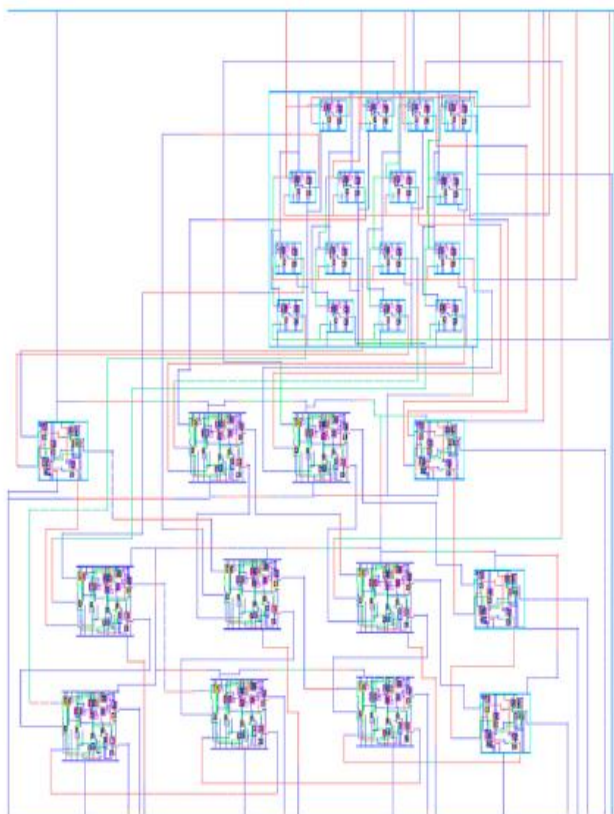
**11. RESULTS**



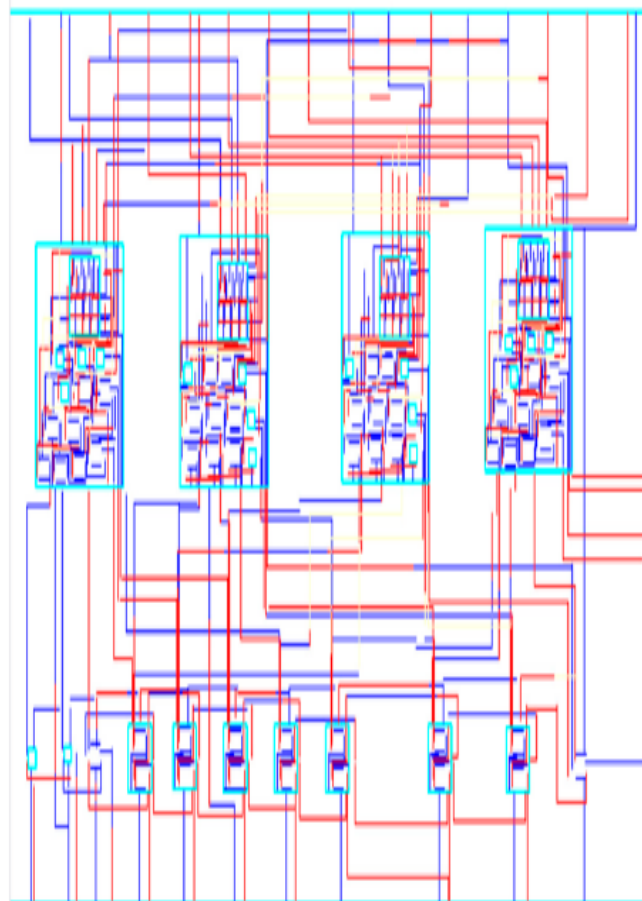
**Figure 7.** The objective of this study is to show a simulation waveform of an 8x8 gate diffusion (GD) multiplier.



**Figure: 8** Comparison of the Proposed Multiplier with the Existing Multiplier



**Figure 9:** The physical design execution of a 4x4 Wallace multiplier was carried out at the DRC and LVS stages.



**Figure 10. :** The DRC and LVS were cleaned extensively during the physical design implementation of an 8x8 Grouping and Decomposition (GD) multiplier.

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## 5. CONCLUSION

The present study introduces an innovative high-speed binary multiplier that utilizes a grouping and decomposing technique. The utilization of the multiplier was executed through the application of the 180nm CMOS technology. The front-end architecture of the suggested multiplier demonstrates a significant reduction of 56.29% in processing time and 53.49% in power-delay product in comparison to parallel architectures. The proposed multiplier use the grouping and decomposition technique to effectively reduce the bit count in a simultaneous manner, irrespective of the quantity of partial products involved. The GD multiplier, as described, exhibits a significant reduction in computational time, with measured decreases of 47.52% and 43.85% when compared to the Wallace and Dadda multipliers, respectively. This paper undertakes a comparative examination of the proposed architecture and existing multipliers, emphasizing the benefits of the parallel grouping and decomposition strategy in contrast to



alternative methodologies like Wallace, Dadda, and similar techniques. This specific characteristic renders it highly appropriate for applications pertaining to high-speed Very Large Scale Integration (VLSI).

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