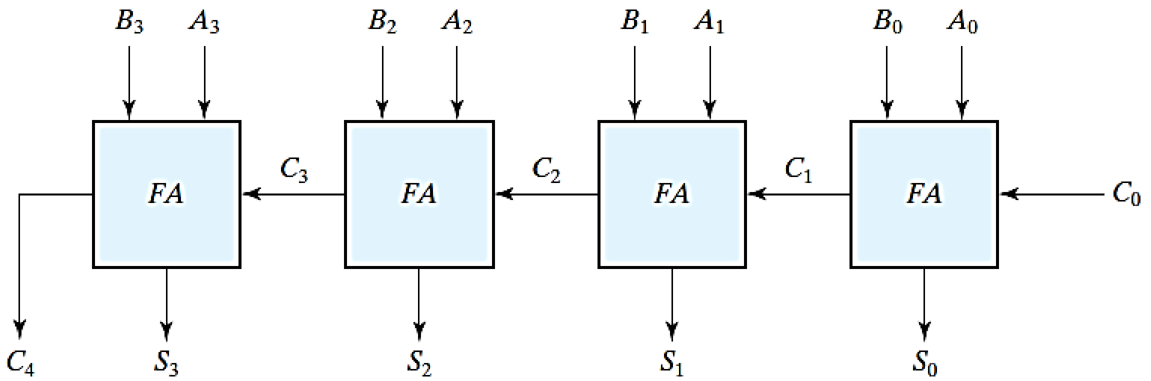
Binary Adder

A binary adder is a digital circuit that produces the arithmetic sum of two binary numbers. It can be constructed with full adders connected in cascade (بشكل متعاقب) with the output carry from each full adder connected to the input carry of the next full adder in the chain.

Addition of n-bit numbers requires a chain of (n) full adders or a chain of one-half adder and (n−1) full adders.

Ex) Draw the diagram of a four-bit binary adder constructed from using full adders only.



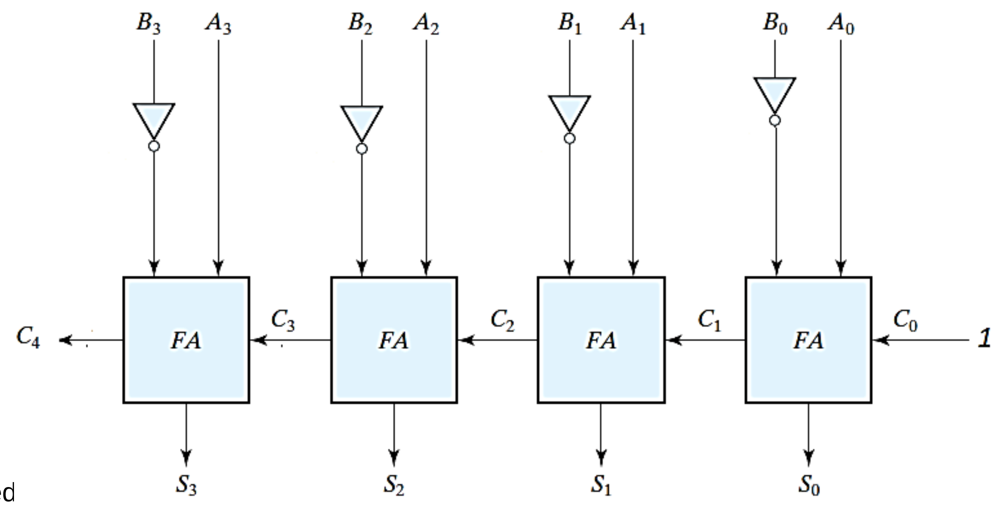
The input carry **Co** is set to zero.

It is important to note all the inputs should be available at the adder in order to get the right output. However, input carry C3 does not settle to its final value until C2 is available from the previous stage. Similarly, C2 has to wait for C1 and so on down to C0. The carry propagation time is an important attribute of the adder because it limits the speed with which two numbers are added.

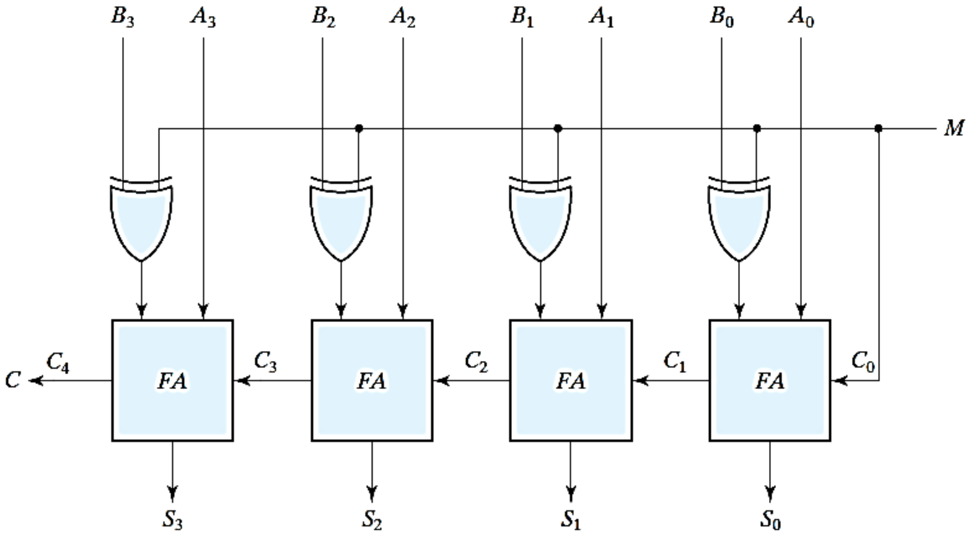
Binary Adder – Subtractor

The subtraction A – B can be done by taking the 2's complement of B and adding it to A. The 2's complement can be obtained by taking the 1's complement and adding 1. The 1's complement can be implemented with inverters.

Thus, the circuit for subtracting A – B consists of an adder with inverters placed between each data input B.



The **addition and subtraction** operations can be combined into one circuit with one common binary adder by including an exclusive-OR gate with each full adder.



The mode input **M** controls the operation. When M = 0, X-OR acts as **buffer** and the circuit is an **Adder**. When M = 1, X-OR acts as inverter and the circuit becomes a **Subtractor**.

BCD Adder

The same binary adder can be used as BCD adder. In BCD code, each decimal digit from 1 to 9 is coded in 4-bit binary numbers. But with 4-bit binary sixteen different groups (0-15) can be obtained, whereas we require only ten groups (0-9) to write BCD code. The other six groups are called forbidden codes in BCD and they are invalid.

BCD Addition Rules

I. First add the two numbers using normal rules for binary addition.

II. If the **4-bit sum** is equal to or less than 9, it becomes a valid BCD number.

III. If the 4-bit sum is greater than 9 or if a carry-out of the group is generated, it is an invalid result. In such a case, since there is a difference of 6 between the binary and BCD, add $(0110)_2$ to the 4-bit sum in order to skip the six invalid states and return the code to BCD format.

Ex) Add the following BCD numbers:

(a) 0111 and 1001

(b) 10010010 and 01011000.

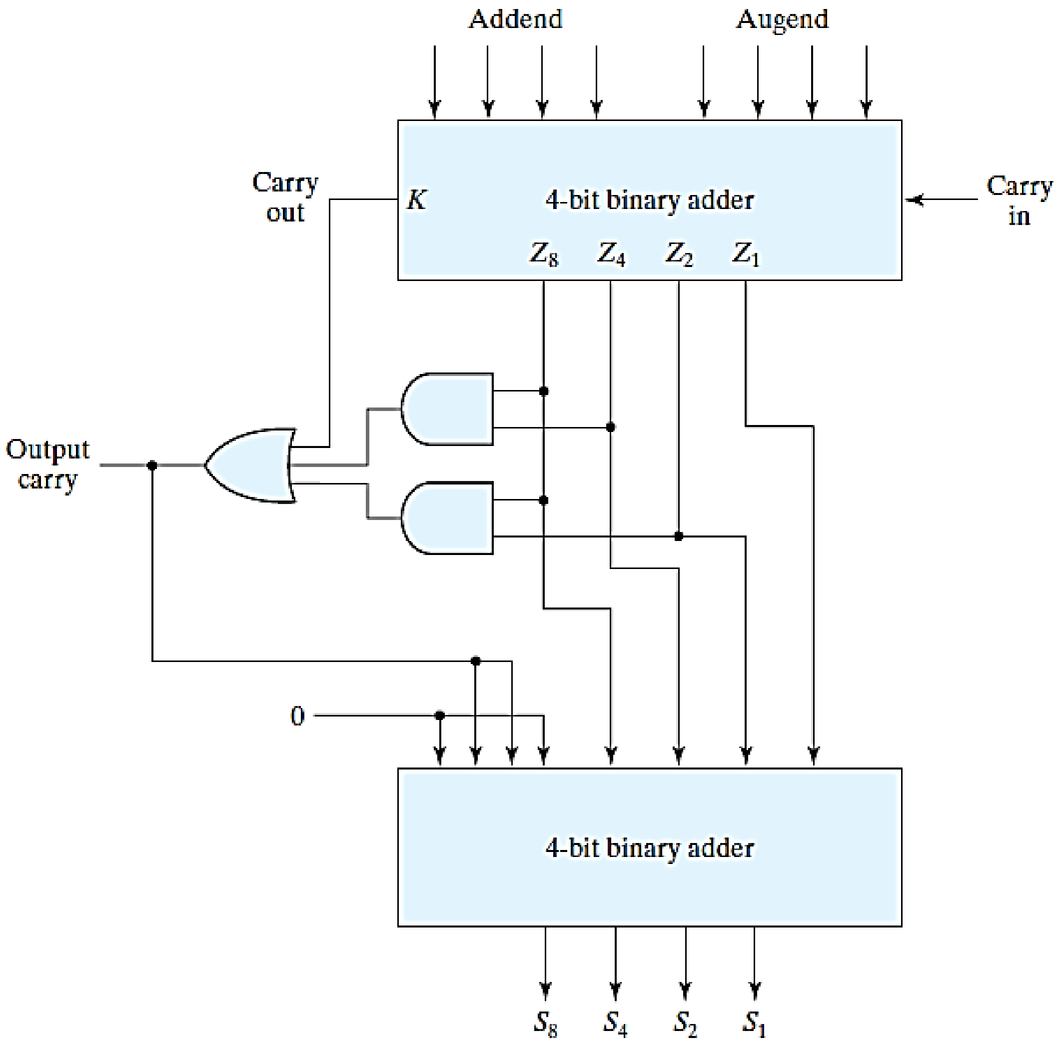
(a)

	0 1 1 1	
	+ 1 0 0 1	
	1 0 0 0 0	→ Invalid BCD number
	+ 0 1 1 0	→ Add 6
0 0 0 1	0 1 1 0	→ Valid BCD number
1	6	

(*b*)

	1 0 0 1	0 0 1 0	
	+ 0 1 0 1	1 0 0 0	
	1 1 1 0	1 0 1 0	→ Both groups are invalid
	+ 0 1 1 0	0 1 1 0	→ Add 6
0 0 0 1	0 1 0 1	0 0 0 0	→ Valid BCD number
1	5	0	

Two 4-bit binary adders can be used to perform BCD addition. The adders will form the sum in binary and produce a result that ranges from 0 through 19 as follow



The first adder performs normal binary addition. Then, the results are checked to see if there the result is greater than 9 or if a carry-out of the group is generated.

It is obvious that a correction is needed when the first binary adder has an output carry of 1. The other six combinations from 1010 through 1111 also need a correction. The result is greater than 9 if Z_8 **and** Z_4 equal to 1 **or** Z_8 **and** Z_2 equal to 1.

The final Boolean function for the correction is

$$C = K + Z_8Z_4 + Z_8Z_2$$

Or you can use the truth table and K-map to find this function **{Homework}**

Binary Multiplier

Multiplication of binary numbers is performed in the same way as multiplication of decimal numbers. The multiplication of two bits produces a 1 if both bits are 1 otherwise, it produces a 0.

		B_1	B_0
		A_1	A_0
	C_1	A_0B_1	A_0B_0
	A_1B_1	A_1B_0	
P_3	P_2	P_1	P_0