

Computer Organization & Architecture

2-5 Multiplication of Unsigned Numbers

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Contents of this lecture

- Manual Multiplication Algorithm
- Array Multiplication
- Sequential Multiplication

Manual Multiplication Algorithm

- Example: $M = 1101$, $Q = 1011$, calculate $P = M \times Q$

1 1 0 1	Multiplicand
\times 1 0 1 1	Multiplier
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- Multiplication of the multiplicand by one bit of the multiplier
 - If the multiplier bit is 1, the multiplicand is entered in the appropriate position.
 - If the multiplier bit is 0, then 0s are entered.

Manual Multiplication Algorithm

- Example: $M = 1101$, $Q = 1011$, calculate $P = M \times Q$

1 1 0 1							
×	1	0	1	1			
<hr/>							
1 1 0 1							
1 1 0 1							
0 0 0 0							
1 1 0 1							
<hr/>							
1	0	0	0	1	1	1	1

Multiplicand
Multiplier

Partial Products

Product

- Note:** The multiplication product of two n -bit binary integers results in a product of up to $2n$ bits in length.

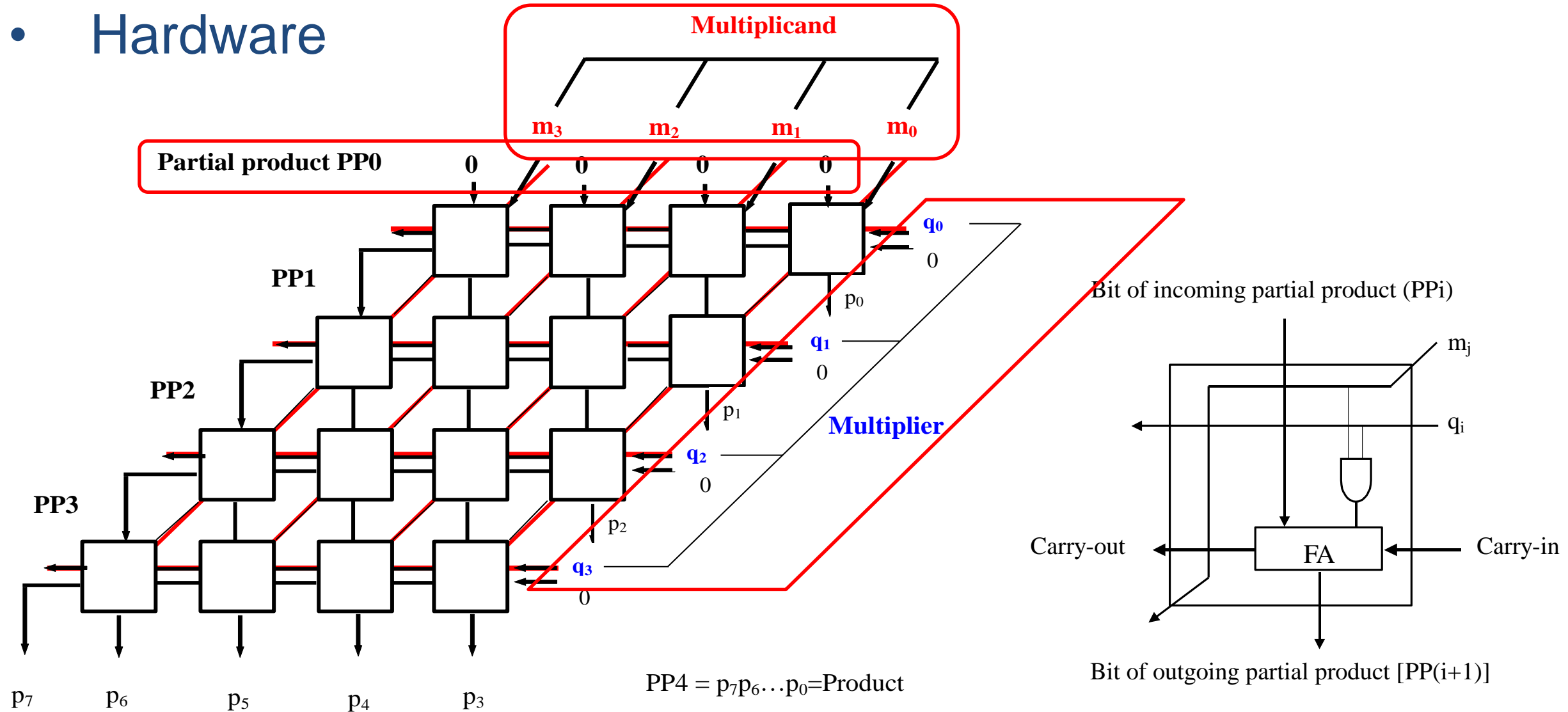
Array Multiplication (1)

- $M = m_3m_2m_1m_0$, $Q = q_3q_2q_1q_0$
- $P = M \times Q = p_7p_6p_5p_4p_3p_2p_1p_0$

$$\begin{array}{rcccc}
 & & m_3 & m_2 & m_1 & m_0 \\
 \times & q_3 & q_2 & q_1 & q_0 & \\
 \hline
 & m_3q_0 & m_2q_0 & m_1q_0 & m_0q_0 & \\
 & m_3q_1 & m_2q_1 & m_1q_1 & m_0q_1 & \\
 & m_3q_2 & m_2q_2 & m_1q_2 & m_0q_2 & \\
 & m_3q_3 & m_2q_3 & m_1q_3 & m_0q_3 & \\
 \hline
 p_7 & p_6 & p_5 & p_4 & p_3 & p_2 & p_1 & p_0
 \end{array}$$

Array Multiplication (2)

- Hardware



Array Multiplication (3)

- Question

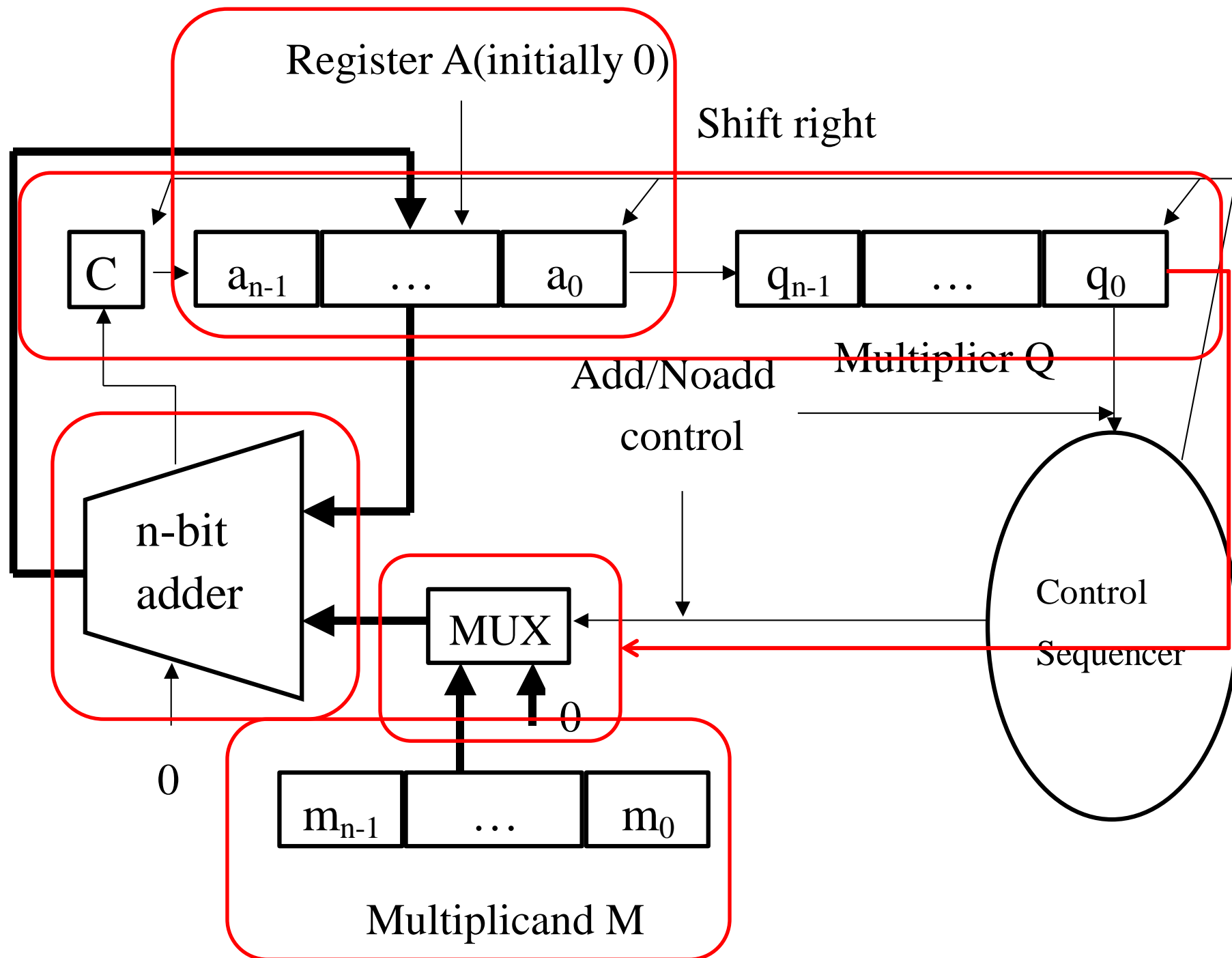
- When calculating $P = M \times Q$ (M and Q are all n bit unsigned binary numbers) , how many FAs and AND gates do we need (using $n \times n$ array multiplier)?

- Answer

- FAs: $n(n-1)$
- AND gates: n^2
- $n=32$, 992 FAs, 1024 AND gates
- $n=64$, 4032 FAs, 4096 AND gates

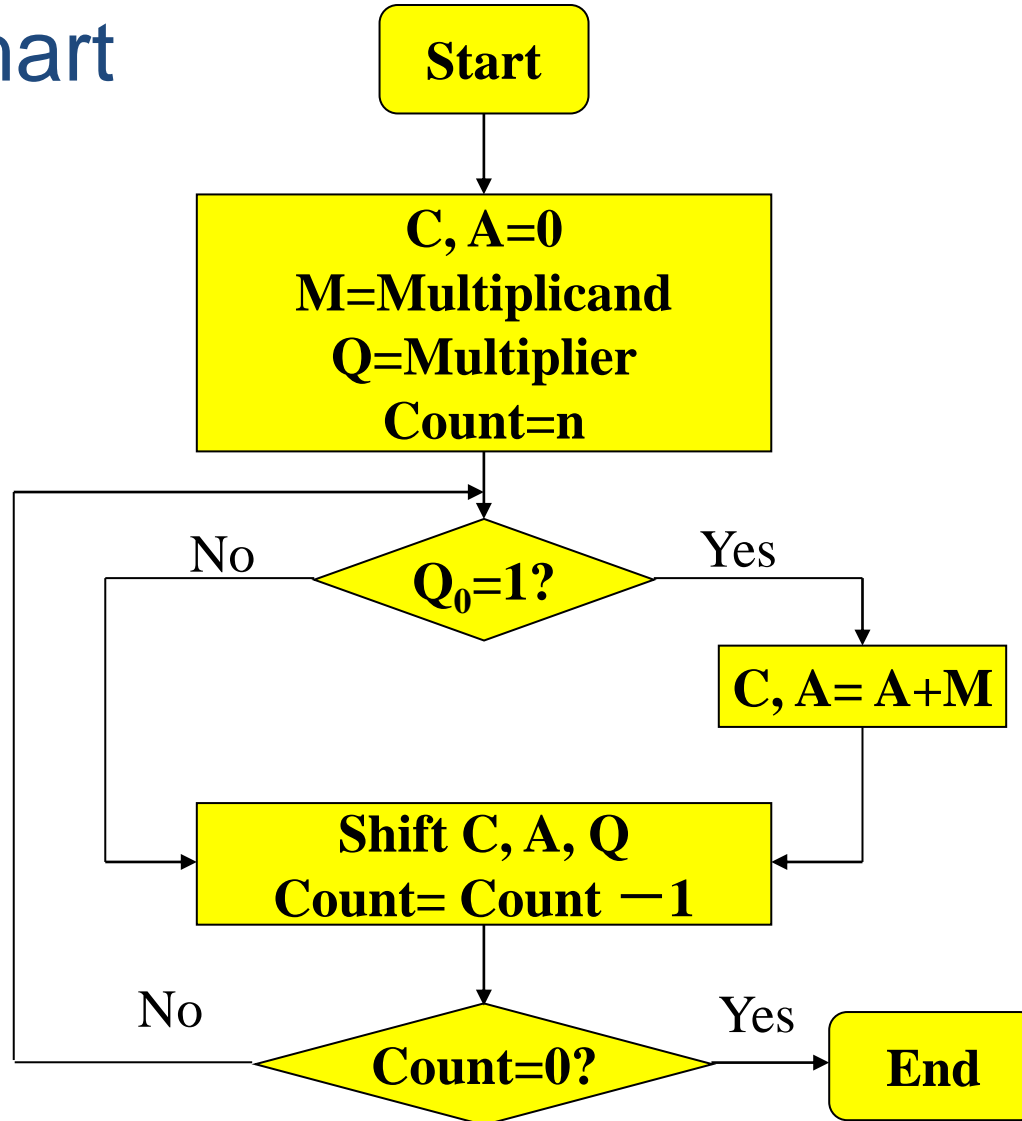
Sequential Multiplication (1)

- Multiplication of two n -bit numbers can also be performed in a sequential circuit that uses a single n -bit adder.
- Hardware



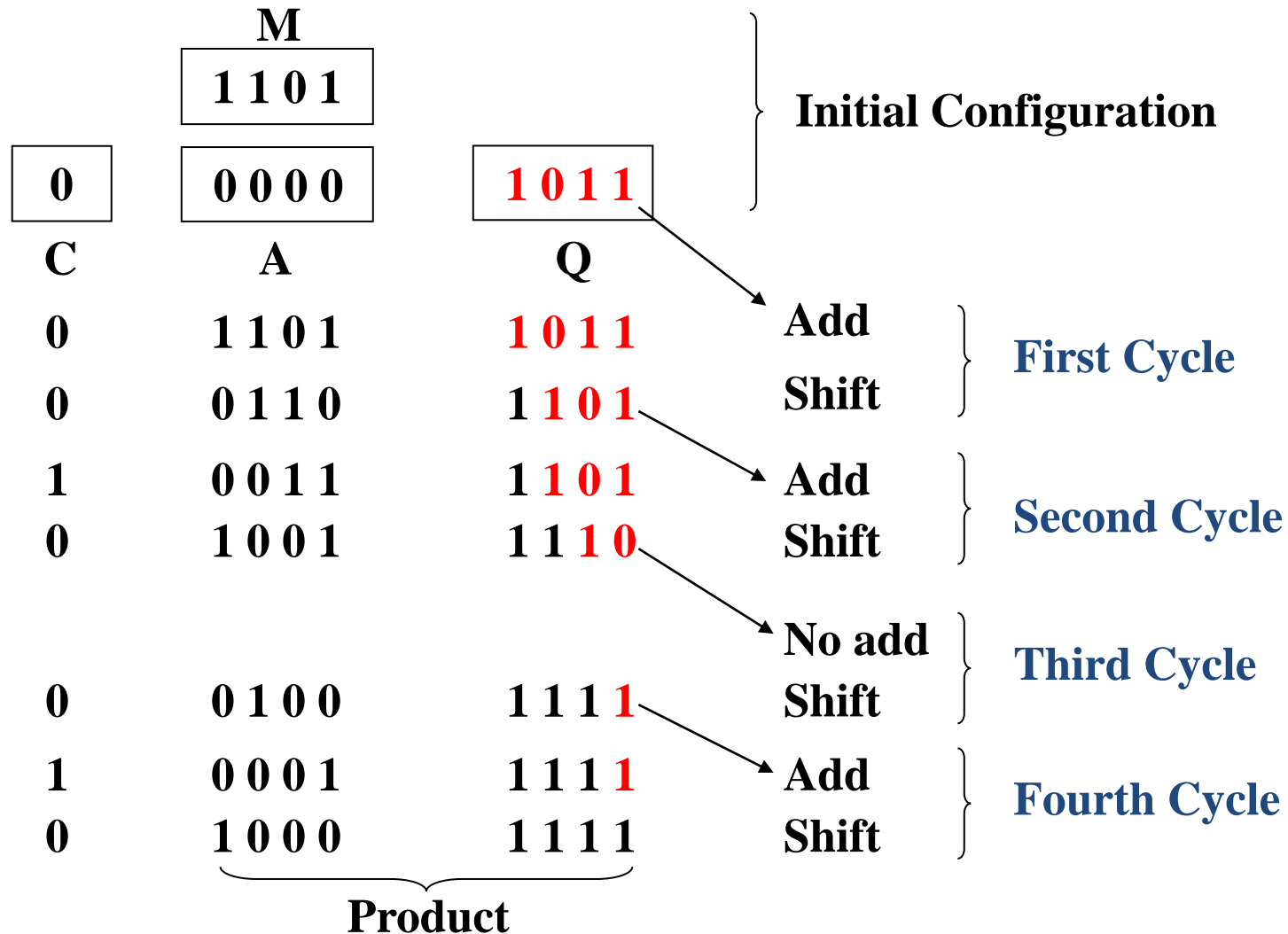
Sequential Multiplication (2)

- Flowchart



Sequential Multiplication (3)

- Example: $M = 1101$, $Q = 1011$, calculate $P = M \times Q$



Quiz

- Multiply A and B (unsigned numbers) using sequential multiplication. Assume that A is the multiplicand and B is the multiplier.

A= 00101 and B=10101

	M		
	00101		
0	00000	10101	Initial configuration
C	A	Q	
0	00101	10101	1st cycle
0	00010	11010	
0	00010	11010	2nd cycle
0	00001	01101	
0	00110	01101	3rd cycle
0	00011	00110	
0	00011	00110	4th cycle
0	00001	10011	
0	00110	10011	5th cycle
0	00011	01001	
	product		