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Fast Speculative Multipliers Based on TDM Carry-Save Tree

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***Abstract*—This paper presents a fast method for integer multiplication based on speculation. Here uses three steps for carry save tree reduction: recoding partial products, partitioning partial products, speculative compression. For speculative compression uses speculative (m : 2) counters, with m > 3. Final carry save addition is done using fast speculative carry-propagate adder and an error correction circuit is used only in rare case of error. Synthesis report shows that the speculative multipliers have high speed compared to conventional multipliers and also quite effective in power dissipation, when a fast operation is needed.**

***Index Terms*—About four key words or phrases in alphabetical order, separated by commas.**

I. INTRODUCTION

Integer multiplication is the basic building block of digital designs. Fast non-Booth multipliers use logarithmic methods such as Dadda ,Wallace or the Three Dimentional Method TDM. They all use carry save compression tree, which consists of full-adders and half-adders to convert multi-operand sum into a two operand addition completed by a, fast carry-propagate adder.

High speed circuits can be obtained by using speculative method. Speculative circuits performs faster but occasionally wrong operation , shifting to a multi-cycle error correction circuit only in the rare case of error.

Speculation has also recently applied to addition. Computation of speculative adder is divided into two cycles: first adder calculates a speculative sum and an error flag, while in the second cycle corrects the speculative result. Speculative multipliers are more complex than adders.

In this paper presents a method to develop fast speculative multiplier. The proposed speculative multiplier uses speculative carry-save reduction by three steps: recoding partial products, partitioning partial products and speculative compression. The speculative carry-save tree uses speculative *(m : 2)* counters, with $m > 3$. Speculative counters are faster than conventional counters. For faster operation TDM carry-save tree calculates the input according to the time arrival of inputs. TDM Carry save tree is completed with a fast speculative adder and an error correction circuit.

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II. SPECULATIVE MULTIPLIER DESIGN

Fig.1(a) shows the partial products matrix (PPM) for a 16 × 16 multiplier. The rightmost and left most columns of the PPM consists of small number of partial products, but the inner columns have more number of partial products. The height of the PPM determines the delay of the circuit: higher the matrix, higher the delay. Speculative carry-save reduction tree is obtained by deleting some partial products which belongs to the inner columns of the PPM. However this would leads to misprediction. Thus uses three steps for partial product reduction: partial products recoding, partial product partitioning and speculative compression.

A. Recoding the partial products

Consider a_ib_j and a_jb_i are the two partial products of the $i + j$-th column of the PPM and also introduce two modified partial products shown below:

$$A_{i,j} = a_ib_j \; AND \; a_jb_i$$
$$O_{i,j} = a_ib_j \; OR \; a_jb_i \qquad (1)$$

From the above equations: $A_{i,j} + O_{i,j} = a_ib_j + a_jb_i$. Thus, we can replace some partial products a_ib_j and a_jb_i with the modified partial products $A_{i,j}$ and $O_{i,j}$

B. Partitioning the partial products

Only partial products in the inner columns which have higher height, are recoded. Fig.1(b) shows the partial products after recoding.

C. Speculative compression

Simple deletion of $A_{i,j}$ terms for obtaining reduction in carry-save tree would introduce very large misprediction. Therefore, we sum $A_{i,j}$ terms by using speculative counters. An *(m : 2)* speculative counter has *m* inputs $(x_0,\ldots..x_{m-1})$ and two outputs sum *S* and carry *C*. The speculative counter counts the number of input bits that are "1" and encode the result on *S* and *C*.

$$2C + S = x_0 + x_1 + \ldots\ldots + x_{m-1} \text{ for : } x_0 + \ldots\ldots + x_{m-1} \leq 3 \qquad (4)$$

For $m > 3$ we could not represent the sum $x_0 + \ldots\ldots + x_{m-1}$ using S and C signals for all input configurations. If more than three inputs are high, speculative counter gives the wrong result and it should be corrected in the next cycle.

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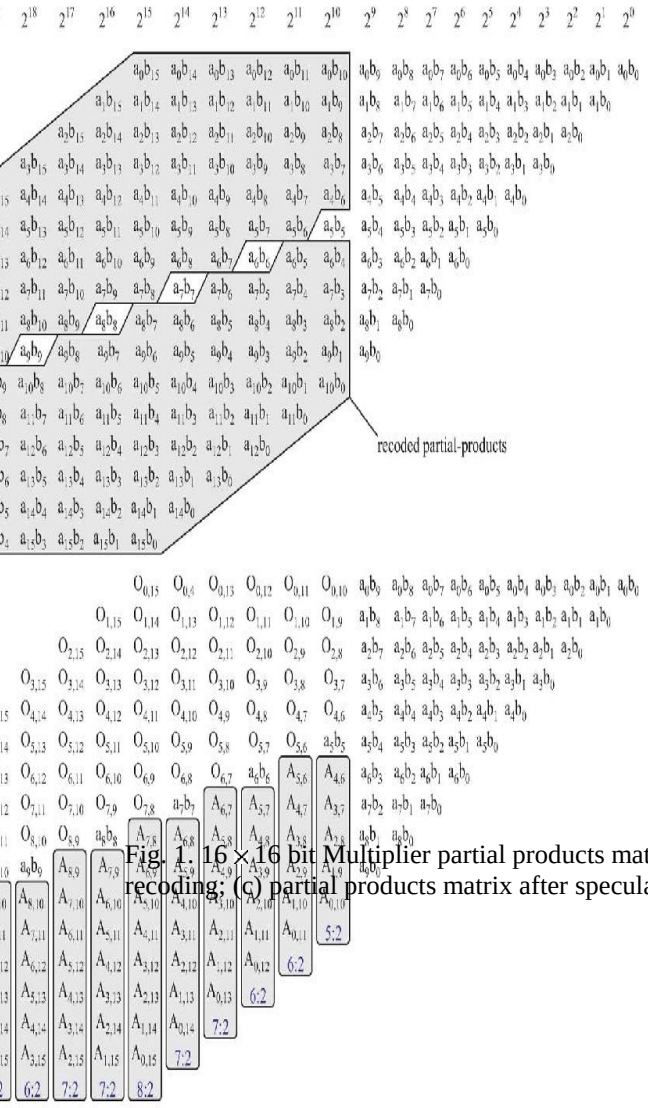

Fig. 1. 16 ×16 bit Multiplier partial products matrixes: (a) initial partial products matrix; (b) partial products matrix after recoding; (c) partial products matrix after speculative compression [1]

D. Multiplier Design

The design of speculative multiplier is shown in fig.2. The multiplier have two inputs A and B. Inputs are firstly given to the partial products generation and recoding block. This block calculates all the partial products and recodes partial products which belonging to the innermost columns of the PPM, producing $A_{i,j}$ and $O_{i,j}$ recoded partial products.

$A_{i,j}$ terms are processed by speculative counters which computes reduced $S_{i,j}$ and $C_{i,j}$ terms. The speculative counter results $S_{i,j}$ and $C_{i,j}$ terms, the un-recoded $a_i b_j$ and the recoded $O_{i,j}$ partial products are added together by using TDM carry-save tree.

The TDM tree has two outputs. This two outputs are summed by using speculative adder, producing speculative result *Ys*.

An error can introduce for each speculative compressor. Thus, a correction block is required for each speculative compressor. The correction block accepts same inputs of the similar speculative compressor and generates two outputs: an error flag *E* and a suitable correction word *EW*. If four or more inputs of the speculative compressor are "1" then the error flag *E* is high. Therefore, adding correction word *EW* to the speculative compressor output achieve the exact result.

Thus from right side of fig.2, all error flags generated by each correction block and error flags of the speculative adder are OR-ed together to get the error flag of the speculative multiplier. The non-speculative result *(Y)* is calculated by adding the the correction words $EW_{i,j}$ and the outputs of the

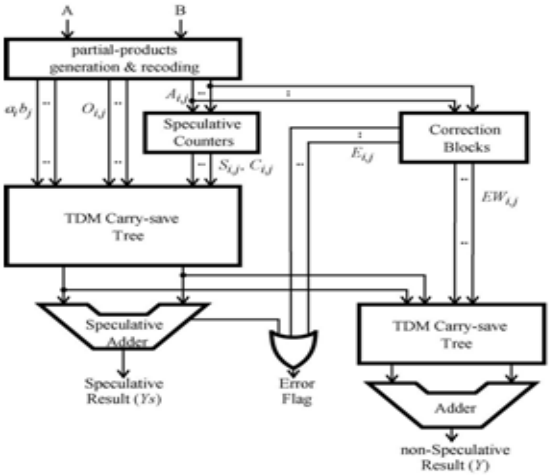

Fig. 2. Design of Speculative Multiplier[1]

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TDM carry-save tree involved in the speculative part of the multiplier.

1. Speculative Counters

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the abbreviation "e.g.," means "for example" (these abbreviations are not italicized).

An excellent style manual and source of information for science writers is [9].

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III. Conclusion

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Appendix

Appendixes, if needed, appear before the acknowledgment.

Acknowledgment

The preferred spelling of the word "acknowledgment" in American English is without an "e" after the "g." Use the singular heading even if you have many acknowledgments. Avoid expressions such as "One of us (S.B.A.) would like to thank ... ." Instead, write "F. A. Author thanks ... ." **Sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page**.

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