

Outline

- Digital CMOS design

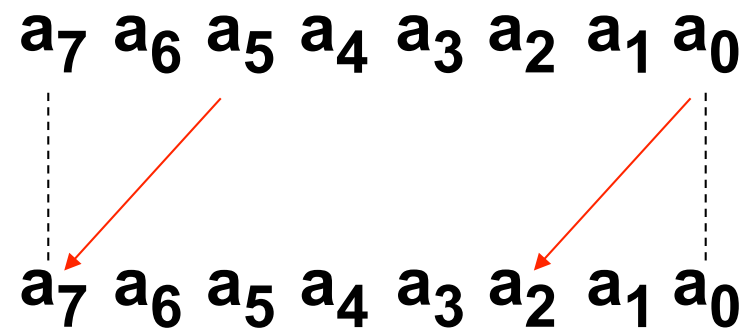
- Arithmetic operators

- 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 ($0 \leq n < 8$)



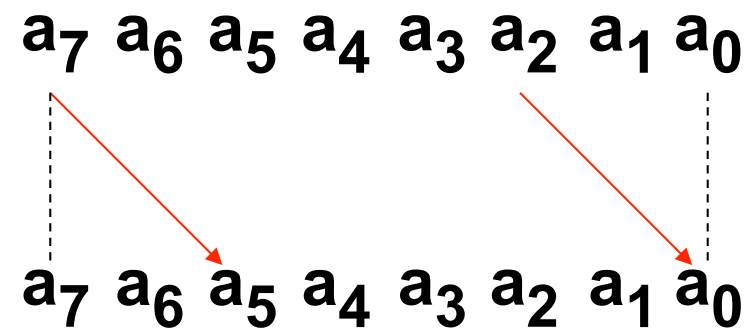
For a natural number, shift left is a multiplication by 2^n

Shifters

Shifting a value

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

8) logic



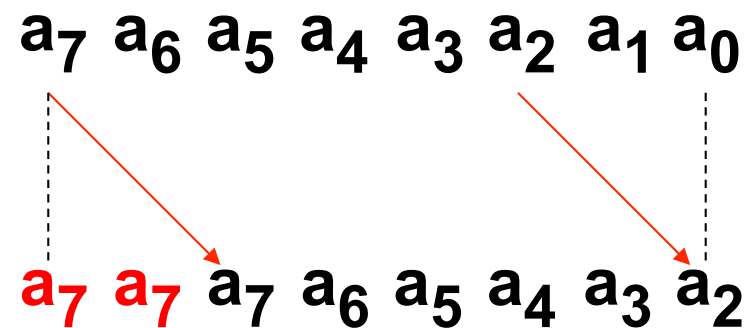
For a natural number, shift right is a division by 2^n

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

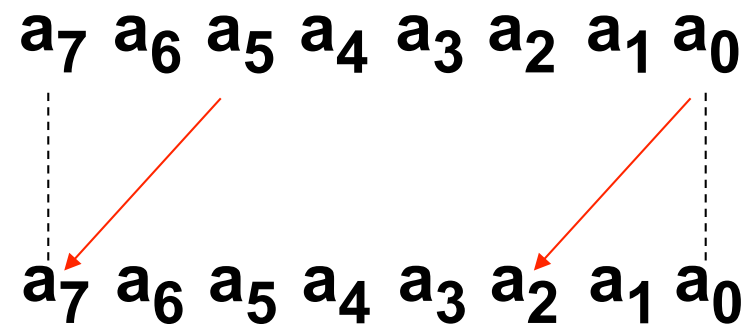


For a **relative** number, shift right is a division by 2^n

Shifters

Shifting a value

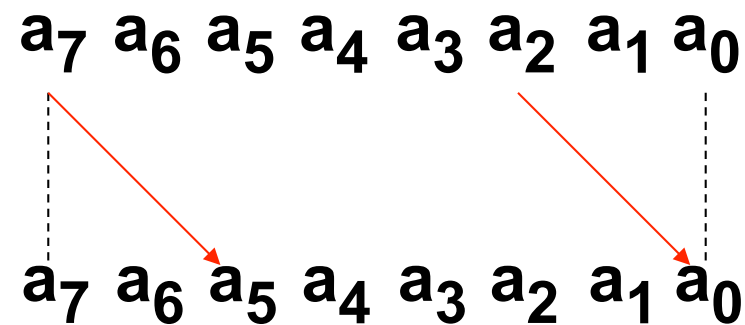
Let consider a value **a** coded on 8 bits
a can be rotated to the left by n positions ($0 \leq n < 8$)



Shifters

Shifting a value

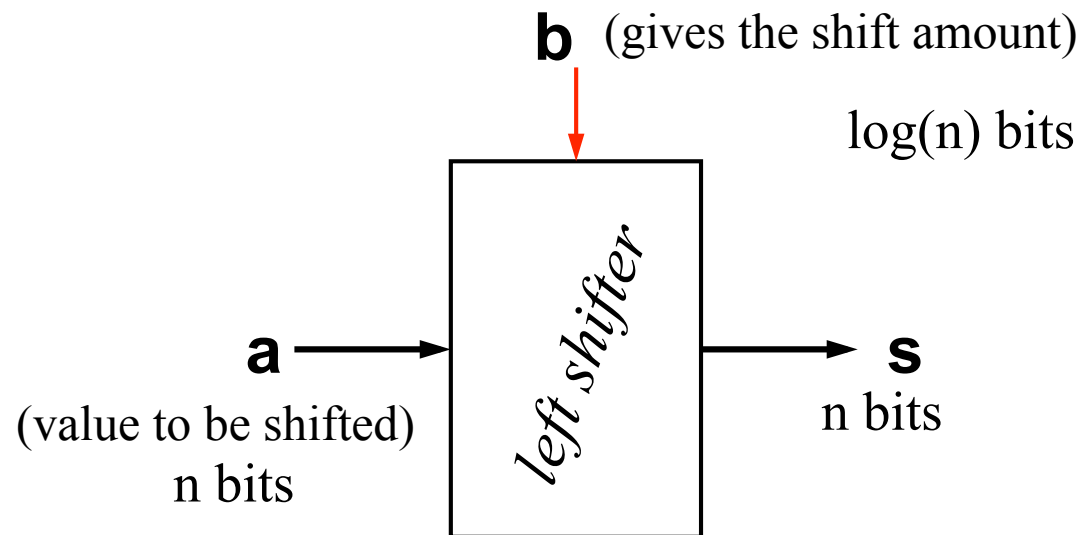
Let consider a value **a** coded on 8 bits
a can be rotated to the right by n positions ($0 \leq n < 8$)



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
 $s_i = a_{i-1}$ assuming $a_{-1} = 0$

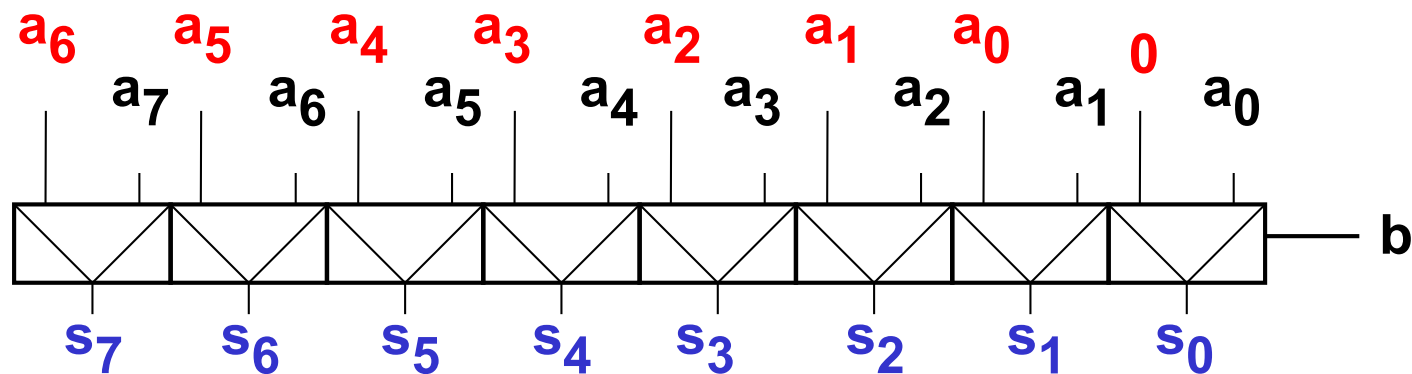
$$s_i = b \cdot a_{i-1} + \overline{b} \cdot a_i \Rightarrow \text{2-input Multiplexer}$$



Shifters

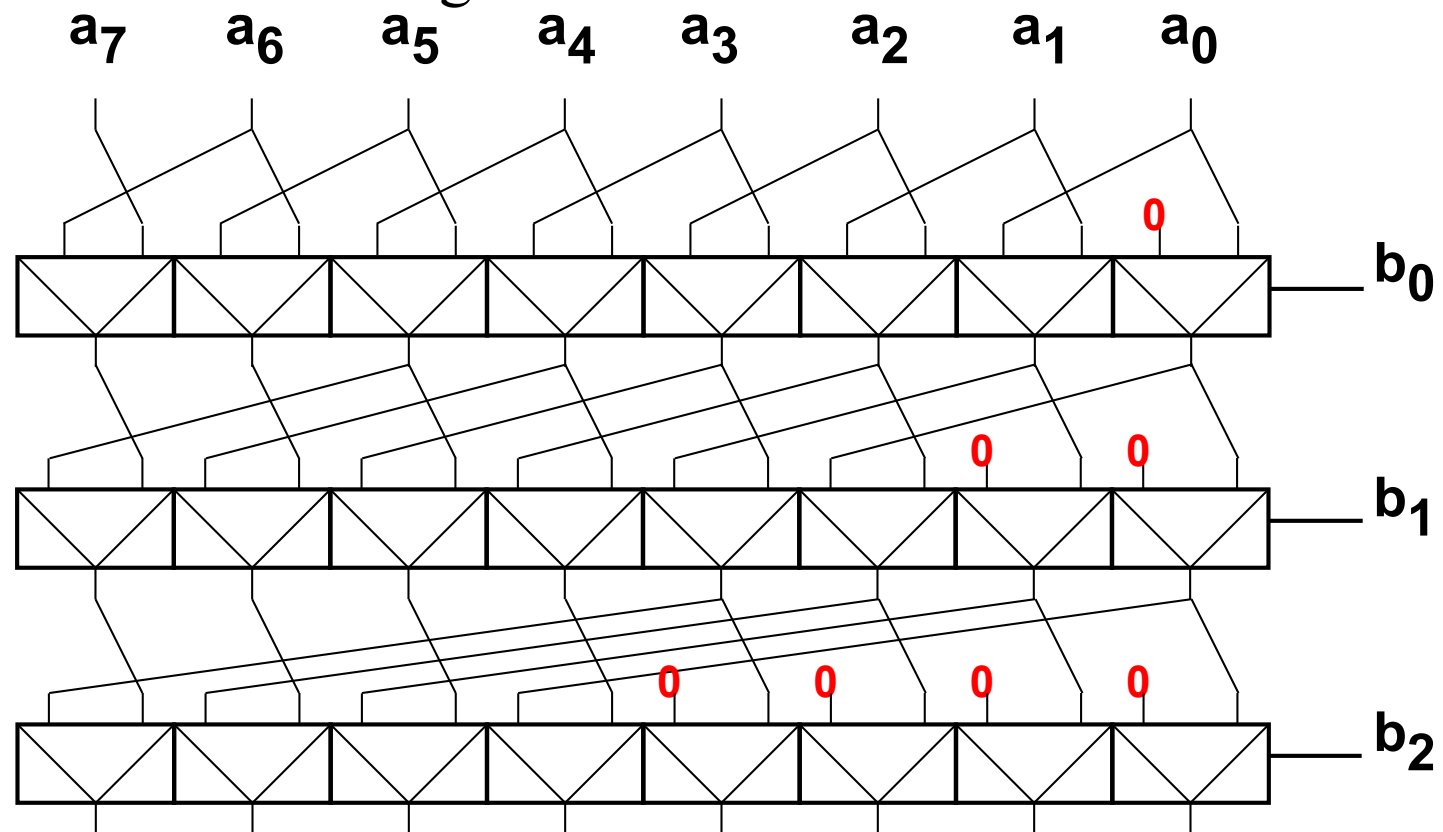
Shifting a value by 1 position to the left

Implementation



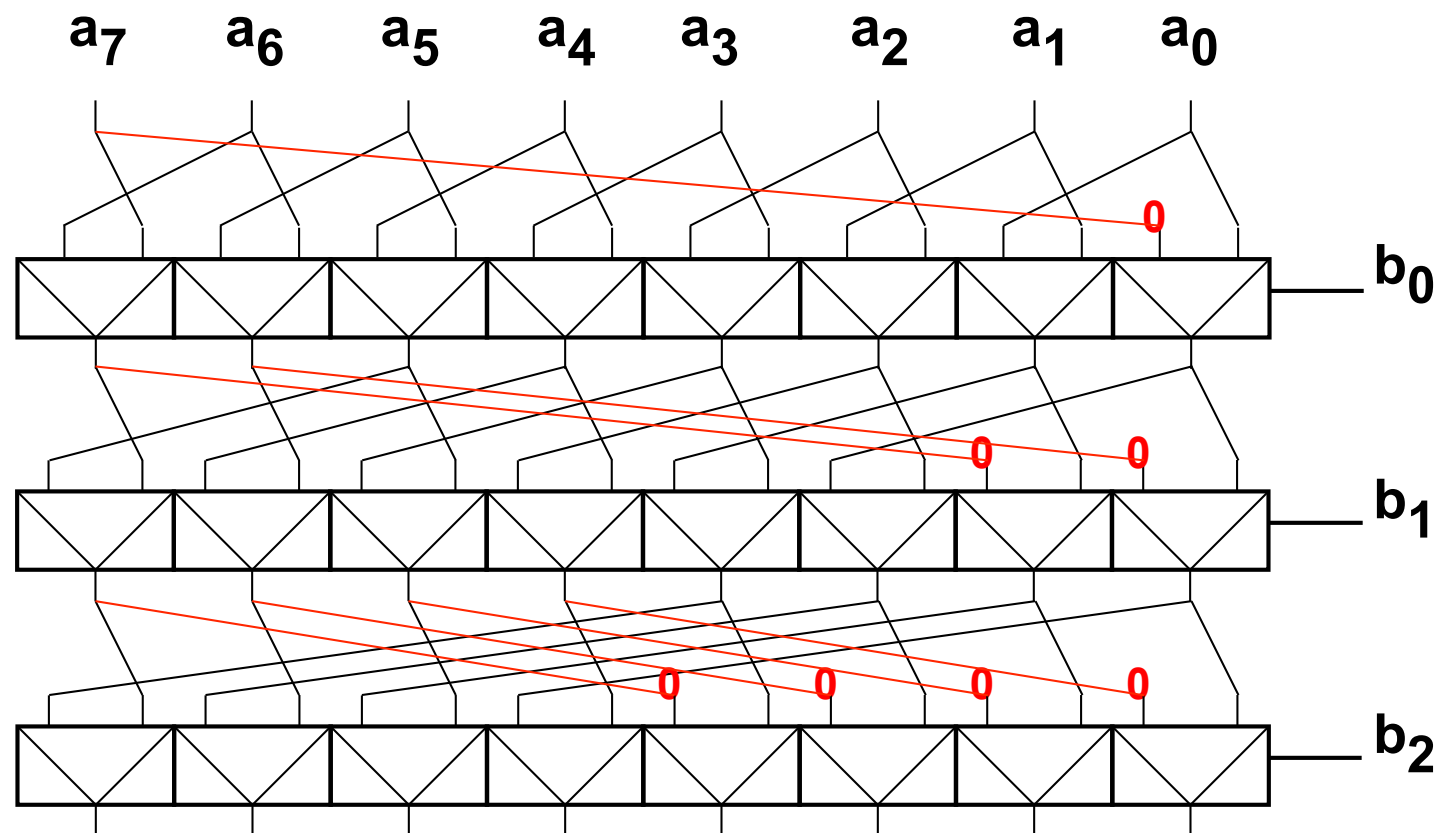
Shifters

Shifting a value to the left



Shifters

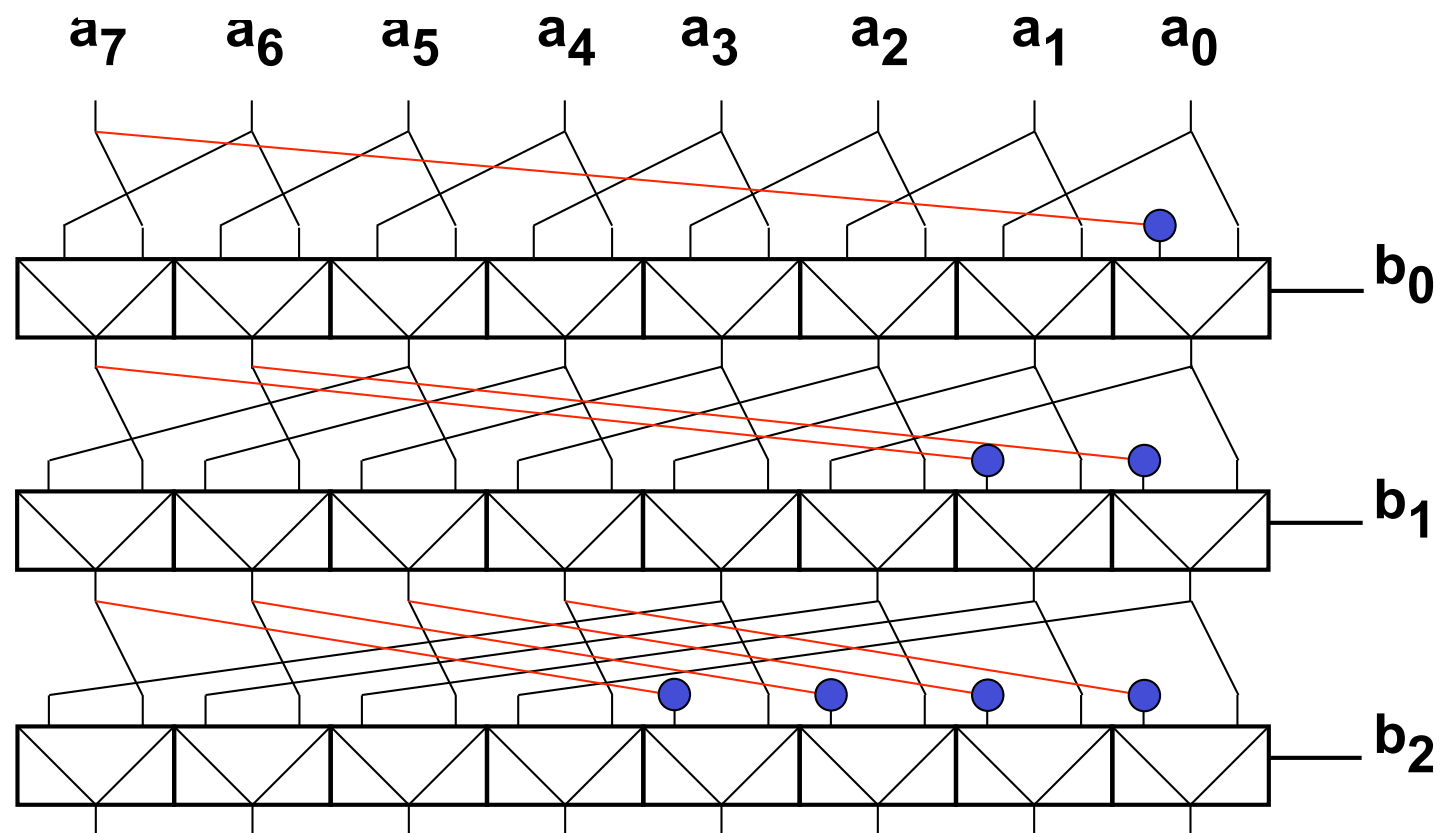
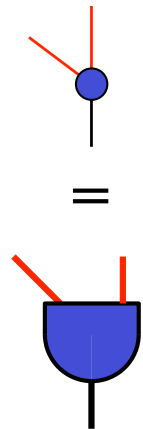
Rotate a value to the left



Shifters

Shift / Rotate a value to the left

shift-left



Shifters

Shifting a value

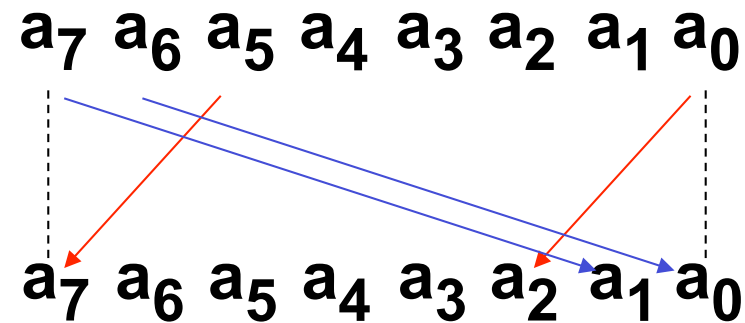
Rotate left by 2

=

Rotate right by 6

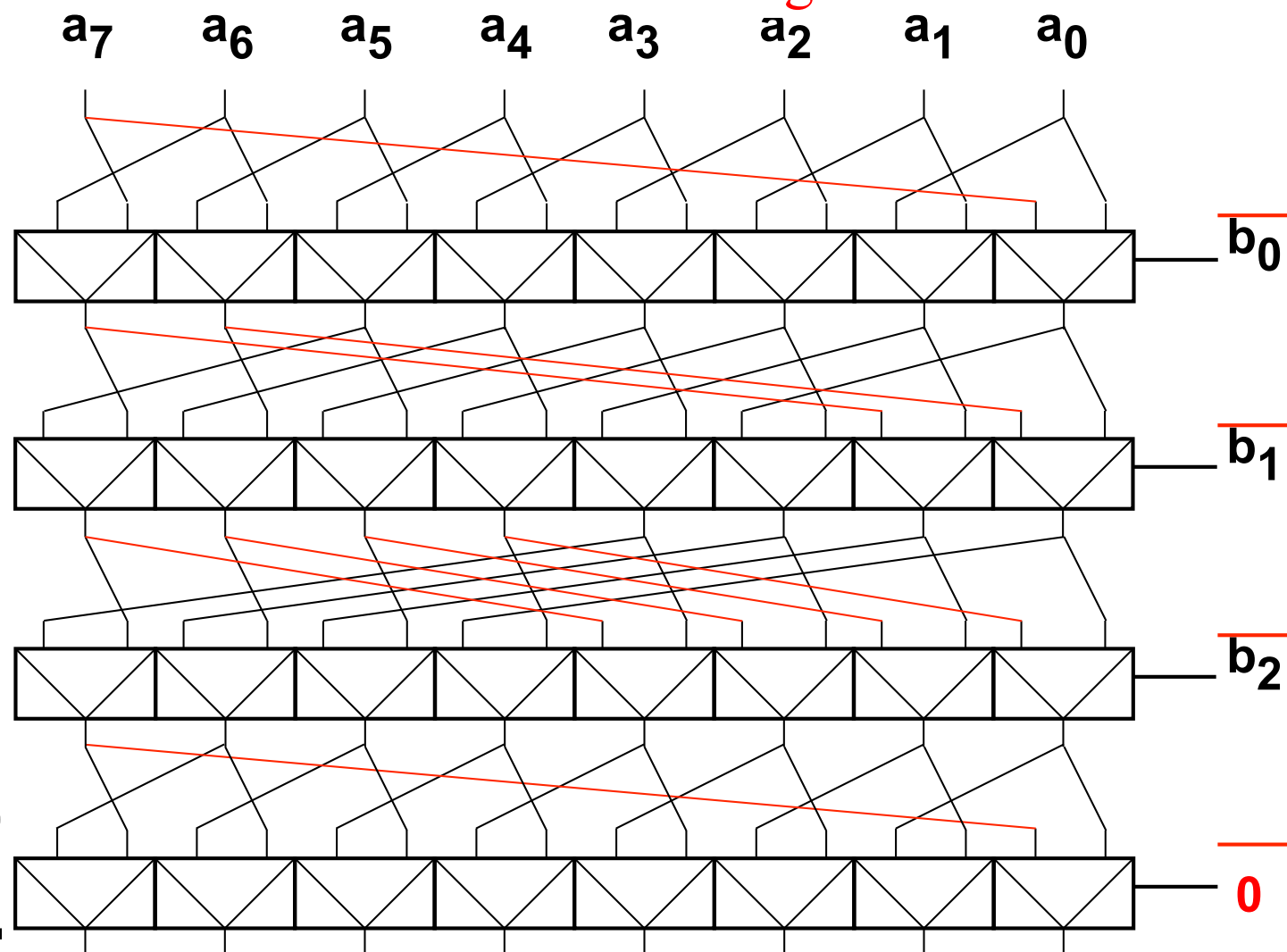
$$6 = -2$$

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



Shifters

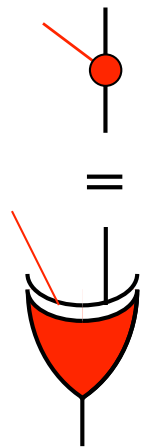
Rotate a value to the **right**



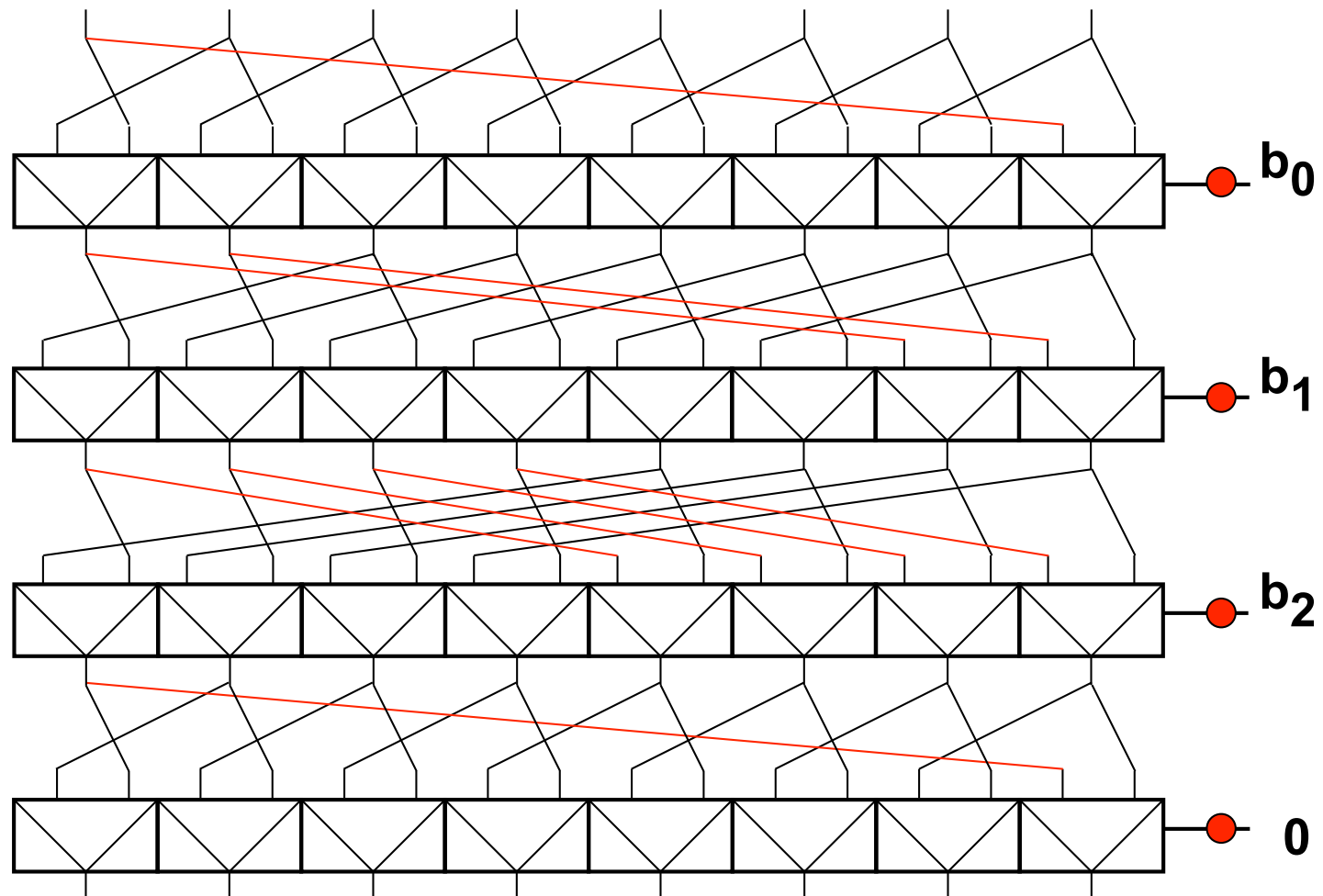
Shifters

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

left

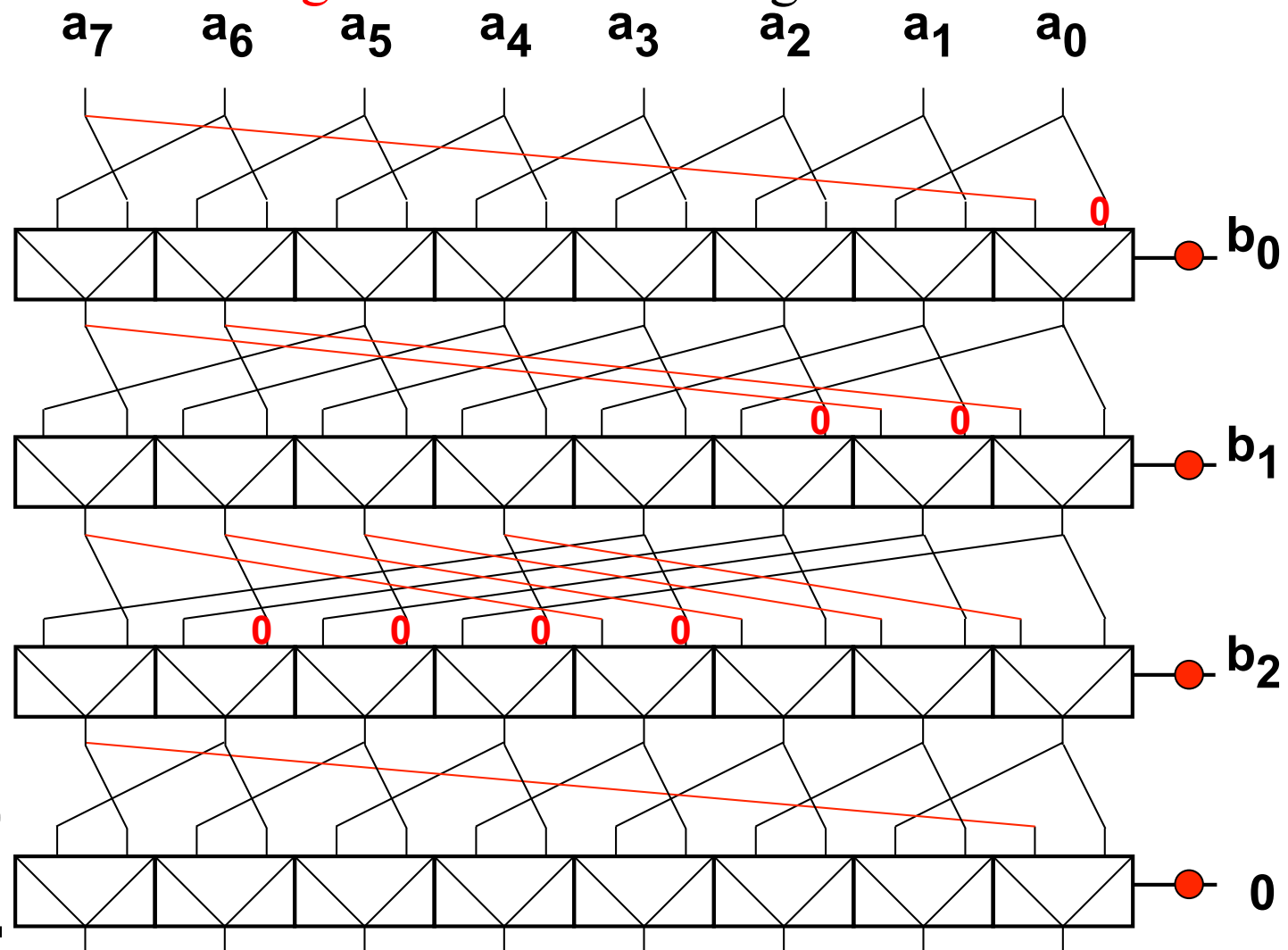


a_7 a_6 a_5 a_4 a_3 a_2 a_1 a_0



Shifters

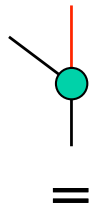
Shift logic a value to the right



Shifters

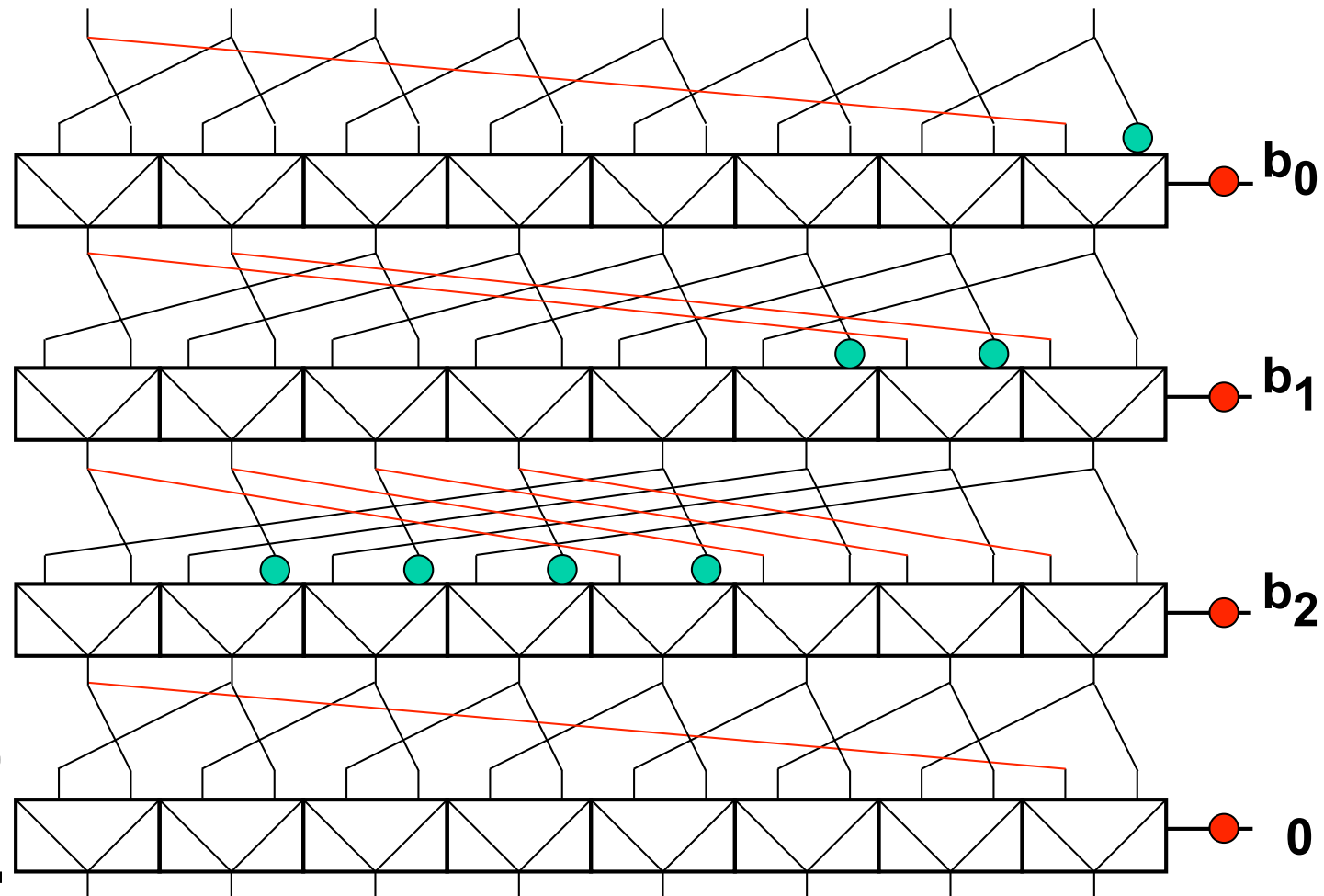
Shift / Rotate a value to the right

a_7 a_6 a_5 a_4 a_3 a_2 a_1 a_0



=

$\text{shift-r-log} \cdot$
 $(\text{shift-r-ari} \cdot a_i$
 $+ \text{shift-r-ari} \cdot$
 $a_7)$



Shifters

Shift / Rotate a value to the left / right

a_7 a_6 a_5 a_4 a_3 a_2 a_1 a_0

