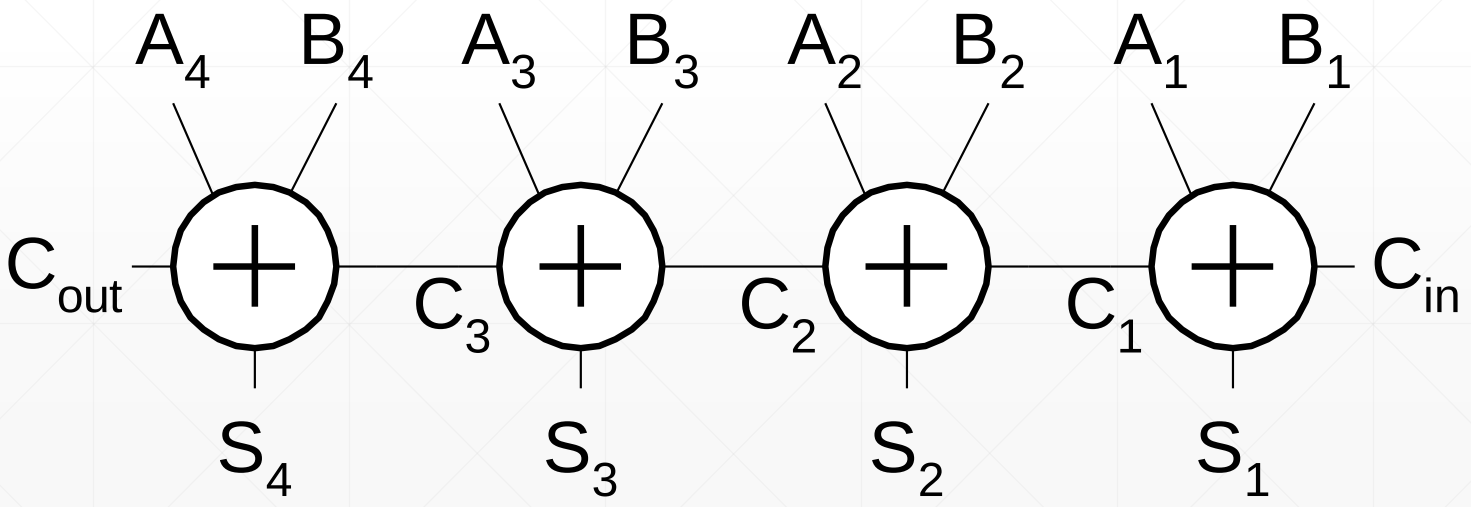
Module – 3
Implementation of Arithmetic system

Contents

- Arithmetic Circuits:
  - High Speed Adders,
  - Carry look-ahead adder,
  - Carry save adders,
  - Conditional Sum adders,
- Sequential and Parallel Multipliers

Ripple Carry Adder

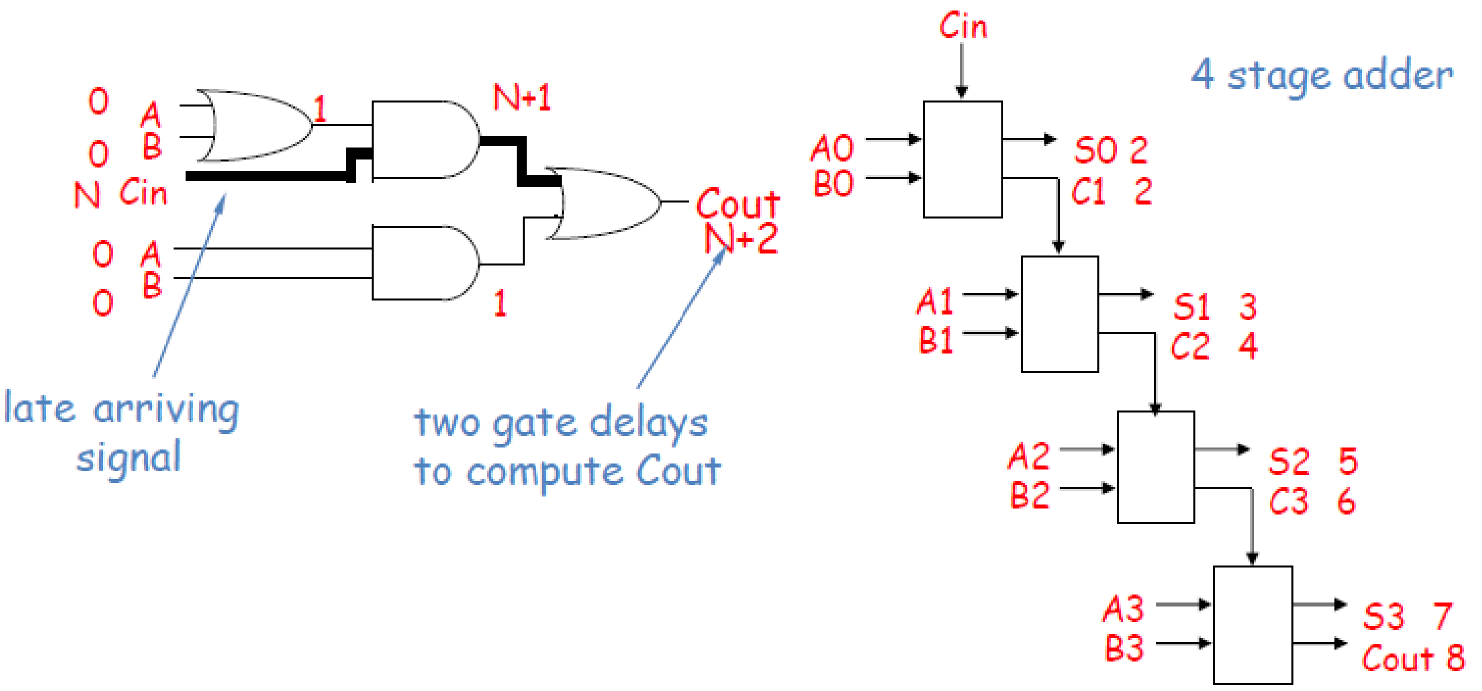
- Simplest design: cascade full adders
  - Critical path goes from Cin to Cout
  - Design full adder to have fast carry delay



Ripple Carry Adder

✓ Critical Delay

- The propagation of carry from low to high order stages



Carry Look-ahead Adder

- Express Sum and Carry as a function of P, G, D.

Generate (G) = AB

Propagate (P) = $A \oplus B$

Delete = $\overline{A}\,\overline{B}$

- Derive expressions for S and Co based on G and P

$$C_o(G, P) = G + PC_i$$

$$S(G, P) = P \oplus C_i$$

Carry Look-ahead Adder

Therefore:

$$C_1 = G_1 + P_1 C_0$$

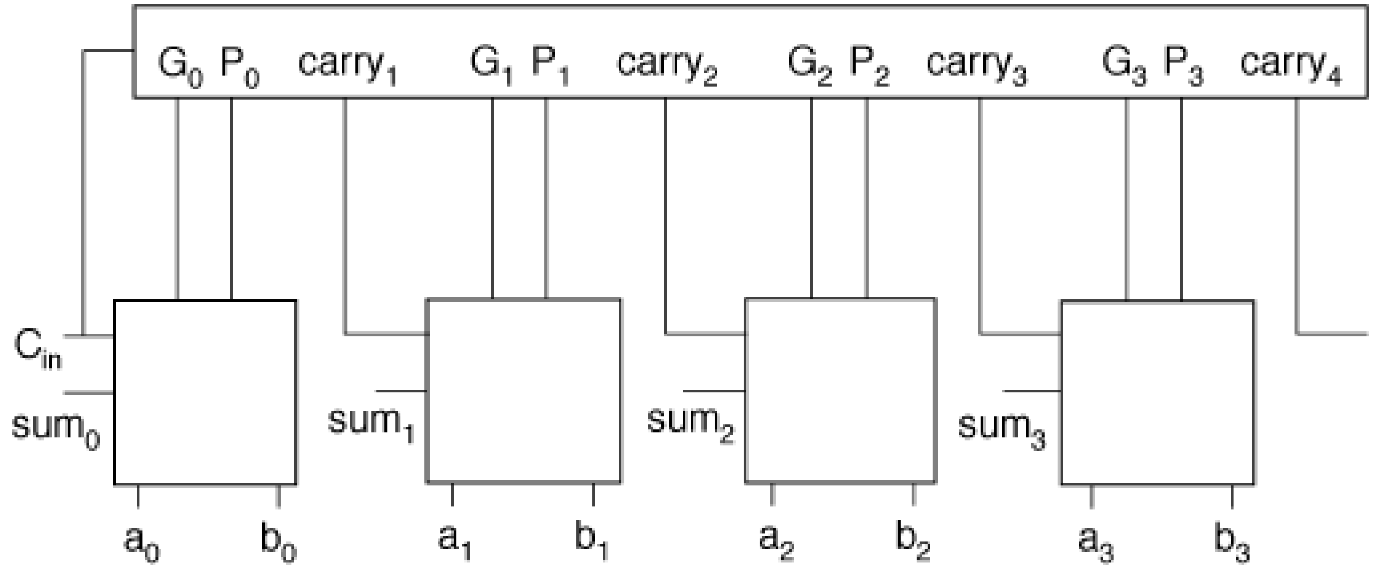
$$C_2 = G_2 + P_2 (G_1 + P_1 C_0)$$

$$C_3 = G_3 + P_3 (G_2 + P_2 (G_1 + P_1 C_0))$$

$$C_4 = G_4 + P_4 (G_3 + P_3 (G_2 + P_2 (G_1 + P_1 C_0)))$$

- Expanded formula does not depend on intermerdiate carries.
- Allows carry for each bit to be computed independently.

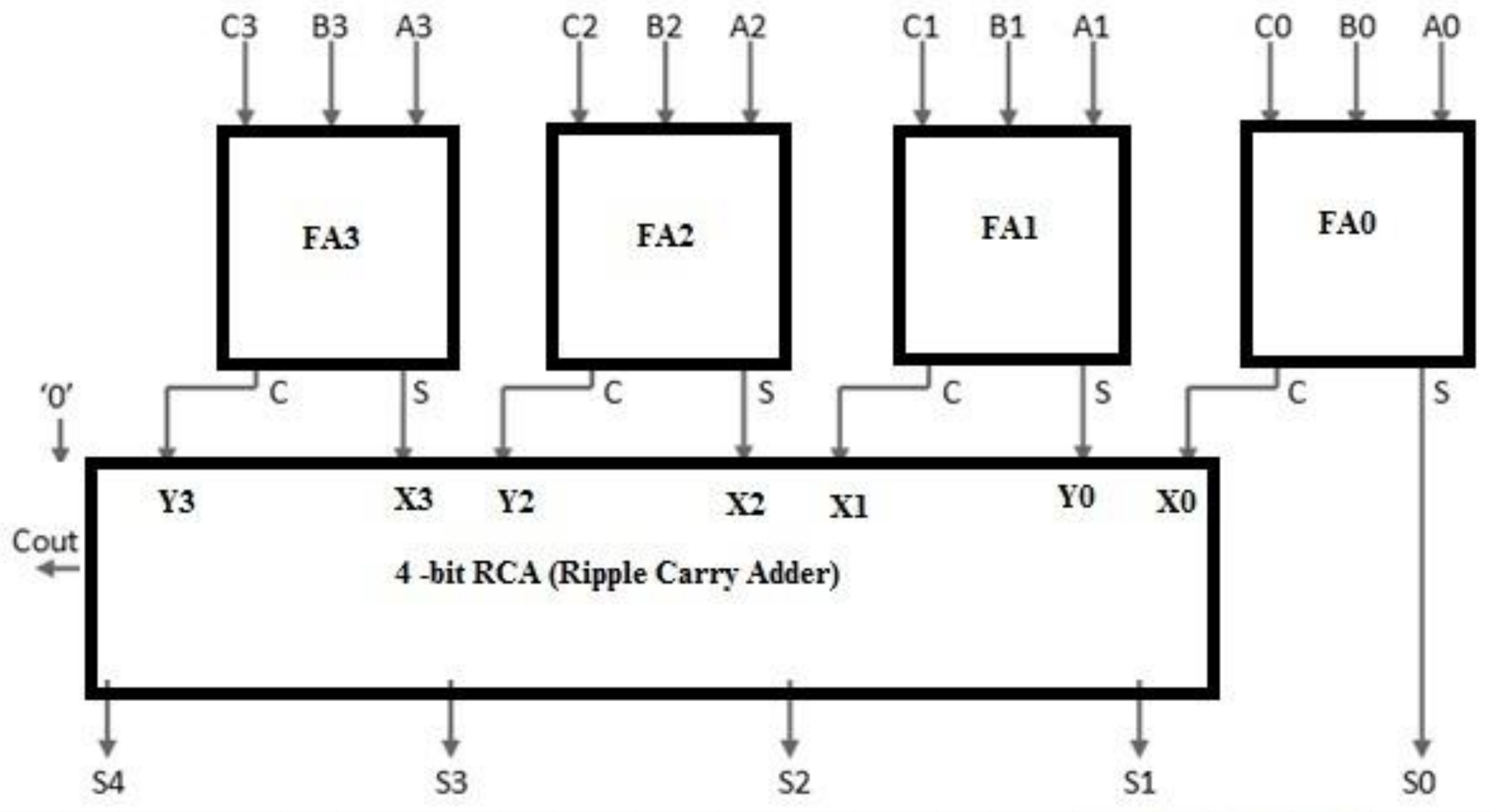
Depth-4 carry-lookahead

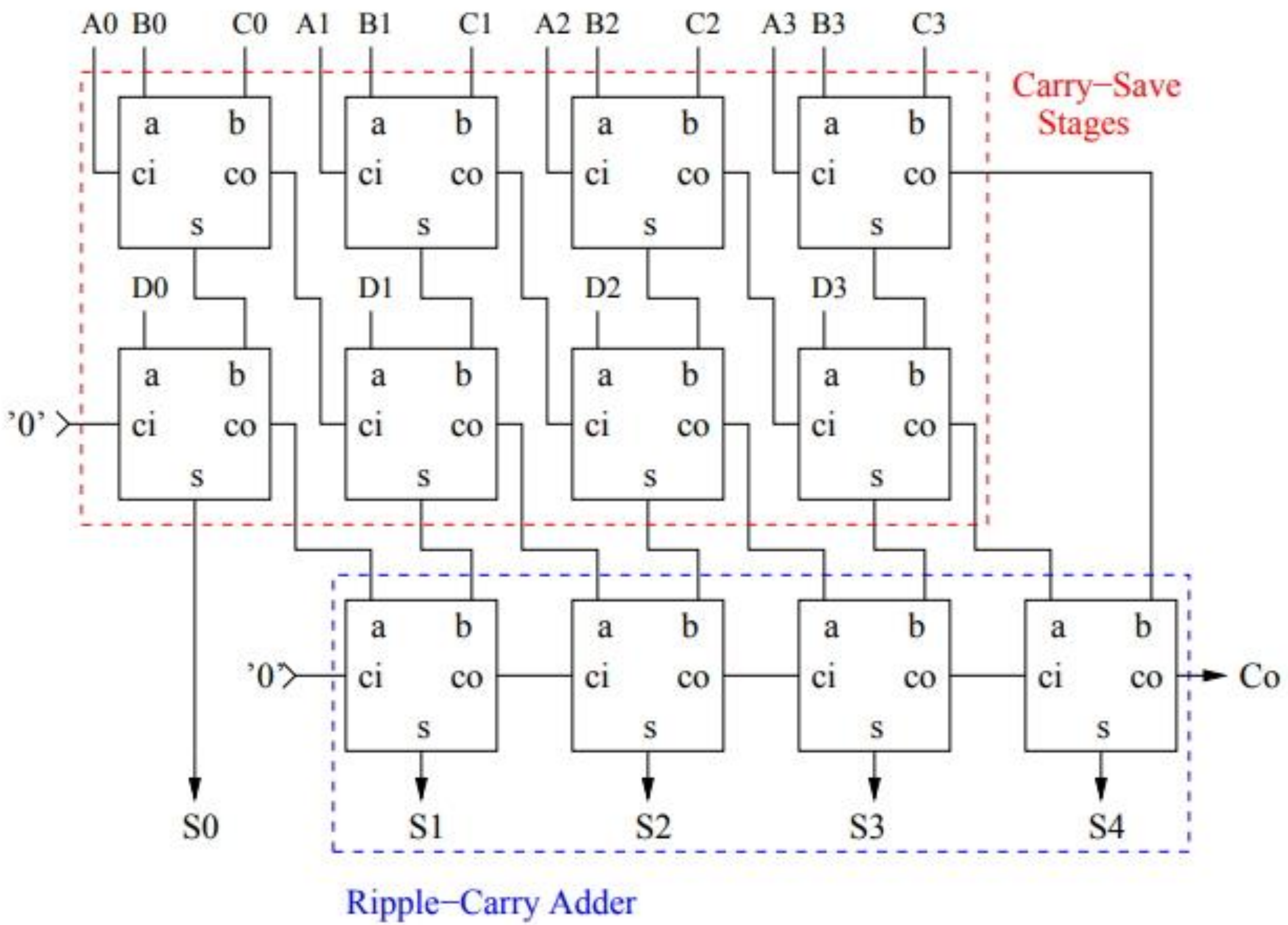


Carry Save Adders

- A carry-save adder or CSA is a type of digital adder mainly used for computing the sum of a minimum of three or above binary numbers very efficiently.
- A CSA is normally used within a binary multiplier because this multiplier involves the addition of the above two binary numbers after multiplication.
- By using this method, a big adder can be implemented which is very faster compared to the usual addition of numbers.

Carry Save Adder



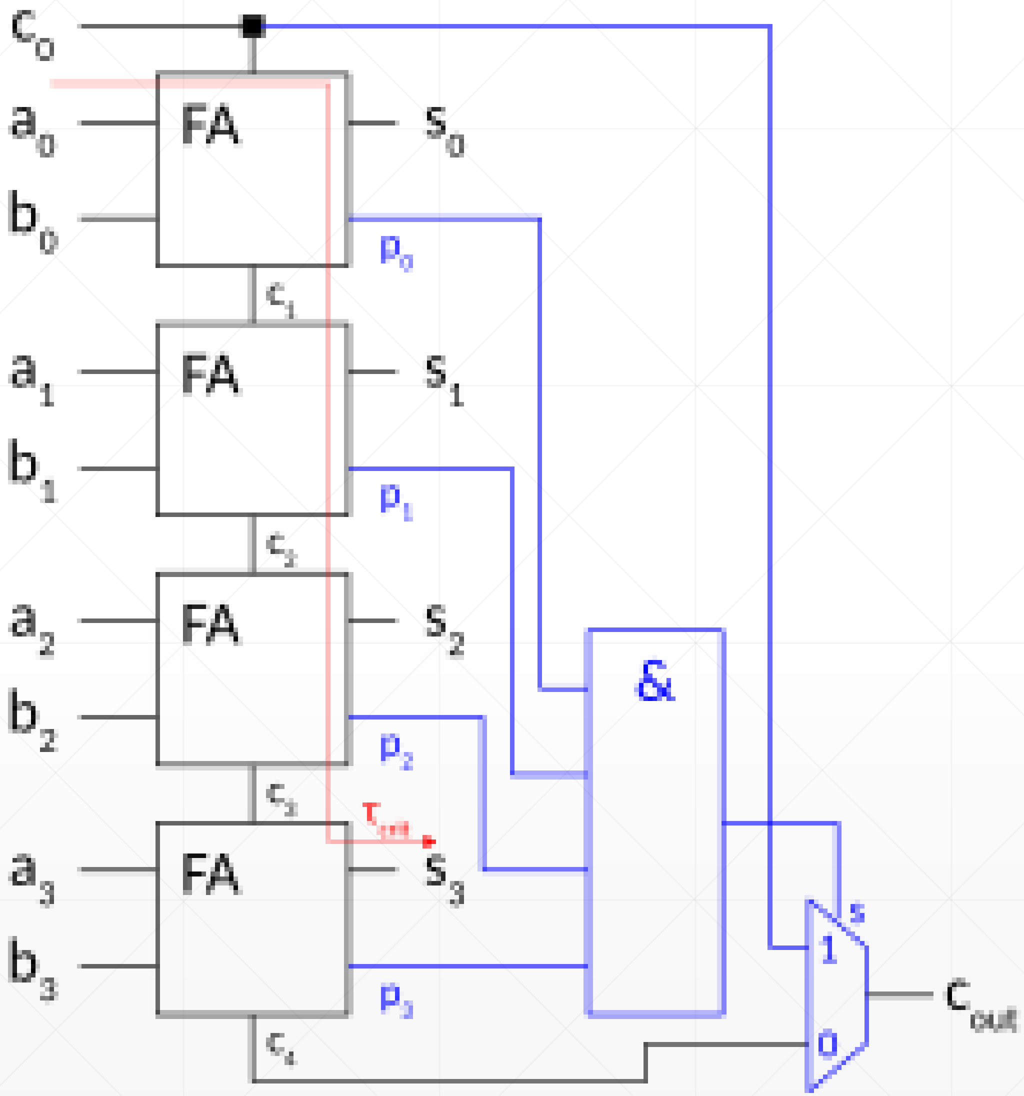

A0 B0 C0 A1 B1 C1 A2 B2 C2 A3 B3 C3
Carry−Save
Stages
a b ci co s
D0 D1 D2 D3
'0'
'0'
Co
S0 S1 S2 S3 S4
Ripple−Carry Adder

Carry-skip adder

- A carry-skip adder (also known as a carry-bypass adder) is an adder implementation that improves on the delay of a ripple-carry adder with little effort compared to other adders.
- The improvement of the worst-case delay is achieved by using several carry-skip adders to form a block-carry-skip adder.
- Unlike other fast adders, carry-skip adder performance is increased with only some of the combinations of input bits. This means, speed improvement is only probabilistic.

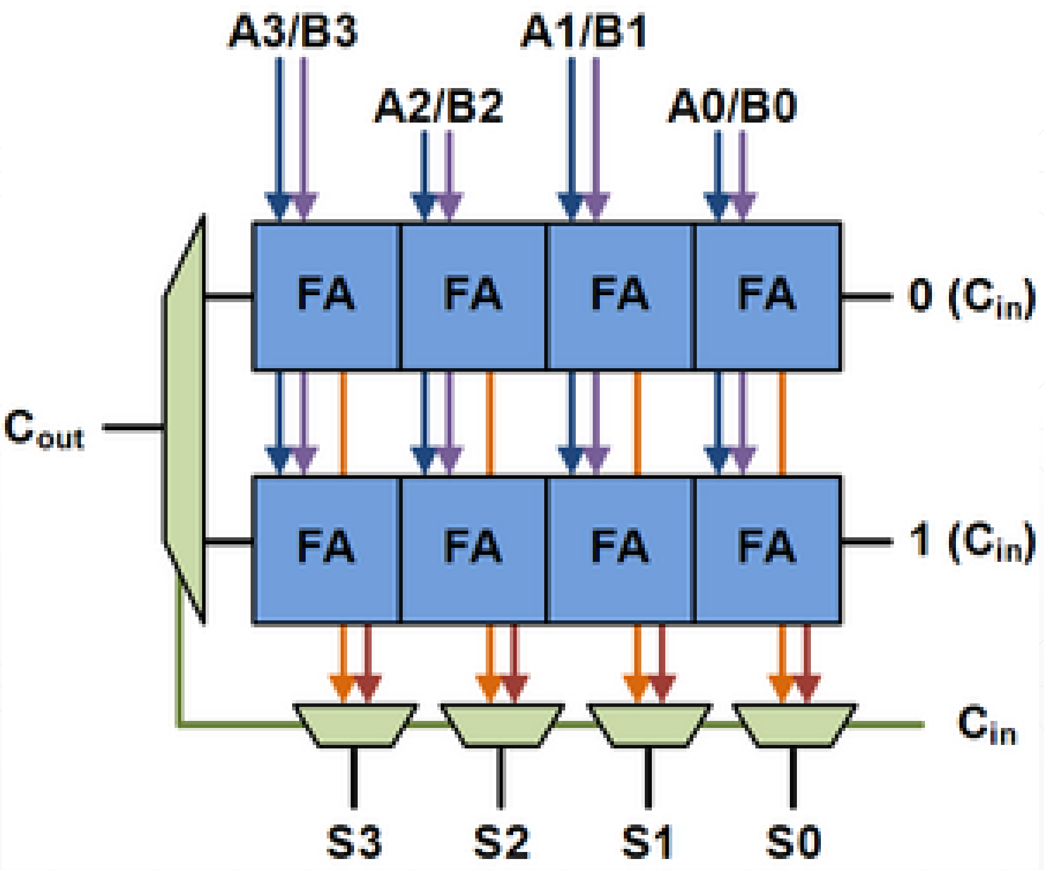
Carry-skip adder

- The n-bit-carry-skip adder consists of a n-bit-carry-ripple-chain, a n-input AND-gate and one multiplexer.
- Each propagate bit p_i , that is provided by the carry-ripple-chain is connected to the n-input AND-gate.
- The resulting bit is used as the select bit of a multiplexer that switches either the last carry-bit c_n or the carry-in c_0 to the carry-out signal c_{out}



Carry Select Adder

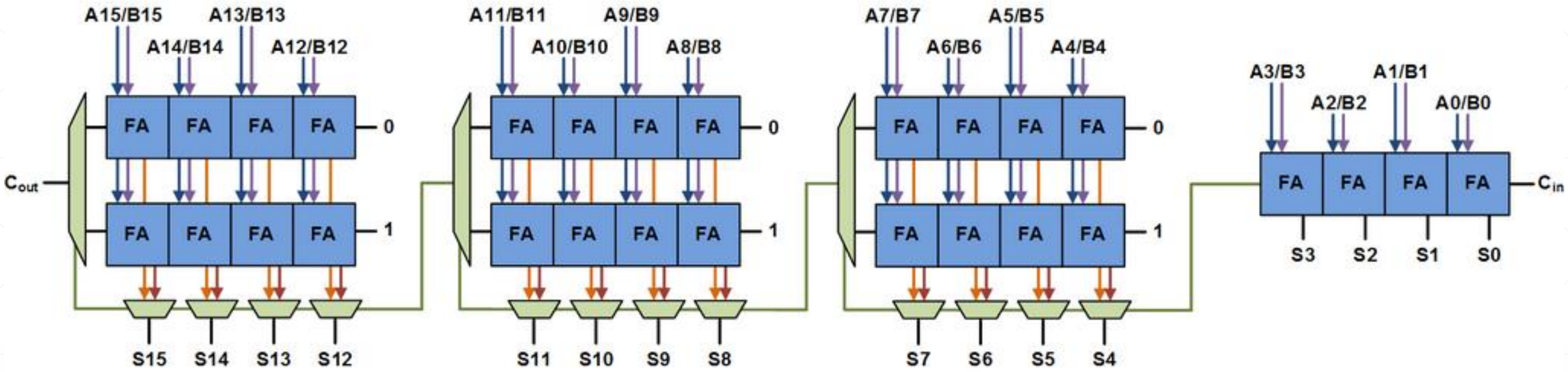
- The carry-select adder generally consists of ripple-carry adders and a multiplexer.
- Adding two n-bit numbers with a carry-select adder is done with two adders (therefore two ripple-carry adders), in order to perform the calculation twice, one time with the assumption of the carry-in being zero and the other assuming it will be one.
- After the two results are calculated, the correct sum, as well as the correct carry-out, is then selected with the multiplexer once the correct carry-in is known.



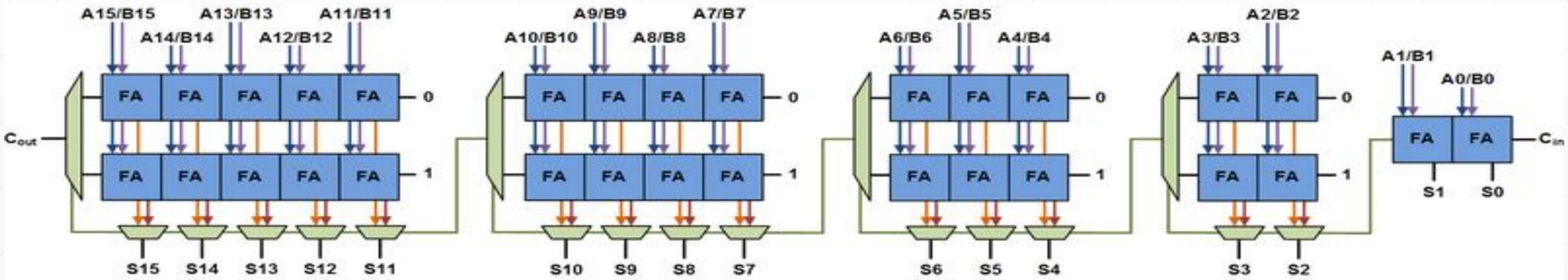
Carry Select Adder

- The number of bits in each carry select block can be uniform, or variable.

Uniform-sized adder



Variable-sized adder



Conditional Sum Adder

- Extension of carry-select adder
- Carry select adder
- One-level using k/2-bit adders
- Two-level using k/4-bit adders
- Three-level using k/8-bit adders
- Assuming k is a power of two, eventually have an extreme where there are $\log_2 k$-levels using 1-bit adders