

Computer Organization & Architecture

2-7 Integer Division

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Contents of this lecture

- Manual Division of Positive Integers
- Restoring Division
- Non-Restoring Division

Manual Division of Positive Integers

- Example: calculate $100010010 \div 1101$

Divisor ← 1 1 0 1

0 0 0 0 1 0 1 0 1 → **Quotient**

1 1 0 1) **1 0 0 0 1 0 0 1 0** → **Dividend**

**Partial
Remainders** ←

1 1 0 1

1 0 0 0 0

1 1 0 1

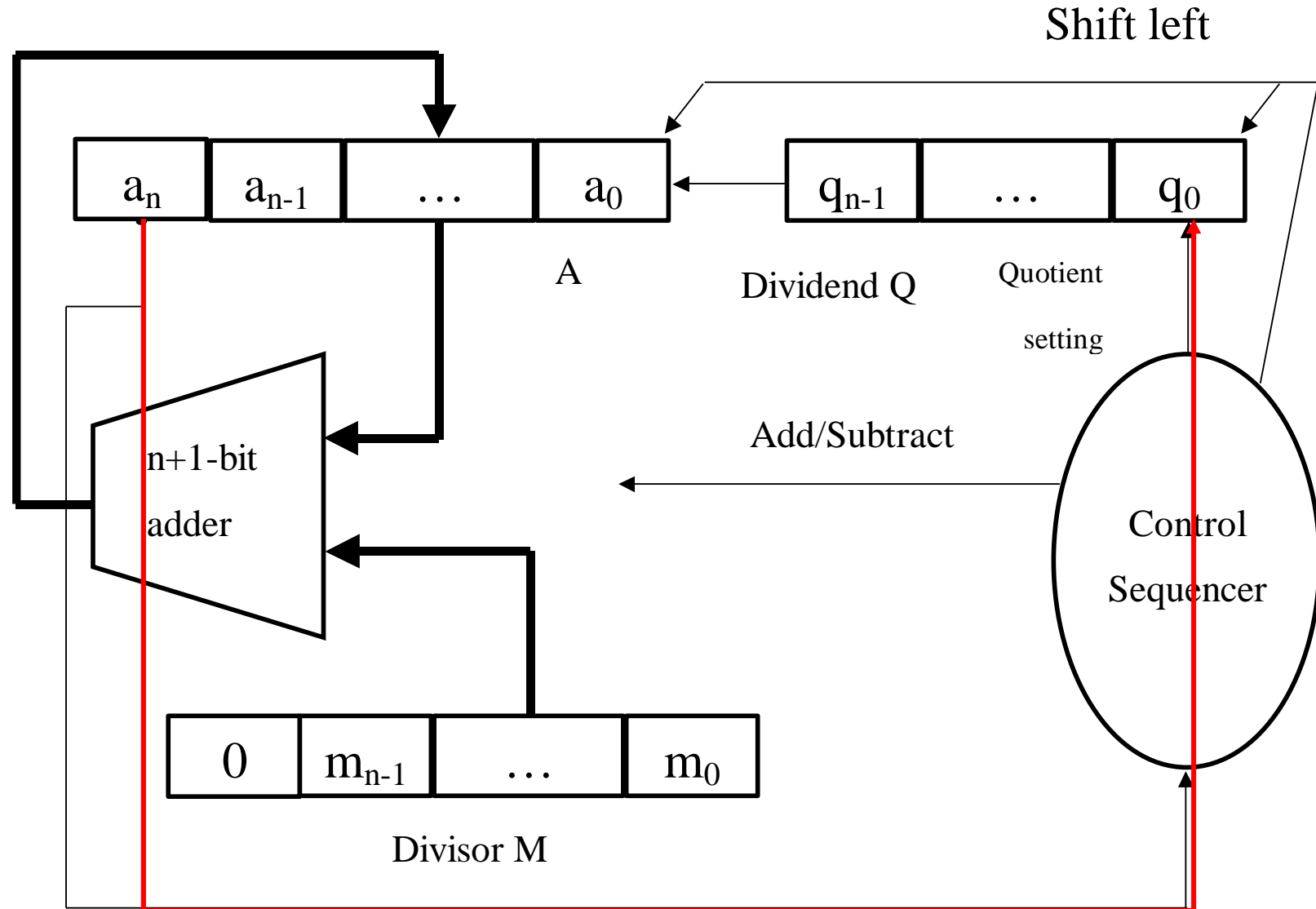
1 1 1 0

1 1 0 1

1 → **Remainder**

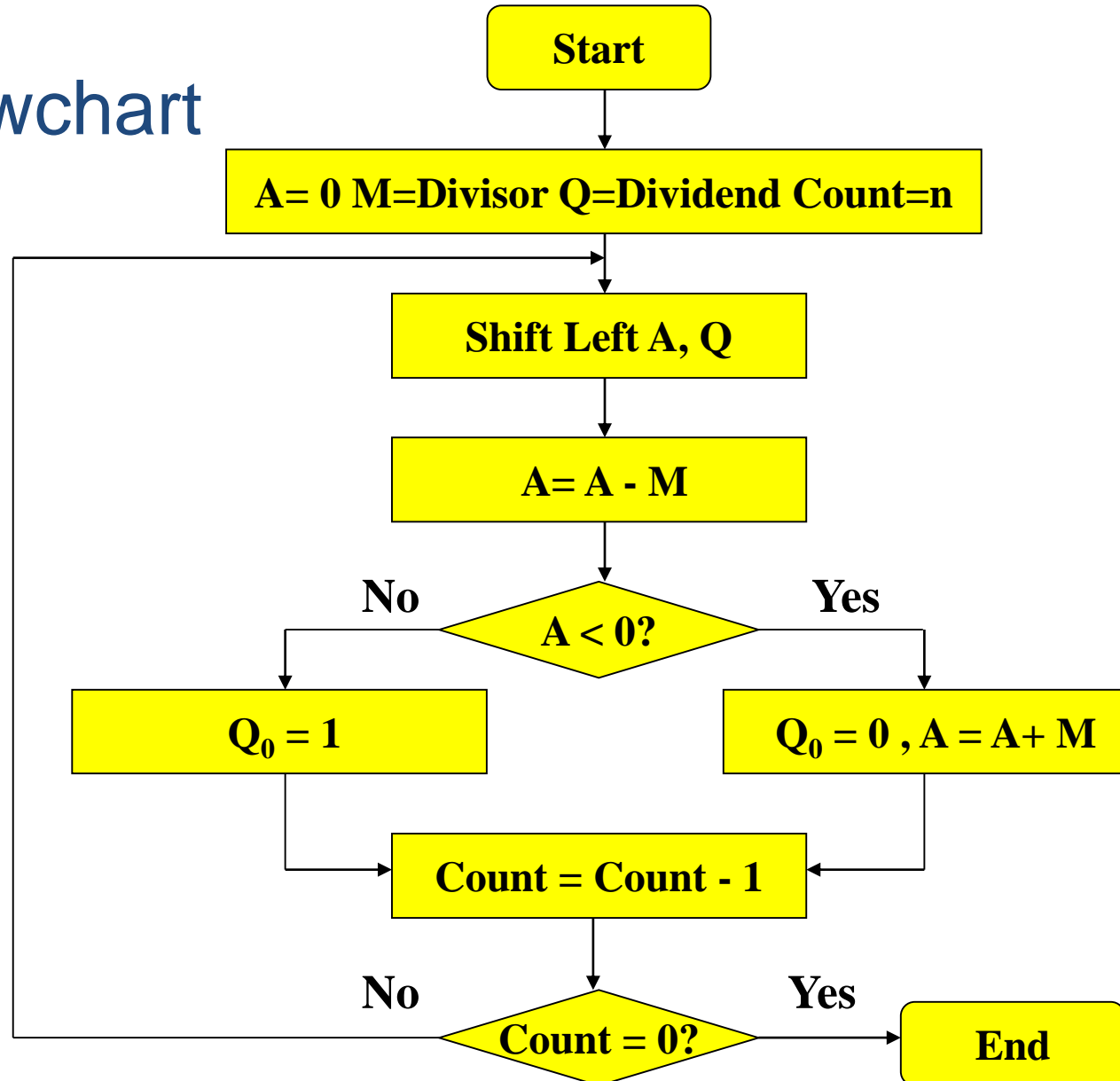
Restoring Division (1)

- Hardware



Restoring Division (2)

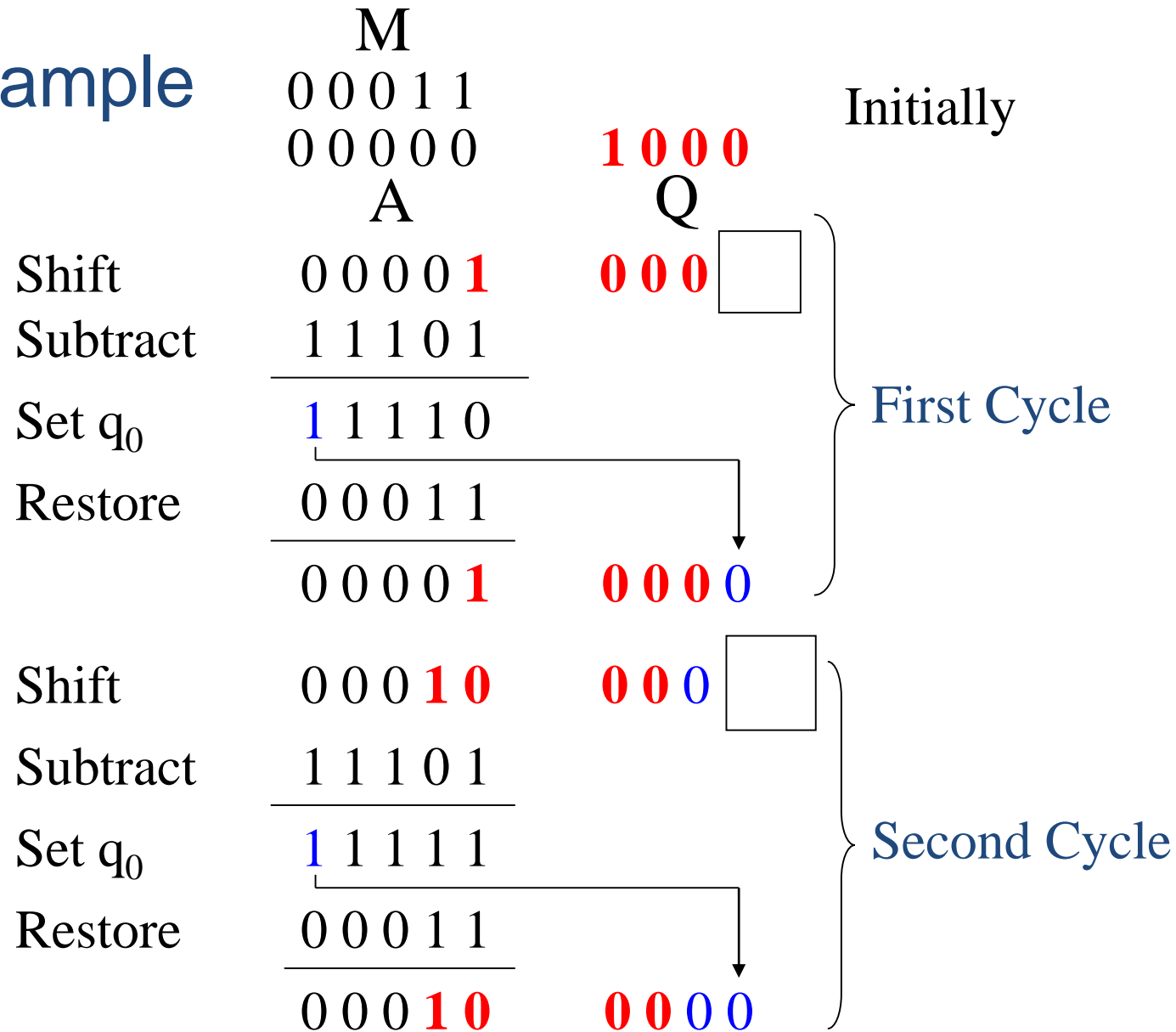
- Flowchart



Quotient in Q
Remainder in A

Restoring Division (3)

- Example



Restoring Division (4)

- Example

Shift	0 0 1 0 0	0 0 0	<div style="border: 1px solid black; width: 30px; height: 30px; display: inline-block;"></div>	} Third Cycle
Subtract	1 1 1 0 1			
Set q_0	0 0 0 0 1	0 0 0 1		

Shift	0 0 0 1 0	0 0 1	<div style="border: 1px solid black; width: 30px; height: 30px; display: inline-block;"></div>	} Fourth Cycle
Subtract	1 1 1 0 1			
Set q_0	1 1 1 1 1			
Restore	0 0 0 1 1			

0 0 0 1 0	0 0 1 0

Remainder
Quotient

		1 0
1 1	√	1 0 0 0
		1 1
		1 0

Non-Restoring Division (1)

- In Restoring Division
 - (i-1) step, R_{i-1}
 - i step, $R_i' = 2R_{i-1} - M$
 - $R_i' > 0$, $Q_0 = 1$, $R_i = R_i'$
 - $R_i' < 0$, $Q_0 = 0$, $R_i = R_i' + M$
 - (i + 1) step, $R_{i+1}' = 2R_i - M$
 - $R_i' > 0$, $R_i = R_i'$, $R_{i+1}' = 2R_i' - M$
 - $R_i' < 0$, $R_i = R_i' + M$, $R_{i+1}' = 2(R_i' + M) - M = 2R_i' + M$

Non-Restoring Division (3)

- Example

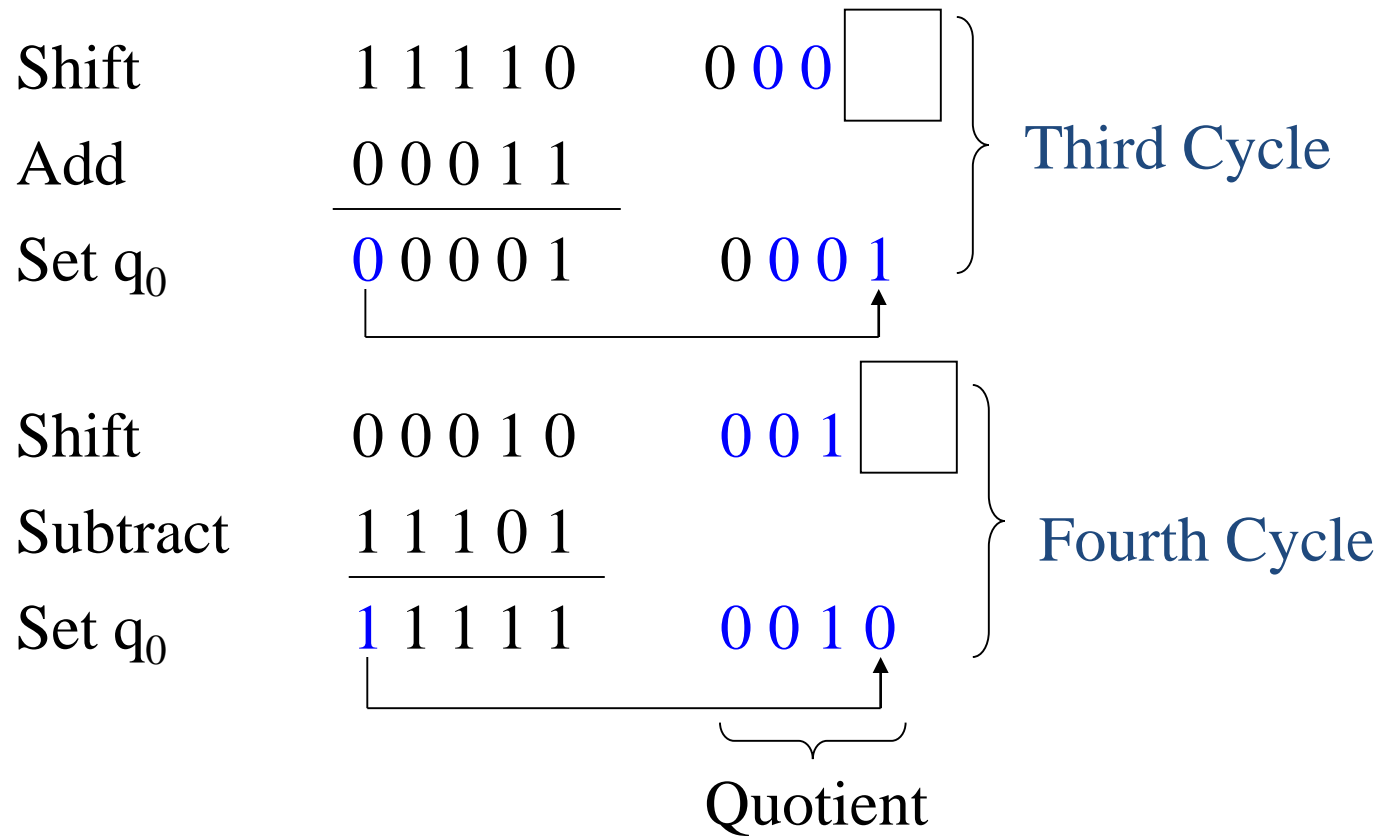
	M		
Initially	0 0 0 1 1		
	0 0 0 0 0	1 0 0 0	
	A		Q
Shift	0 0 0 0 1	0 0 0	<div></div>
Subtract	1 1 1 0 1		
Set q_0	1 1 1 1 0	0 0 0	0
			↑
Shift	1 1 1 0 0	0 0 0	<div></div>
Add	0 0 0 1 1		
Set q_0	1 1 1 1 1	0 0 0	0
			↑

First Cycle

Second Cycle

Non-Restoring Division (4)

- Example



Add	1 1 1 1 1	} Restoring Remainder
	0 0 0 1 1	
	0 0 0 1 0	
	Remainder	

Conclusion

- Notes
 - There are no simple algorithms for directly performing division on signed operands that are comparable to the algorithms for signed multiplication.
 - In division, the operands can be processed to transform them into positive values.
 - After using one of the algorithms (restoring division or non-restoring division), the results are transformed to the correct signed values, as necessary.

Quiz

- Using non-restoring division algorithm, perform the operation $A \div B$ on the 4-bit unsigned numbers $A = 0111$ and $B = 0011$.

Initially 0 0 0 0 0 0 1 1 1₄

0 0 0 1 1₄

Shift 0 0 0 0 0 1 1 1

Subtract 1 1 1 0 1₄

—————

Set q0 1 1 1 0 1 1 1 1 0₄

Shift 1 1 0 1 1 1 1 0

Add 0 0 0 1 1 1 1 0 0₄

—————

Set q0 1 1 1 1 0 1 1 0 0₄

Shift 1 1 1 0 1 1 0 0

Add 0 0 0 1 1 1 0 0 1₄

—————

Set q0 0 0 0 0 0 1 0 0 1₄

Shift 0 0 0 0 1 0 0 1

Subtract 1 1 1 0 1₄

—————

Set q0 1 1 1 1 0 0 0 1 0₄

First Cycle₄

Second Cycle₄

Third Cycle₄

Fourth Cycle₄

Add 1 1 1 1 0
 0 0 0 1 1
 ———
 0 0 0 0 1

Restore
remainder₄

Quotient=0010

Remainder=0001