

2384-7

**ICTP Latin-American Advanced Course on FPGA Design for Scientific
Instrumentation**

19 November - 7 December, 2012

**Digital Design
(Part 7)**

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Outline

- Digital CMOS design

- Arithmetic operators

 - Adders

 - Comparators

 - Shifters

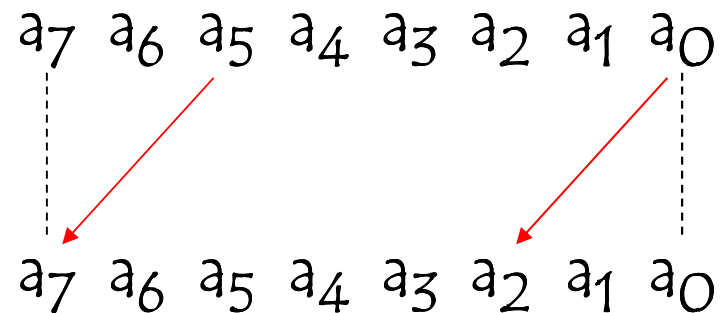
 - Multipliers



Shifters

Shifting a value

Let consider a value a coded on 8 bits
 a can be shifted to the left by n positions ($0 \leq n < 8$)



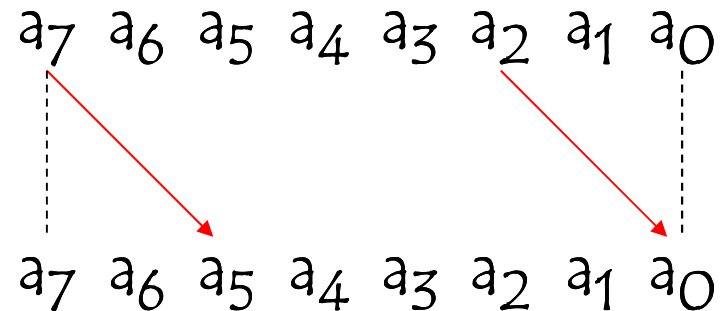
For a natural number, shift left is a multiplication by 2^n

Shifters

Shifting a value

Let consider a value a coded on 8 bits
 a can be shifted to the right by n positions ($0 \leq n < 8$)

logic



For a natural number, shift right is a division by 2^n

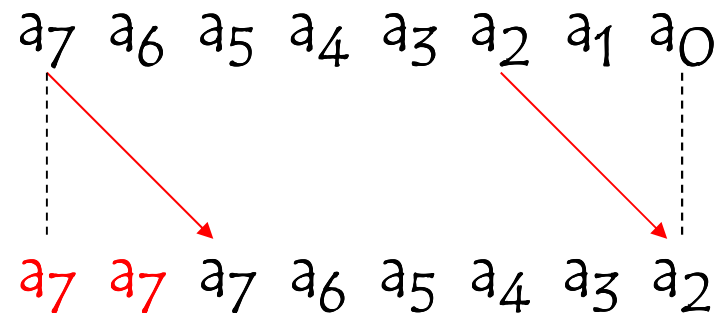


Shifters

Shifting a value

Let consider a value a coded on 8 bits
 a can be shifted to the right by n positions ($0 \leq n < 8$)

arithmetic



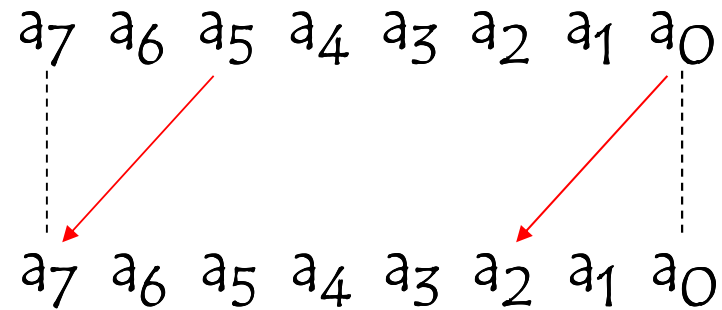
For a **relative** number, shift right is a division by 2^n



Shifters

Shifting a value

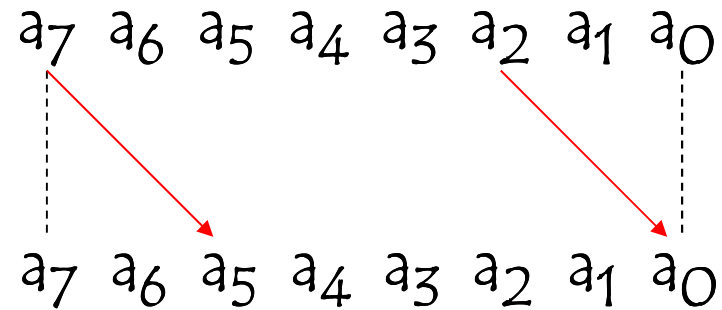
Let consider a value a coded on 8 bits
 a can be rotated to the left by n positions ($0 \leq n < 8$)



Shifters

Shifting a value

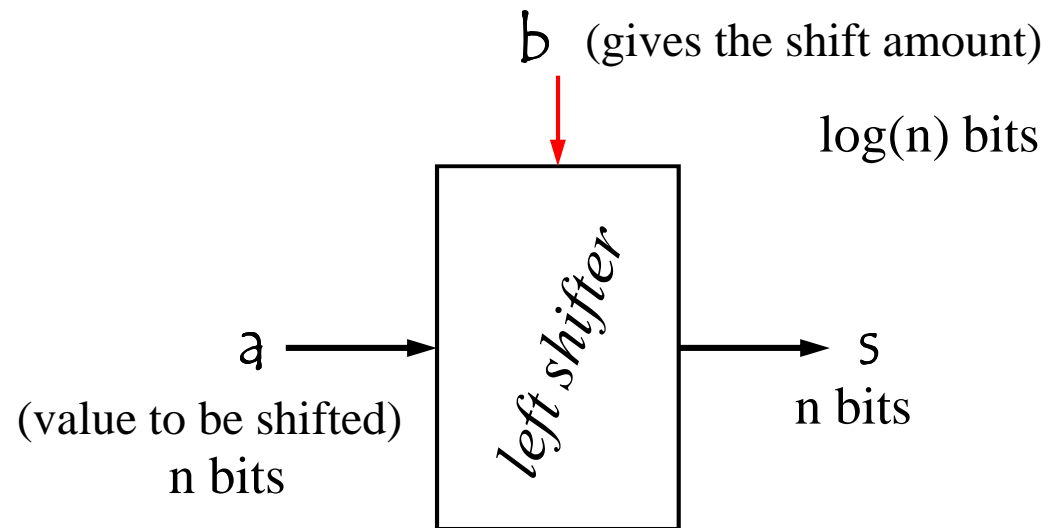
Let consider a value a coded on 8 bits
 a can be rotated to the right by n positions ($0 \leq n < 8$)



Shifters

Shifting a value

Implementation (left shifter)



Shifters

Shifting a value by 1 position to the left

Boolean function

b coded on 1 bit

If $b = 0$

$$s_i = a_i$$

else

$$s_i = a_{i-1} \quad \text{assuming } a_{-1} = 0$$

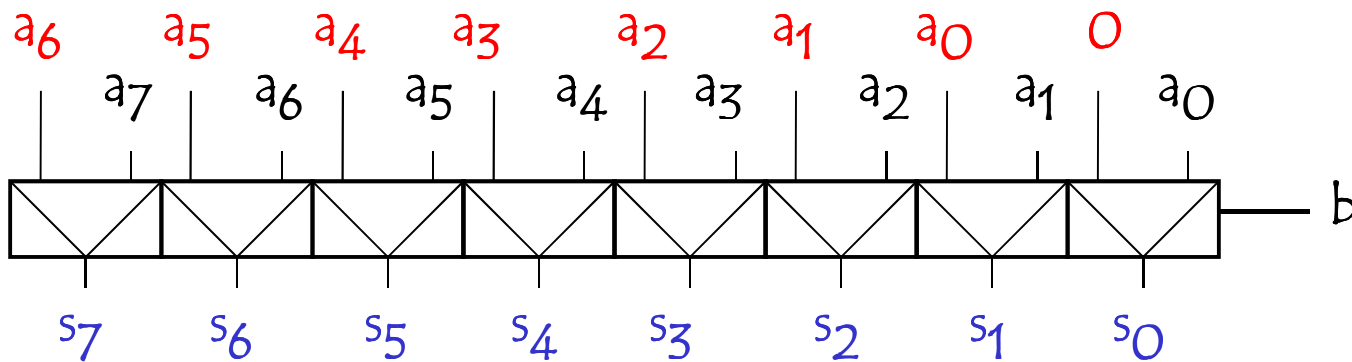
$$s_i = b \cdot a_{i-1} + \bar{b} \cdot a_i \quad \Rightarrow \quad \text{2-input Multiplexer}$$



Shifters

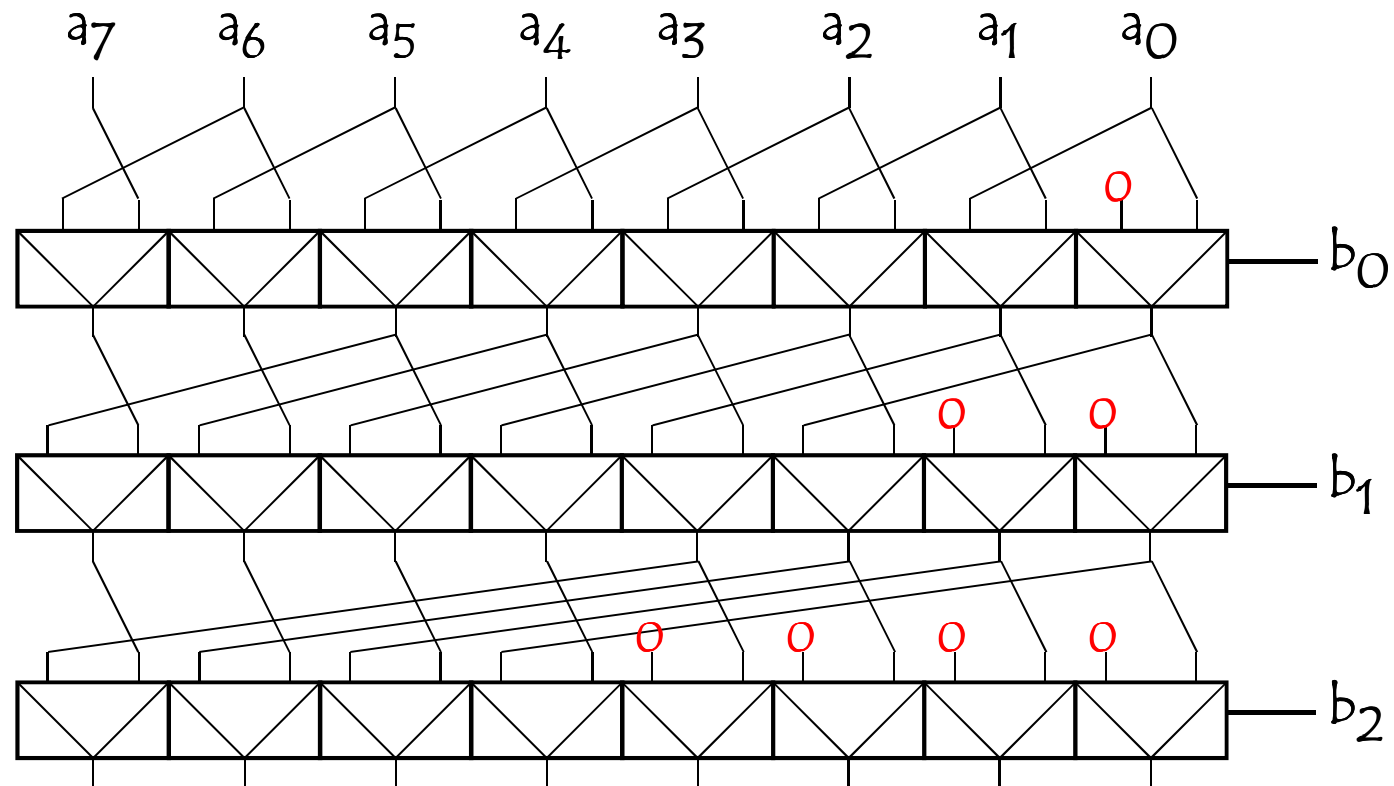
Shifting a value by 1 position to the left

Implementation



Shifters

Shifting a value to the left

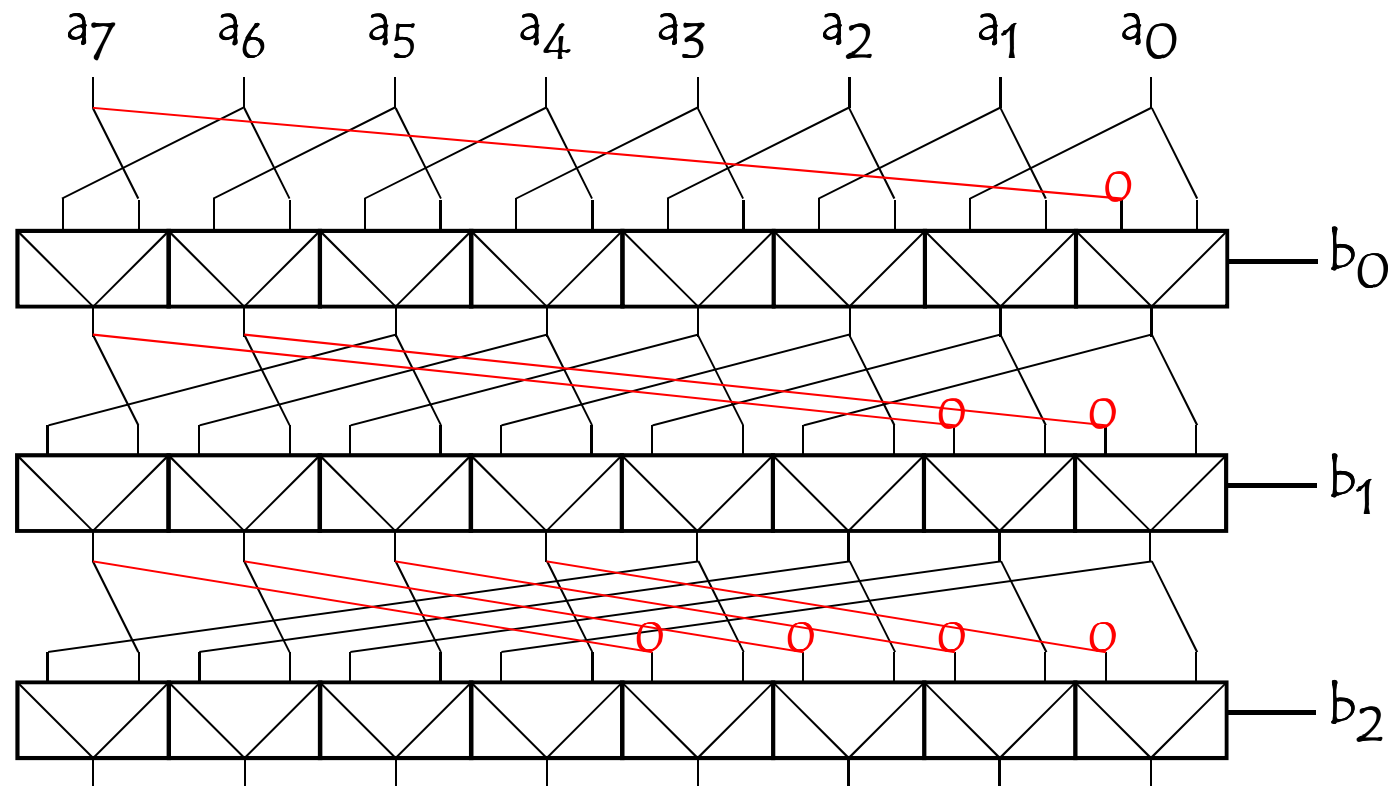


Pirouz Bazargan Sabet

Area $\propto n \log(n)$ Delay $\propto \log(n)$

Shifters

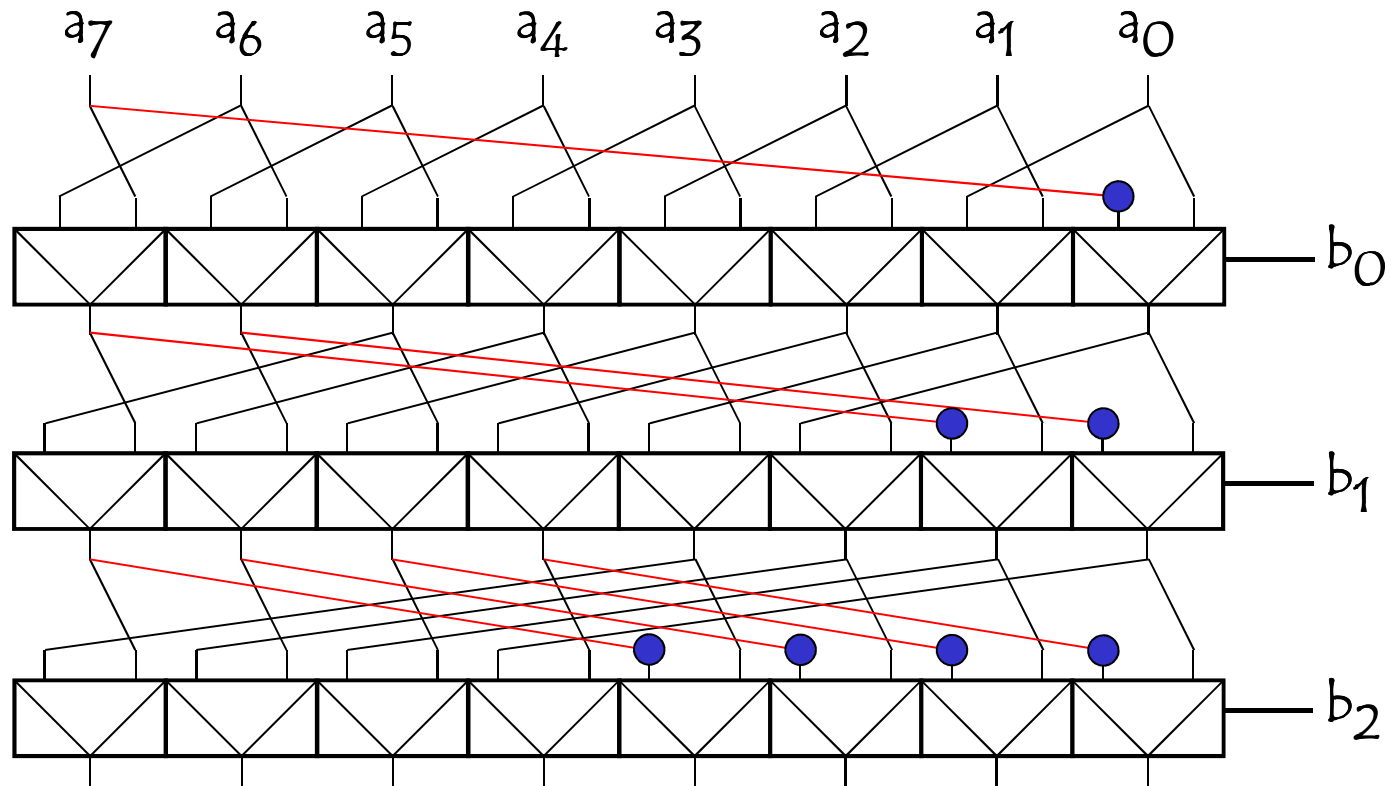
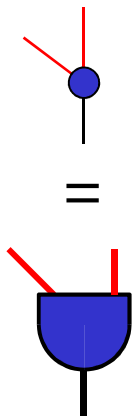
Rotate a value to the left



Shifters

Shift / Rotate a value to the left

shift-left



Shifters

Shifting a value

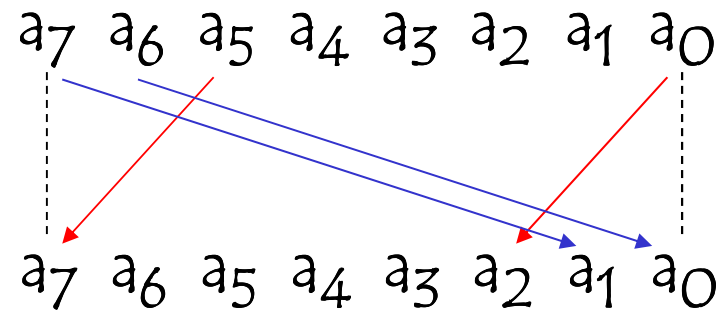
Rotate left by 2

=

Rotate right by 6

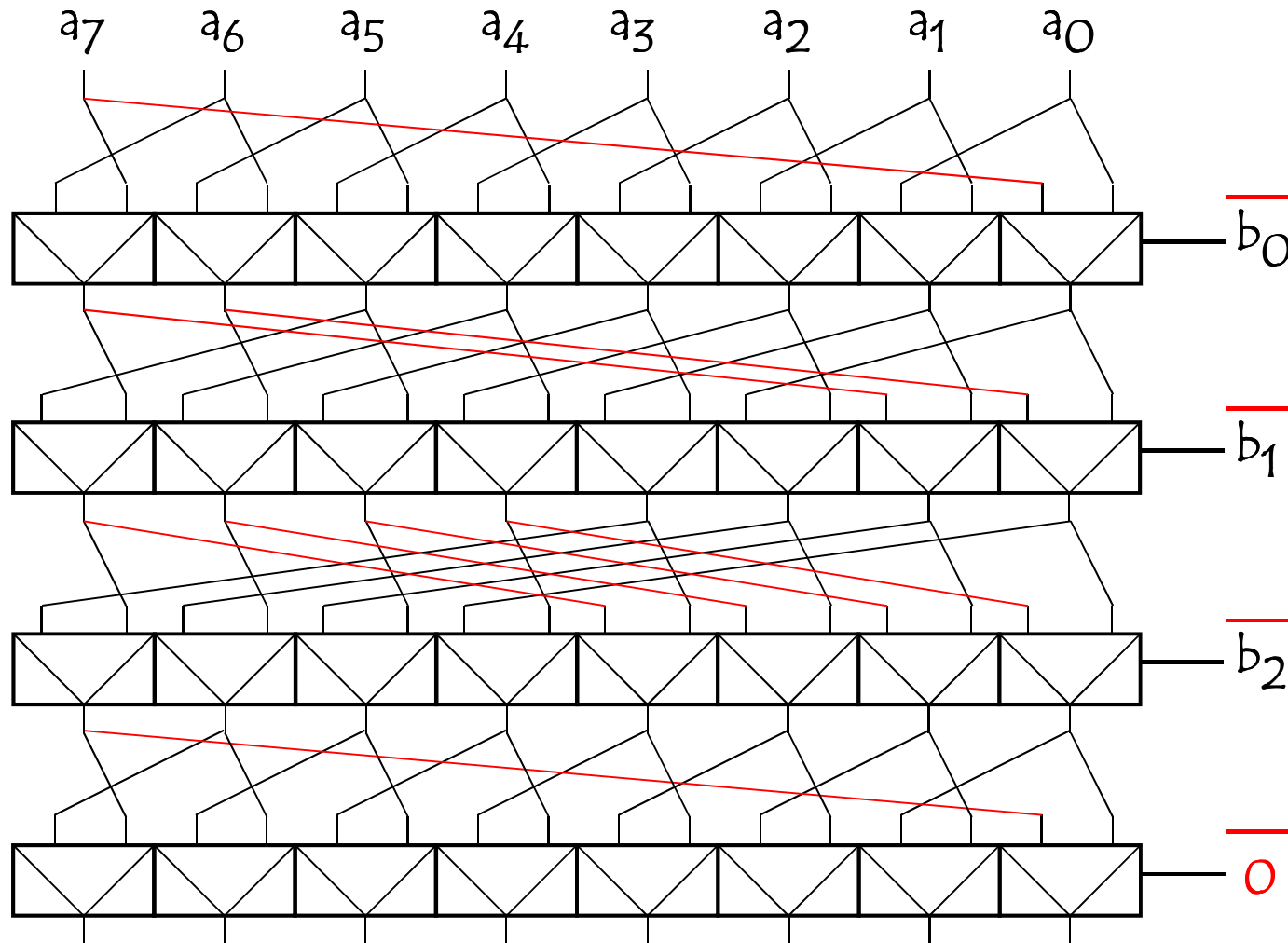
$$6 = -2$$

$$110 = \overline{010} + 1$$



Shifters

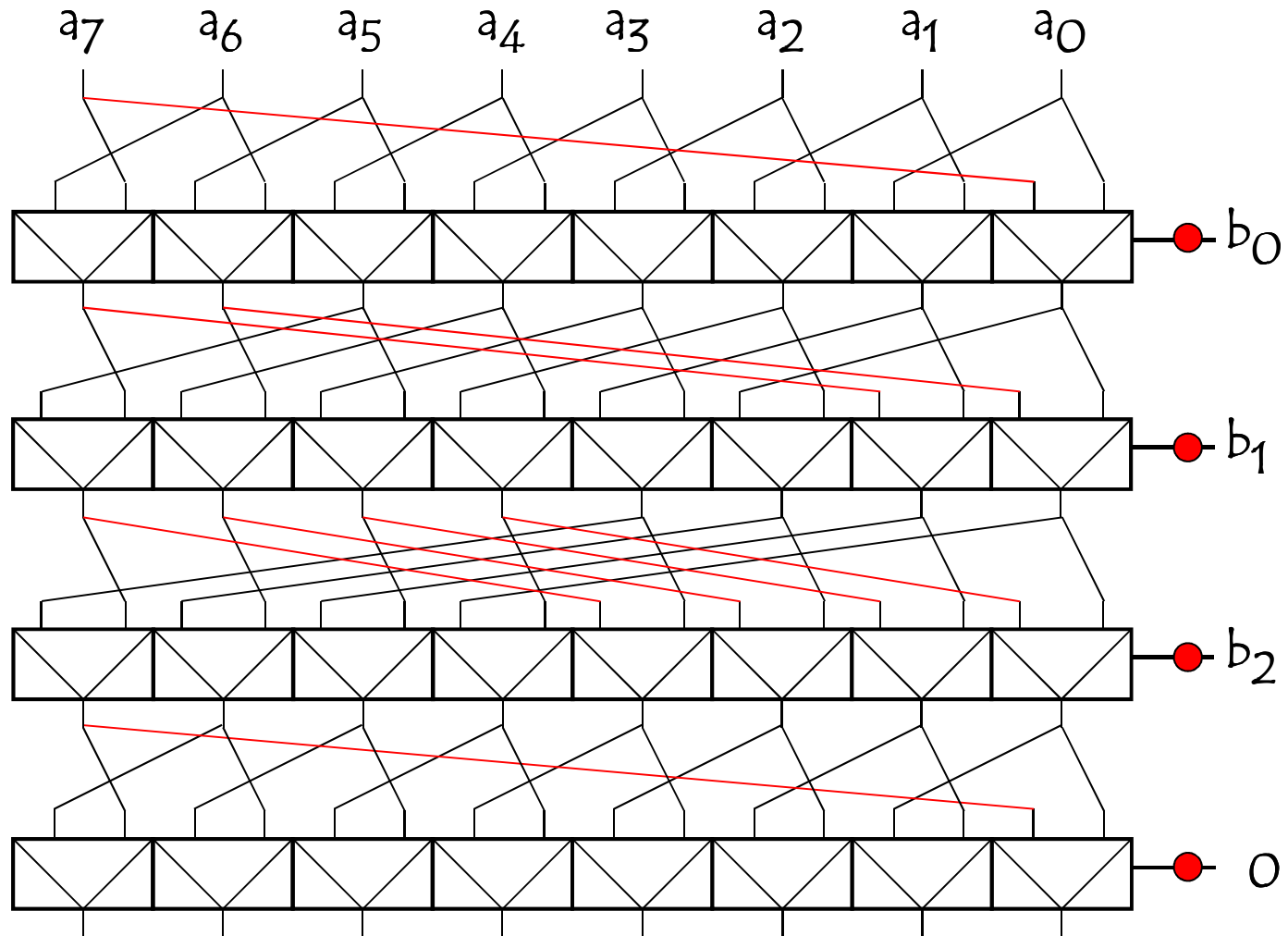
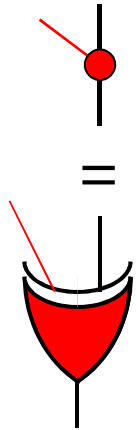
Rotate a value to the **right**



Shifters

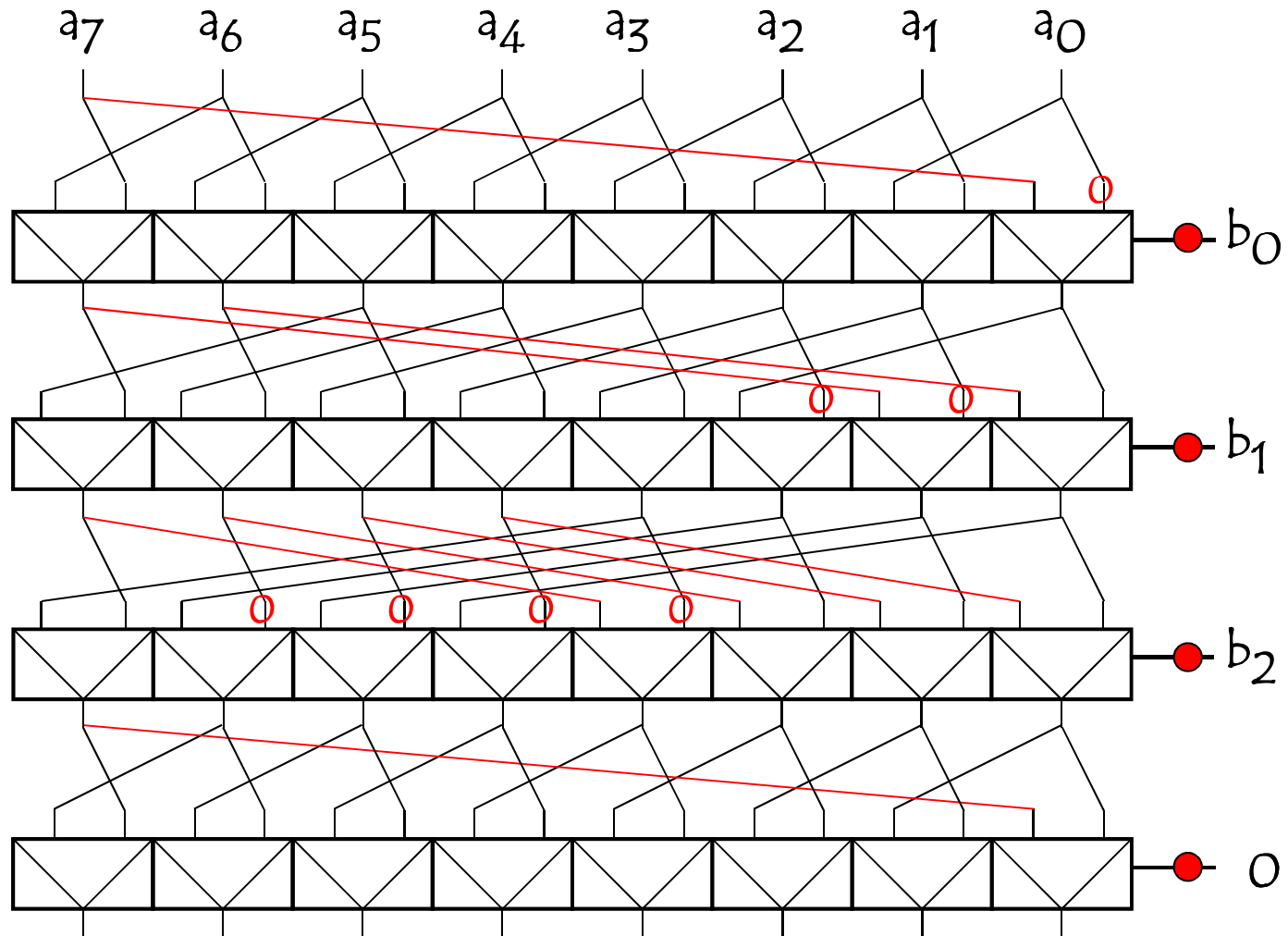
Rotate a value to the **left** / **right**

$\overline{\text{left}}$



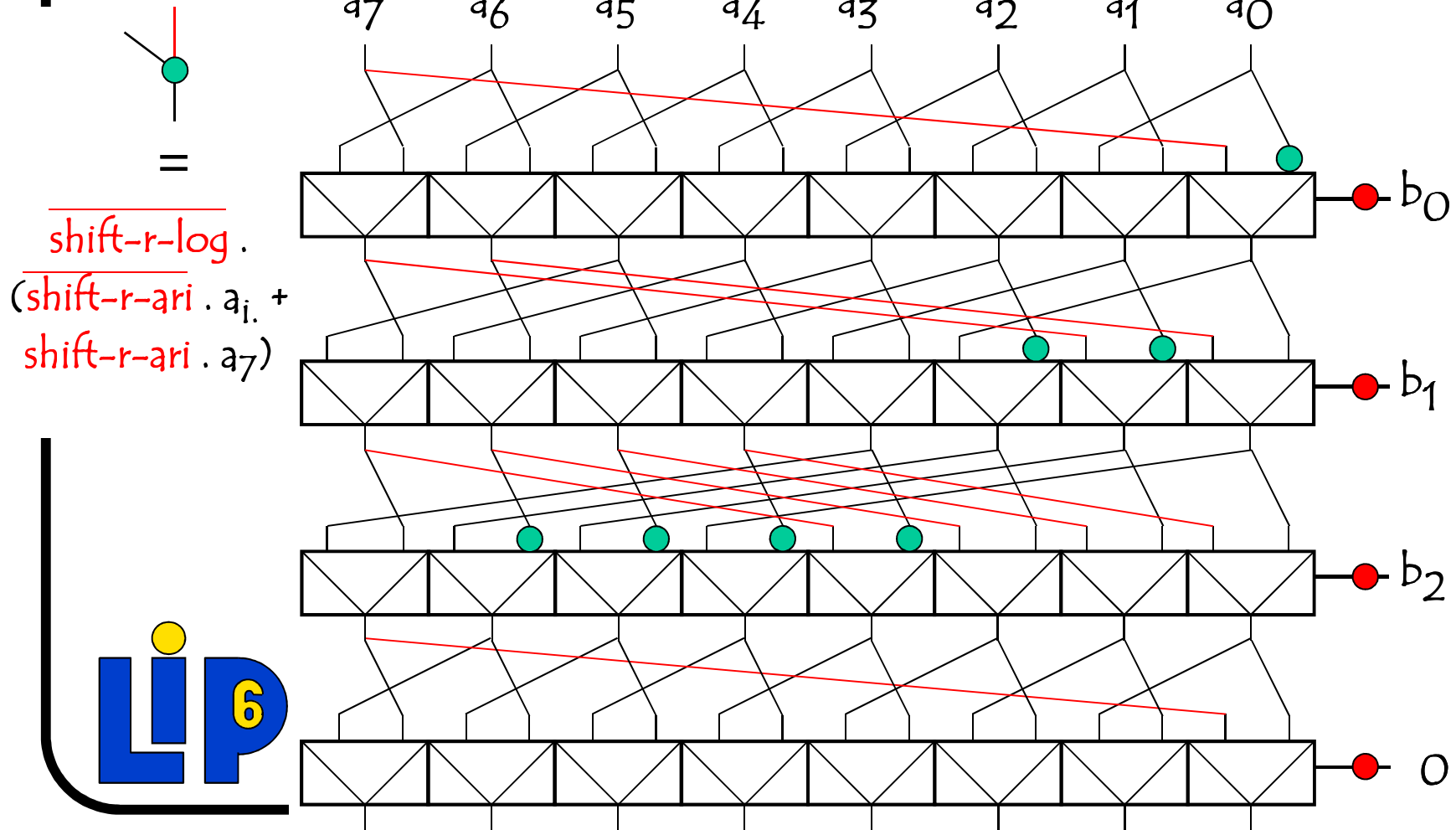
Shifters

Shift logic a value to the right



Shifters

Shift / Rotate a value to the right



Shifters

Shift / Rotate a value to the left / right

