Teaching London Computing

Programming for GCSE Topic 9.2: Circuits for Adding

William Marsh
School of Electronic Engineering and Computer Science
Queen Mary University of London

Aims

- Show how computers are built from logic gates
- Circuit for Adding
  - … two inputs
  - … three inputs – one column
  - … many columns

Key Idea:
- Represent numbers as binary digits
- Digits as logic levels

Half Adder

Half Adder

- Simplest circuit for binary addition
  - input: two bits A and B
  - output: sum S and carry C
- Sums → ? → circuit

0 + 0 = 0
0 + 1 = 1
1 + 0 = 1
1 + 1 = 0 carry 1

Example:

Half Adder – Truth Table

- Binary addition – truth table
  - input: two bits A and B
  - output: sum S and carry C

A	B	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Quiz: Determine the formula for S and C

Half Adder – Formula

- Simplest circuit for binary addition
  - input: two bits A and B
  - output: sum S and carry C

A	B	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

$$S = \overline{A}.B + A.\overline{B}$$

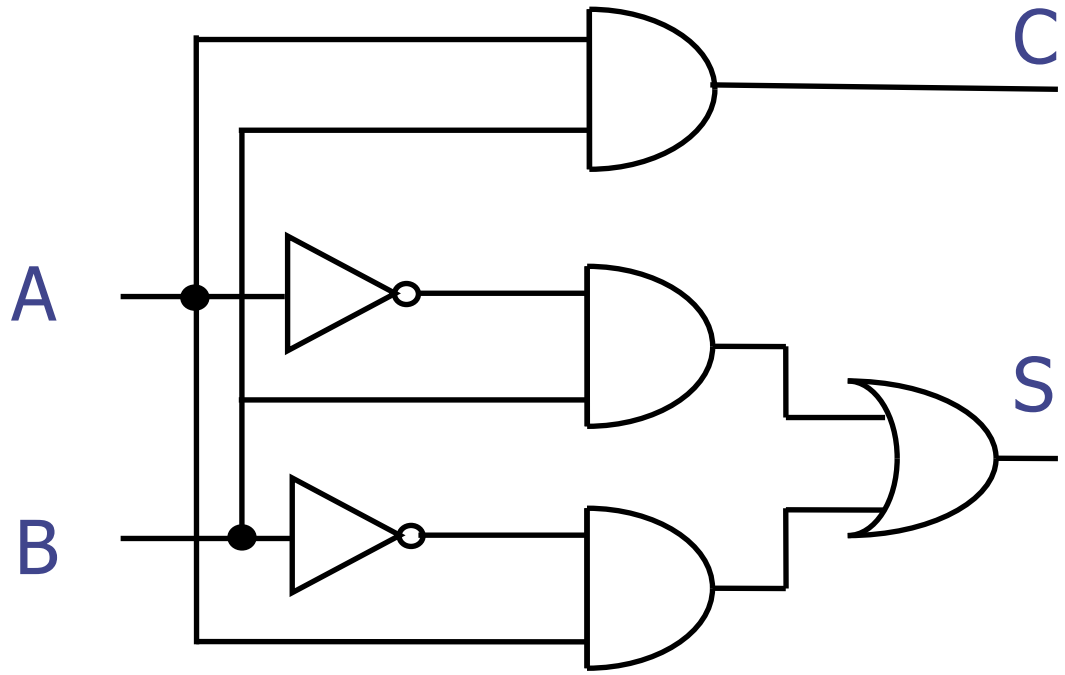
$$C = A.B$$

Quiz: draw the circuit

Half Adder – Circuit

- Simplest circuit for binary addition
  - input: two bits A and B
  - output: sum S and carry C

A	B	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

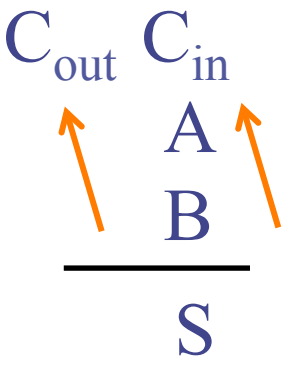


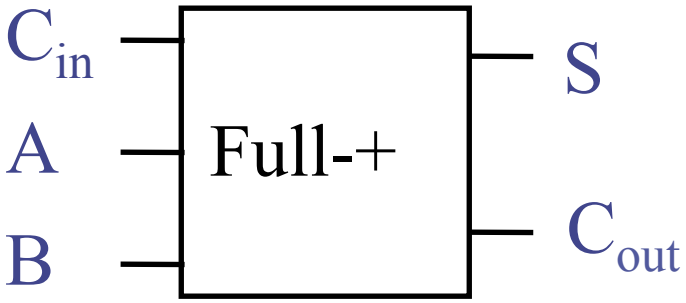
Full Adder

One Columns of a Binary Addition

Full Adder – One Column

- Each digit (column) of binary add has 3 inputs
  - A, B and carry C_{in}

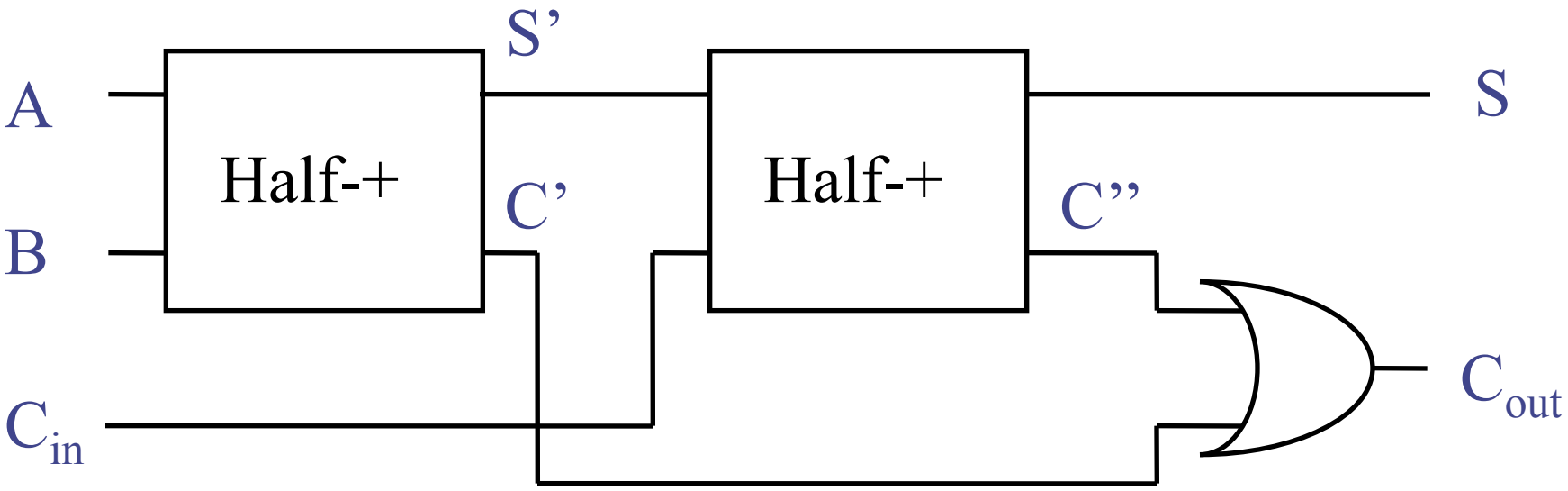




A	B	C_{in}	C_{out}	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

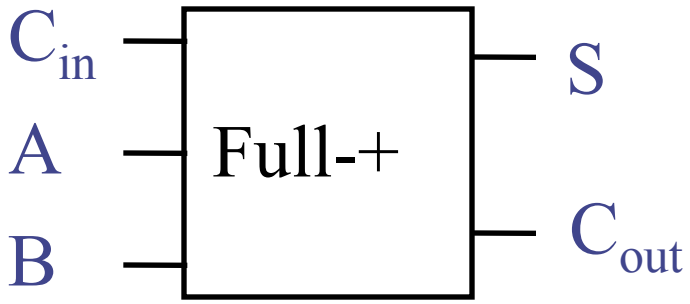
Full-Adder from 2 Half Adders

- Step 1: add A + B
- Step 2: add carry to result
- Step 3: carry



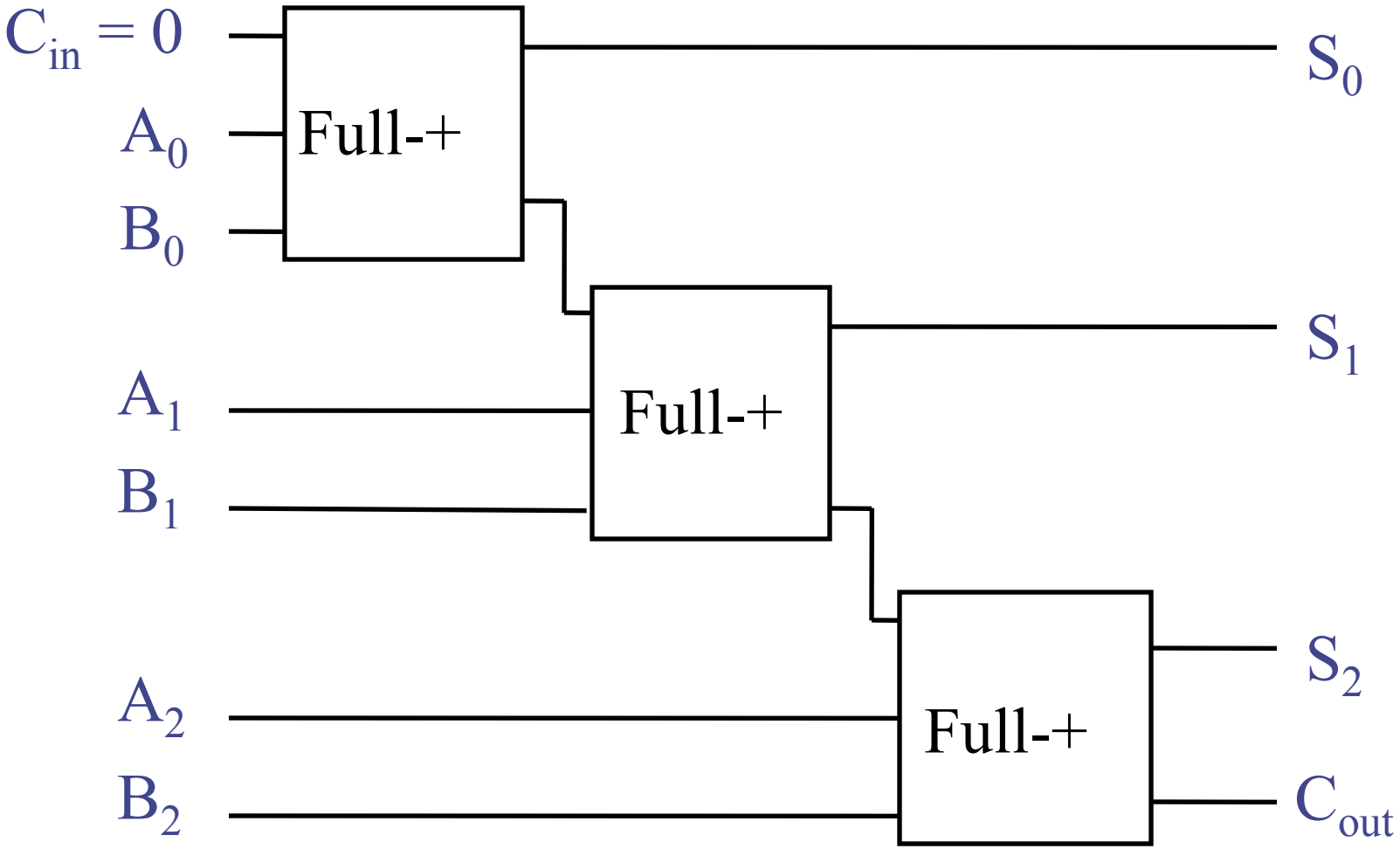
Ripple Adder

- Add each bit, carry from previous bit



Ripple Adder

- Add each bit, carry from previous bit



SYLLABUS

Syllabus – Binary

- GCSE (OCR)
  - Logic circuits: and, or , not
  - Truth tables
  - Writing boolean expressions
- AS/A2 (AQA)
  - (AS) More boolean algebra
  - (AS) More gates

Joined up view?
How to make sense of logic unless used e.g. adder circuit.

binary → truth table
→ circuit

Summary

- Show how logic circuits build a computer
  - Binary digits become logic inputs
  - Circuits operate on numbers
- Adder stages
  - One column, no carry
  - One column, with carry
  - Many columns