

Squaring using Vedic mathematics and its architectures: a survey

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Abstract— Vedic Mathematics is an ancient Indian Arithmetic where calculations are made based on 16 sutras. In many high speed applications like cryptography and digital signal processing an efficient and high speed multipliers are needed for an excellent performance. Squaring is a particular case of multiplication. A dedicated squaring hardware may significantly improve the computation time and reduces the delay to a large extent. In this paper we discuss on Vedic Mathematics and study has been made on several squaring sutras using Vedic Mathematics by reviewing several papers.

Keywords— Squaring, Vedic Mathematics, Yavadunam Sutra, Dwandwa yoga sutra, Ekadhikina Purvena sutra

I. INTRODUCTION

Vedic Maths is an old ancient Mathematic technique given to us by our early sages which was later rejuvenated by Swami Bharati Krishna Tirthaji Maharaj (1884-1960). Veda is a Sanskrit word which means 'to know without limit'. We know that there are four Vedas, namely Rig, Sama, Yajur, Atharva and four up Vedas: Ayurveda, Ghandharva Veda, Sthapatya Veda and Dhanurveda. Sthapatya Veda deals with all sorts of Mathematical calculations, planning, designing and construction of houses, cities and villages. Vaastu Shastra, the Indian Science of Architecture has its origin in Sthapatya Veda. It is a unique technique of calculations based on simple principles and rules, with which any mathematical problem be it arithmetic, algebra, geometry, calculus, convolution or trigonometry can be solved mentally without much usage of pen paper [6].

Vedic Maths helps a person to solve problems in a more rapid way. Since the calculations are done mentally it perks up the concentration. It is not essential to fix to the set of rules, any sutra or up sutra can be pooled to obtain the preferred outcome, consequently the logical thinking process gets improved. On the whole Vedic maths is swift, interesting, contemporary, builds up logical thinking and construal aptitude and rational [6].

II. VEDIC SUTRAS

Vedic Mathematics refers to a set of sixteen Mathematical formula or sutras and their corollaries. The following are the sixteen sutras.

1. *Ekadhikina Purvena*
2. *Nikhilam Navatashcaramam Dashatah*
3. *Urdhva-Tiryagbhyam*
4. *Paraavartya Yojayet*
5. *Shunyam Saamyasamuccaye*
6. *(Anurupye) Shunyamanyat*
7. *Sankalana-vyavakalanabhyam*
8. *Puranapurabyham*
9. *Chalana-Kalanabyham*
10. *Yavadunam*
11. *Vyashtisamanstih*

12. *Shesanyankena Charamena*
13. *Sopaantyadvayamantyam*
14. *Ekanyunena Purvena*
15. *Gunitasamuchyah*
16. *Gunakasamuchyah*

Each of the sutras is intended for different mathematic computations, like division, multiplication, addition, square root, cube and so on. Among the 16 sutras there are only three sutras to perform squaring operation [6]. The following are the sutras for squaring operations:

1. *Yavadunam*
2. *Ekadhikina Purvena*
3. *Dwantwa yoga*

III. YAVADUNAM

The Sanskrit word Yavadunam means “By the deficiency”. The difference between the given number and the base is termed as deficiency. If a number is 8 then the base will be 10 and deficiency can be found by getting the difference between the number and the base. Thereby now the deficiency = Base – number = $10-8= 2$. Here the deficiency is positive. Similarly if the number is 1002 then the base is 1000 and deficiency = $1000 - 1002 = -2$. Here the deficiency is negative. Yavadunam Tavadunikrtya Vargancha Yojayet is an up sutra of the sutra Yavadunam. This Sutra is one of the squaring sutras of Vedic arithmetic .It is a precise technique to determine square of numbers with the specific condition that the number to be squared should be close to the power of 10 i.e.10,100,1000,... This sutra means “whatever the extent of its deficiency lessen it still further to that very extent; and also set up the square of that deficiency” [6].

The steps followed to obtain the square of a number using Yavadunam are stated below:

- Step: 1)* Calculate the deficiency with the help of the nearest base.
- Step: 2)* Square the deficiency and let it be RHS.
- Step: 3)* Add the deficiency to the number and let it be LHS.
- Step: 4)* Result = [Number + Deficiency + Carry over]
&
[Square of the deficiency]

Example: 1 To find the square of 5

- Step: 1) $5-10=5$, Deficiency = -5
 Step: 2) square of deficiency = $-5 = 25 = \text{RHS}$
 Step: 3) Deficiency + Number = $5-5 = 0 = \text{LHS}$
 Step: 4) Result = LHS & RHS = 25

Example: 2 To find the square of 97

- Step: 1) $97=100-3$, Deficiency = -3
 Step: 2) square of deficiency = $9 = 09$ =RHS
 Step: 3) Deficiency + Number = $97-3 = 94$ =LHS
 Step: 4) Result = LHS & RHS = 9409

Example: 3 To find the square of 1002

- Step: 1) $1002=1000+2$, Deficiency = 2
 Step: 2) square of deficiency = $4 = 004 = \text{RHS}$
 Step: 3) Deficiency + Number = $1002+2 = 1004 = \text{LHS}$
 Step: 4) Result = LHS & RHS = 1004004

Example: 4 To find the square of 14

- Step: 1) $14=10+4$, Deficiency = 4
 Step: 2) square of deficiency= $4=16=6$ =RHS, 1=carry over
 Step: 3) Deficiency + Number = $14+4 = 18 = 18+1=19$ =LHS
 Step: 4) Result = LHS & RHS = 196

IV. EKADHIKINA PURVENA

This sutra Ekadhikina Purvena means, “By one more than the previous”. This sutra can be used to find the square of numbers with the specific condition that the number to be squared has the 5 as last digit [6]. Eg:2935, 98274635, 5, 895,...

The steps to be followed to find the square of a number are given below:

- Step: 1)* Square the last digit 5 i.e.25 and let it be RHS.
Step: 2) Multiply the number except last digit with the next number and let it be LHS.
Step: 3) Result=LHS & RHS

Example: 1 To find the square of 55

- Step: 1) squaring last digit $5 = 25 = \text{RHS}$
 Step: 2) Number except last digit is 5
 Step: 3) increase it by $1 = 6$
 Step: 4) $5 * 6 = 30 = \text{LHS}$
 Step: 5) Result = LHS & RHS = 3025

Example: 2 To find the square of 325

- Step: 1) squaring last digit $5 = 25 = \text{RHS}$
 Step: 2) Number except last digit is $= 32$
 Step: 3) increase it by $1 = 33$
 Step: 4) $32 * 33 = 1056 = \text{LHS}$
 Step: 5) Result = LHS & RHS = 105625

Example: 3 To find the square of 2345

- Step: 1) squaring last digit $5 = 25 = \text{RHS}$
 Step: 2) Number except last digit is 234
 Step: 3) increase it by $1 = 235$
 Step: 4) $234 * 235 = 54990 = \text{LHS}$
 Step: 5) Result = LHS & RHS = 5499025

V. DWANDWAYOGA

Dwantwayoga is the up sutra of the sutra Urdhva Tiryagbhyam which means “Duplex Method”, Duplex means two. It entails two actions by squaring and by cross multiplying. It is a general formula which can be used to square any number [6].

The steps to be followed to obtain the square of a three digit number are stated below:

- Step: 1) Compute D (1st digit)
- Step: 2) Compute D (1st two digits)
- Step: 3) Compute D (all three digits)
- Step: 4) Compute D (last two digits)
- Step: 5) Compute D (last digit)
- Step: 6) Add carry forward
- Step: 7) Result

Example: 1 To find the square of 37

- Step: 1) D (3) = 9
- Step: 2) D (37) = 42
- Step: 3) D (7) = 49
- Step: 4) Result = 9 42 49 = 1369

Example: 2 To find the square of 493

- Step: 1) D (4) = 16
- Step: 2) D (49) = 72
- Step: 3) D (493) = 105
- Step: 4) D (93) = 54
- Step: 5) D (3) = 9
- Step: 7) Result = 16 72 105 54 9 = 243049

Example: 3 To find the square of 3121

- Step: 1) D (3) = 9
- Step: 2) D (31) = 6
- Step: 3) D (312) = 13
- Step: 4) D (3121) = 10
- Step: 5) D (121) = 6
- Step: 6) D (21) = 4
- Step: 7) D (1) = 1
- Step: 8) Result = 9 6 13 10 6 4 1 = 9740641

Figure 1 depicts the 4 bit squaring architecture using Dwandwa Yoga Sutra. This architecture requires one 2*2 Vedic multiplier, two 2bit Vedic squaring circuits, one 4 bit carry save adder and one 4 bit carry-look ahead adder. Here the 2 bit Vedic squaring circuit is nothing but 2 *2 bit Vedic multiplier. This 2*2 Vedic multiplier which is used to design 4*4 Vedic multiplier is shown in figure 2. Consider an example to square the number 10. where $a_0=0, a_1=1, b_0=0, b_1=1$. The steps followed to square are shown in Figure 2. From the steps it is understood that the 2*2 Vedic multiplier requires four AND gates and two half-adders. Figure 3 represents the block diagram of a 2*2 Vedic multiplier.

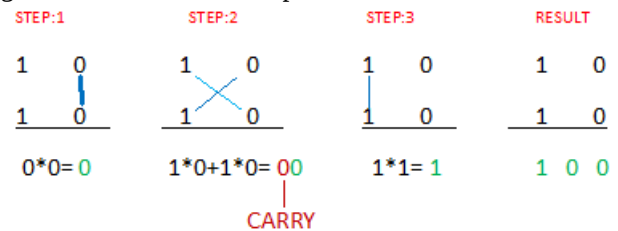


Figure 2. Steps followed for squaring using Dwandayoga

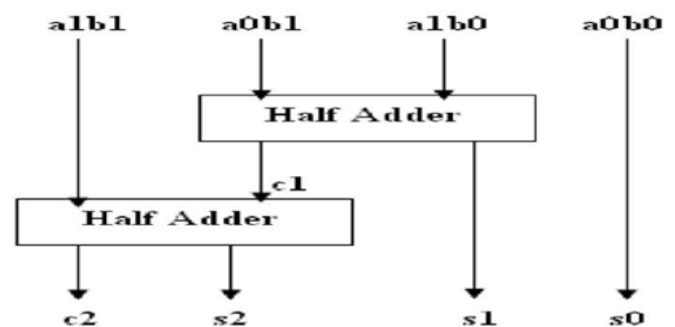


Figure 3. Block diagram of 2*2 Vedic multiplier

VI. REVIEW ON SQUARING ARCHITECTURES

Keeping the end goal in mind to get the square of the binary number wide variety of multipliers like Braun Array, Baugh Wooley strategies for two's supplement, Booth multiplier, Wallace trees, Dadda, and so forth are unbelievable [5]. Though at present they happen to be superseded and plenty of progressive strategies are emerging for even greater quicker operations [1], [3]. Various architectures have been proposed for squaring any given number. Some architecture are designed based on the squaring sutras of Vedic Mathematics, some architectures are based on multiplication sutras of Vedic Mathematics as squaring is a particular case of multiplication.

- A high speed squaring architecture using Dwantwayoga is reported in [2]. This method is advantageous than other Vedic and conventional methods. This method requires less computations compared to Urdhava Tiryagbhyam. This method reduces carry

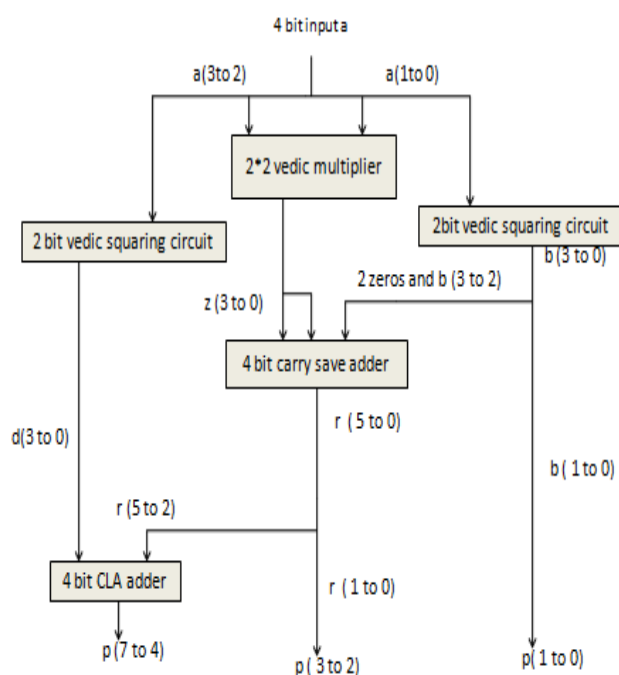


Figure 1. Block diagram of 4 bit Vedic squaring circuit

propagation delay and requires low power and small area.

- An improved squaring architecture based on Dwantwayoga property is proposed in [9]. This modified Dwantwayoga squaring architecture use only one carry look ahead adder whereas the Dwantwayoga sutra architecture requires one carry save adder and one carry look ahead adder. Thereby reducing the delay and area.
- A high speed Vedic square architecture using Urdhava Tiryagbhyam and Karatsuba ofman algorithm is projected in [4]. The speed has been improved than the conventional methods. Karatsuba algorithm multiplies long integers in
- A squaring architecture using Urdhava Tiryagbhyam is described in [8]. Two basic operations multiplication and addition are used. A concurrent operation of the multipliers and adders reduces the delay, but to compute squaring of n-bit number 4 numbers of such Vedic multipliers are required which requires more space and increases the delay.
- [7] Proposed a squaring circuit to square binary numbers. Here Urdhava Tiryagbhyam sutra is used to design a multiplier. And this multiplier circuit is used to design the squaring circuit. Vedic sutras are applied to binary multipliers with the help of the carry save adders. Initially a binary multiplier generating partial products and performing addition operation in parallel is developed and later squaring circuit is designed with proper modification in the Vedic multiplier algorithm. Instead of four multiplier circuits only one multiplier is used but one squaring circuit is used twice. Thereby the delay is reduced.

- [9] Designed a squaring architecture by using Dwantwayoga sutra. In order to square by following the duplex property the principles of Urdhava Tiryagbhyam are used. Instead of adding the multiplier result twice and later adding to the concatenate LHS square lower half and RHS square upper half, they add them altogether thereby increasing the speed and reducing the area.
- [10] and [11] proposed an architecture using the Nikhilam Sutra and Karatsuba algorithm. A generic architecture has been designed for the Nikhilam Sutra. The architecture gives the correct output for any input irrespective of the range of base values. This architecture produces the optimised result. It is suitable for high speed applications.

VI. PROPOSED WORK

Several researches are being done on conventional and Vedic multipliers. But not many researches are going on squaring sutras. Currently no architecture is existing for the squaring sutra Yavadunam. This made us to take keen interest on Yavadunam sutra. Our future work is to build up a generic squaring architecture for the Yavadunam sutra.

VII. CONCLUSION

This paper elucidates about the Vedic Mathematics, 16 Sutras and up sutras, the squaring sutras and their details with examples. It also gives a concise note on a few types of Vedic squaring architectures.

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