4x4 Matix Multiplication

ELEC 522, Juan Garza, Fall 2022

High Level Method

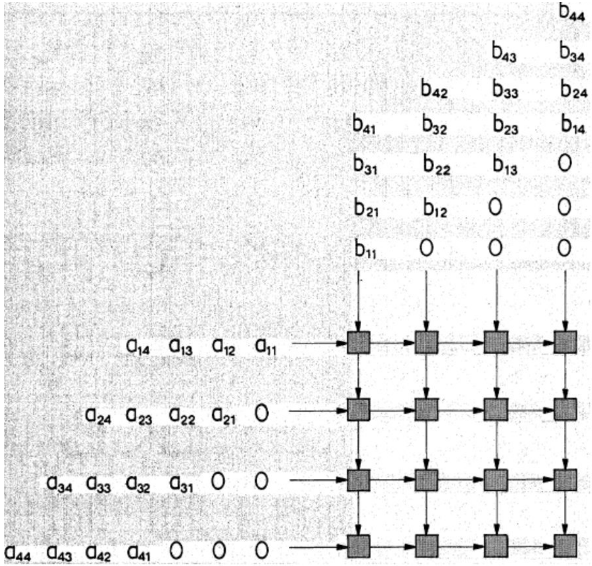
A * B where A is loaded from the left side with each row and B is loaded from the right with the columns loaded in, this takes four cycles for the 4 coefficients for the first column

Control cycles - every 5th (clock cycle after last coefficient is loaded) which will act as a buffer between two matrices

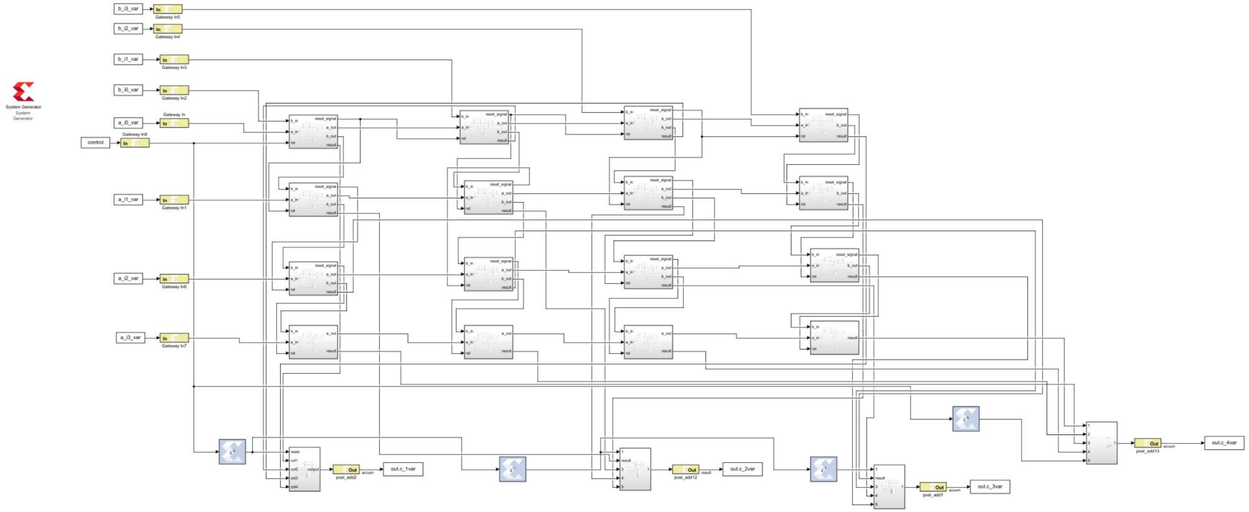
Ex : $a_{11}a_{12}a_{13}a_{14}$ 0 $a_{11}a_{12}a_{13}a_{14}$ 0 $a_{11}a_{12}a_{13}a_{14}$ 0

Ex : $b_{11}b_{21}b_{31}b_{41}$ 0 $b_{11}b_{21}b_{31}b_{41}$ 0 $b_{11}b_{21}b_{31}b_{41}$ 0

Ex : 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1

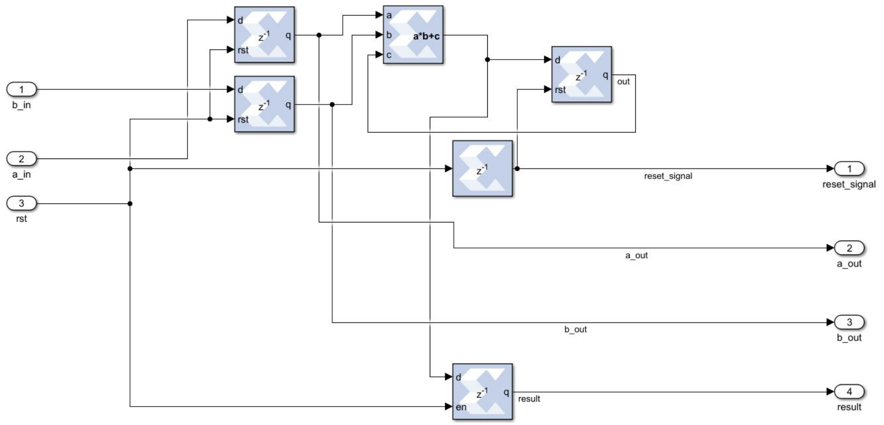


Processing element



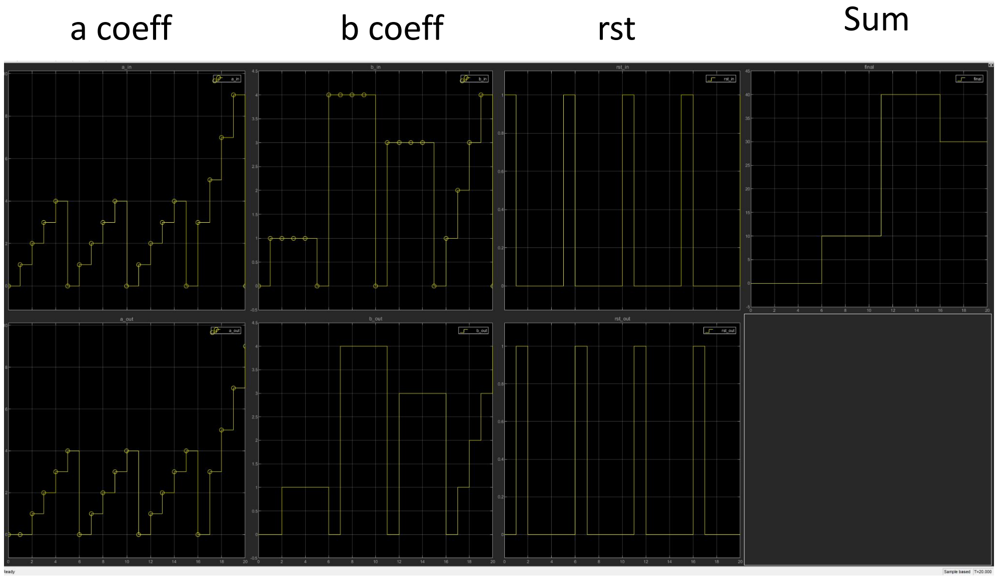
Data is loaded with A having its rows fed to the right and B having its columns fed down

Processing element



You add and accumulate for each coefficient a_i and b_j. This accumulated sum is kept in a register. The control signal (goes high after every 4 coefficients) would reset the component and store the result for output

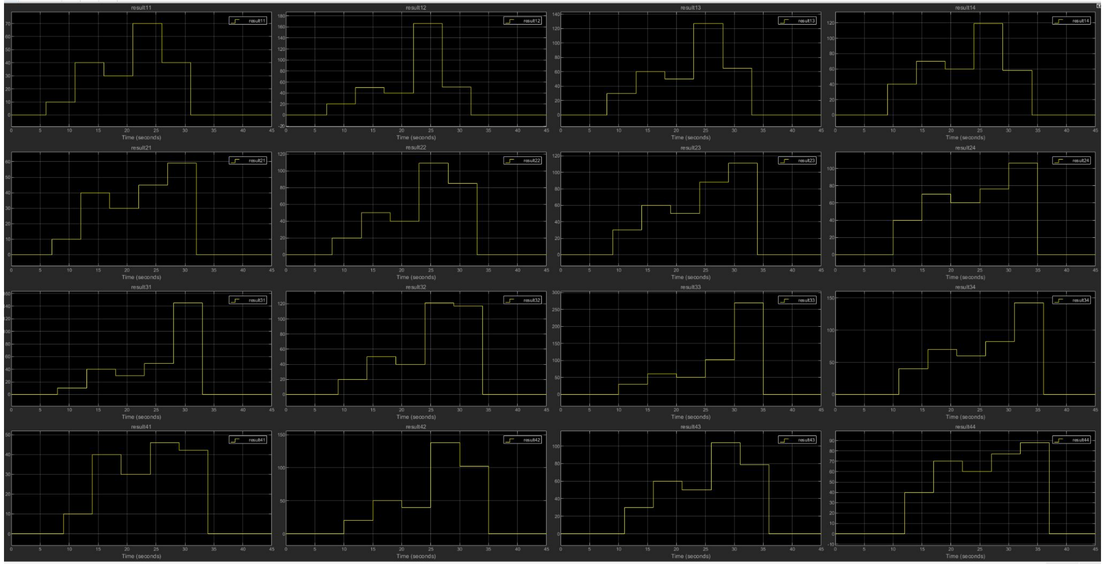
Processing Element Waveforms



The a and b coefficient are passed along with a delay of 1 cycle.

The sum is seen to latch to a new value once it has been calculated

Total timing



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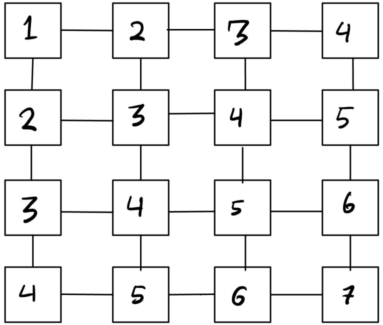
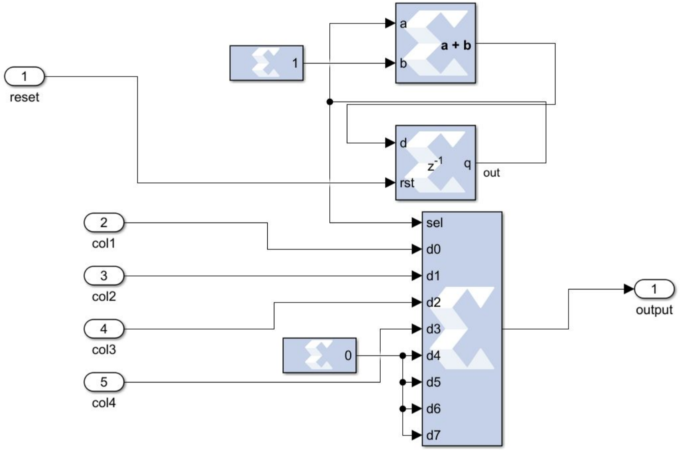


Delivering Output to workspace



Uses A Mux and a counter which iterates through each selection. The control signal would indicate when it would iterate to the next matrix resultant row

Testing Matrix Multiplications

$$\begin{pmatrix} 1 & 2 & 3 & 4 \\ 1 & 2 & 3 & 4 \\ 1 & 2 & 3 & 4 \\ 1 & 2 & 3 & 4 \end{pmatrix}\begin{pmatrix} 1 & 2 & 3 & 4 \\ 1 & 2 & 3 & 4 \\ 1 & 2 & 3 & 4 \\ 1 & 2 & 3 & 4 \end{pmatrix} = \begin{pmatrix} 10 & 20 & 30 & 40 \\ 10 & 20 & 30 & 40 \\ 10 & 20 & 30 & 40 \\ 10 & 20 & 30 & 40 \end{pmatrix}$$

$$\begin{pmatrix} 3 & 2 & 4 & 5 \\ 4 & 5 & 9 & 6 \\ 24 & 5 & 7 & 8 \\ 0 & 8 & 6 & 5 \end{pmatrix}\begin{pmatrix} 4 & 1 & 8 & 2 \\ 2 & 9 & 5 & 4 \\ 1 & 0 & 4 & 6 \\ 4 & 6 & 3 & 4 \end{pmatrix} = \begin{pmatrix} 40 & 51 & 65 & 58 \\ 59 & 85 & 111 & 106 \\ 145 & 117 & 269 & 142 \\ 42 & 102 & 79 & 88 \end{pmatrix}$$

```
>> c_var_out_disp
    0   10   20   30   40    0   40   50   60   70    0   30   40   50   60    0   70  166  127  119    0   40   51   65   58

    0   10   20   30   40    0   40   50   60   70    0   30   40   50   60    0   45  109   88   76    0   59   85  111  106

    0   10   20   30   40    0   40   50   60   70    0   30   40   50   60    0   49  121  102   82    0  145  117  269  142

    0   10   20   30   40    0   40   50   60   70    0   30   40   50   60    0   46  138  104   77    0   42  102   79   88

>>
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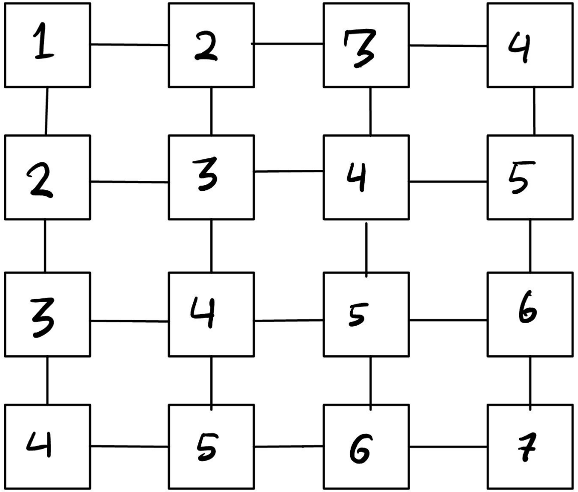
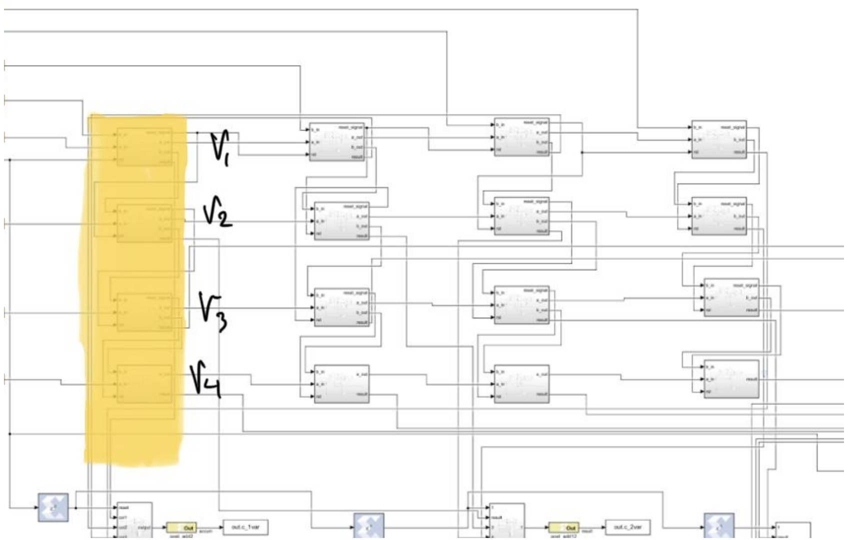
Vectors Multiplications

Only four p
these will t
similar to tr
columns be





Testing vectors Multiplications

$$\begin{pmatrix} 1 & 2 & 3 & 4 \\ 1 & 2 & 3 & 4 \\ 1 & 2 & 3 & 4 \\ 1 & 2 & 3 & 4 \end{pmatrix}\begin{pmatrix} 1 \\ 1 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 10 \\ 10 \\ 10 \\ 10 \end{pmatrix}$$

$$\begin{pmatrix} 3 & 2 & 4 & 5 \\ 4 & 5 & 9 & 6 \\ 24 & 5 & 7 & 8 \\ 0 & 8 & 6 & 5 \end{pmatrix}\begin{pmatrix} 4 \\ 2 \\ 1 \\ 4 \end{pmatrix} = \begin{pmatrix} 40 \\ 59 \\ 145 \\ 42 \end{pmatrix}$$

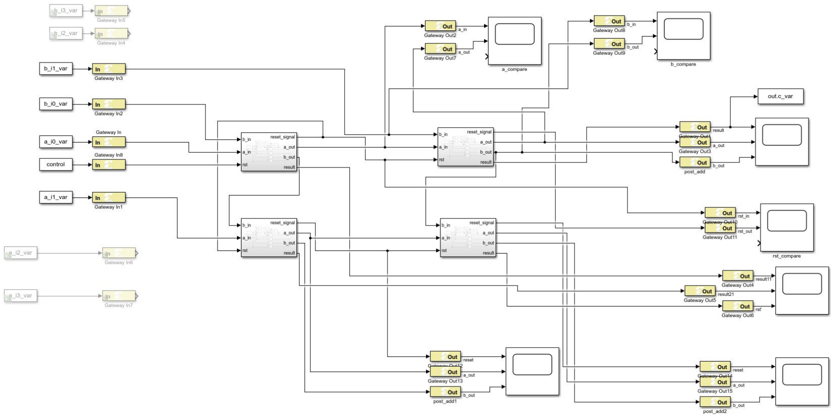
```
>> c_var_out_disp
   0   10    0    0    0    0   40    0    0    0    0   30    0    0    0    0   70    0    0    0    0   40

   0   10    0    0    0    0   40    0    0    0    0   30    0    0    0    0   45    0    0    0    0   59

   0   10    0    0    0    0   40    0    0    0    0   30    0    0    0    0   49    0    0    0    0  145

   0   10    0    0    0    0   40    0    0    0    0   30    0    0    0    0   46    0    0    0    0   42
```

Scalability



Tested at first as a 2 x 2 matrix