

Design and Estimation of Delay, Power and Area for Parallel Prefix Adders

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Abstract:

In Very Large Scale Integration (VLSI) designs, Parallel prefix adders (PPA) have the better delay performance. The binary addition is the basic arithmetic operation in digital circuits and it became essential in most of the digital systems including Arithmetic and Logic Unit (ALU), microprocessors and Digital Signal Processing (DSP). At present, the research continues on increasing the adder's delay performance. In many practical applications like mobile and telecommunications, the Speed and power performance improved in FPGAs is better than microprocessor and DSP's based solutions. Additionally, power is also an important aspect in growing trend of mobile electronics, which makes large-scale use of DSP functions.

Because of the Programmability, structure of configurable logic blocks (CLB) and programming interconnects in FPGAs, Parallel prefix adders have better performance. This paper investigates four types of PPA's (Kogge Stone Adder (KSA), Spanning Tree Adder (STA), Brent Kung Adder (BKA) and Sparse Kogge Stone Adder (SKA)). Additionally Ripple Carry Adder (RCA), Carry Look ahead Adder (CLA) and Carry Skip Adder (CSA) are also investigated. These adders are implemented in Verilog Hardware Description Language (HDL) using Xilinx Integrated Software Environment (ISE) 14.4 Design Suite.

Key words:

Parallel prefix adders; carry tree adders.

1. INTRODUCTION:

The binary addition is the basic arithmetic operation in digital circuits and it became essential in most of the digital systems including Arithmetic and Logic Unit (ALU), microprocessors and Digital Signal Processing (DSP). At present, the research continues on increasing the adder's delay performance. In many practical applications like mobile and telecommunications, the Speed and power performance improved in FPGAs is better than microprocessor and DSP's based solutions. Additionally, power is also an important aspect in growing trend of mobile electronics, which makes large-scale use of DSP functions. Because of the Programmability, structure of configurable logic blocks (CLB) and programming interconnects in FPGAs, Parallel prefix adders have better performance. The delays of the adders are discussed [1]. In this paper, above mentioned PPA's and RCA and CSA are implemented and characterized on a Xilinx14.4. Finally, delay, power and area for the designed adders are presented and compared..

II. DRAWBACKS OF EXISTING ADDERS TECHNIQUES:

In figure1, the first sum bit should wait until input carry is given, the second sum bit should wait until previous carry is propagated and so on. Finally the output sum should wait until all previous carries are generated. So it results in delay.

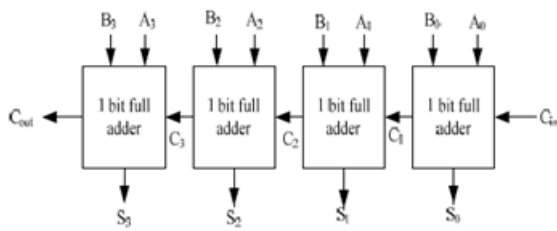


Fig. 1. 4 bit ripple carry adder

In order to reduce the delay in RCA (or) to propagate the carry in advance, we go for carry look ahead adder. Basically this adder works on two operations called propagate and generate. The propagate and generate equations are given by.

$$P_i = A_i \oplus B_i \quad (1)$$

$$G_i = A_i \cdot B_i \quad (2)$$

For 4 bit CLA, the propagated carry equations are given as

$$C_1 = G_0 + P_0 C_0 \quad (3)$$

$$C_2 = G_1 + P_1 G_0 + P_1 P_0 C_0 \quad (4)$$

$$C_3 = G_2 + P_2 G_1 + P_2 P_1 G_0 + P_2 P_1 P_0 C_0 \quad (5)$$

$$C_4 = G_3 + P_3 G_2 + P_3 P_2 G_1 + P_3 P_2 P_1 G_0 + P_3 P_2 P_1 P_0 C_0 \quad (6)$$

Equations (3),(4),(5) and (6) are observed that, the carry complexity increases by increasing the adder bit width. So designing higher bit CLA becomes complexity. In this way, for the higher bit of CLA's, the carry complexity increases by increasing the width of the adder. So results in bounded fan-in rather than unbounded fan-in, when designing wide width adders. In order to compute the carries in advance without delay and complexity, there is a concept called Parallel prefix approach.

III. DIFFERENCE BETWEEN PARALLEL-PREFIX ADDERS AND OTHERS:

The PPA's pre-computes generate and propagate signals are presented in [2]. Using the fundamental carry operator (fco), these computed signals are combined in [3]. The fundamental carry operator is denoted by the symbol " $\square \square$ ",

$$(g_L, p_L) \circ (g_R, p_R) = (g_L + p_L \cdot g_R, p_L \cdot p_R) \quad (7)$$

For example, 4 bit CLA carry equation is given by

$$C_4 = (g_4, p_4) \circ [(g_3, p_3) \circ [(g_2, p_2) \circ (g_1, p_1)]] \quad (8)$$

For example, 4 bit PPA carry equation is given by

$$C_4 = [(g_4, p_4) \circ (g_3, p_3)] \circ [(g_2, p_2) \circ (g_1, p_1)] \quad (9)$$

Equations (8) and (9) are observed that, the carry look ahead adder takes 3 steps to generate the carry, but the bit PPA takes 2 steps to generate the carry.

IV. PARALLEL-PREFIX ADDER STRUCTURE:

Parallel-prefix structures are found to be common in high performance adders because of the delay is logarithmically proportional to the adder width [2].

PPA's basically consists of 3 stages

Pre computation

Prefix stage

Final computation

The Parallel-Prefix Structure is shown in figure 2.

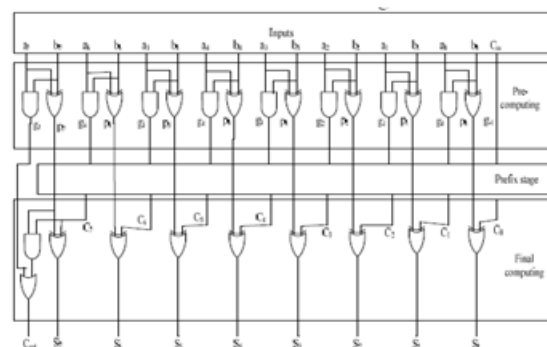


Fig. 2. Parallel-Prefix Structure with carry save notation

A. Pre computation:

In pre computation stage, propagates and generates are computed for the given inputs using the given equations (1) and (2).

B. Prefix stage:

In the prefix stage, group generate/propagate signals are computed at each bit using the given equations.

The black cell (BC) generates the ordered pair in equation (7), the gray cell (GC) generates only left signal, following [2].

$$G_{ik} = G_{ij} + P_{ij} \cdot G_{j-1;k} \quad (10)$$

$$P_{ik} = P_{ij} \cdot P_{j-1;k} \quad (11)$$

More practically, the equations (10) and (11) can be expressed using a symbol “o” denoted by Brent and Kung. Its function is exactly the same as that of a black cell i.e.

$$G_{ik} : P_{ik} = (G_{ij} : P_{ij}) o (G_{j-1;k} : P_{j-1;k}) \quad (12)$$

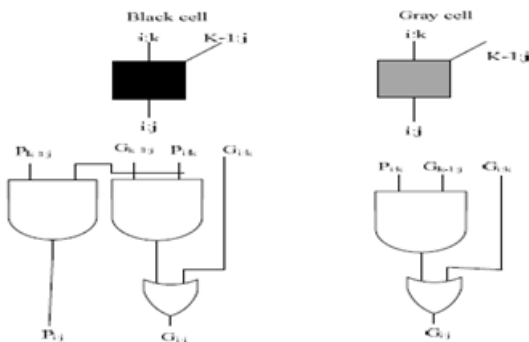


Fig. 3. Black and Gray Cell logic Definitions

The “o” operation will help make the rules of building prefix structures.

C. Final computation

In the final computation, the sum and carryout are the final output.

$$S_i = P_i \cdot G_{i-1;-1} \quad (13)$$

$$C_{out} = G_{n;-1} \quad (14)$$

Where “-1” is the position of carry-input. The generate/propagate signals can be grouped in different fashion to get the same correct carries. Based on different ways of grouping the generate/propagate signals, different prefix architectures can be created. Figure 3 shows the definitions of cells that are used in prefix structures, including BC and GC. For analysis of various parallel prefix structures, see [2], [3] & [4]. The 16 bit SKA uses black cells and gray cells as well as full adder blocks too.

This adder computes the carries using the BC’s and GC’s and terminates with 4 bit RCA’s. Totally it uses 16 full adders. The 16 bit SKA is shown in figure 4. In this adder, first the input bits (a, b) are converted as propagate and generate (p, g). Then propagate and generate terms are given to BC’s and GC’s. The carries are propagated in advance using these cells. Later these are given to full adder blocks. Another PPA is known as STA is also tested [6]. Like the SKA, this adder also terminates with a RCA. It also uses the BC’s and GC’s and full adder blocks like SKA’s but the difference is the interconnection between them [7]. The 16 bit STA is shown in the below figure 5.

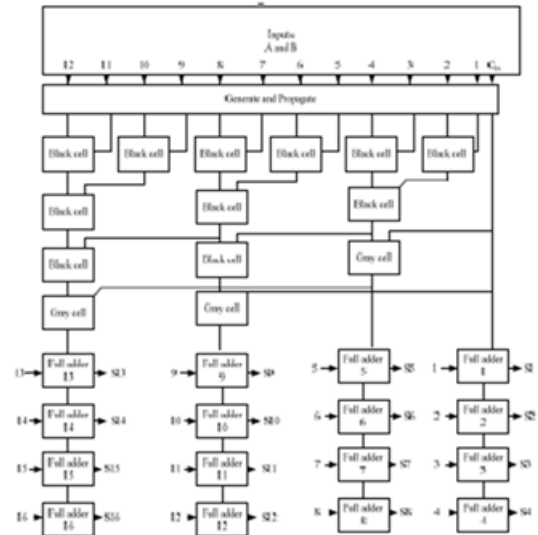


Fig 4.16 bit spars kogge stone adder

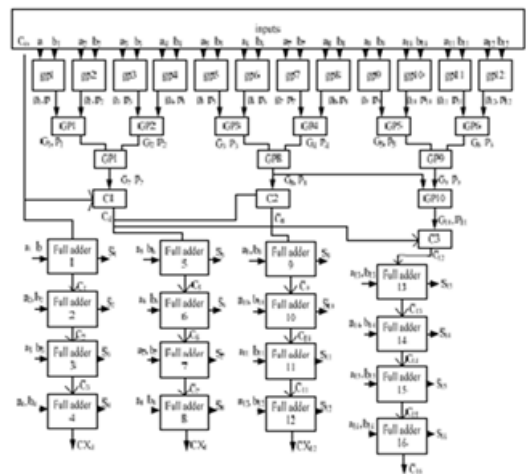


Fig 5.16 bit spanning tree adder

KSA is another of prefix trees that use the fewest logic levels. A 16-bit KSA is shown in Figure 6. The 16 bit kogge stone adder uses BC's and GC's and it won't use full adders. The 16 bit KSA uses 36 BC's and 15 GC's. And this adder totally operates on generate and propagate blocks. So the delay is less when compared to the previous SKA and STA. The 16 bit KSA is shown in figure 6. In this KSA, there are no full adder blocks like SKA and STA [5] & [6]. Another carry tree known as BKA which also uses BC's and GC's but less than the KSA. So it takes less area to implement than KSA. The 16 bit BKA uses 14 BC's and 11 GC's but kogge stone uses 36 BC's and 15 GC's. So BKA has less architecture and occupies less area than KSA. The 16 bit BKA is shown in the below figure 7.

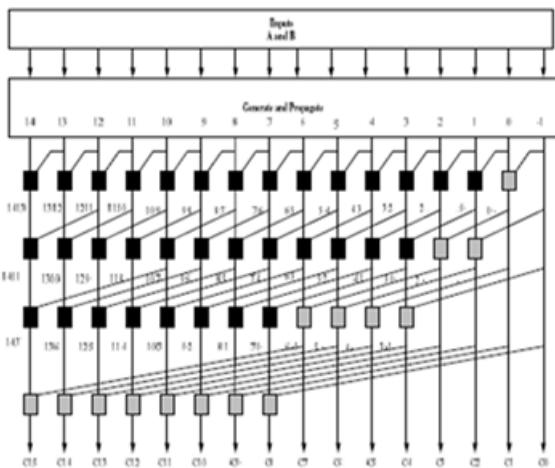


Fig 6.16 bit kogge stone adder

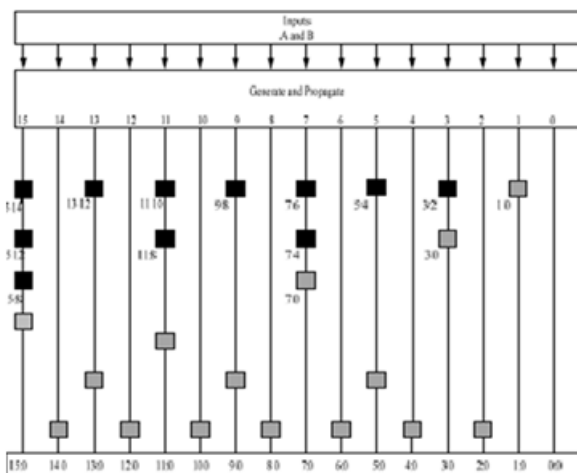


Fig 7.16 bit BrentKung adder

BKA occupies less area than the other 3 adders called SKA, KSA, STA. This adder uses limited number of propagate and generate cells than the other 3 adders. It takes less area to implement than the KSA and has less wiring congestion. The operation of the 16 bit Brent kung adder is given below [3].

V.SIMULATION RESULTS:

We have coded for parallel prefix adders in Verilog HDL using the proposed designs and the existing adders designs of [6] and [7] for bit-widths 8,16. All the designs are synthesized in the Xilinx Synthesis Tool and Simulated using Xilinx ISE simulator. The synthesis result confirms that the proposed parallel prefix adders involves significantly less area and less delay and consumes less power than the existing designs. The schematics and simulated outputs are found from fig8 and fig9.

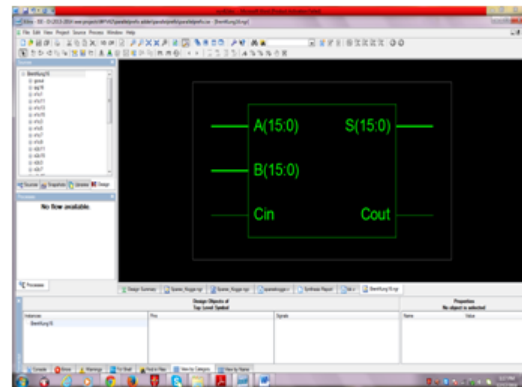


Fig.8. (a) RTL schematic of Proposed 16 bit BK

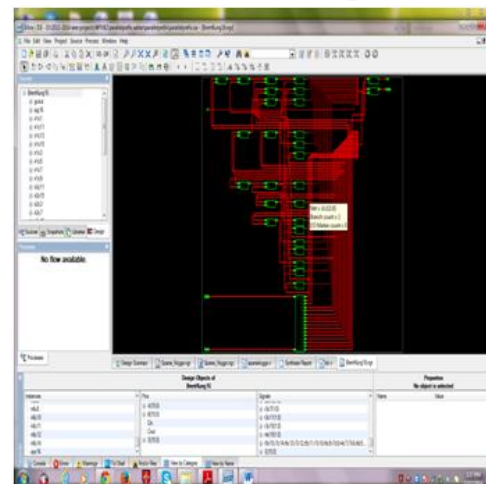


Fig.8. (b) Sub RTL schematic of Proposed 16 bit BK

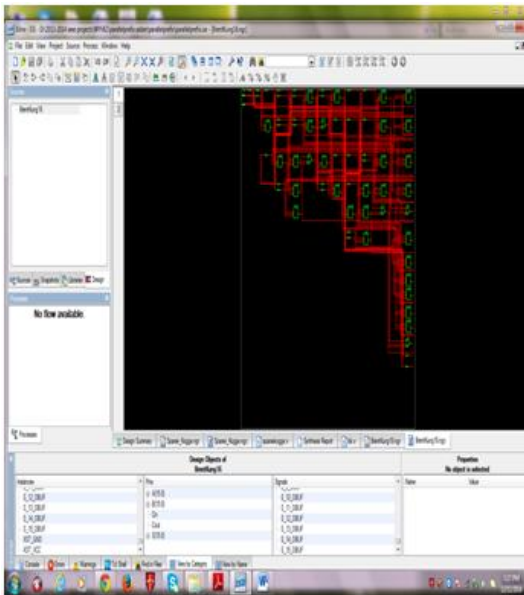


Fig.8. (c) Technology schematic of Proposed 16 bit BK

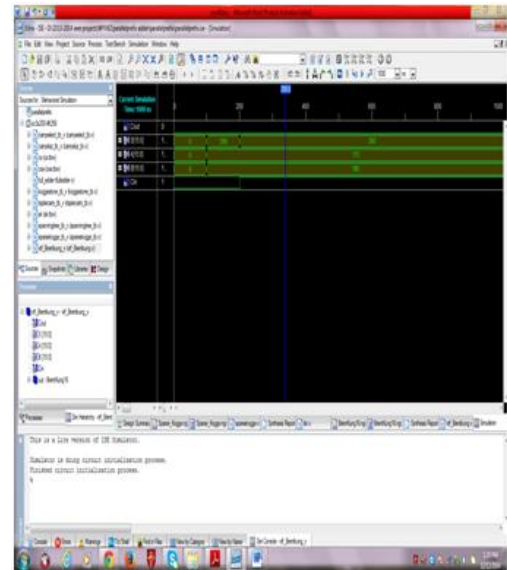


Fig.10. Simulation output of BK

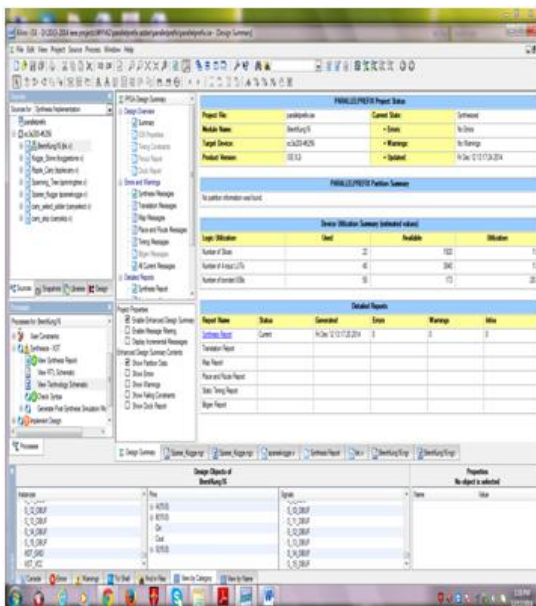


Fig.9. Synthesis summary of Proposed 16 bit BK

VI. CONCLUSION:

A simple approach is proposed in this paper to reduce the area and delay of parallel prefix adders architectures. The proposed parallel prefix adders design involves significantly less area and delay than the recently proposed parallel prefix adders. Due to the small carry output delay, the proposed parallel prefix adder design is a good candidate for the high speed adders. From the study of analysis done on area and delay, we have concluded that the efficiency is improved by 5.77 % in our delay for RCA, when compared to [1] and for KSA it is improved by 19.28 % when compared with [1].

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