World Journal of Advanced Engineering Technology and Sciences
eISSN: 2582-8266
Cross Ref DOI: 10.30574/wjaets
Journal homepage: https://wjaets.com/

(REVIEW ARTICLE)

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Probability-based error adjustment and area-efficient approximate 4-2 compressor for approximate multiplier

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World Journal of Advanced Engineering Technology and Sciences, 2024, 11(02), 429–436

Publication history: Received on 03 March 2024; revised on 10 April 2024; accepted on 13 April 2024

Article DOI: https://doi.org/10.30574/wjaets.2024.11.2.0134

Abstract

For error-tolerant applications like image processing, many multipliers based on approximation compressors have been created to save power; however, the combination of these multipliers has not been well researched. This short builds a hybrid multiplier based on the compressors, a constant approximation, and an AND gate for error correction. It also suggests a novel 4 gate 4-2 approximate compressor that is complementary with other compressors from previous work. The simulation results show that, in comparison to the exact multiplier, the proposed hybrid approximation multiplier has superior accuracy and electrical performance tradeoff, reducing the power-delay-area product (PDAP) by 66% with an MRED of 2.5%.

Keywords: Partial products; Error correction; Approximate computing; 4-2 compressor; Digital multiplier; Compressor combination; Error compensation

1. Introduction

Energy minimization is significant necessities in practically any electronic frameworks, particularly the convenient ones like advanced cells, tablets, and various devices. It is incredibly wanted to achieve this minimization with insignificant execution (speed) punishment. Computerized signal handling (DSP) blocks are most needed in movable parts for acknowledging different media applications. The computational center of these blocks is the ALU where the augmentations and increments are the significant part. The most widely utilized arithmetic units are approximate multipliers because they are simple to adjust. Approximation methods can be used for the three parts of a multiplier: final addition, partial product accumulation and reduction, and partial product generation. During the multiplication process, the second part—which reduces partial products by accumulation—uses the greatest amount of resources. The duplications plays preeminent activity in the handling components which can prompts maximum usage of energy and power. Using the suggested compressor as a basis, an approximate multiplier with minimal resource costs is created. The simulation results show that, in terms of PDAP and accuracy tradeoff, the suggested approximation multiplier performs better than the current multipliers.

A significant number of the DSP centers carry out picture and video handling calculations where last results are either pictures or recordings arranged for human utilizations. It works with to go for approximations for working on the speed and energy in the number juggling circuits. This begins from the restricted perceptual capacities in noticing a picture or a video for people. Notwithstanding the picture and video handling applications, there are different regions where the precision of the number-crunching tasks isn't basic to the usefulness of the framework. Inexact processing gives a precision, speed and power/energy utilization. The benefit of estimated multiplier decreases the blunder rate and gain fast. For remedying the division mistake think about activity and a memory turn upward is expected for the every

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operand is required which builds the time delay for whole increase process. At different degree of deliberation including circuit, rationale and design levels the guess is handled. In the classification for estimate strategies in capability, various approximating number-crunching building blocks, like adders and multipliers, at various plan levels have been recommended in different designs. Broken exhibit multiplier was intended for effective VLSI execution. The blunder of mean and difference of the loose model increment by just 0.63% and 0.86% with adoration to the exact WPA and the most extreme mistake increments by 4%. Low-Power DSP utilizes rough adders which are utilized in various calculations and plan for signal handling. Interestingly, with standard multiplier, the dispersed power for the ETM dropped from 75% to 90%. While keeping up with the below mistake from the customary strategy, the proposed ETM accomplishes a noteworthy reserve funds of over half for a 12 x 12 fixed-width duplication. The critical piece of the math units are fundamentally worked by the multiplier equipment, so multipliers assume a conspicuous part in any plan. On the off chance that we think about a Computerized signal handling (DSP) the inner blocks of number-crunching rationale plans, where multiplier assumes a significant part among different tasks in the DSP frameworks. In this way, in the plan of multiplier and collect unit (Macintosh) multipliers assume a significant part. Then, significant plan in the Macintosh unit is the Viper. Adders likewise share the equivalent significant in this plan. By the proper capability strategies various types of adders and multipliers plans are been proposed. By the surmised registering the creator can make compromises, exactness, speed, energy and power utilization

2. Related work

2.1. Compressors with identical output weight.

Pei and colleagues [6] and Esposito and colleagues [7] created a range of novel approximate compressors that produced identical weight outputs. These compressors are unquestionably competitive in terms of electrical performance because they have fewer gates and no XOR or XNOR gates. Even if these compressors always produce an output that is less than the precise output when the bulk of the inputs are 1, the inaccuracy should not be substantial because first partial products are three times more likely to be 1 than 0. Nonetheless, the first partial products serve as the foundation for the compressor design that Esposito et al. suggested in [7]. Two levels of compressors make up the construction of the 8-bit approximate multiplier; the compressors in the second layer accept inputs with a larger Pei and colleagues [6] and Esposito and colleagues [7] created a range of novel approximate compressors that produced identical weight outputs. These compressors are unquestionably competitive in terms of electrical performance because they have fewer gates and no XOR or XNOR gates. because there is a three-fold chance that an initial partial product will become a 1. There is a significant mistake rate when utilizing Esposito's approximate compressors on the second layer, and a high-power consumption when employing accurate compressors. The trade-off between their approximate multipliers' electrical performance and accuracy in this instance is insufficient.

Table 1 Truth table of approximate 4-2 compressor

Input p1-p4	**Prob.**	**Exact**	**Esposito**		**Esposito**	**Proposed**	
		C S	W2	W1	E	CS	E
0000	81/256	00	0	0		00	
0001	27/256	01	0	1		01	
0010	27/256	01	0	1		01	
0011	9/256	10	1	1	-1	01	-1
0100	27/256	01	1	0	+1	10	+1
0101	9/256	10	1	1		10	
0110	9/256	10	1	1		10	
0111	3/256	11	1	1	-1	10	-1
1000	27/256	01	1	0	+1	10	+1
1001	9/256	10	1	1		10	
1010	9/256	10	1	1		10	
1011	3/256	11	1	1	-1	10	-1

1100	9/256	10	1	1		10	
1101	3/256	11	1	1		11	
1110	3/256	11	1	1		11	
1111	1/256	100	1	1	-1	11	-1

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2.2. Error Correction and Constant Approximation Module

A 4-2 compressor devised by Kumar et al. [8] produces an output error of minus one when the final two bits of the input are 1. Similar to [10], an AND gate linked to the final two bits of the comparator's input is utilized to make up for the error. In addition, an unconventional technique is used to truncate the final four bits of the multiplier, replacing the conventional 0000 with the average number 0110. This reduces the error without requiring more work. Among the multipliers utilizing the compressor with four error scenarios in the truth table, the approximation multiplier in [8] has the highest accuracy. However, the multiplier changes a half adder to a full adder and a full adder to an exact compressor in order to accept the output of the error correcting AND gate in the first level. Additionally, the error correcting modules lengthen the propagation channel to some degree, increasing the multiplier's latency.

3. Proposed Method

3.1. Appraisal multiplier unsigned

Compressor faults can be fixed using a basic logic gate if we force the incorrect output to occur at particular input characteristics, as seen in [8]. The process can be expanded to include situations where there are more than four of the sixteen input pattern defects. To improve the regularity of the Karnaugh map and get the total of S (sum) and C (carrier) as close to the precise result as feasible, a new area efficient 4-2 compressor is created. The suggested compressor's S and C outputs are displayed in Table I. Based on Table I, the C is OR, as indicated by equation (1). De Morgan's laws state that the suggested formulation of S is displayed in equation (2) with the presumption that utilizing.

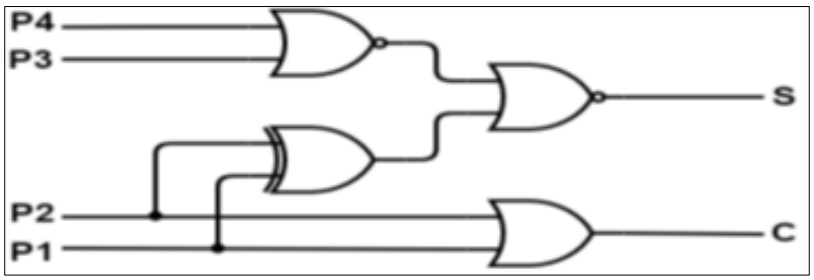

Figure 1 Architecture of the proposed compressor

$$C = P1 + P2 \quad (1)$$

$$S = (\overline{P1} \cdot \overline{P2} + P1 \cdot P2)(P3 + P4)$$
$$= \overline{(P1 \oplus P2) + \overline{(P3 + P4)}} \quad (2)$$

Fig. 1 shows the architecture of the suggested 4-2 compressor. This compressor uses very few transistors because it only has two NOR gates, one XOR gate, and one OR gate. Its six faults out of sixteen input patterns notwithstanding, the design is nonetheless appealing and competitive.

3.2. Error correction using probability

The likelihood of each input is displayed in Table I, and the overall probability of error is 70/256 = 0.273, which is a quite high number. The plus-one error rate is 54/256 = 0.211, whereas the minus-one error rate is 16/256 ≈ 0.063. For the first partial products, the likelihood of being 1 is 1/4 and the probability of being 0 is 3/4, therefore the corresponding plus-one mistake for 0100 and 1000 is highly likely to occur. It is imperative that the suggested compressors not be used at the first level, where the compressors' inputs are immediately connected to the initial partial products, in order to remedy this negative circumstance. Esposito's approximation compressors from [7] are used to

adjust the error probability in the first level, and the error generated by the suggested compressors in the second level is compensated for. Table I displays the 4-2 compressor's behavior from Esposito. If two or more of the inputs are 1, the output of Esposito's 3-2 or 4-2 compressor will be 11. Combining Esposito's compressors for the first partial products with the suggested compressor at the second layer, we discover that the error probability can be partly mitigated. Fig. 2 shows the architecture of the proposed 8-bit hybrid approximate multiplier, which utilizes the AND gate and constant approximation from [8] as well as two separate approximate compressorsA ripple carry adder (RCA) is used for the last addition. The first level uses two different types of Esposito's compressors, 3-2 and 4-2, as Fig. 2 illustrates. According to Table I, the likelihood that outputs w1 and w2 of Esposito's 4-2 compressor will be 0 is 135/256 = 0.527. The likelihood that one of the two outputs, w1 and w2, will be zero for Esposito's 3-2 compressor is 36/64 ≈ 0.563 and 45/64 ≈ 0.703. C4 to C1 are the names of the four inexact columns with distinct input patterns, respectively.

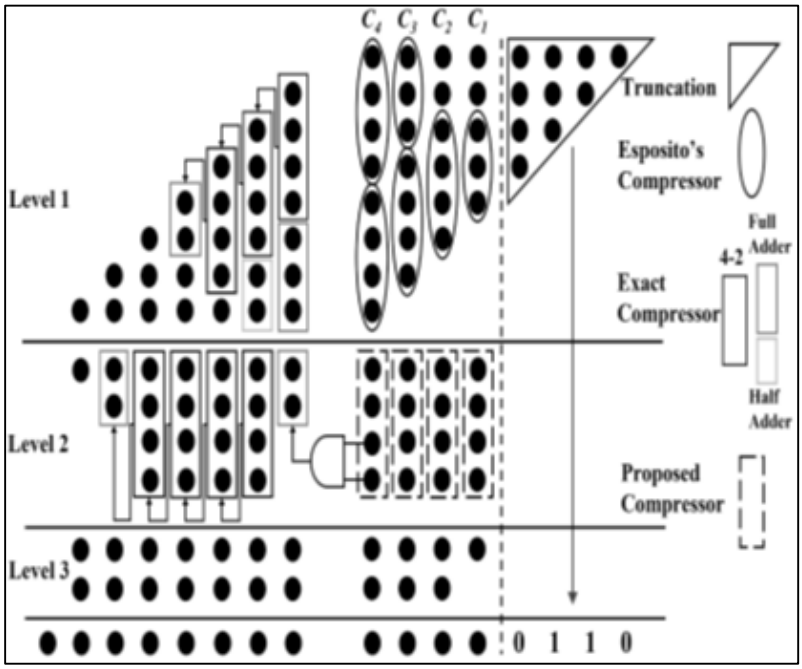

Figure 2 Proposed hybrid approximate multiplier structure

Table 2 Probability table of the proposed compressor

Input P1-p4	**Probability**					**Proposed**	
	Origin	C4	C3	C2	C1	CS	E
0000	0.316	0.077	0.110	0.156	0.222	00	
0001	0.105	0.069	0.099	0.140	0.094	01	
0010	0.105	0.069	0.099	0.140	0.173	01	-1
0011	0.035	0.062	0.088	0.126	0.073	01	+1
0100	0.105	0.069	0.046	0.052	0.074	10	
0101	0.035	0.062	0.042	0.047	0.031	10	
0110	0.035	0.062	0.042	0.047	0.058	10	-1
0111	0.012	0.056	0.037	0.042	0.024	10	+1
1000	0.105	0.069	0.086	0.052	0.074	10	
1001	0.035	0.062	0.077	0.047	0.031	10	
1010	0.035	0.062	0.077	0.047	0.058	10	-1
1011	0.012	0.056	0.069	0.042	0.024	10	

1100	0.035	0.062	0.036	0.017	0.025	10	
1101	0.012	0.056	0.032	0.016	0.010	11	
1110	0.012	0.056	0.032	0.016	0.019	11	
1111	0.004	0.050	0.029	0.014	0.008	11	-1
P_{total}	0.273	0.362	0.355	0.328	0.278		
p-1	0.063	0.223	0.223	0.223	0.130		
P+1	0.211	0.139	0.132	0.104	0.148		

Table 2 reports plus-one and minus-one errors in each column. The origin in Table II refers to the same as "Prob." in Table I, which is the probability of the corresponding input patterns of compressors at the first level in which initial partial products are directly connected. Although the total error possibility (PTotal) of each individual approximate compressor at the second level has increased due to the use of Esposito's compressors at the first level, the higher plus-one and lower minus-one error probabilities make the proposed hybrid approximate multiplier more reasonable when using the error correcting AND gate. Esposito's compressors are used at the first and third levels of a 16-bit approximation multiplier in the suggested hybrid design. two error fixing AND

4. Experimental results

The 8-bit and 16-bit unsigned approximate multipliers are contrasted in this section. Several compressors presented in [4], [5], [6], [7], [8], [9], and one in this brief (presented) are applied to the unified Dadda structure shown in paper [3] using the same truncation technique for the 8-bit approximate multiplier. Take note that just the suggested compressors are used by Proposed. Additionally, the hybrid structure depicted in Fig. 2 (ProposedH) is designed and contrasted. Ten columns of approximate compressors and six columns of constant approximation are used to construct 16-bit approximate multipliers. Specifically, in light of the authors' objectives, the extra error correction modules in [6] and [8] are applied to respective multipliers. Regarding the multiplier in [7], its compressors are only utilized at the first layer due to significant errors at the second layer.

4.1. Error Analysis

The normalized mean error distance (NMED) and mean relative error distance (MRED) are commonly used error metrics when judging the accuracy of approximate computing.To obtain reliable error metrics results, we carry out exhaustive65536 cases for 8-bit multipliers and take the average resultof ten times independent 1 million random cases for 16-bit multipliers. The results are respectively shown in fig 3

4.2. ASIC Synthesis

All the stated approximate multipliers are modeled using Verilog and synthesized as combinational circuits by Synopsys Design Compiler using a commercial 65 nm process with a nominal supply voltage of 0.7 V, toggle rate of 20% and maximum delay constraint of 6 ns for 8-bit multipliers and 12 ns for 16-bit multipliers. The power-delay-area product (PDAP) is a decisive metric that we utilize to fully describe the electrical performance, which includes area, total power consumption, and maximum delay. The evaluation results are shown in fig 3.The synthesis results demonstrate that Sabetzadeh’s design has unquestionably the best PDAP reduction but suffers from the largest NMED and MRED.

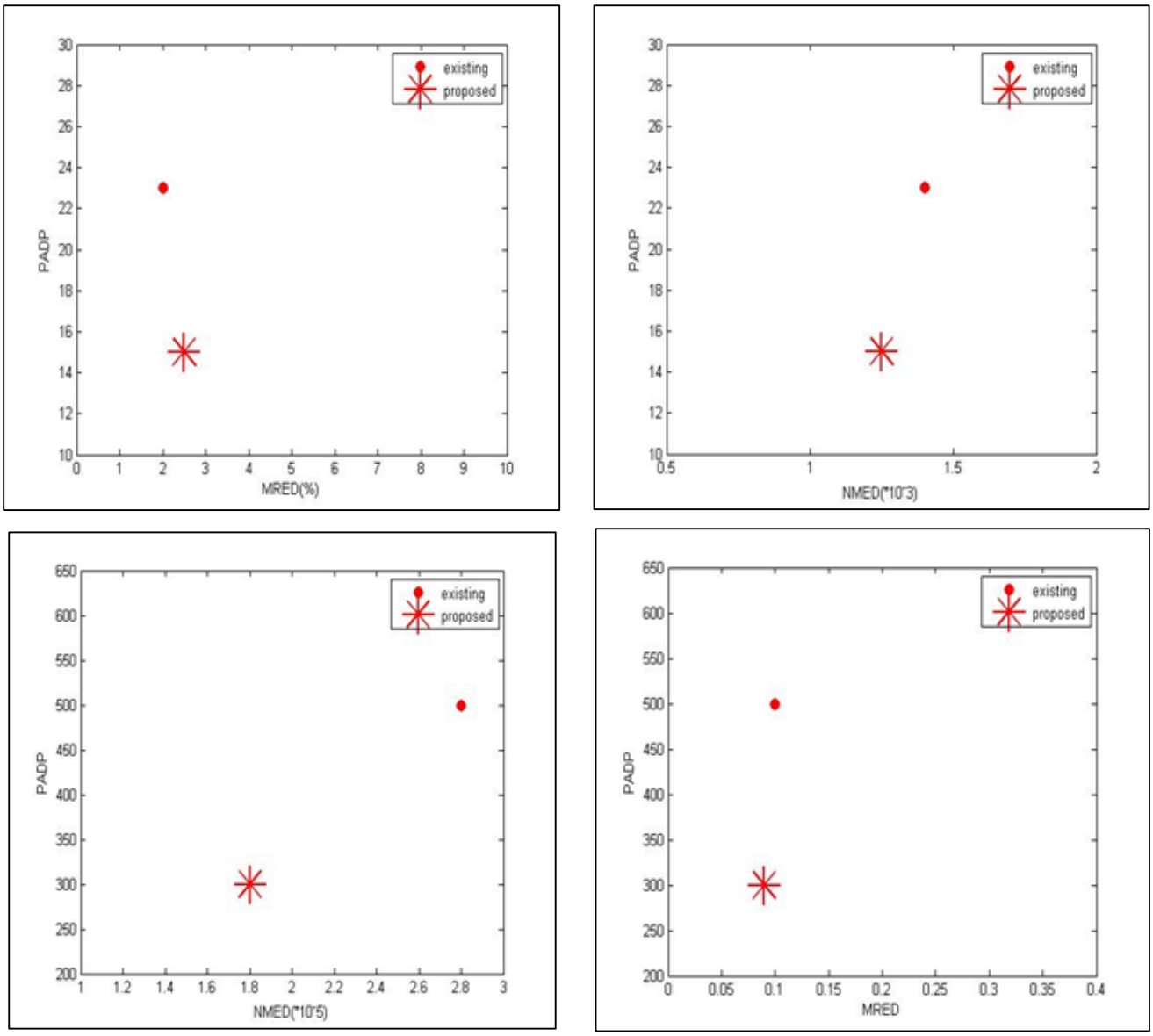

Figure 3 Trade-off between hardware and accuracy on different multipliers .(8-bit PDAPand MRED comparison,8-bit PDAP and NMED comparison,16-bit PDAP and MRED comparison. And 16-bit PDAP and NMED comparison.)

4.3. Image processing

Table 3 PSNR results for image sharpening application

Design	$PSNR_{barbara}$	$PSNR_{baboon}$	$PSNR_{lena}$
existing	37.15	36.44	37.13
pei.4	36.48	36.73	36.58
proposed	27.57	27.38	27.42
proposedH	33.30	33.24	33.06

Image processing is one of the most common error-resilientapplications. Three photos, titled “Barbara,” “Baboon,” and “Lena” that were downloaded from the same website are sub- jected to image sharpening. The pixel depth of all these photosis 8 bits, so we use 8-bit approximate multipliers to take care of the exact multiplication function during image sharpen-ing using MATLAB . The original image “Barbara” and images sharpened using an exact multiplier and four approx- imate multipliers which performed .To access the quality of the sharpening application, thepeak signal-to-

noise ratio (PSNR) is calculated . Proposed$_H$ multiplier has a lower but close PSNR compared with the other two multipliers, with an average result of 33.20dB, but has the best PDAP performance. On the other hand, it is difficult to tell the difference between the sharpenedimages with the naked eye.

5. Conclusion

In this brief, we introduced a fresh area efficient 4-2 compressor and a brand-new hybrid combination approach of probabilistic adjustment using approximate compressors devised by us and Esposito et al. for an approximate multiplier. The suggested hybrid approximate multiplier has one of the lowest PDAP (66% decrease with 2.5% MRED) and a far more enticing electrical performance and accuracy tradeoff when compared to existing multipliers. A 33.20dB PSNR is obtained when the suggested hybrid approximate multiplier is also tested for picture sharpening. In essence, designing an approximation multiplier with absolute advantage is quite difficult, and the best solution is usually the one that best fits the intended use. We provide a contender with a competitive error-electrical performance tradeoff in our approximate multiplier design.

Compliance with ethical standards

Acknowledgements

The authors would like to acknowledge the contribution of all parties involved in the project.

Disclosure of conflict of interest

Mr. E. Rama Krishna Reddy (*Assistant professor*) was involved in providing proprietary software used in the study, conclusions was done byBandaru Usha Sri. The other authors declare no conflicts of interest.

Statement of informed consent

All clinical study participants agreed to the terms set by the research team and signed an informed consent form, prior to their inclusion in the study.

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