Vedic Mathematics Sutras -A Review

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Abstract— Real time applications such as controlling environmental conditions demand quick response of the processor for processing the acquired signals. Multiplier is an important feature of signal processing and digital computer systems. Multipliers have large area, long latency and consume considerable power. Hence good multiplier architecture increases the efficiency and performance of a system. Vedic multiplier is one such high speed, low area multiplier architecture. Vedic Mathematics provides principles of high speed multiplication. In this paper, we have discussed 16 Vedic Mathematics Sutra which can be used to increase the speed and reduce the area, delay of multiplier.

Keywords— *Multiplier, Vedic multiplier, UrdhavaTriyagbhyam, Sutras.*

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I. INTRODUCTION

Vedic Mathematics is an ancient system of mathematics existed in India. In this eminent approach, methods of basic arithmetic are simple, powerful and logical. Another advantage is its regularity. Because of these advantages, Vedic Mathematics has become an important topic for research. The technique use in Vedic Mathematics is mainly based on sixteen Sutras. Vedic mathematics was reconstructed from the ancient Indian scriptures (Vedas) by Swami Bharati Krishna Tirthaji Maharaja (1884-1960) after his eight years of research on Vedas[1]. Vedic mathematics is mainly based on sixteen principles or word-formulae which are termed as sutras [2]. This is a very interesting field and presents some effective algorithms which can be applied to various branches of engineering such as computing and digital signal processing. Integrating multiplication with Vedic Mathematics techniques would result in the saving of computational time.

These are the 16-basic sutra of Vedic mathematic:

1) Ekadhikina Purvena- By one more than the previous One.
2) Ekanyunena Purvena - By one less than the previous one.
3) (Anurupye) Shunyamanyat -If one is in ratio, the other is zero.
4) ChalanaKalanabyham -Differences and similarities.
5) Sankalana- vyavakalanabhyam -By addition and by subtraction.
6) Shesanyankena Charamena- The remainders by the last digit.
7) Puranapuranabyham - By the completion noncompletion.
8) Urdhva-tiryakbhyam -Vertically and crosswise.
9) Nikhilam Navatashcaramam Dashatah -All from 9 and last from 10.
10) Paraavartya Yojayet-Transpose and adjust.
11) Shunyam Saamyasamuccaye -When the sum is same then sum is zero.
12) Yaavadunam- Whatever the extent of its deficiency.
13) Vyashtisamanstih -Part and Whole.
14) Gunitasamuchyah-The product of sum is equal to sum of the product.
15) Sopaantyadvayamantyam -The ultimate and twice the penultimate.
16) Gunakasamuchyah-Factors of the sum is equal to the sum of factors.

II. EKADHIKENA PURVENA

It means one more than previous one we relate this sutra to multiplication of numbers (suppose a with digit $[a_1,a_0]$ and b with digit $[b_1, b_0]$) whose last digit addition(b_0+a_0) comes out to be 10 and previous digit both number $(a_1=b_1)$ is same, but along with this condition number of digit in two number should be same [1]. This sutra, gives the procedure as follows:

a) Last digit a_0x $b_0 = x_1x_0$ (2 digit number).
b) Previous digit $(a_1=b_1) = a_1$x$(a_1+1) = y_2y_1y_0$.
c) Concatenate result of equations mentioned in point no. 2 and 1 gives$y_2y_1y_0x_1x_0$ (i.e. equal to numeric value of a x b).

Example:

1) Square of 25
   [Addition of last digit *5+5 =10*]
   a) Last digit is 5: *5* x *5=25*
   b) Previous digit 2 : *2* x *(2+1) = 2* x *3 = 6*
   c) Concatenate result of equations mentioned in point no. *b* and *a* we get square of 25i.e.*625.*

2) Square of 185
   [Addition of last digit *5+5 =10*]
   a) Last digit 5: *5* x*5 =25*
   b) Previous digit 18: *18* x *(18+1) = 18* x*19 = 342*
   c) Concatenate result of equations mentioned in point no. *b* and *a* we get square of 185 i.e. *34225.*

3) 42 x 48
   [Addition of last digit *1+9 =10]*
   a) Last digit is 2 and 8*: 2*x*8 =16*[2-digit number]

b) Previous digit 4: *4x (4+1) = 4 x5 = 20*
c) Concatenate result of equations mentioned in point no. *b* and *a* we get square of 42 x 48 i.e. *2016*.

4) 191 x 199
[Addition of last digit *1+9 =10*]
a) Last digit is 1 and 9: *1* x*9 =09*[2-digitnumber]
b) Previous digit 19: *19* x *(19+1) = 19* x*20 = 380*
c) Concatenate result of equations mentioned in point no. *b* and *a* we get square of 191 x 199 i.e. *38009*.

III. EKANYUNENA PURVENA

It means one less than previous one or one less than one before, it is considered as a sub-sutra of "nikhilamnavatashcaramamdashatoh" [3]. This sutra applicable for multiplication of two numbers where multiplicand is any integer and multiplier is 9 or array of 9.

Examples:

1) 7 x 9
Step 1: *7-1 = 6*
[Subtract the result from multiplier i.e. 9 or array of 9]
Step 2*: 9-6 = 3*
Answer*: 7* x *9=63*.

2) 25 x 99
Step 1: 25-1 = *24*
[Subtract the result from multiplier i.e. 9 or array of 9]
Step 2: *99-24 = 75*
Answer: *25*x*99=2475*.

Now consider examples for application of sutra on multiplication of two numbers with different number of digits [3].
When array of 9 has more number of digits than other multiplicand.

3) 23 x 999
Step 1: *23-1 = 22*
Step 2: *999-22 = 977*
Answer: *23* x*999=22977*.

When multiplicand has more number of digit than multiplier (array of 9) [3].

4) 436 x 99
Separate 436 into two parts, this separation depends upon number of digits in array of 9, here array of 9 consist of 2 digits therefore separation will be 4|36.
Step 1: *4+1=5*
436-5 = 431.
Step 2: *99-36 = 63*.
63+1=64.
Step 3: Concatenate result of step 1 and step 2 gives final result of multiplication i.e. *436* x*99 = 43164*.

5) 20462 x 999
Separate 20462 into two parts, this separation depends upon number of digits in array of 9, here array of 9 consist of 3 digit therefore separation will be 20|462.
Step 1: *20+1=21*
20462-21 = 20441.
Step 2: *999-462 = 537*.
537+1=538.
Step 3: Concatenate result of step 2 and step 1 gives final result of multiplication *20462* x*999 = 20441538*.

IV. ANURUPYE SUNYAMANYAT SUTRA

The Sutra Anurupye Sunyamanyatsays if one is in ratio, the other one is zero [4]. We use this Sutra in solving a special type of simultaneous simple equations in which the coefficients of 'one' variable are in the same ratio to each other as the independent terms are to each other. In such a context the Sutra says the 'other' variable is zero from which we get two simple equations in the first variable (already considered) and of course give the same value for the variable.

Examples:

1) $5x + 9y = 4$
$3x + 36y = 16$
The y-coefficients are in the ratio $9:36 = 1:4$, the ratio of the constants is $4:16 = 1:4$. Hence putting other variable $x = 0$ in any oneof the above equations, we get $9y = 4$ or $36y = 16$ which gives $y= 4/9$[4].

2) $6x + 4y = 1$
$4x + 12y = 3$
The ratio of y-coefficients is $4:12 = 1:3$, which is same as the ratio of independent terms or constants i.e. $1:3$.
Hence putting other variable $x = 0$ in any one of the above equations, we get $4y = 1$ or $12y = 3$which gives$y = 1/4$.

V. CHALANA-KALANABHYAM:

The Sutra means 'Sequential motion' or "By calculus".

Example:

It is used to find the roots of a quadratic equation
$(x^2 – 3x + 1) = 0$.
Now by calculus formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$2ax + b = \pm\sqrt{b^2 - 4ac}$$

$$2x–3 = \pm\sqrt{5}$$

$$x = 3\pm\sqrt{5} / 2$$

Every Quadratic can thus be broken down into two binomial factors.

VI. GUNAK SAMUCCAYAH

This sutra means that factor of sum is equal to the sum of factor

$$ax^2 + bx + c = (x + d)(x + e)$$

Where d and e are factors of c and addition of d and e is equal to b.

By calculus formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$2ax + b = \pm\sqrt{b^2 - 4ac}$$

Sutra says $2ax + b = (x + d) + (x + e)$

Example:

$$x^2 + 5x + 4 = (x+4)(x+1)$$
$$(2x + 5) = \underline{(x+4) + (x+1)}$$

VII. SANKALANAVYAVAKALANABHYAM:

Sankalana - Vyavakalanabhyam sutra is same as Anurupye - Shunyamanyat and is used for solving simultaneous equations. This sutra is used when the coefficients are interchanged [5].

Example:

$$45x - 23y = 113 \quad (1)$$
$$23x - 45y = 91 \quad (2)$$

The x-coefficients and the y-coefficients (45 and 23) are interchanged in equation (1) and (2). The procedure to solve for variable x and y is as follows [5]:

Step 1: Addition of equation (1) and (2)

$$(45x - 23y) + (23x - 45y) = 113 + 91$$
$$68x - 68y = 68$$

By simplifying the equation we get

$x - y = 3$(3)

Step2:Subtraction: of equation (1) and (2)

$$(45x - 23y) - (45x - 23y) = 113 - 91$$
$$22x + 22y = 22$$

By simplifying the equation, we get

$x + y = 1$(4)

Step 3: Solving equations (3) and (4) simultaneously

$$\begin{array}{r} x - y = 3 \\ \underline{x + y = 1} \\ 2x = 4 \end{array}$$

We get $x = \underline{2.}$

Put the value of x in equation (1) we get the value of y.

$$\begin{array}{r} x - y = 3 \\ \underline{2 - y = 3} \\ -y = 3 - 2 \end{array}$$

We get $y = \underline{1}$

VIII. SHESANYANKENA CHARAMENA:

Shesanyankena Charamena means remainder by last digit .This sutra can be used to express a fraction as a decimal, up to required decimal places.

Example: Express 1/7 as a decimal.

Step 1:

a) Concatenatezero to the numerator10 if this numerator is less than the denominator7, Concatenate another zero. If numerator is greater than the denominator, then divide numerator by the denominator,we get the quotient: $10 / 7 = 1$ andremainder 3.
b) Concatenate zero to remainder3 and divide it by the denominator 7, we get quotient $30 / 7 = 4$ and remainder 2.
c) Concatenate zero to remainder2 and divide it by the denominator 7, we get quotient $20 / 7 = 2$ and remainder 6.
d) Concatenate zero to remainder 6 and divide it by the denominator 7, we get quotient $60 / 7 = 8$ and remainder 4.
e) Concatenate zero to remainder 4 and divide it by the denominator 7, we get quotient $40 / 7 = 5$ and remainder5.
f) Concatenate zero to remainder 5 and divide it by the denominator 7, we get quotient $50 / 7 = 7$ and remainder 1.
g) At this point, the remainder 1 is the same number as the original numerator 1. The answer is going to repeat hence, we will stop divide.
h) The remainders, are written in order, will be used for step two: 3, 2, 6, 4, 5, and 1.

Step 2:

a) Multiply the denominator by the first remainder in the above sequence$7 \times 3 = 21$ write down the left most digit of this product(1) and drop all the other digits.
b) Multiply the denominator by the second remainder in the sequence above$7 \times 2 = 14$,write down the left most digit of this product (4) and drop all the other digits.
c) Multiply the denominator by the third remainder in the sequence above$7 \times 6 = 42$,Write down the left most digit of this product (2) and drop all the other digits.
d) Multiply the denominator by the fourth remainder in the sequence above$7 \times 4 = 28$, write down the left most digit of this product (8) and drop all the other digits.

e) Multiply the denominator by the fifth remainder in the sequence above: *7* x *5* = *35*, write down the left most digit of this product (5) and drop all the other digits.

f) Multiply the denominator by the sixth and last remainder in the sequence above *7* x *1* = *7*, write down the left most digit of this product (7) and drop all the other digits.

g) We get these products in sequence:
1 4 2 8 5 7
Thus we get, *1/7* = *0.142857142857…*

IX. PURANAPURANABYHAM:

Puranapuranabyham is used to simplify or solve algebraproblems.

*Example*1:$x^3+6x^2+11x+6=0$(5)

a) Case 1: $(x + 1)^3$we don't even have to work out the answer to know this is going to be too low 1 cubed is still just 1.
Case 2: $(x + 2)^3=x^3+6x^2+12x+8$(6)
We'll stop here, because case 2 is very close to the equation (5).

b) Subtract equation (5) and (6) we get $(x^3 + 6x^2 + 12x + 8) - (x^3 + 6x^2 + 11x + 6) = x + 2$.

c) Add $(x + 2)$ to both sides of the equation (5), we get
$x^3 + 6x^2 + 11x + 6+x+2= x + 2$
$x^3 + 6x^2 + 12x + 8= x + 2$
$(x+2)^3=(x+2)$.

d) Now we have a common term, $(x + 2)$, on both sides of the equation. Put
$y = (x +2)$(7)
we get $y^3=y$.

e) Only $y= 0$ or 1 or -1 satisfy the equation $y^3=y$, if we put $y=2$ it does not satisfy equation $y^3=y$.

f) Now substitute the values of y in equation (7)

If $y = 0$ then $x + 2 = 0$ we get$x = -2$
If $y = 1$ then $x + 2 = 1$ we get x = -1
If $y = -1$ then $x + 2 = -1$ we get x = -3
Thus, $x = -1, -2, -3$.

X. URDHVA-TIRYAKBHYAM:

The word "Urdhva-Tiryakbhyam" resources vertical and crosswise multiplication [6]. This multiplication formula is equally applicable to all cases of algorithm for N bit numbers. Conventionally this sutra is used for the multiplication of two numbers in decimal number system. The same concept can be applicable to binary number system . Advantage of using this type of multiplier is that as the number of bits increases, delay and area increases very slowly as compared to other conventional multipliers [6].

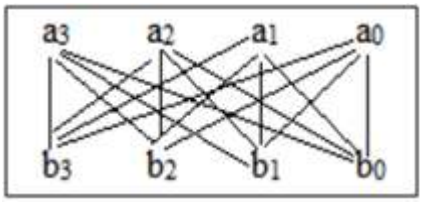

Fig -1 Example of 4x4 multiplication using Urdhva-triyakbhyam Sutra

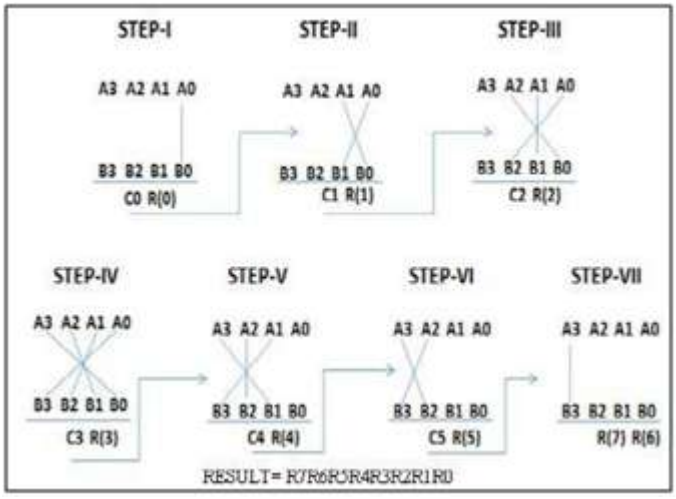

Fig.2Multiplication method of Urdhva-Tiryakbhyam**.**

In the above figure-1, 4-bit binary numbers $A_0A_1A_2A_3$ and $B_0B_1B_2B_3$ are considered. The result obtained is stored in$R_0R_1R_2R_3R_4R_5R_6R_7$.In the first step $[A_0,B_0]$ is multiplied and the result obtained is stored inR_0. Similarly, in second step $[A_0,B_1]$ and $[A_1,B_0]$ are multiplied using a full adder and the sum is stored in R_1 and carry is transferred to next step. Likewise, the process continues till we get the result [6].

*Example***:** 325 x 738

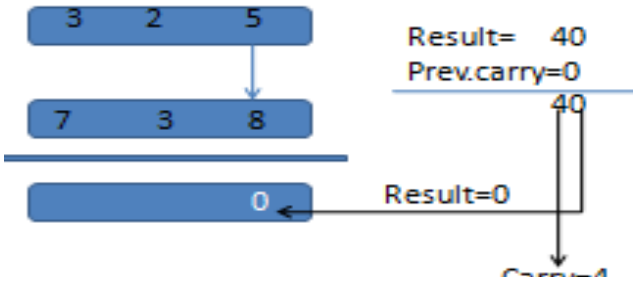

Fig.3 Step 1.

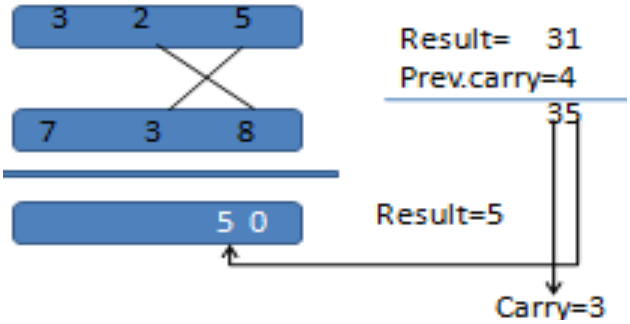

Fig.4 Step 2

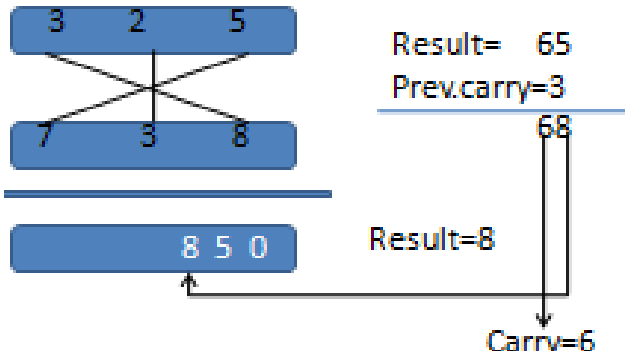

Fig.5 Step 3

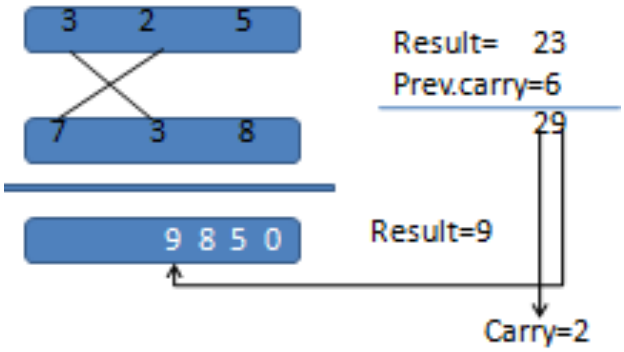

Fig.6.Step 4

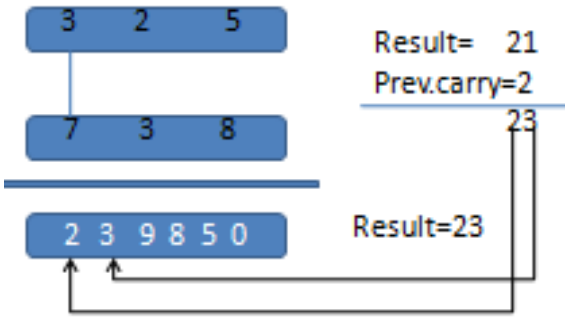

Fig.7.Step 5

Thus, we get *352* x *738* = *239850*

XI. PARAVARTYA YOJAYET

'Paravartya– Yojayet' means 'transpose and apply. In transpose and apply divisors are slightly greater than power of 10 [7]. In division method (From left to right) write the Divisor leaving the first digit, write the other digit or digits using negative (-) sign and place them [7].

Consider the division by divisors of more than one digit, and when the divisors are slightly greater than powers of 10.

Example:Divide 1225 by 12.

Step 1: (From left to right) write the Divisor leaving the first digit, write the other digit or digits using negative (-) sign and place them below the divisor asshown.

12
-2

Step 2: Write down the dividend to the right. Set apart the last digit for the remainder.
i.e. 12 122 5
- 2

Step 3: Write the 1st digit below the horizontal line drawn under the dividend. Multiply the digit by –2, write the product below the 2nd digit and add.
i.e., 12 122 5
-2 -2

10

Since 1 *x –2 = -2* and *2 + (-2) = 0*

Step 4: We get second digits sum as '0'. Multiply the second digits' sum thus obtained by –2 and writes the product under 3rd digit and adds.

12 122 5
- 2 -20

102 5

Step 5 : Continue the process to the last digit.

i.e., 12 122 5
- 2 -20 -4

102 1

Step 6: The sum of last digit is the remainder and the result to its left is quotient thus *q=102* and *r=1*

XII. NIKHILAM NAVATASHCARAMAM DASHATAH

Nikhilam Sutra means "all from 9 and last from 10"[9]. Nikhilam Sutra stipulates subtraction of a number from the nearest power of 10 i.e. 10, 100, 1000, etc. The power of 10 from which the difference is calculated is called the Base. These numbers are considered to be references to find out whether given number is less or more than the Base. If the given number is 104,the nearest power of 10 is 100 and is the base. Hence the difference between the base and the number is 4, which is Positive and it is called nikhilam. The value of Nikhilam may be reference base, the Nikhilam of 87 is -13 and that of 113 is +13 respectively [9].

Nikhilam Sutra in Vedic Mathematics can be used as shortcuts to multiply numbers, divide numbers in faster approach. In English, it is translated as All from 9 and last from 10[9]. i.e. subtract last digit from 10 and rest of digits from 9.

Multiplication using Nikhilam Sutra is used when numbers are closer to power of 10 i.e. 10, 100, 1000, etc.
The procedure are as follows:

a. Numbers are below the base number.

b. Numbers are above the base number.
c. One number is above the base and the other number is below it.
d. Numbers are not near the base number, but are near a multiple of the base number, like 20, 30, 50,250,600etc.
e. Numbers near different bases like multiplier is near to different base and multiplicand is near to different base.

a. Numbers are below the base number.
Working with Base 10.

Let us take an simple example to start this technique. Suppose we have to multiply 6 by 8. Now the base is 10. Since it is near to both the numbers. Place the two numbers 6 and 8 above and below on the left hand side (as shown below). Subtract the base value (i.e. 10 in this case) from both of the numbers and write down the remainders (i.e. 4 and 2) on the right-hand side with their deviation sign (-)[8].

Example: 6 x 8

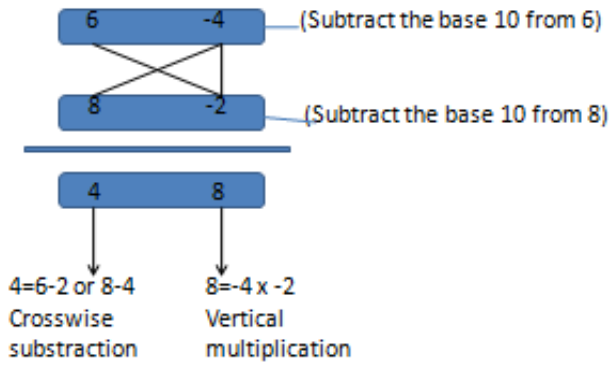

Fig.8 Nikhilam

Left-side
a) *6 + (- 2)= 4* (add top left to bottom right)
b) *8 + (- 4)= 4*(add bottom left to top right)
c) *6 + 8 - 10= 4*(add numbers in the left column and subtract from base)
d) *10 + (-4)+(-2)= 4*(add numbers in the right column and the base)
Right-side
(-4) x *(-2) = 4* (multiply numbers of right column)
Final answer: *6* x *8= 48*

b. Numbers are above the base number.
Working with Base 10.

Suppose we have to multiply 13 by 14. Now the base is 10. Place the two numbers 13 and 14 above and below on the left hand side (as shown below). Subtract base (10) from each of the numbers and write down the remainders (3 and 4) on the right-hand side with their deviation sign (+) [8].

Example: 13x14
13 +3
14 +4
---
17 | 1 2
+1
18 2 =182

Left side (4 ways to calculate left side)
a) *13 + (+ 4)= 17* (add top left to bottom right)
b) *14 + (+ 3)= 17* (add bottom left to top right)
c) *13 + 14 - 10= 17*(add numbers in the left column and subtract from base)
d) *10 + (+ 3) + (+ 4)= 17*(add numbers in the right column and the base)
Right side
(+3) x *(+4) = 12* (multiply numbers of right column)
Since 12 is 2-digit number, so carry the 1 over to the 7. Therefore, left hand side is now. (17 + 1 = 18)
Final answer:*13* x *14 = 182*

c. One number is above the base and the other number is below it.

In this, one deviation is positive and the other is negative. So, the product of deviations becomes negative. So, the right-hand side of the answer obtained will therefore be subtracted [8] i.e. right side answer get subtracted from (left side answer x base).

Working with Base 10
suppose we have to multiply 13 by 4. The nearest base is 10.

Example: 13x4

13 +3
4 -6
---
7 | -18 = 7 x 10 - 18 = 70 - 18 = 52

Left side:
a) *13 - 6= 7* (add top left to bottom right)
b) *4 + 3= 7* (add bottom left to top right)
c) *13 + 4 - 10= 7*(add numbers in left column, subtract 100).
d) *10 + (+ 3) + (- 6) = 7*(add numbers in the right column and the base)
Right side:
(+3) x (-6) = -18 (multiply numbers of right column)
So,*13x4=7|18*
= (7 x 10) - 18
=70-18 = 52
Final answer:*13* x *4 = 52*

XII.NIKHILAM SUTRA FOR DIVISION:

Nikhilam Sutra in Division is appliedwhen divisor is closer to and slightly lesser than power of 10. Nikhilam Sutra

is a Specific Method to Divide Numbers using Vedic Mathematics. This Vedic Math's Division Method can be applied when Divisor is closer to power of 10 but less than that of it [8].

Example:12/9

1. *9* is *1*(deficiency) less than *10*(nearest power of 10). (that 1 is written in white color below divisor in below example)
2. Split Dividend in 2 parts (Quotient & Remainder) in such a way Remainder to have same number of digits as that of Divisor. In this case its 1 digit.
3. Take 1st digit – 1 down as it is.
4. Multiply the above deficiency (1) with the 1and put below 2 and add them column wise.
5. Thus *Quotient=1&Remainder=3.*

1 / 2 *9 =1*

↓ *1*

1 *3*

*Example*2:3483/99

1. 99 is 01(deficiency) less than 100(nearest power of 10).
2. Split Dividend in 2 parts (Quotient & Remainder) in such a way Remainder to have same digits asthat of Divisor. In this case its 2.
3. Take 3 as it is down.
4. Multiply the above deficiency (01) with the 3 and put them below 4 and 8(as shown), add 1st column (*4+0=4).*
5. Multiply the above deficiency (01) with the 4 now and put in next columns (as shown), add 1st column (*8+3+0=11*).
6. Repeat this process till a number comes in last column. In this example a number (4) hasAppeared in last column so stop here.
7. Thus *Quotient=35&Remainder=18*.

3 4 / 8 3
0 3 9 9

0 40 1 ↓

3 4/ 1 17

3 5 / 1 8

XIII.SHUNYAM SAMYASAMUCCAYE SUTRA:

When the sum is same then sum is zero. The sutra 'sunyamsamyasamuccaye' says that 'Samuccaya is the same, than Samuccaya is Zero'[10].

There are six cases in this sutra as follows:-

1. Samuccaye terms occur as a common factor and equate that common factor to zero.
   Ex:-$5(x+1)=3(x+1)$, by sutra $x+1=0$
2. Applicable for same numerator (sum of denominator=0).
   Ex:-$1/(3x-2)=1/(2x-1)$, by sutra $5x-3=0$
3. Samuccaya =the sum of the numerator and the sum of denominator is same then sum equals to zero.
   Ex :-$(3x+4)/ (3x+5) = (3x+5)/ (3x+4)$,

By sutra $6x+9=0$

4. For any constant factor k
   Ex :-$(2x+3)/(4x+5)=(x+1)/(2x+3)$,

Bysutra $3x+4=2(3x+4)$, $3x+4=0$

5. For same denominator
   Ex:-$1/(x-4)+1/(x-6)=1/(x-2)+1/(x-8)$,

$2x-10=0$

6. In the context of a quadratic equation (Numerator=*N*, Denominator=*D*)
   Ex: $-3x+2/2x+5=2x+5/3x+2$
   a) if $N_1+N_2=D_1+D_2$, then $N_1+N_2=0$ or $D_1+D_2=0$, by sutra $5x+7=0$
   b) if $N_1-D_1=N_2-D_2$, then $N_1-D_1=0$ or $N_2-D_2=0$, by sutra $x-3=0$

XIV.YAAVADUNAM SUTRA:

This sutra means that whatever the extent of its deficiency, it is use for Calculating square of numbers near (or lesser) to power of 10[11].

Example:

1. Square of 98
   a) nearest power of 10 to 98 is 100
   b) 100 as base
   c) *100-98=2*, here 2 is deficiency
   d) *98-2=96*, here 96 is left side of answer
   e) Square of deficiency =right side of answer (square of *2=04*), 04 in spite of 4 because number of digit in square number is equal to number of zeros in base
   f) Answer is *9604*

XV. VYASHTISAMANSTIH SUTRA (PART AND WHOLE)

This sutra is use for finding the part-whole ratio [12]. It gives us the amount of a content from the overall mixture as shown in below

Example:

1. A bag contains 4 Apple, 8 Mangoes, 12 Bananas
   Total quantity =24
   Now, part-whole ratio of apple = 4/24
   Part-whole ratio of mango = 8/24
   Part-whole ratio of banana = 12/24

XVI. GUNITASAMUCHYAH SUTRA

This sutra means the product of sum is equal to sum of product [13]. This sutra is for checking the correctness of any given equation

Example:

1. $(x+3)(x+2) = x^2 + 5x + 6$
   Coefficient of x in $x+3$ is 1, coefficient of x in $x+2$ is 1, coefficient of x in x^2 is 1, coefficient of x in $5x$ is 5
   For correctness of any given equation, product of sum of coefficients=sum of coefficients in product.
   $(1+3)(1+2) = 12$,
   $1+5+6=12$……. correct

2. $12x^2 + 13x - 4 = (3x-4)(4x+1)$
   coefficient of x in $12x^2$ is 12, coefficient of x in $13x$ is 13, coefficient of x in $3x$ is 3, coefficient of x in $4x$ is 4
   $12+13-4=21$,
   $(3-4)(4+1) = -5$…...incorrect

XVII.SOPAANTYADVAYAMANTYAM SUTRA

This sutra means the ultimate and twice the penultimate of given multiplication [14].
Example:

1. For single digit value (132 x 12)

a) Zero sandwich for 132(01320)
b) Last digit + 2(second last digit) $=0+2(2)=4$
c) Second last digit + 2(third last digit) $=2+2(3)=8$
d) Third last digit + 2(fourth last digit) $=3+2(1)=5$
e) Fourth last digit + 2(fifth last digit) $=1+2(0)=1$
   Answer take value from bottom to top=<u>*1584*</u>, from b) to e) 4,8,5 &1 are single digit values.

2. For double digit value (187 x 12)

a) Zero sandwich for 187(01870)
b) Last digit + 2(second last digit) = $0+2(7)=14$, double digit value
c) Second last digit + 2(third last digit) $=7+2(8)=23$, double digit value
d) Third last digit + 2(fourth last digit) $=8+2(1)=10$, double digit value
e) Fourth last digit + 2(fifth last digit) $=1+2(0)=1$
   Answer take value from bottom to top$=1|10|23|14=1+1|0+2|3+1|4=2244$

XVIII. CONCLUSION AND FUTURE SCOPE

Design with vedic sutras is seen to be efficient in speed, and area in digital designs with respect to other logical Circuits. Considering all the sutras discussed above, we can conclude that the vedic sutras based multiplier with UrdhvaTiryakbhyam sutra and nikhilam navatashcaramamdashatah are seen as a promising technique in terms of speed, area and also might be in power also. The work can be further extended with the design of such multiplier in arithmetic logical unit, multiply accumulator unit and comparing the results with existing designs for the same.

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