



DIGITAL DESIGN & COMPUTER ORGANISATION

Multiplication-1

Sudarshan T S B., Ph.D.
Department of Computer Science
& Engineering



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MULTIPLICATION - 1

Course Outline

- Digital Design
 - ▶ Combinational logic design
 - ▶ Sequential logic design
 - ★ Multiplication – 1

- Computer Organisation
 - ▶ Architecture (microprocessor instruction set)
 - ▶ Microarchitecture (microprocessor operation)

Concepts covered

- Binary Multiplication



MULTIPLICATION - 1

Array Multiplication

- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers



MULTIPLICATION - 1

Array Multiplication

- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

$$\begin{array}{r} 13 \\ \times 11 \\ \hline 13 \\ 13 \\ \hline 143 \end{array}$$



MULTIPLICATION - 1

Array Multiplication

- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

$$\begin{array}{r} 13 \\ \times 11 \\ \hline \end{array}$$

1 1 0 1

$$\begin{array}{r} 13 \\ 13 \\ \hline \end{array}$$

143

$$\begin{array}{r} \\ \\ \hline \end{array}$$



MULTIPLICATION - 1

Array Multiplication

- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

$$\begin{array}{r} 13 \\ \times 11 \\ \hline \end{array}$$

$$\begin{array}{r} 1101 \\ \times 1011 \\ \hline \end{array}$$



MULTIPLICATION - 1

Array Multiplication



- Manual method of multiplication of 2 decimal numbers
 - Similarly we can accomplish multiplication of 2 binary numbers

$$\begin{array}{r}
 13 \\
 \times 11 \\
 \hline
 13 \\
 13 \\
 \hline
 143
 \end{array}$$

MULTIPLICATION - 1

Array Multiplication



- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

13 X 11 ----- 13 13 ----- 143 -----	$\begin{array}{r} 1101 \\ \times 1011 \\ \hline \end{array}$	<p>(13) Multiplicand, M (11) Multiplier, Q</p>
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MULTIPLICATION - 1

Array Multiplication



- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

13 X 11 ----- 13 13 ----- 143 -----	1 1 0 1 X 1 0 1 1 -----	<p>(13) Multiplicand, M (11) Multiplier, Q</p>
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MULTIPLICATION - 1

Array Multiplication



- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

13 X 11 ----- 13 13 ----- 143 -----	1 1 0 1 X 1 0 1 1 ----- 1 1 0 1	<p>(13) Multiplicand, M (11) Multiplier, Q</p>
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MULTIPLICATION - 1

Array Multiplication



- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

13 X 11 ----- 13 13 ----- 143 -----	1 1 0 1 X 1 0 1 1 ----- 1 1 0 1 1 1 0 1 -----	<p>(13) Multiplicand, M (11) Multiplier, Q</p>
--	--	--

MULTIPLICATION - 1

Array Multiplication



- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

13 X 11 ----- 13 13 ----- 143	$\begin{array}{r} 1101 \\ \times 1011 \\ \hline \end{array}$ <p>(13) Multiplicand, M (11) Multiplier, Q</p> $\begin{array}{r} 1101 \\ 1101 \\ \hline 0000 \end{array}$
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MULTIPLICATION - 1

Array Multiplication



- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

13 X 11 ----- 13 13 ----- 143	$\begin{array}{r} 1101 \\ \times 1011 \\ \hline \end{array}$ $\begin{array}{r} 1101 \\ 1101 \\ 0000 \\ 1101 \\ \hline \end{array}$	<p>(13) Multiplicand, M (11) Multiplier, Q</p>
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MULTIPLICATION - 1

Array Multiplication



- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

13 X 11 ----- 13 13 ----- 143	<p>1 1 0 1 (13) Multiplicand, M X 1 0 1 1 (11) Multiplier, Q ----- 1 1 0 1 1 1 0 1 ----- 0 0 0 0 1 1 0 1 -----</p>
---	---

MULTIPLICATION - 1

Array Multiplication



- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

13 X 11 ----- 13 13 ----- 143 -----	1 1 0 1 X 1 0 1 1 ----- 1 1 0 1 1 1 0 1 0 0 0 0 1 1 0 1 ----- 1 0 0 0 1 1 1 1	<p>(13) Multiplicand, M</p> <p>(11) Multiplier, Q</p>
--	---	---

MULTIPLICATION - 1

Array Multiplication



- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

13 X 11 ----- 13 13 ----- 143 -----	1 1 0 1 X 1 0 1 1 ----- 1 1 0 1 1 1 0 1 0 0 0 0 1 1 0 1 ----- 1 0 0 0 1 1 1 1	<p>(13) Multiplicand, M (11) Multiplier, Q</p> <p>(143) Product, P</p>
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MULTIPLICATION - 1

Array Multiplication

- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

- This algorithm applies to unsigned numbers or positive signed numbers.
- The product of two n-digit numbers will result in $2n$ digit result.

13	1 1 0 1	(13) Multiplicand, M
X 11	X 1 0 1 1	(11) Multiplier, Q
<hr/>		
13	1 1 0 1	
13	1 1 0 1	
<hr/>		
143	0 0 0 0	
	1 1 0 1	
<hr/>		
	1 0 0 0 1 1 1 1	(143) Product, P

MULTIPLICATION - 1

Array Multiplication

- Manual method of multiplication of 2 decimal numbers
- Similarly we can accomplish multiplication of 2 binary numbers

- This algorithm applies to unsigned numbers or positive signed numbers.
- The product of two n-digit numbers will result in $2n$ digit result.

13	1 1 0 1	(13) Multiplicand, M
X 11	X 1 0 1 1	(11) Multiplier, Q
-----	-----	
13	1 1 0 1	
13	1 1 0 1	
-----	0 0 0 0	
143	1 1 0 1	
-----	1 0 0 0 1 1 1 1	(143) Product, P

- Multiplication of binary numbers can be represented using AND function
- The product can be obtained by adding partial product in each stage
- Multiplication of binary numbers can be achieved using an array of combinational elements

MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

$m_3 \quad m_2 \quad m_1 \quad m_0$

MULTIPLICATION - 1

Array Multiplication

1 1 0 1 (13) Multiplicand, M
X 1 0 1 1 (11) Multiplier, Q

0 0 0 0 Initial Partial Product, PP₀

m₃ m₂ m₁ m₀

MULTIPLICATION - 1

Array Multiplication

1 1 0 1 (13) Multiplicand, M
X 1 0 1 1 (11) Multiplier, Q

0 0 0 0 Initial Partial Product, PP₀

PP₀

0 m₃ 0 m₂ 0 m₁ 0 m₀

MULTIPLICATION - 1

Array Multiplication

1 1 0 1 (13) Multiplicand, M
X 1 0 1 1 (11) Multiplier, Q

0 0 0 0 Initial Partial
1 1 0 1 Product, PP₀

PP₀

0 m₃ 0 m₂ 0 m₁ 0 m₀

MULTIPLICATION - 1

Array Multiplication

1 1 0 1 (13) Multiplicand, M
X 1 0 1 1 (11) Multiplier, Q

0 0 0 0 Initial Partial
1 1 0 1 Product, PP₀

PP₀

0 m₃ 0 m₂ 0 m₁ 0 m₀

MULTIPLICATION - 1

Array Multiplication

1 1 0 1 (13) Multiplicand, M
X 1 0 1 1 (11) Multiplier, Q

0 0 0 0 Initial Partial
1 1 0 1 Product, PP₀

1 1 0 1 Partial Product, PP₁

PP₀

0 m₃ 0 m₂ 0 m₁ 0 m₀

MULTIPLICATION - 1

Array Multiplication

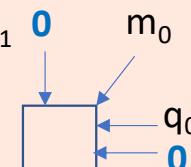
$$\begin{array}{r} 1101 \\ \times 1011 \\ \hline \end{array} \quad \begin{array}{l} (13) \text{ Multiplicand, } M \\ (11) \text{ Multiplier, } Q \end{array}$$

$$\begin{array}{r} 0000 \\ 1101 \\ \hline \end{array} \quad \begin{array}{l} \text{Initial Partial} \\ \text{Product, } PP_0 \end{array}$$

$$1101 \quad \text{Partial Product, } PP_1$$

PP₀

0 m₃ 0 m₂ 0 m₁ 0 m₀



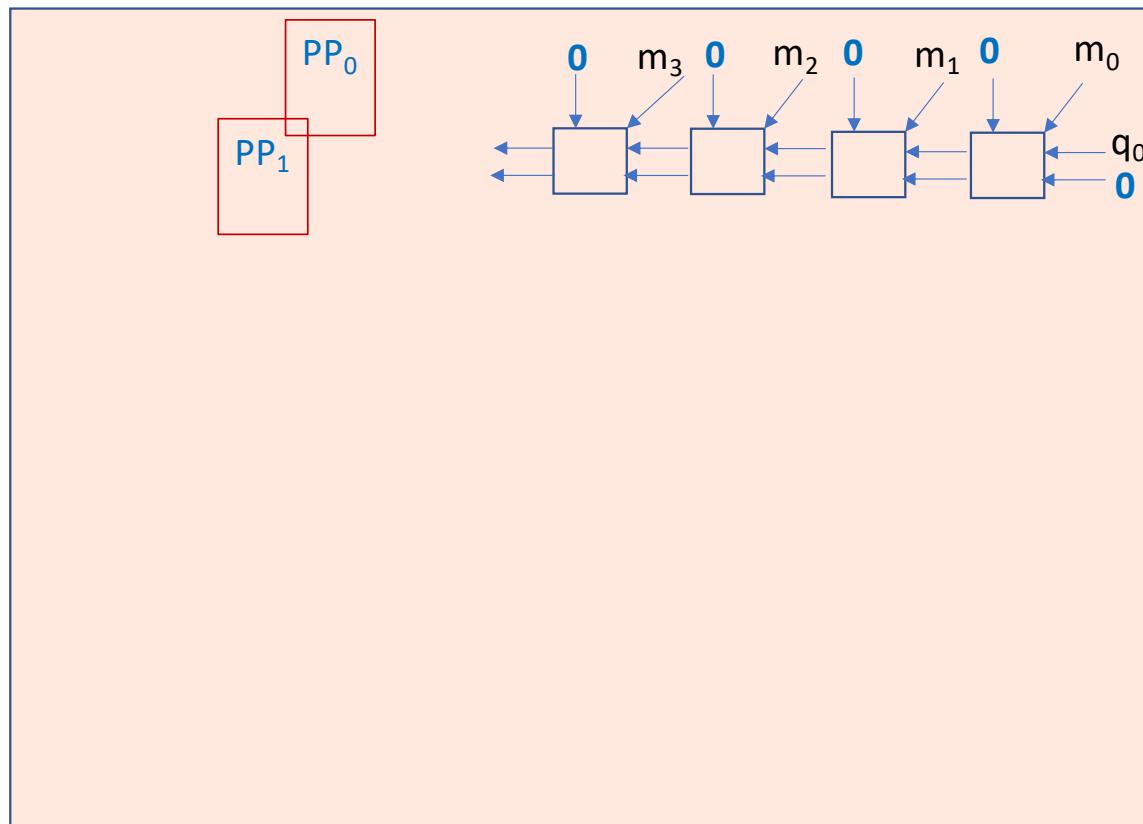
MULTIPLICATION - 1

Array Multiplication

$$\begin{array}{r} 1101 \\ \times 1011 \\ \hline \end{array} \quad \begin{array}{l} (13) \text{ Multiplicand, } M \\ (11) \text{ Multiplier, } Q \end{array}$$

0 0 0 0 Initial Partial
1 1 0 1 Product, PP_0

1 1 0 1 Partial Product, PP_1



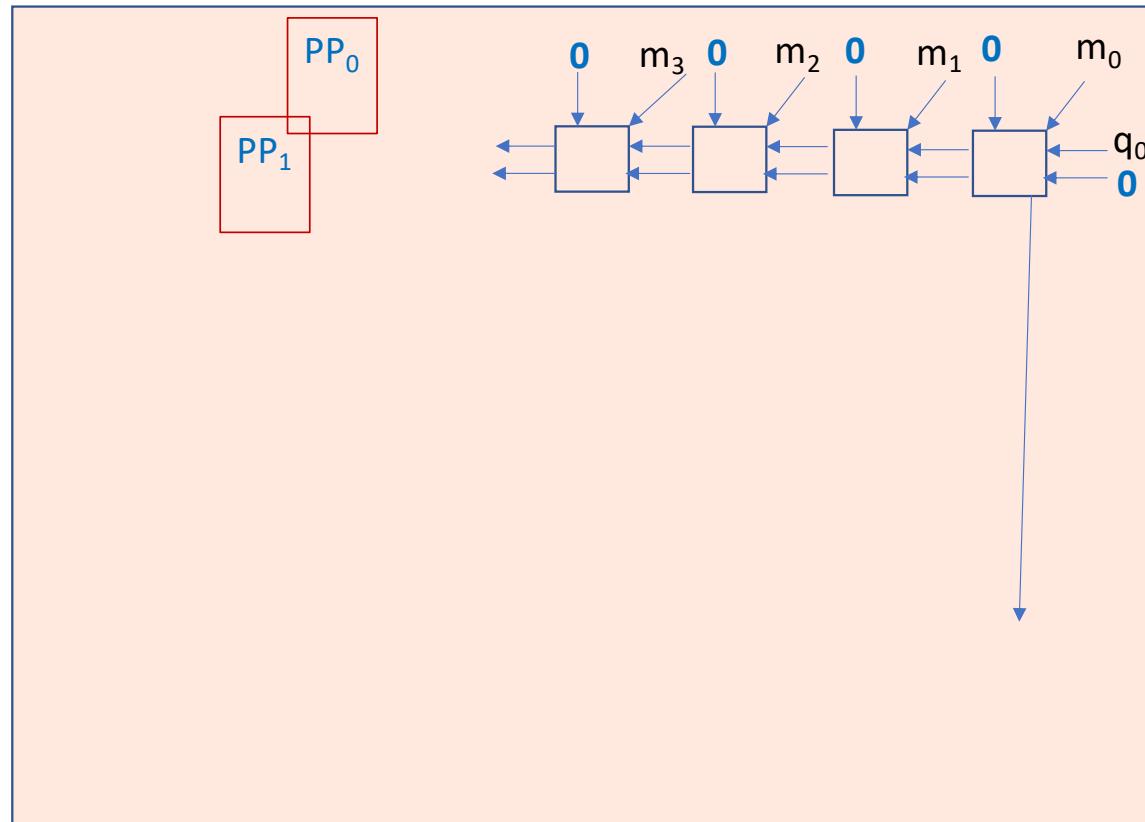
MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	

1 1 0 1	Partial Product, PP ₁



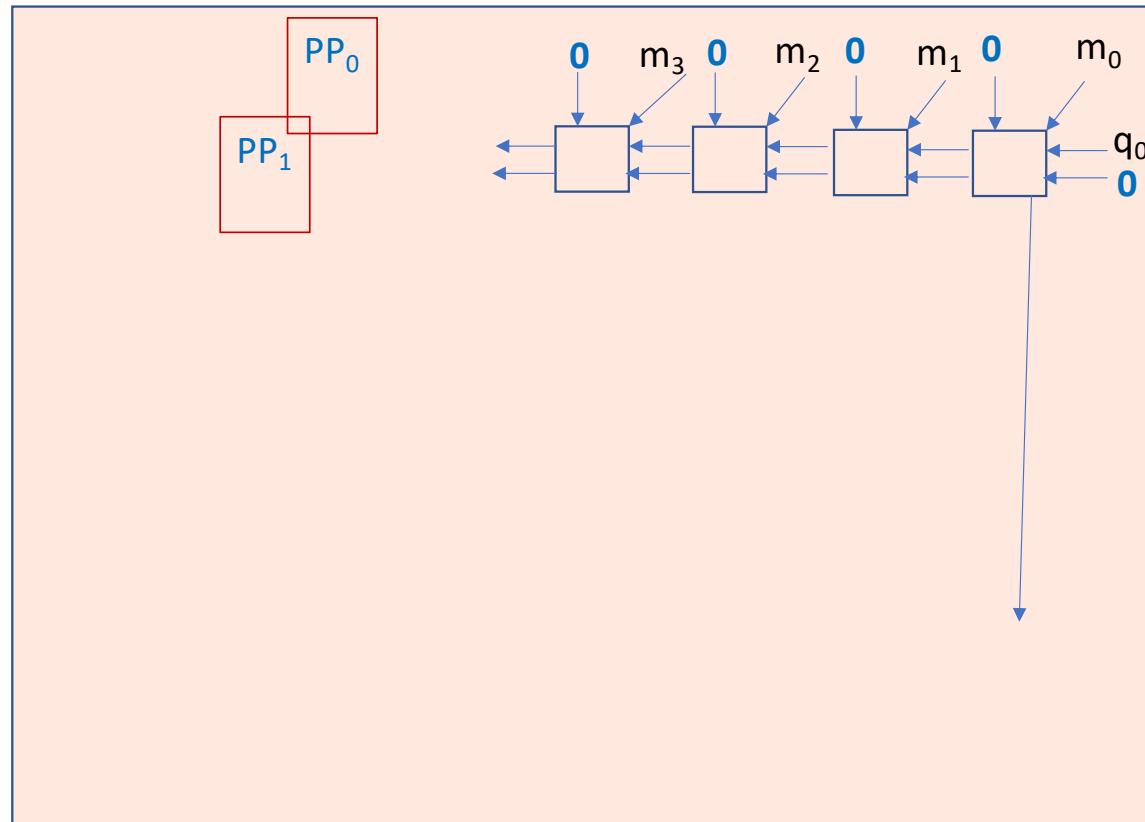
MULTIPLICATION - 1

Array Multiplication

$$\begin{array}{r} 1101 \\ \times 1011 \\ \hline \end{array} \quad \begin{array}{l} (13) \text{ Multiplicand, } M \\ (11) \text{ Multiplier, } Q \end{array}$$

0 0 0 0 Initial Partial
1 1 0 1 Product, PP_0

1 1 0 1 Partial Product, PP_1
1 1 0 1



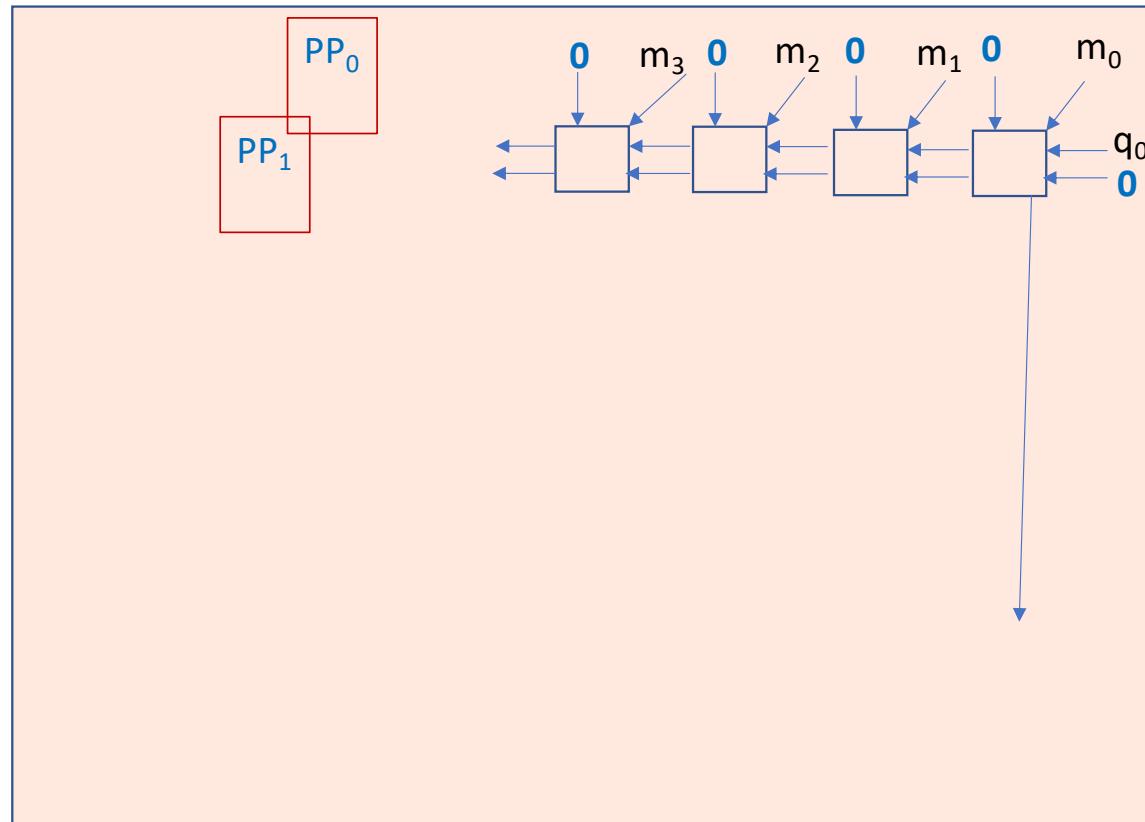
MULTIPLICATION - 1

Array Multiplication

$$\begin{array}{r} 1101 \\ \times 1011 \\ \hline \end{array} \quad \begin{array}{l} (13) \text{ Multiplicand, } M \\ (11) \text{ Multiplier, } Q \end{array}$$

$$\begin{array}{r} 0000 \\ 1101 \\ \hline \end{array} \quad \begin{array}{l} \text{Initial Partial} \\ \text{Product, } PP_0 \end{array}$$

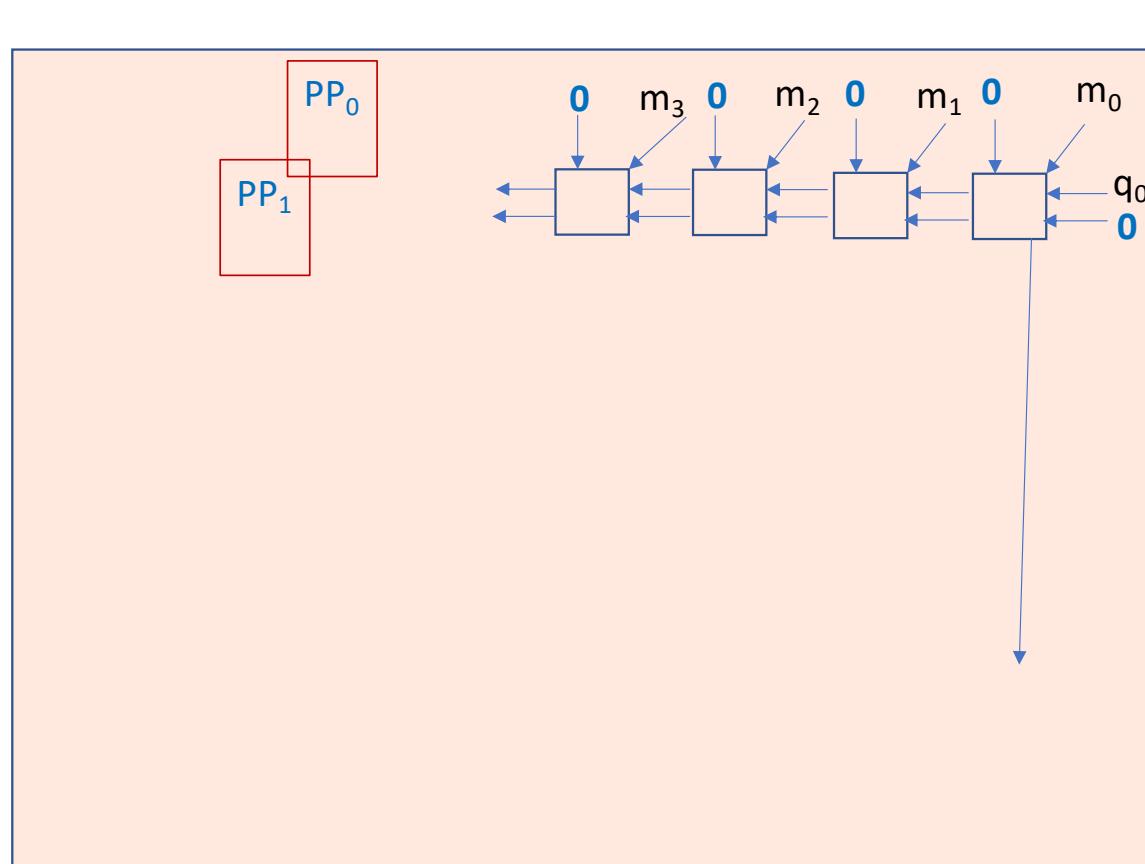
$$\begin{array}{r} 1101 \\ 1101 \\ \hline \end{array} \quad \begin{array}{l} \text{Partial Product, } PP_1 \end{array}$$



MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q
<hr/>	
0 0 0 0	Initial Partial Product, PP ₀
<hr/>	
1 1 0 1	Partial Product, PP ₁
1 1 0 1	
<hr/>	
1 0 0 1 1 1	



MULTIPLICATION - 1

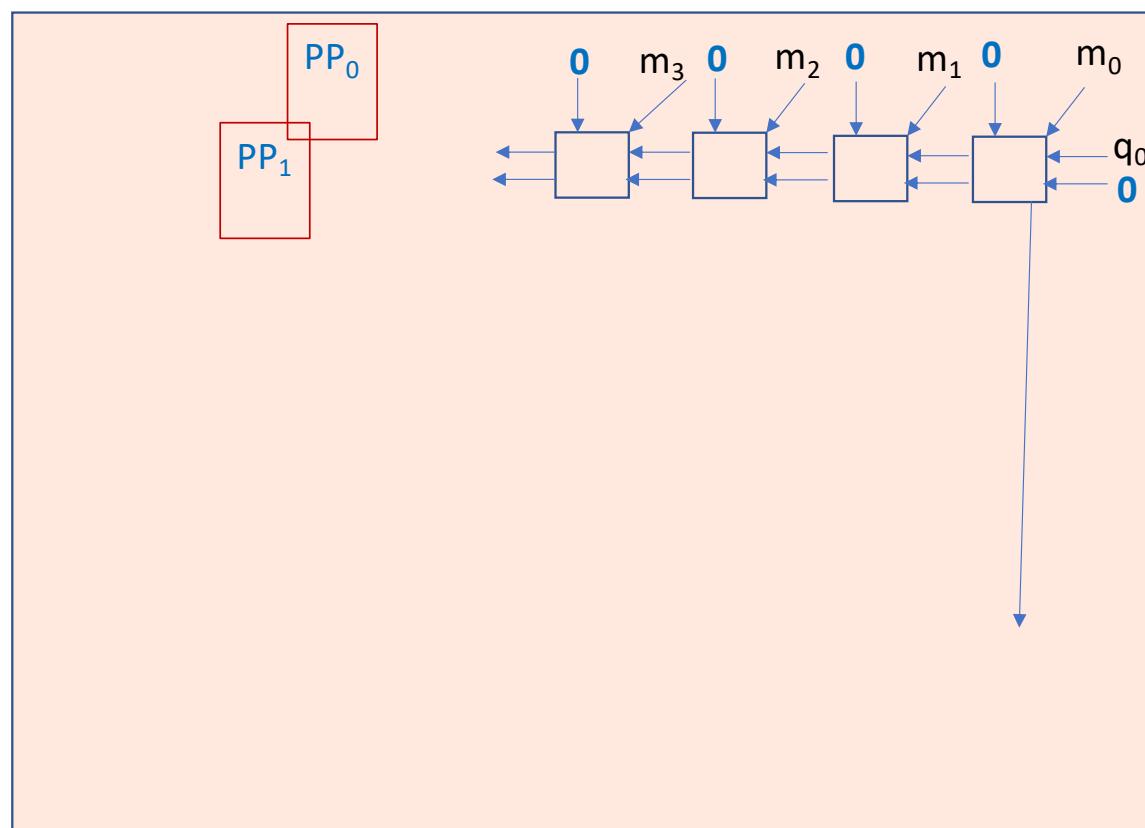
Array Multiplication

$$\begin{array}{r} 1101 \\ \times 1011 \\ \hline \end{array} \quad \begin{array}{l} (13) \text{ Multiplicand, } M \\ (11) \text{ Multiplier, } Q \end{array}$$

$$\begin{array}{r} 0000 \\ 1101 \\ \hline \end{array} \quad \begin{array}{l} \text{Initial Partial} \\ \text{Product, } PP_0 \end{array}$$

$$\begin{array}{r} 1101 \\ 1101 \\ \hline \end{array} \quad \begin{array}{l} \text{Partial Product, } PP_1 \end{array}$$

$$\begin{array}{r} 100111 \\ \hline \end{array} \quad \begin{array}{l} \text{Partial Product, } PP_2 \end{array}$$



MULTIPLICATION - 1

Array Multiplication

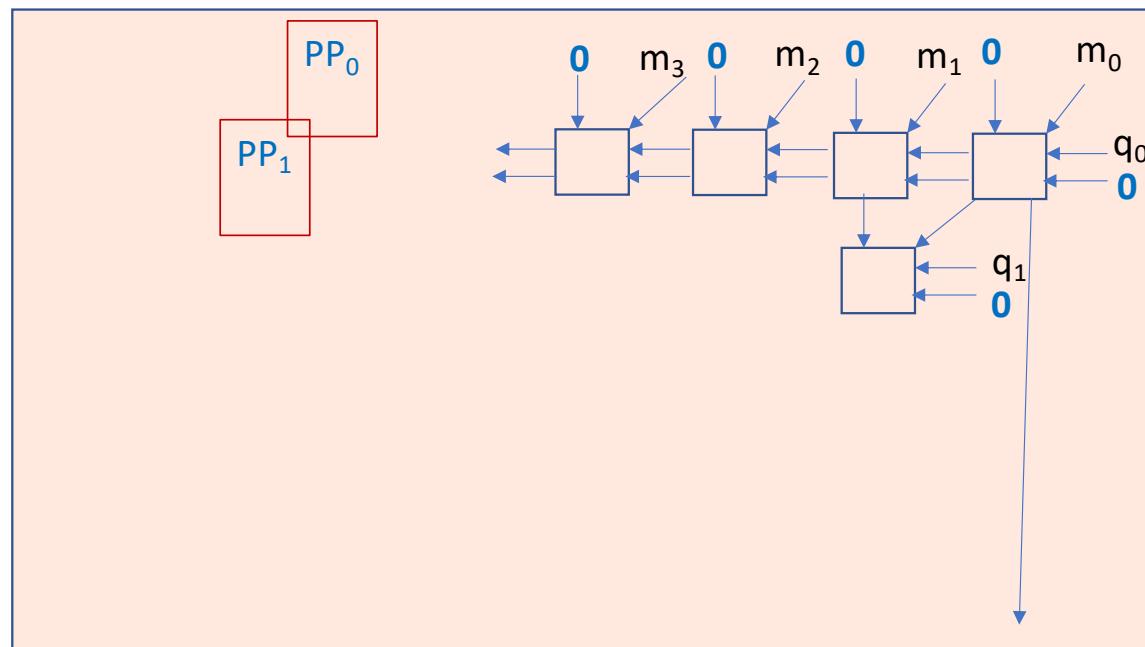


$$\begin{array}{r} 1101 \\ \times 1011 \\ \hline \end{array}$$

0 0 0 0 Initial Partial
1 1 0 1 Product, PP_0

1 1 0 1 Partial Product, PP₁
1 1 0 1

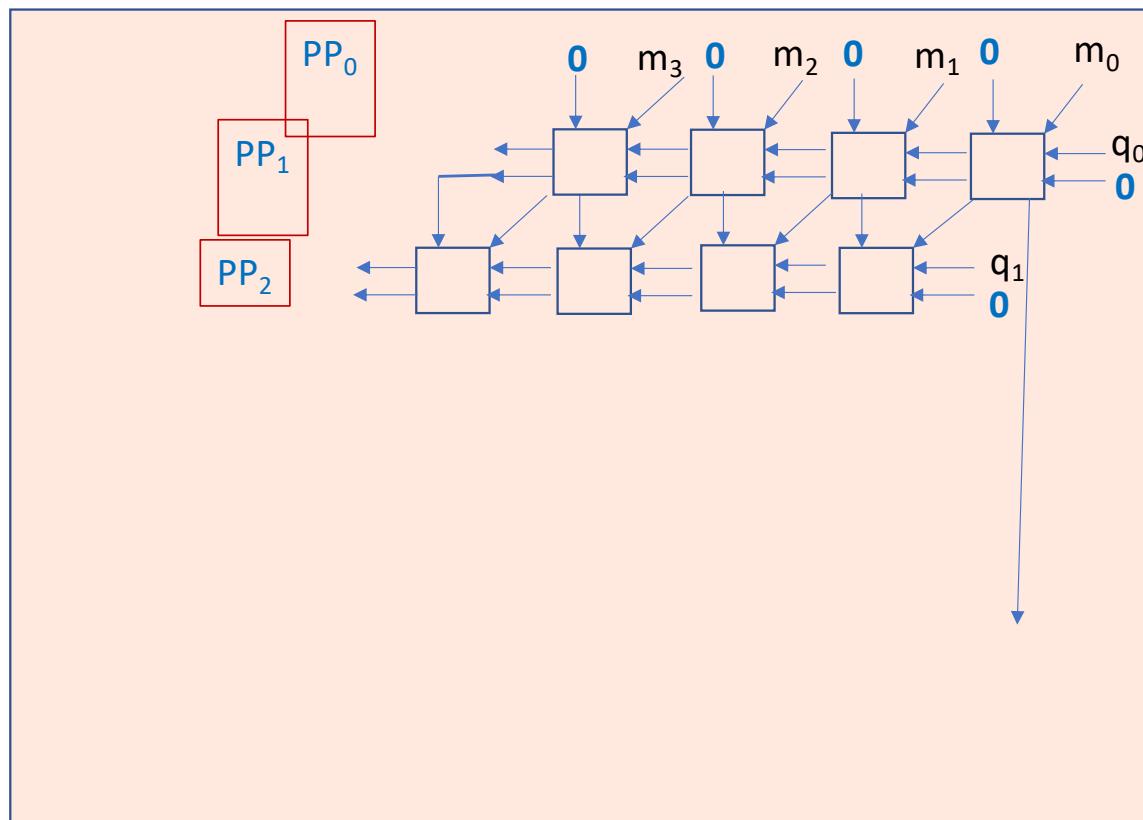
1 0 0 1 1 1 Partial Product, PP₂



MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q
<hr/>	
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	
<hr/>	
1 1 0 1	Partial Product, PP ₁
1 1 0 1	
<hr/>	
1 0 0 1 1 1	Partial Product, PP ₂



MULTIPLICATION - 1

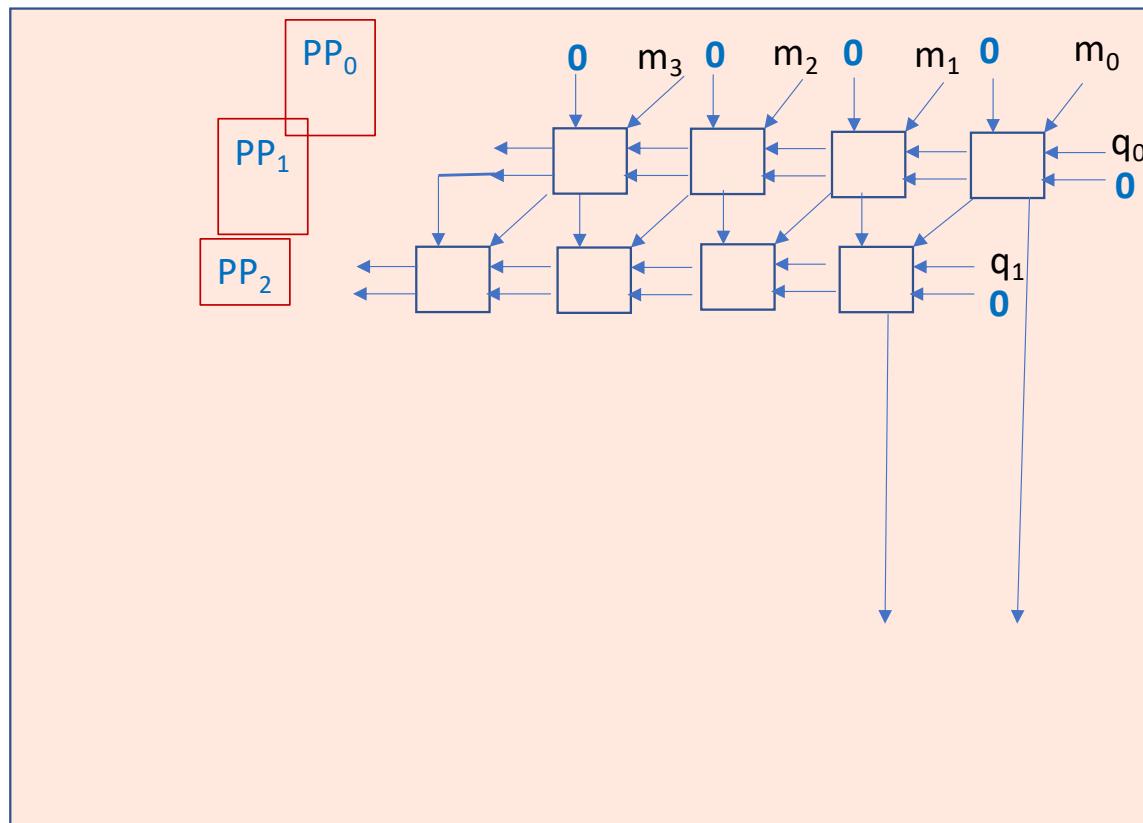
Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	

1 1 0 1	Partial Product, PP ₁
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₂



MULTIPLICATION - 1

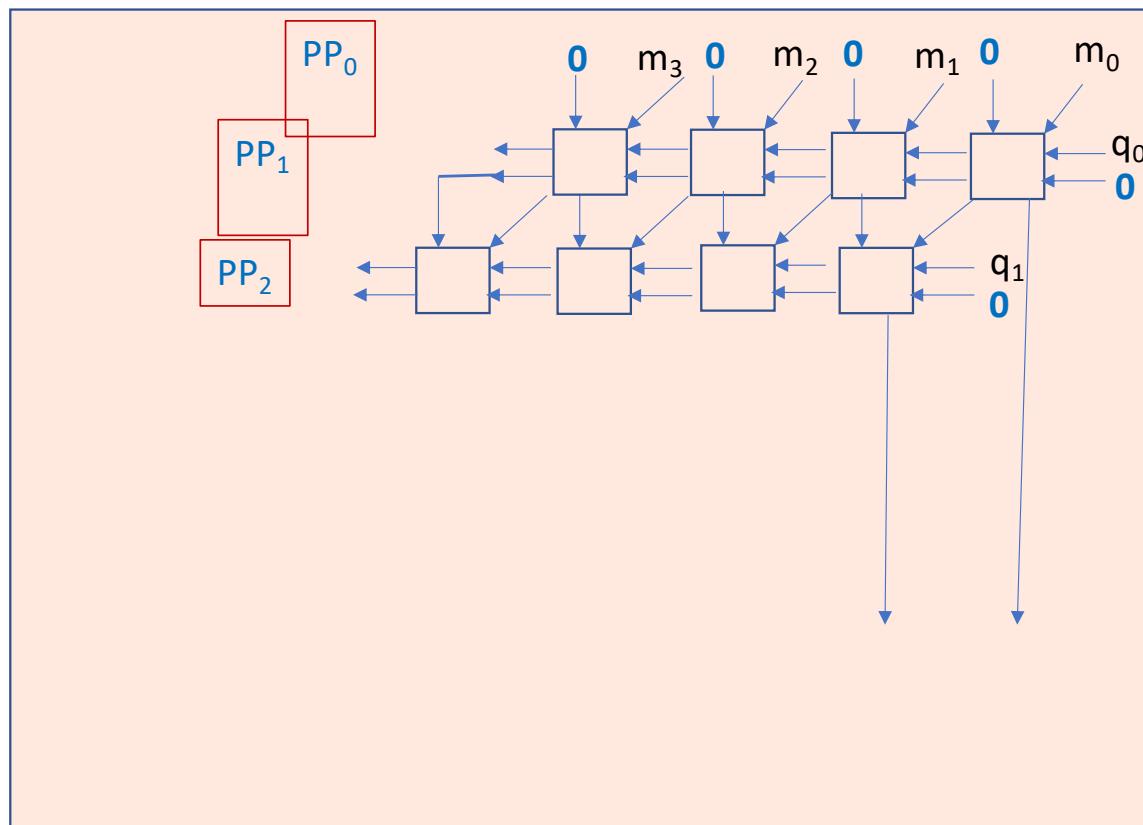
Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	

1 1 0 1	Partial Product, PP ₁
1 1 0 1	

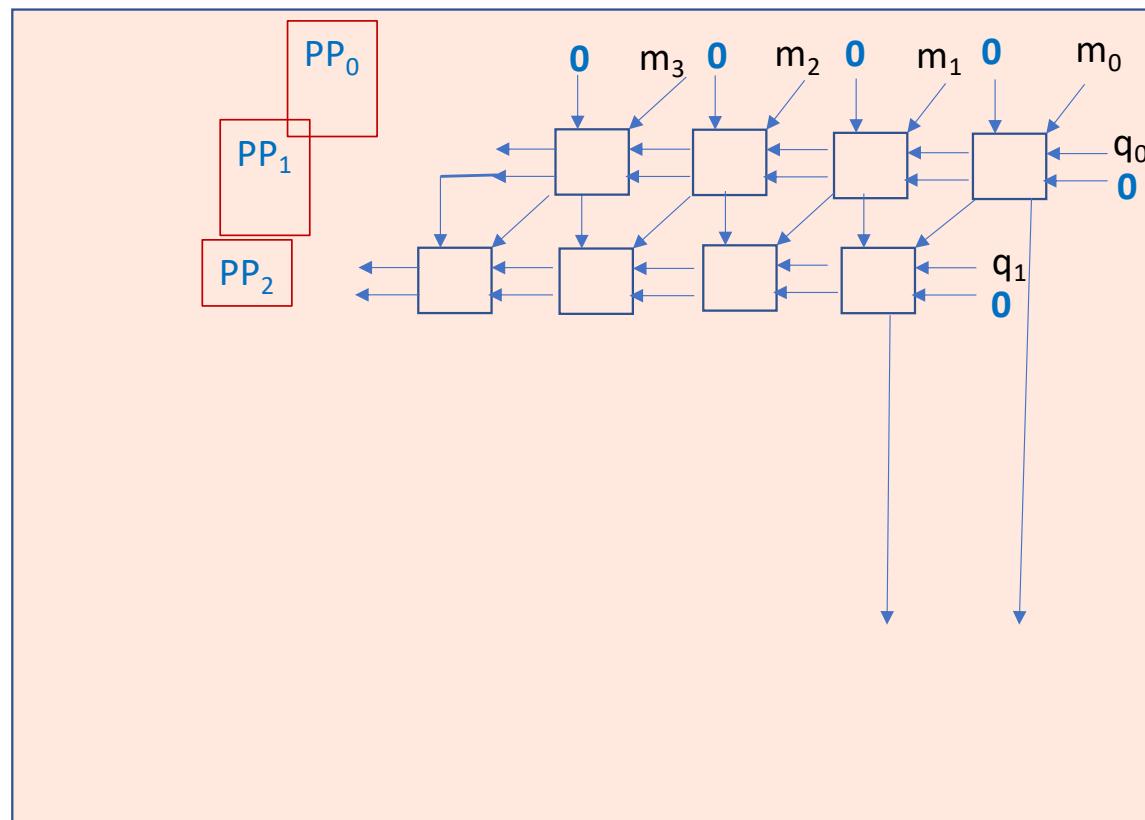
1 0 0 1 1 1	Partial Product, PP ₂
0 0 0 0	



MULTIPLICATION - 1

Array Multiplication

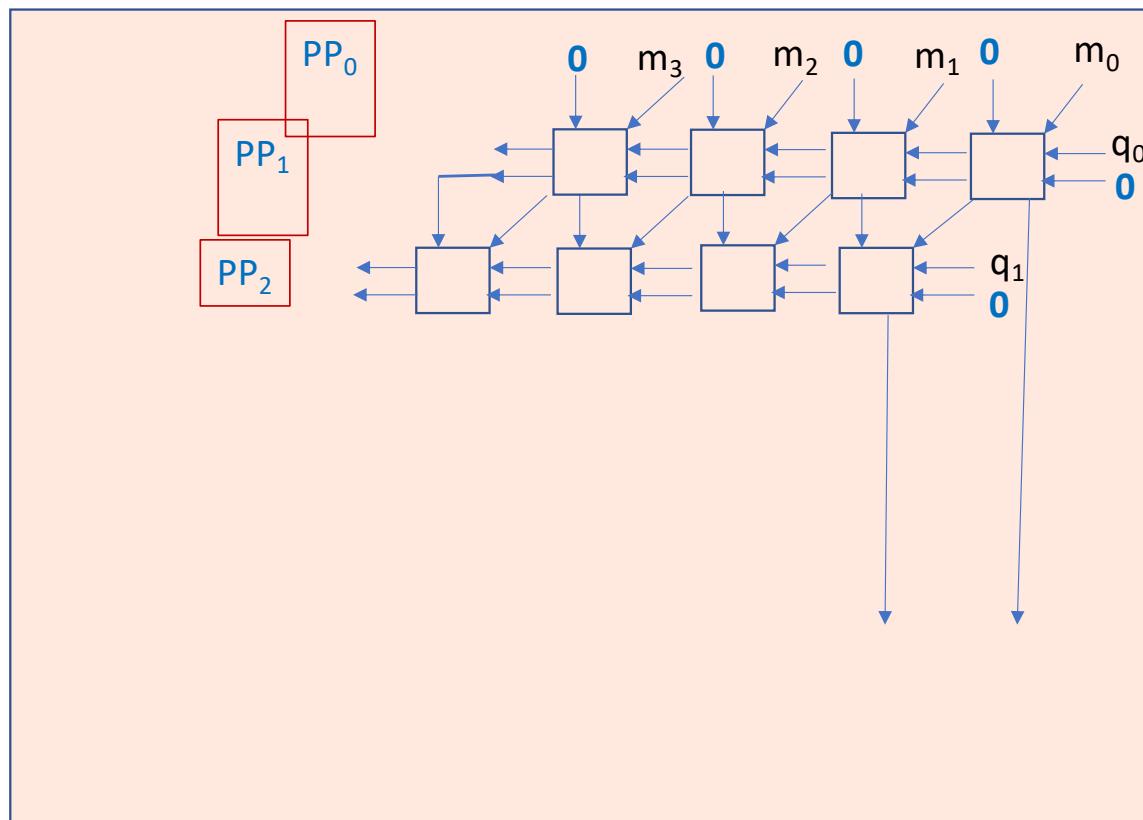
1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q
<hr/>	
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	
<hr/>	
1 1 0 1	Partial Product, PP ₁
1 1 0 1	
<hr/>	
1 0 0 1 1 1	Partial Product, PP ₂
0 0 0 0	
<hr/>	



MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q
<hr/>	
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	
<hr/>	
1 1 0 1	Partial Product, PP ₁
1 1 0 1	
<hr/>	
1 0 0 1 1 1	Partial Product, PP ₂
0 0 0 0	
<hr/>	
1 0 0 1 1 1	



MULTIPLICATION - 1

Array Multiplication

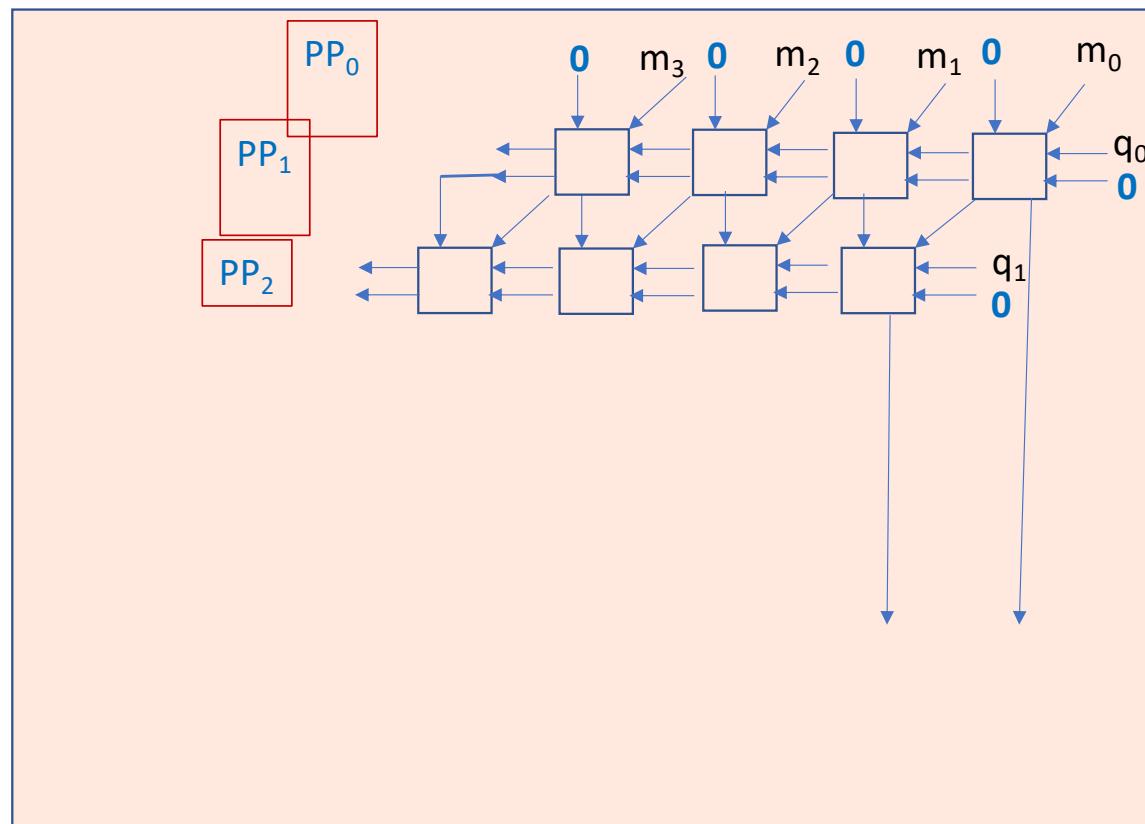
1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	

1 1 0 1	Partial Product, PP ₁
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₂
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃



MULTIPLICATION - 1

Array Multiplication

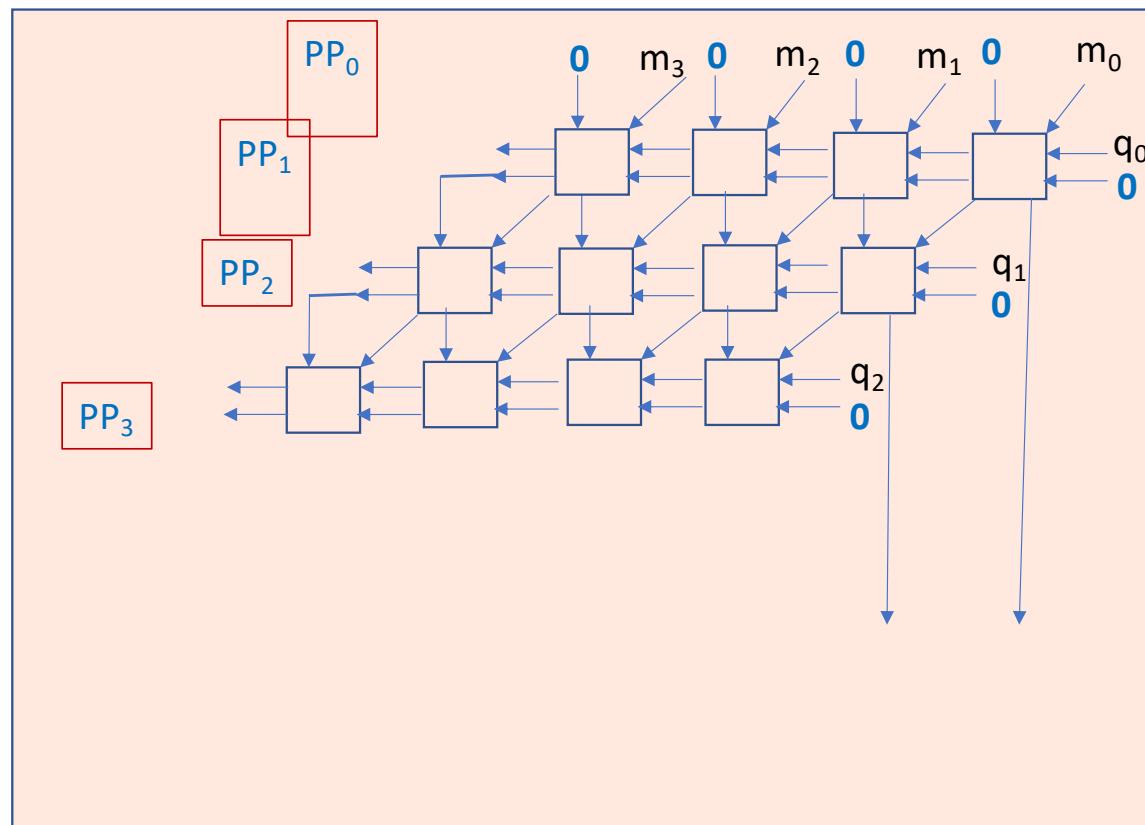
1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	Partial Product, PP ₁

1 1 0 1	Partial Product, PP ₂
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₃
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃



MULTIPLICATION - 1

Array Multiplication

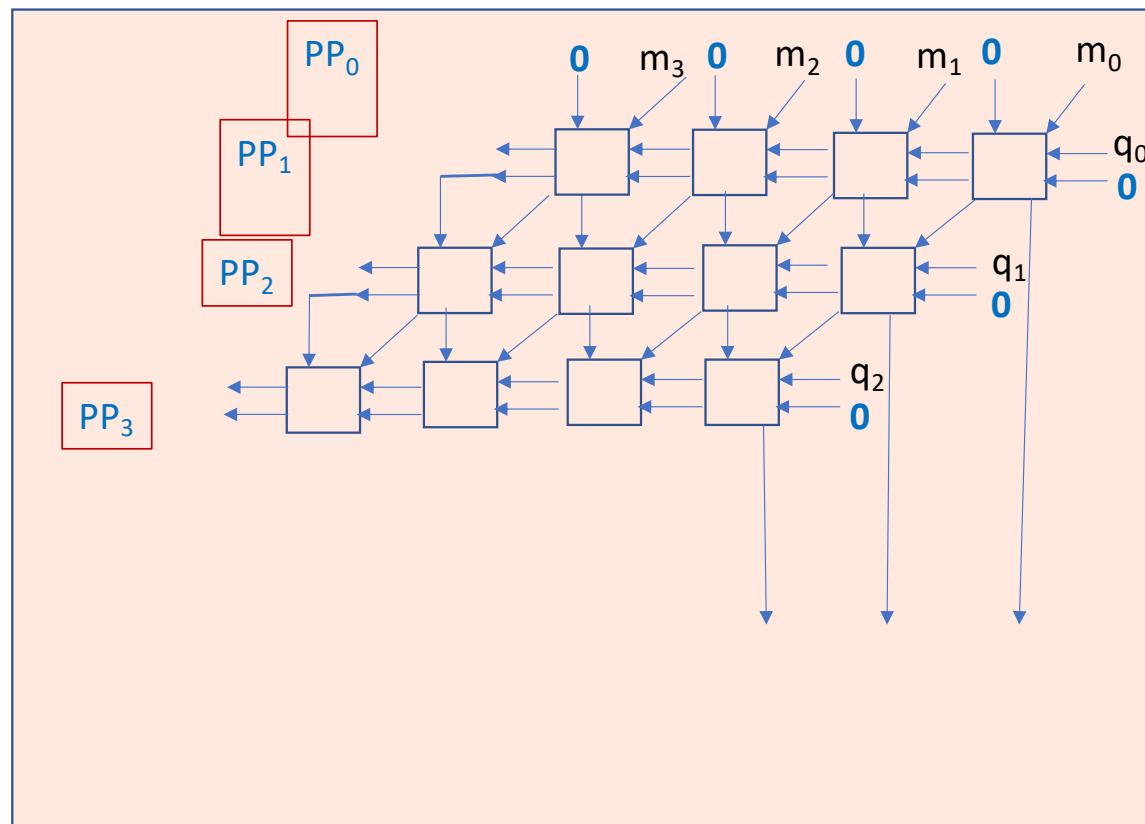
1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	Partial Product, PP ₁

1 1 0 1	Partial Product, PP ₂
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₃
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃



MULTIPLICATION - 1

Array Multiplication

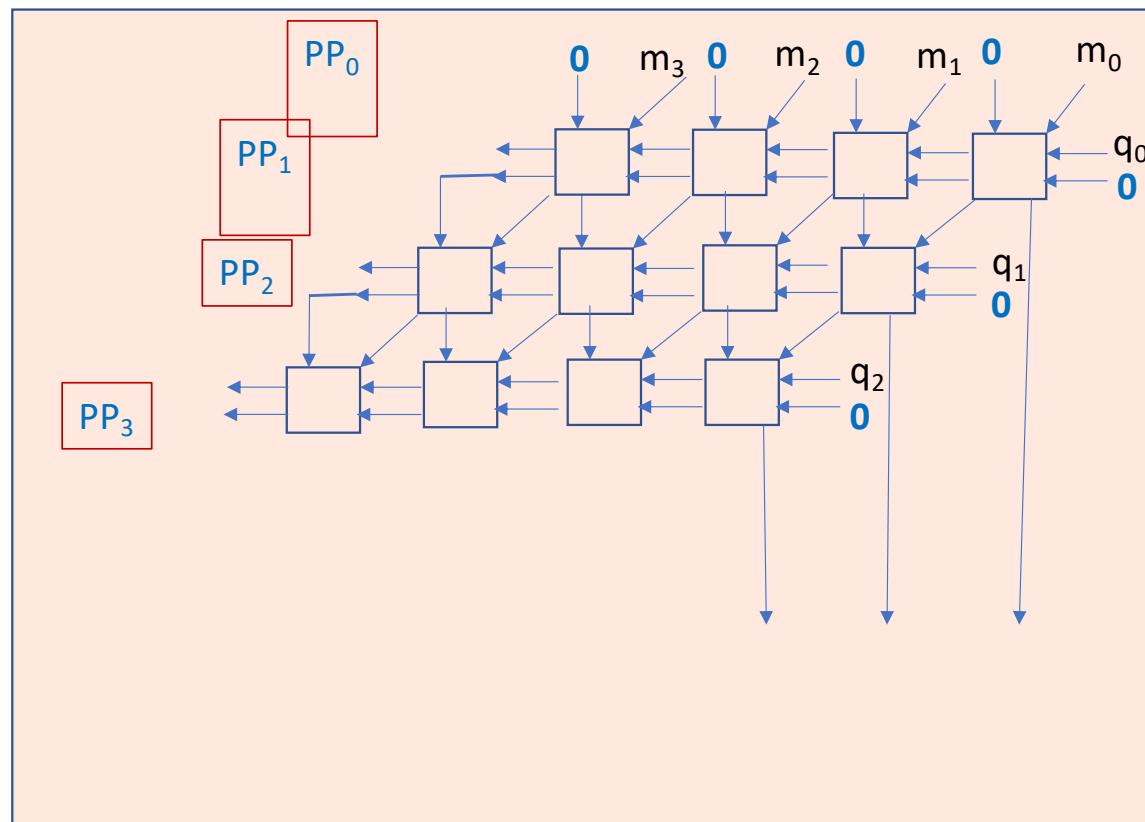
1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	

1 1 0 1	Partial Product, PP ₁
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₂
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃
1 1 0 1	



MULTIPLICATION - 1

Array Multiplication

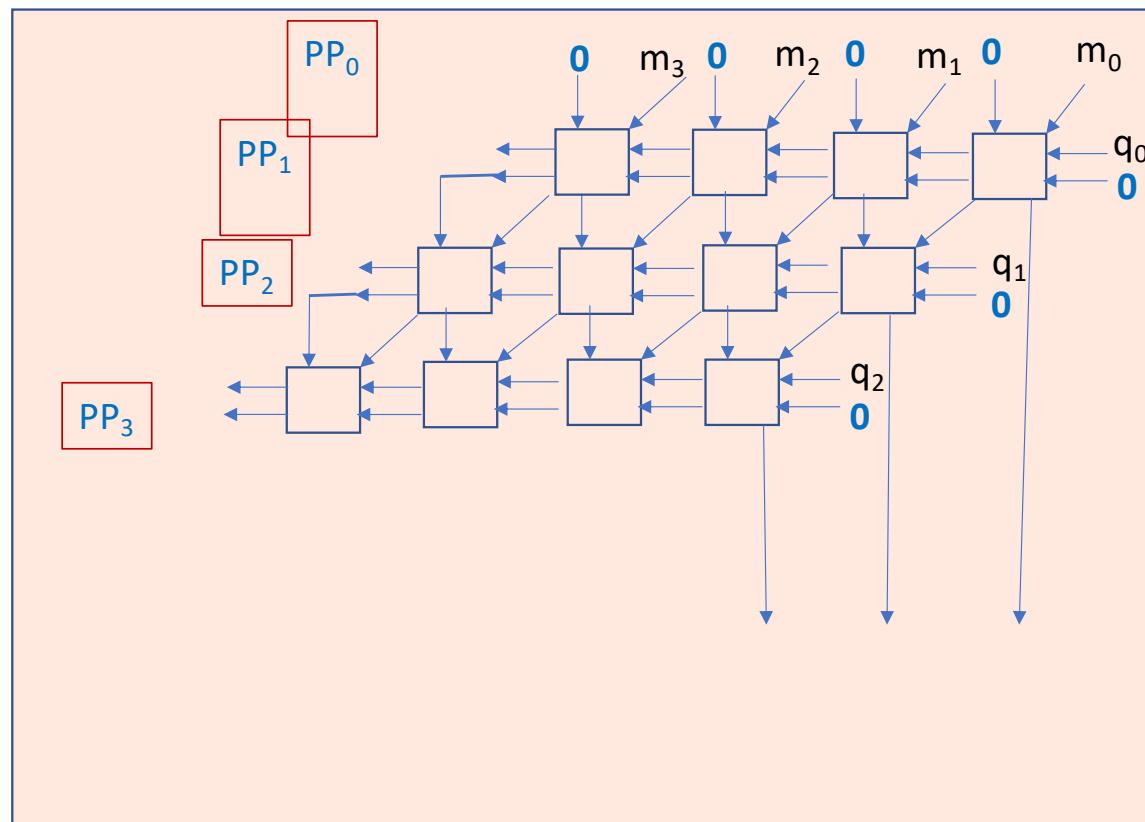
1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	

1 1 0 1	Partial Product, PP ₁
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₂
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃
1 1 0 1	



MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

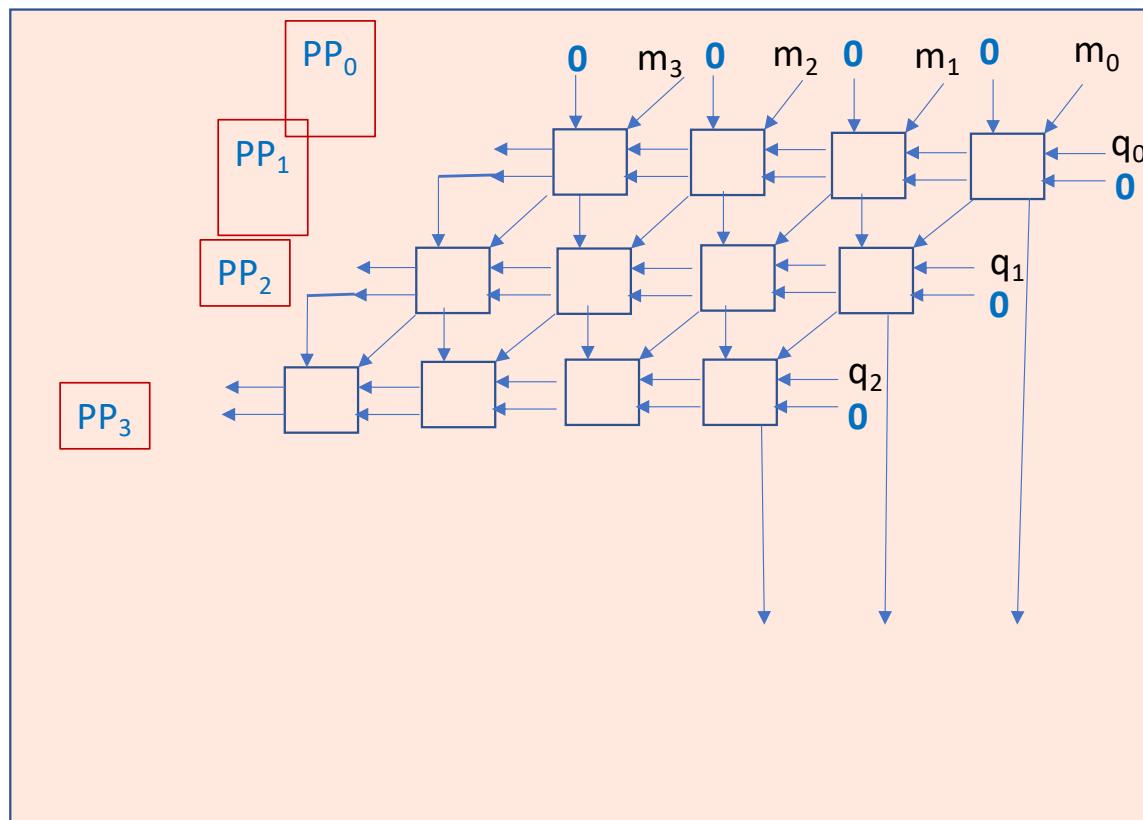
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	Partial Product, PP ₁

1 1 0 1	Partial Product, PP ₂
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₃
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃
1 1 0 1	

1 0 0 0 1 1 1 1	



MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

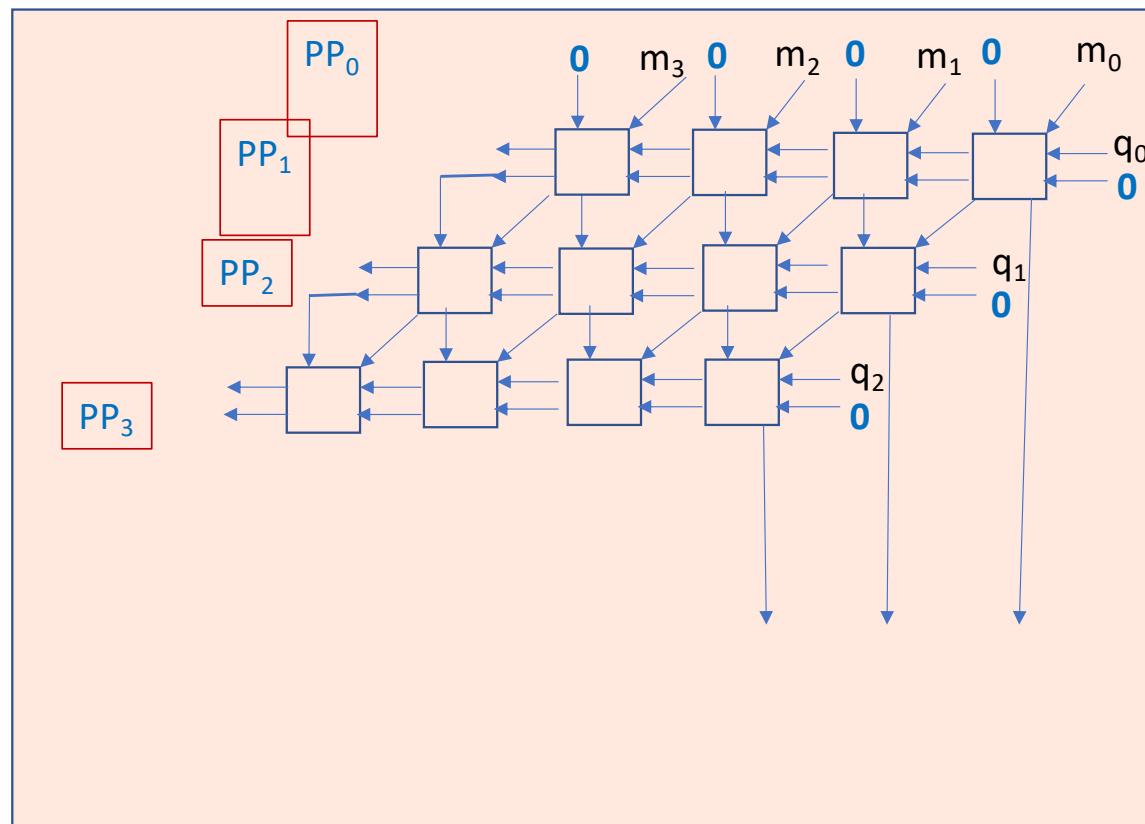
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	

1 1 0 1	Partial Product, PP ₁
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₂
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃
1 1 0 1	

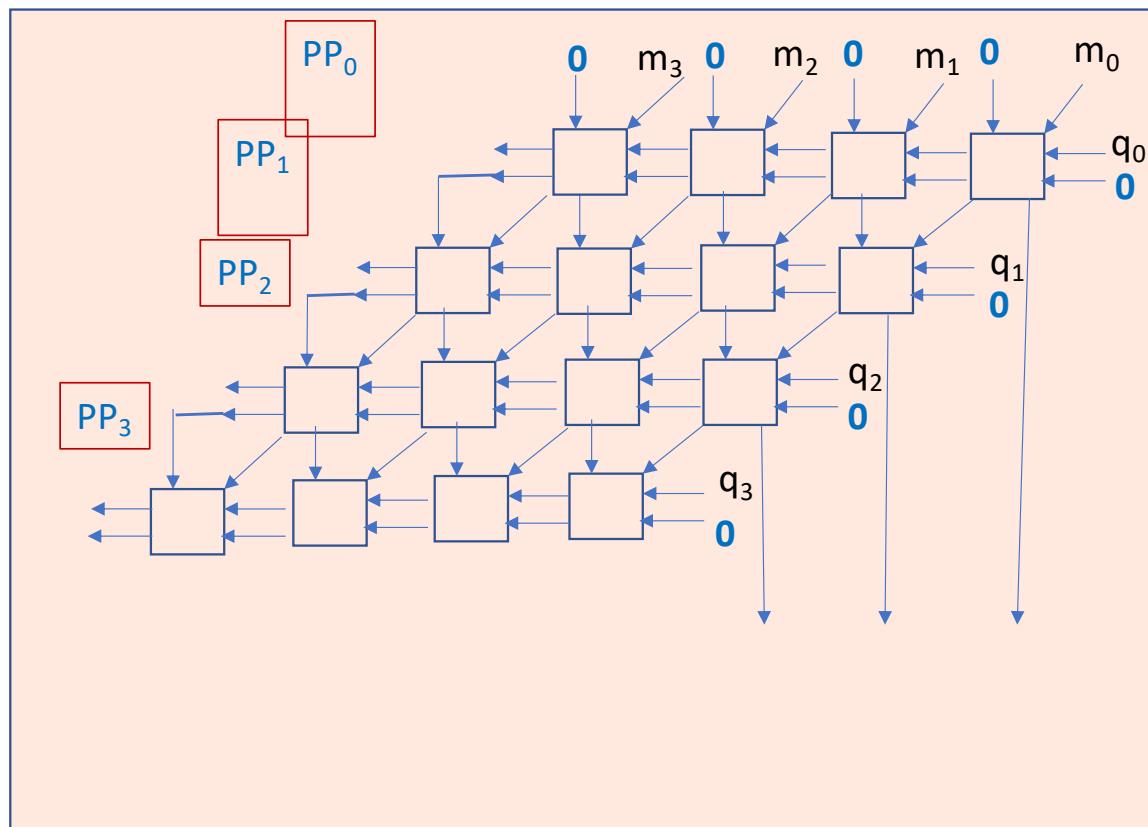
1 0 0 0 1 1 1 1	(143) Product, P



MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q
<hr/>	
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	Partial Product, PP ₁
<hr/>	
1 1 0 1	Partial Product, PP ₂
1 1 0 1	
<hr/>	
1 0 0 1 1 1	Partial Product, PP ₃
0 0 0 0	
<hr/>	
1 0 0 1 1 1	Partial Product, PP ₃
1 1 0 1	
<hr/>	
1 0 0 0 1 1 1 1	(143) Product, P



MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

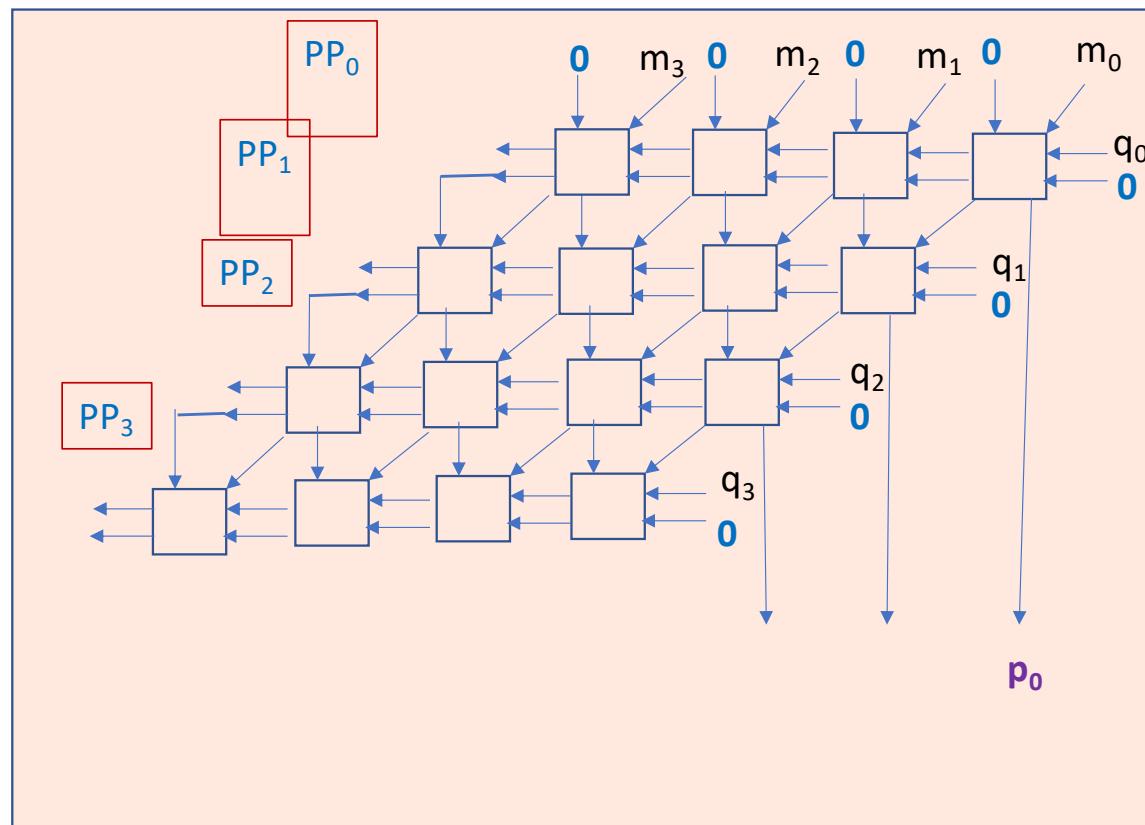
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	Partial Product, PP ₁

1 1 0 1	Partial Product, PP ₂
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₃
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃
1 1 0 1	

1 0 0 0 1 1 1 1	(143) Product, P



MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

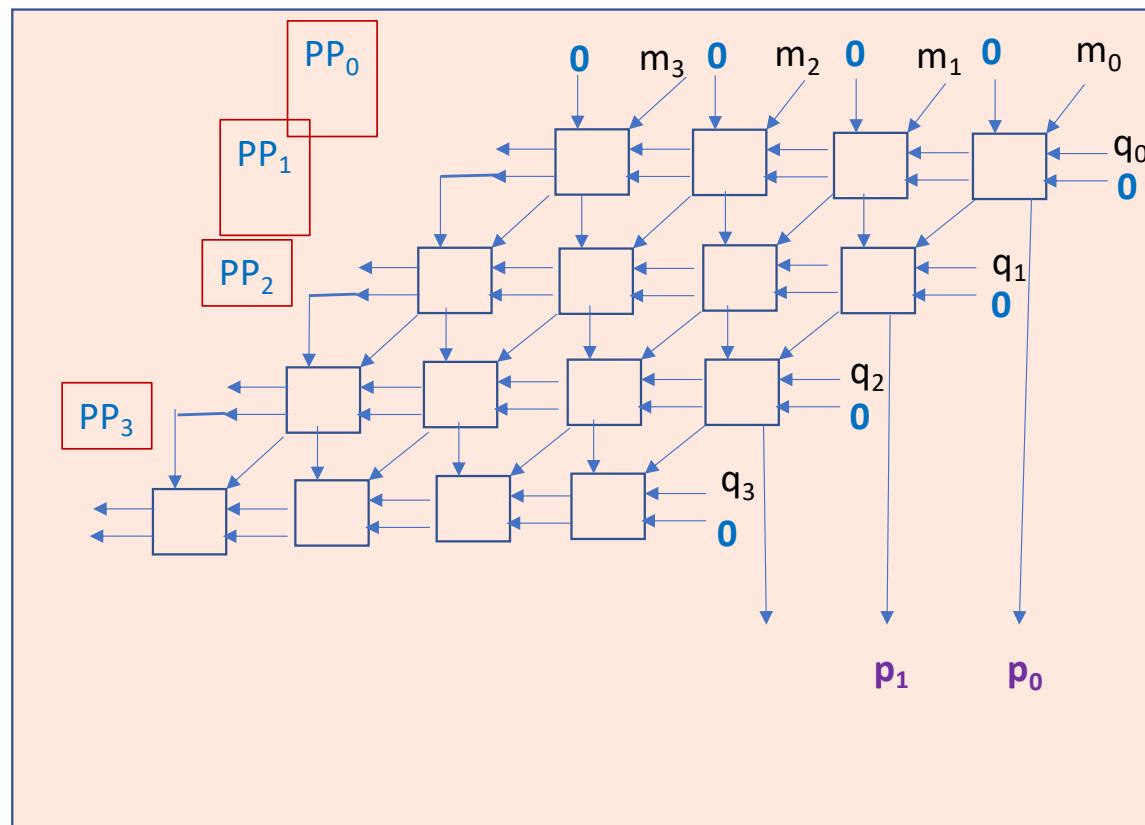
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	Partial Product, PP ₁

1 1 0 1	Partial Product, PP ₂
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₃
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃
1 1 0 1	

1 0 0 0 1 1 1 1	(143) Product, P



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Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

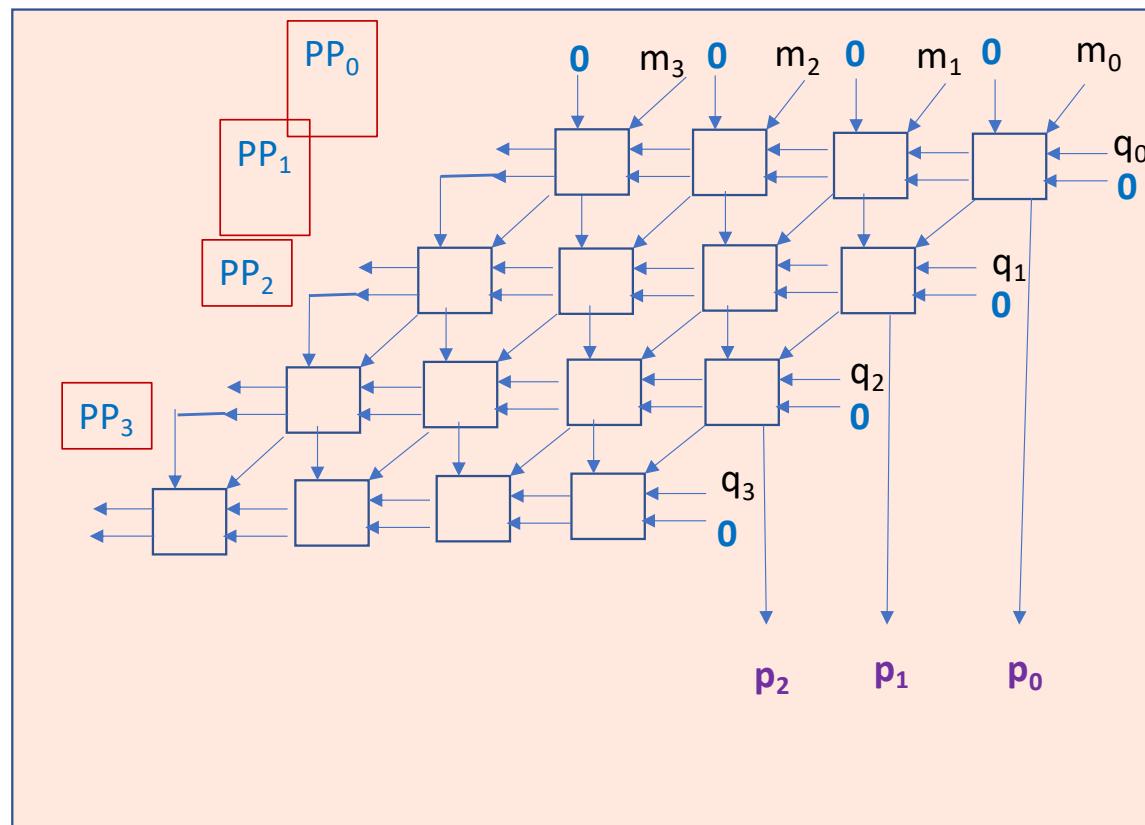
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	Partial Product, PP ₁

1 1 0 1	Partial Product, PP ₂
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₃
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃
1 1 0 1	

1 0 0 0 1 1 1 1	(143) Product, P



MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

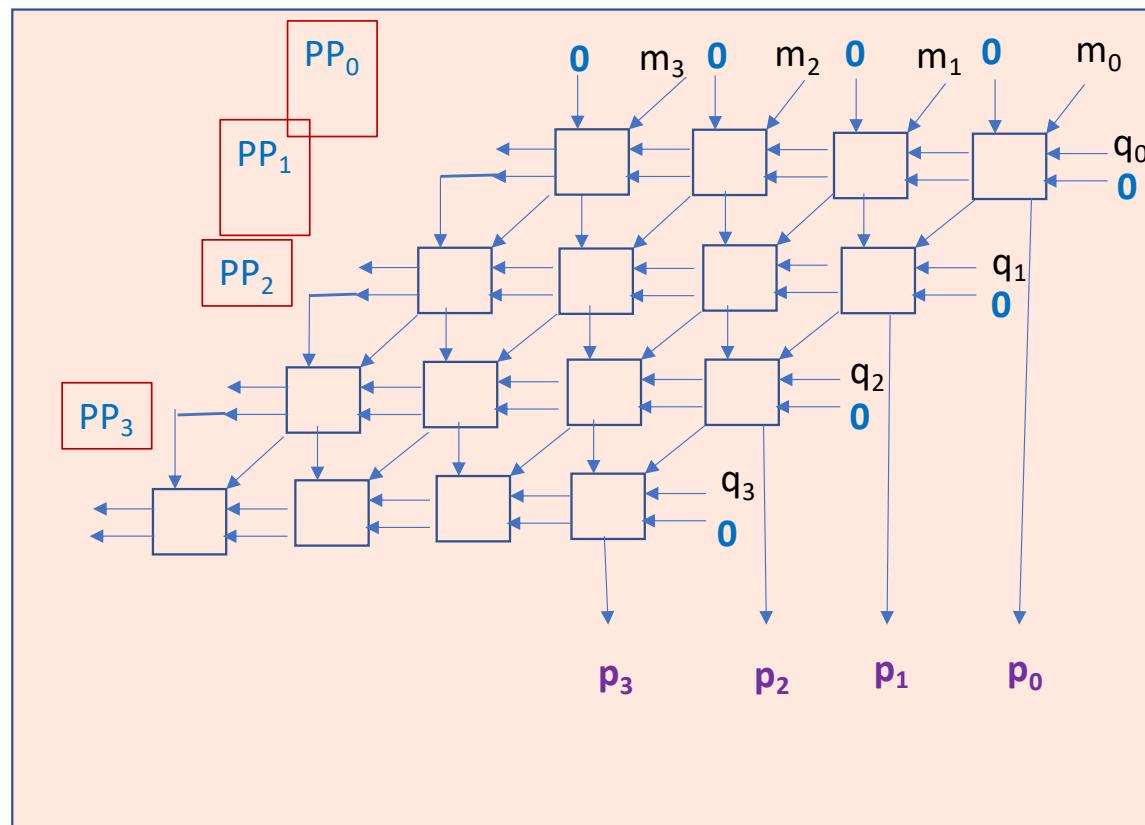
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	Partial Product, PP ₁

1 1 0 1	Partial Product, PP ₂
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₃
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃
1 1 0 1	

1 0 0 0 1 1 1 1	(143) Product, P



MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

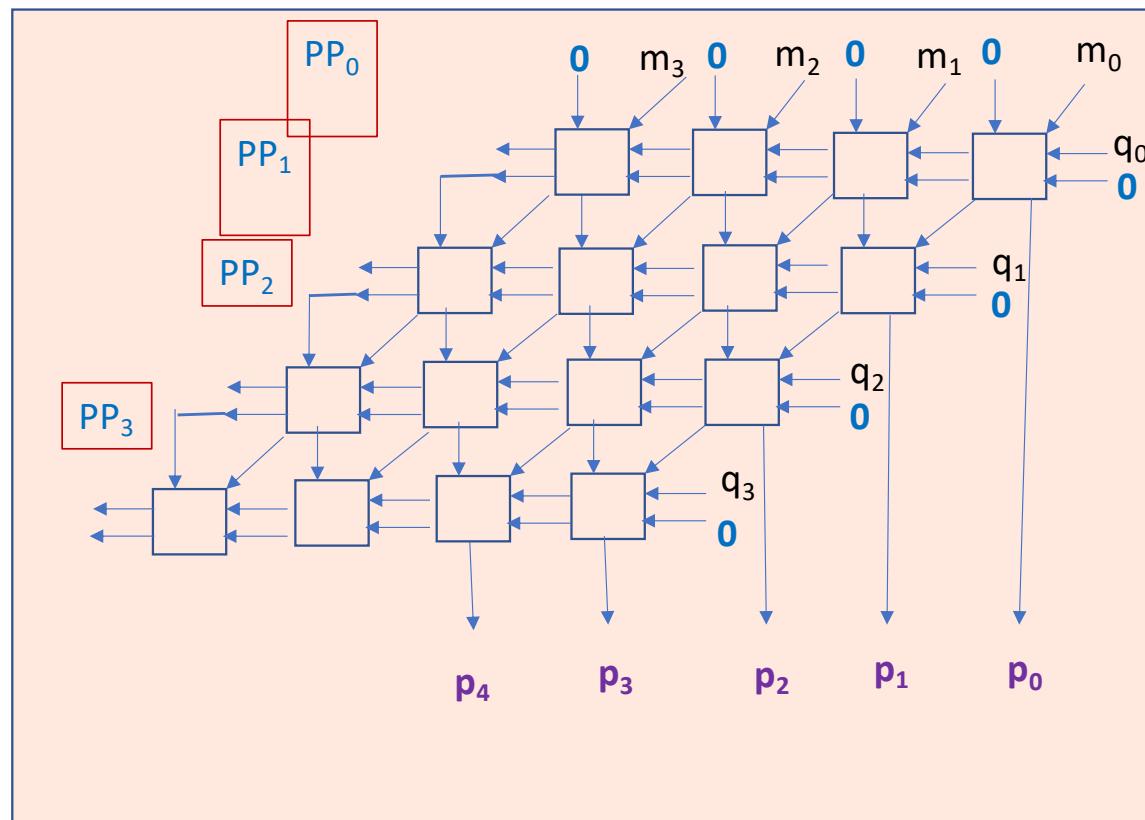
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	Partial Product, PP ₁

1 1 0 1	Partial Product, PP ₂
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₃
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃
1 1 0 1	

1 0 0 0 1 1 1 1	(143) Product, P



MULTIPLICATION - 1

Array Multiplication

1 1 0 1	(13) Multiplicand, M
X 1 0 1 1	(11) Multiplier, Q

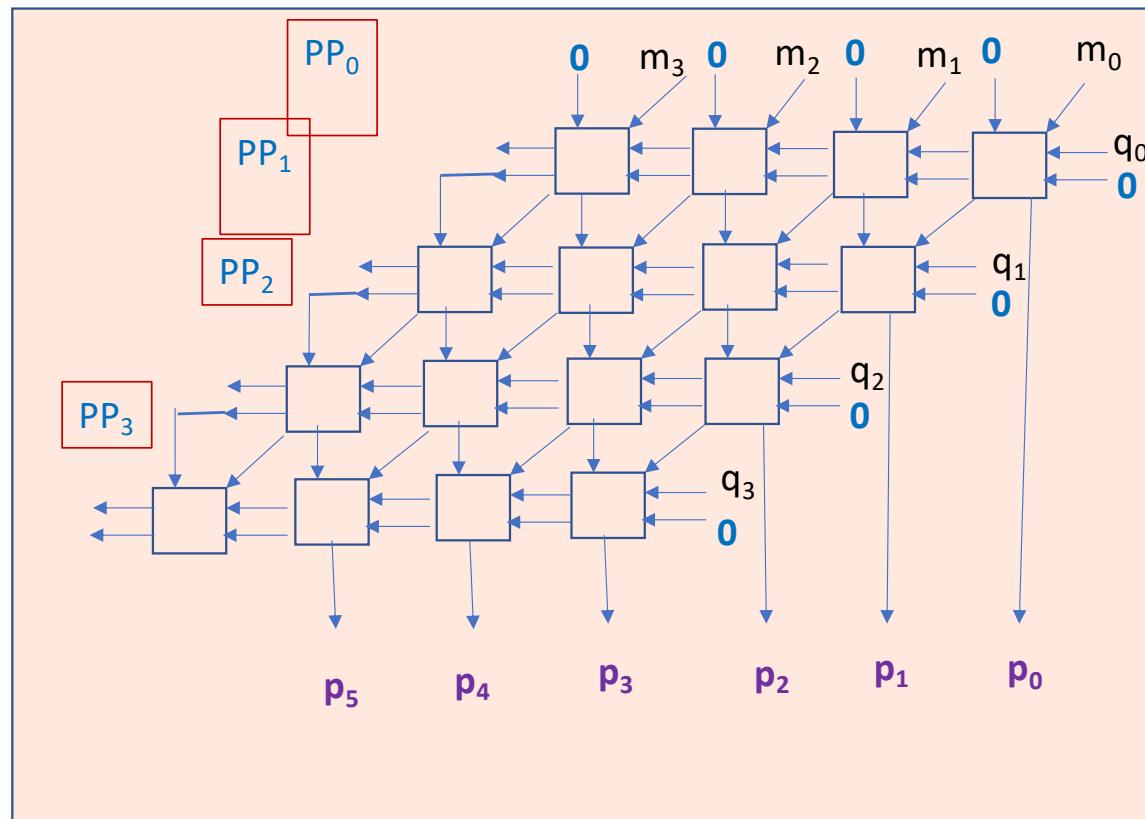
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	Partial Product, PP ₁

1 1 0 1	Partial Product, PP ₂
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₃
0 0 0 0	

1 0 0 1 1 1	Partial Product, PP ₃
1 1 0 1	

1 0 0 0 1 1 1 1	(143) Product, P



MULTIPLICATION - 1

Array Multiplication

	1 1 0 1	(13) Multiplicand, M
X	1 0 1 1	(11) Multiplier, Q

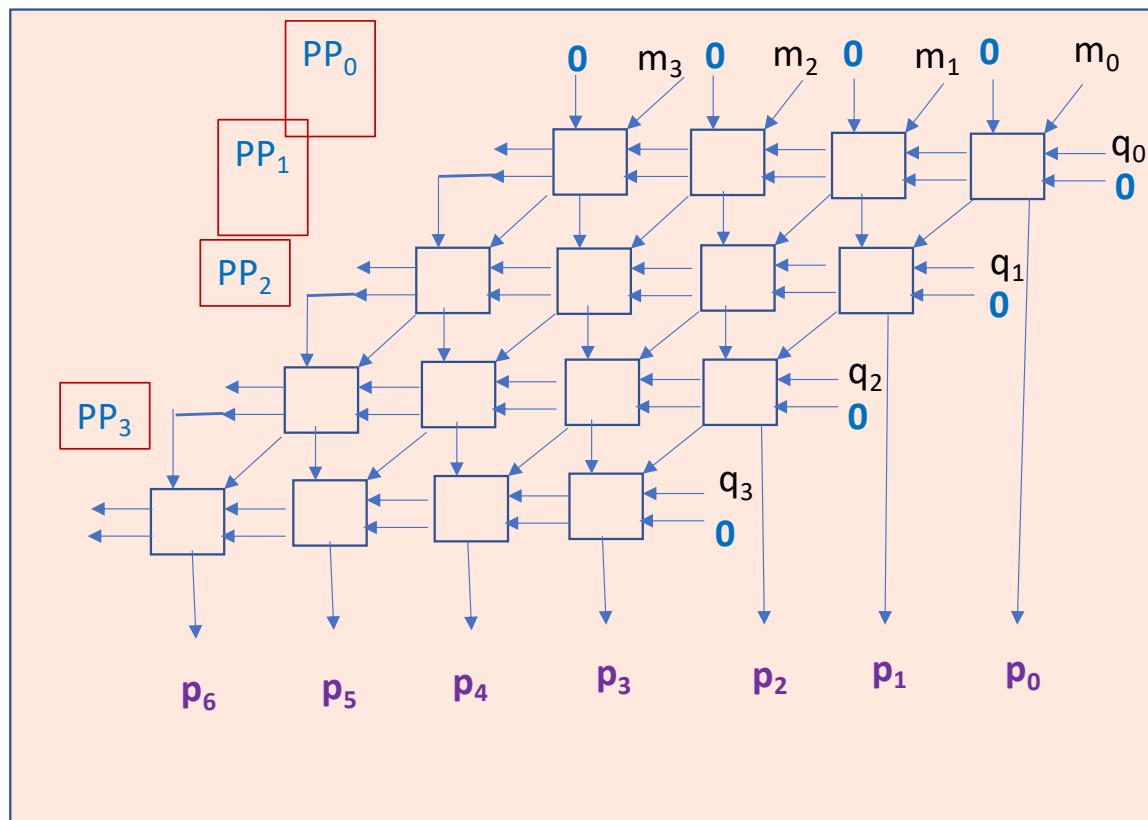
	0 0 0 0	Initial Partial Product, PP ₀
	1 1 0 1	

	1 1 0 1	Partial Product, PP ₁
	1 1 0 1	

	1 0 0 1 1 1	Partial Product, PP ₂
	0 0 0 0	

	1 0 0 1 1 1	Partial Product, PP ₃
	1 1 0 1	

	1 0 0 0 1 1 1 1	(143) Product, P



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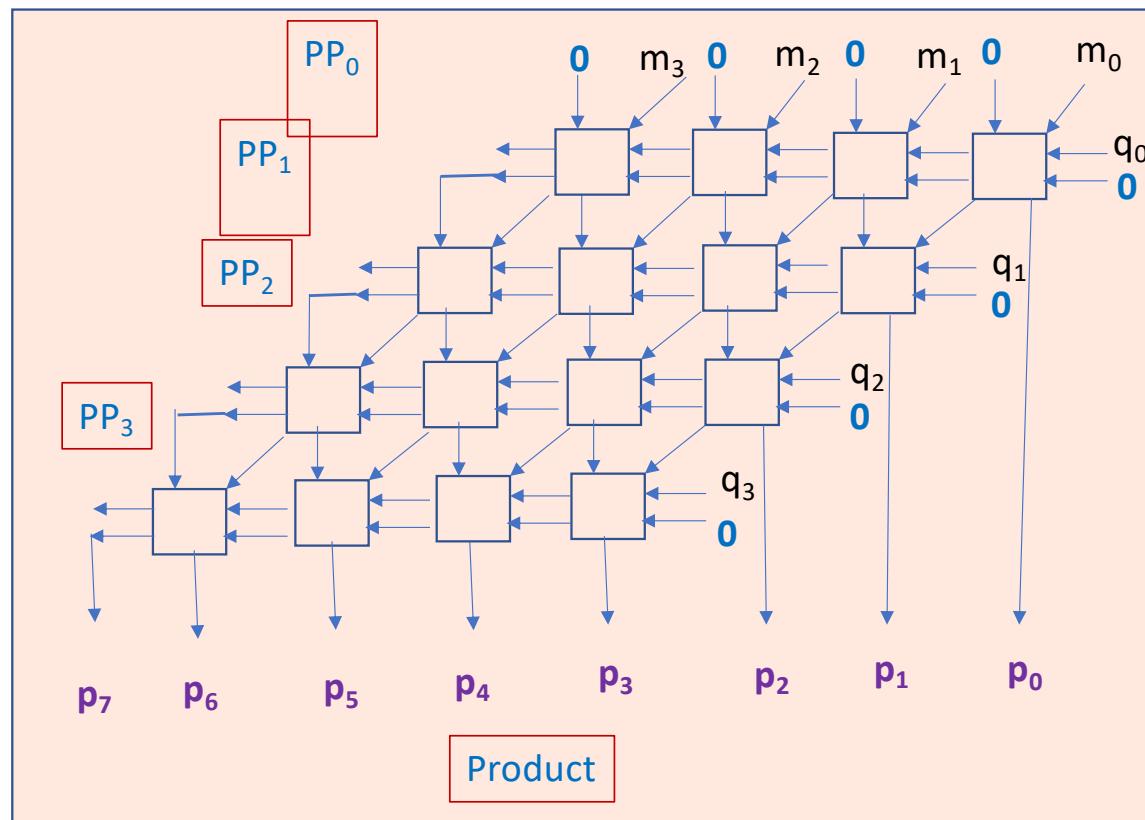
0 0 0 0	Initial Partial Product, PP ₀
1 1 0 1	Partial Product, PP ₁

1 1 0 1	Partial Product, PP ₂
1 1 0 1	

1 0 0 1 1 1	Partial Product, PP ₃
0 0 0 0	

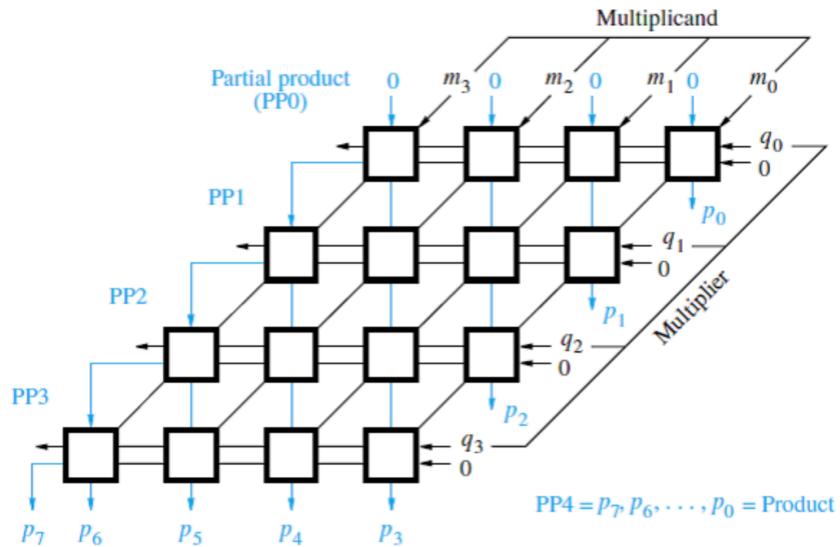
1 0 0 1 1 1	Partial Product, PP ₃
1 1 0 1	

1 0 0 0 1 1 1 1	(143) Product, P



MULTIPLICATION - 1

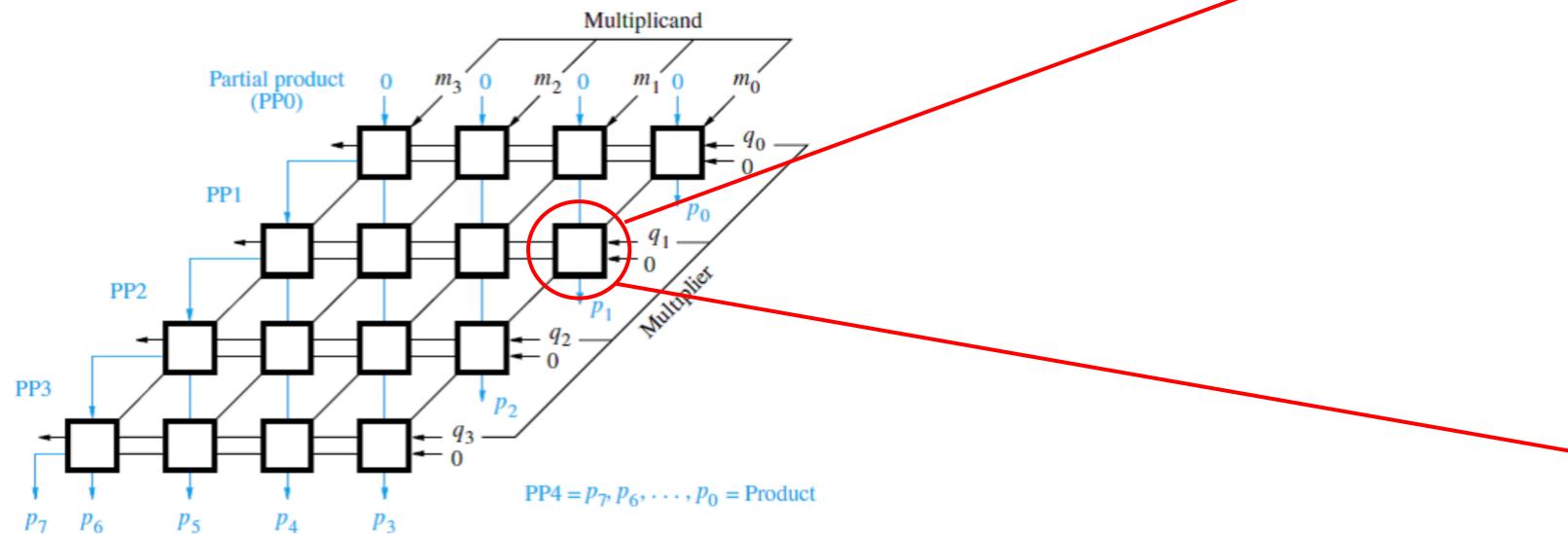
Array Multiplication



- AND gate in each cell performs $m_j \cdot q_i$ product
- A Full Adder adds this with the previous partial product bit PP_i along with previous bit Carry-in and generates $PP_{(i+1)}$ and Carry-out.
- m_j is shifted to downward cell whereas q_i is connected to all the cells in a row.

MULTIPLICATION - 1

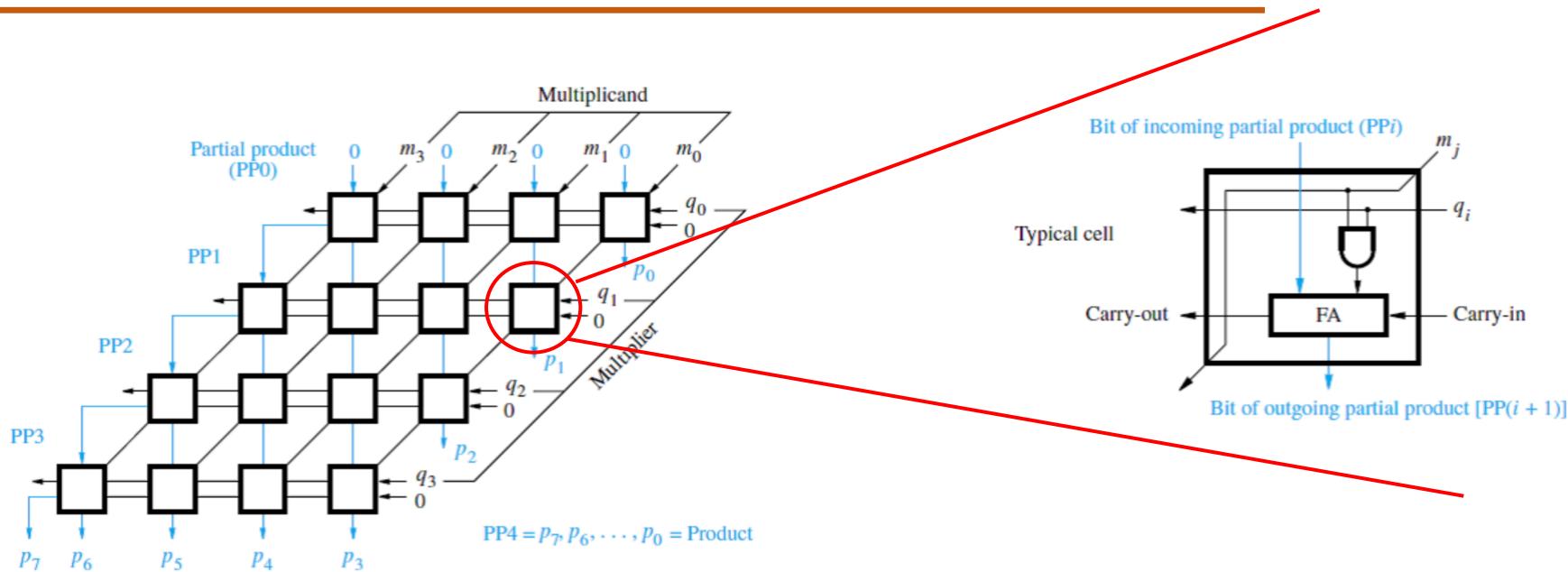
Array Multiplication



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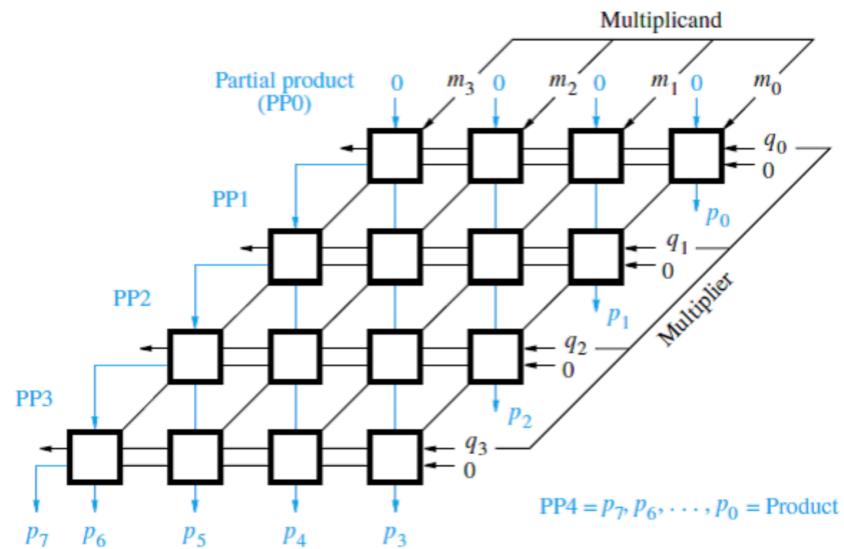
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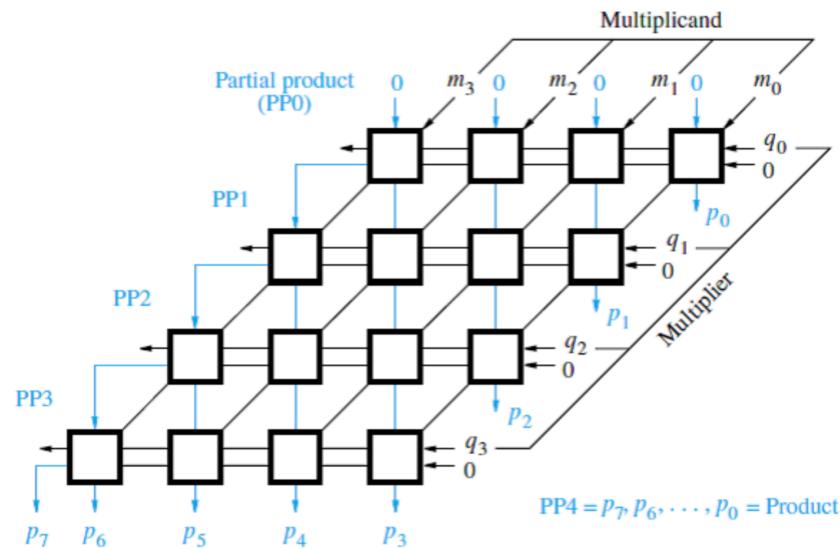
MULTIPLICATION - 1

Think about it



MULTIPLICATION - 1

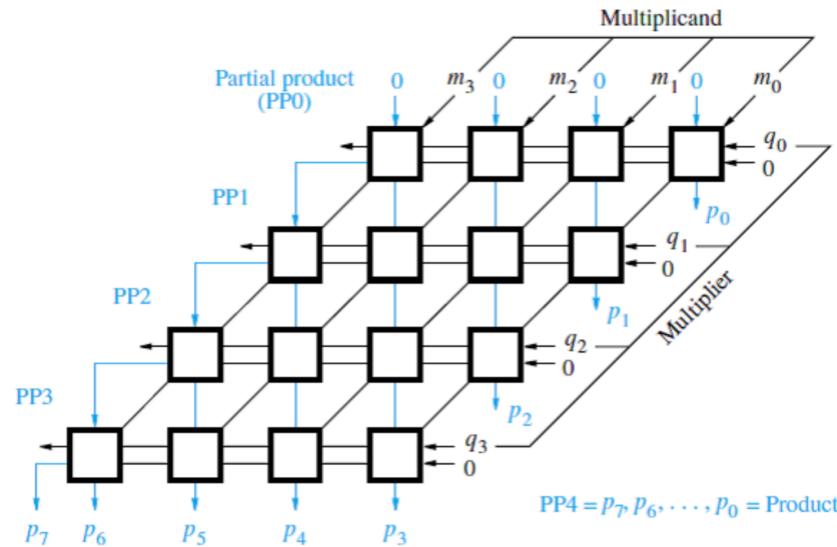
Think about it



- What is the worst case propagation delay?

MULTIPLICATION - 1

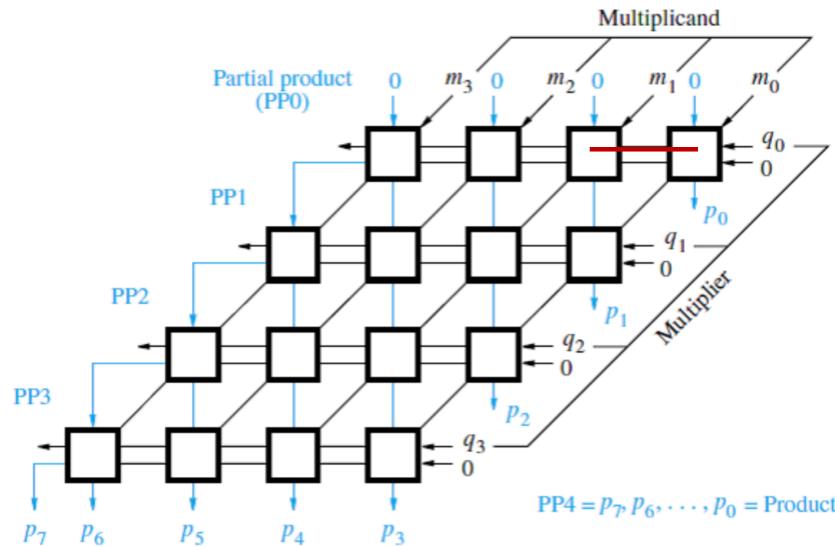
Think about it



- What is the worst case propagation delay?
- Assume FA has 2 gate delays and all AND gates has 1 gate delay. Also, the first row can have only AND gates.

MULTIPLICATION - 1

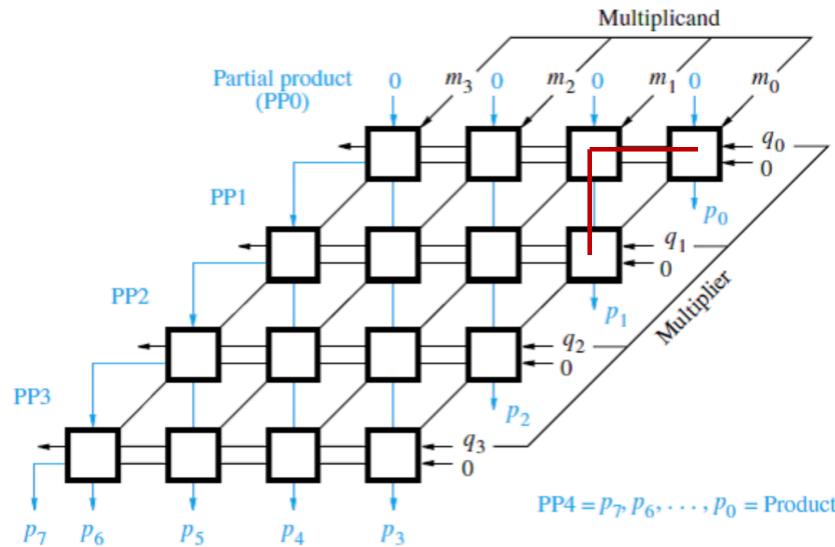
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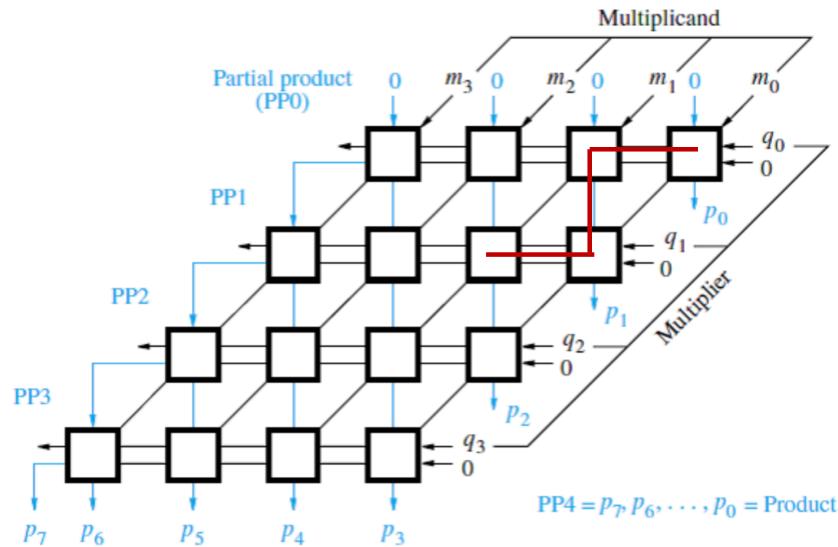
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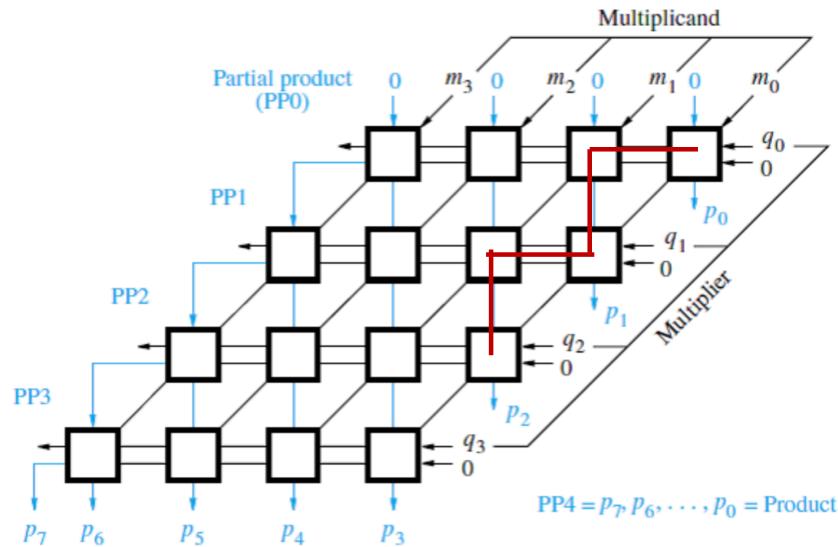
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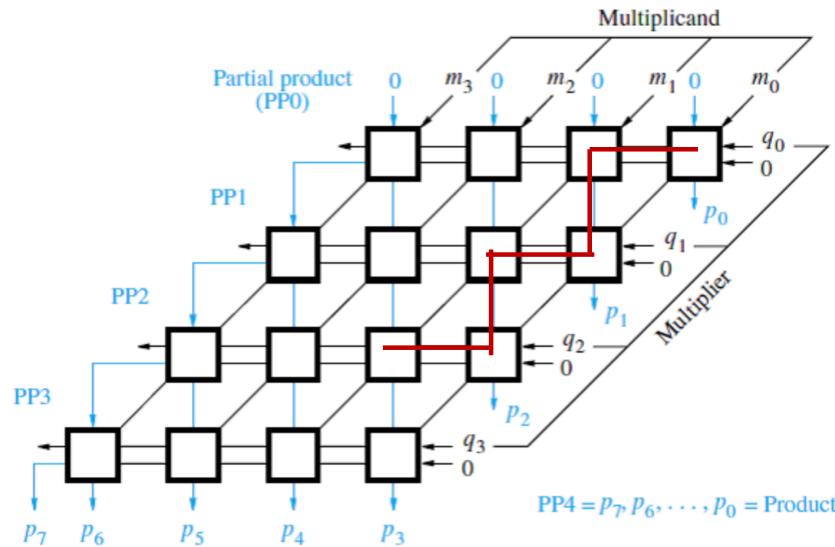
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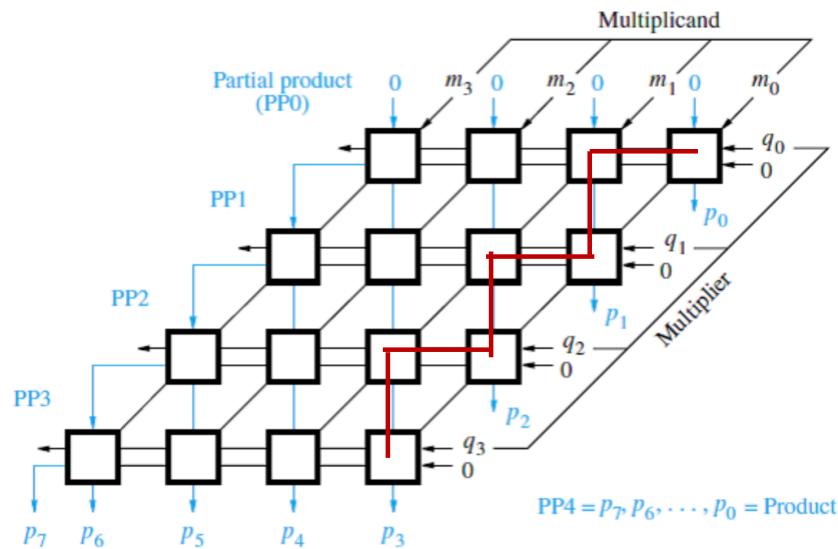
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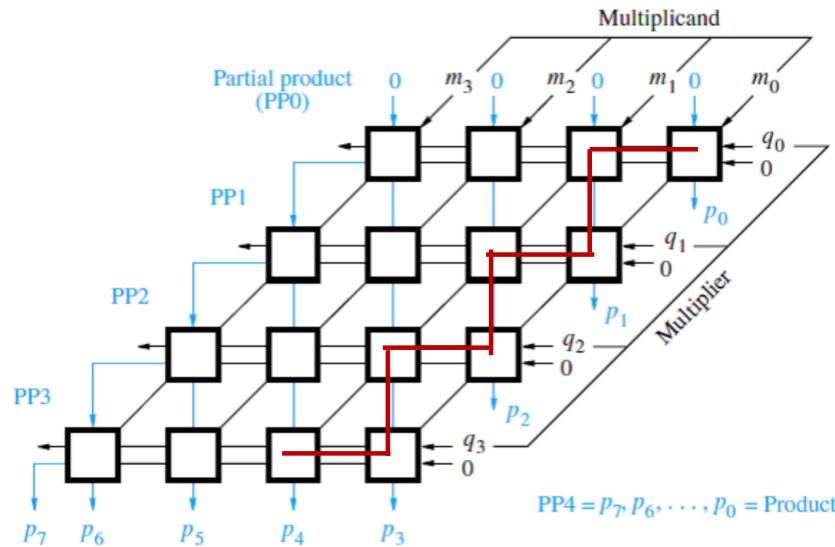
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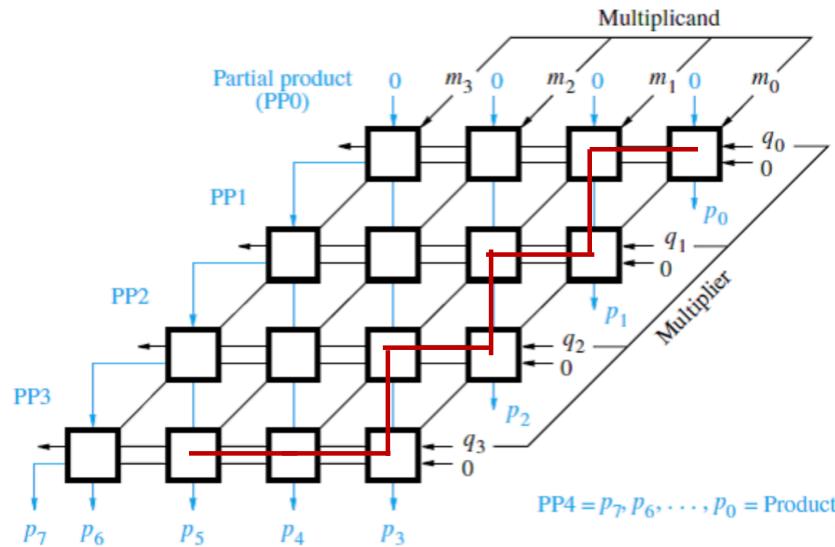
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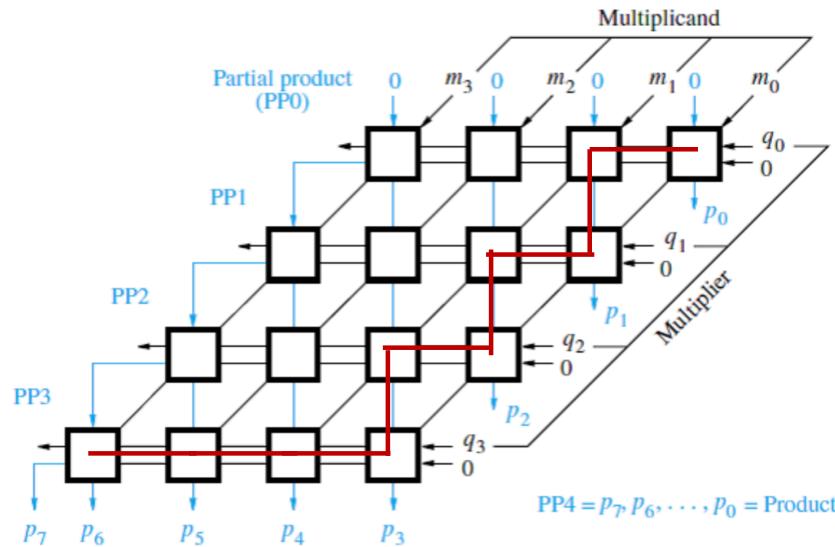
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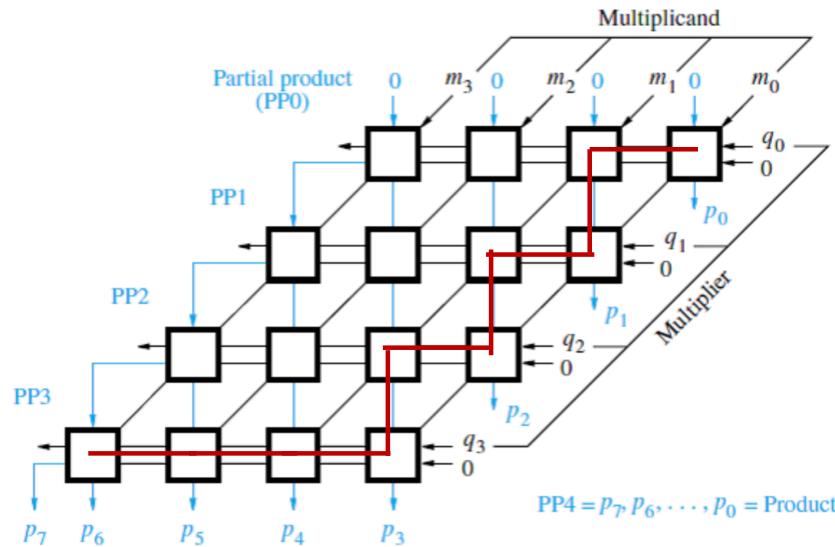
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MULTIPLICATION - 1

Think about it



- What is the worst case propagation delay?
- Assume FA has 2 gate delays and all AND gates has 1 gate delay. Also, the first row can have only AND gates.
- How many gates are required for $m \times n$ array multiplication?



THANK YOU

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