

# Computer Organization and Architecture

## Digital Circuits

**Veena Thenkanidiyoor**  
**National Institute of Technology**  
**Goa**



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## Recap

✓ Design of arithmetic circuit

✓ Adders

- RCA ✓

- CLA ✓

*n-bit adders*

— *Combinational*  
*array techniques*

✓ Multiplier

*Unsigned*

✓ ~~Combinational array multiplier~~

— *Sequential*

— *Gates 32-bit, 64-bit*

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## Digital Circuits

- **Combinational circuits:**

- Circuits in which the outputs are entirely determined by its current inputs

- **Sequential circuits:**

- Circuits where the output depends on both the present and sequence of previous inputs
- The information regarding the past information need to be stored
- Information storage is performed by memory elements
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- Driven by a clock

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## Combinational Circuits

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## Full Adder



$x$	$y$	$C_{in}$	$C_{out}$	$S$
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

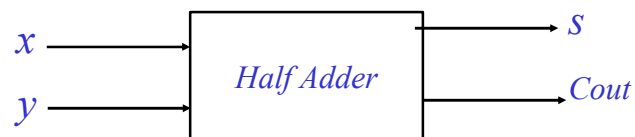
$$S_i = \bar{x}_i \bar{y}_i C_i + \bar{x}_i y_i \bar{C}_i + x_i \bar{y}_i \bar{C}_i + x_i y_i C_i$$

$$C_{out} = y_i C_{in} + x_i C_{in} + x_i y_i$$

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## Half Adder



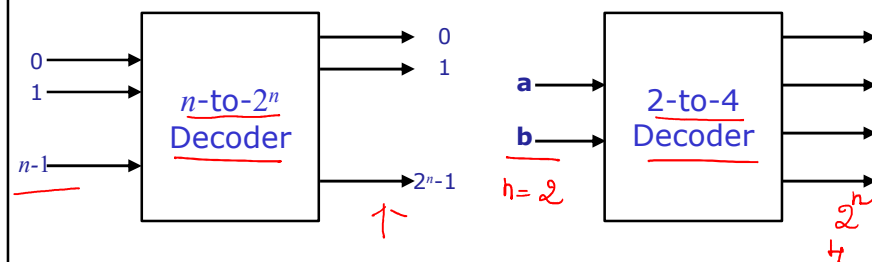
$x$	$y$	$S$	$C_{out}$
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

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## Decoder

- Circuit that takes an  $n$ -bit number as input and uses it to select exactly one of the  $2^n$  output lines



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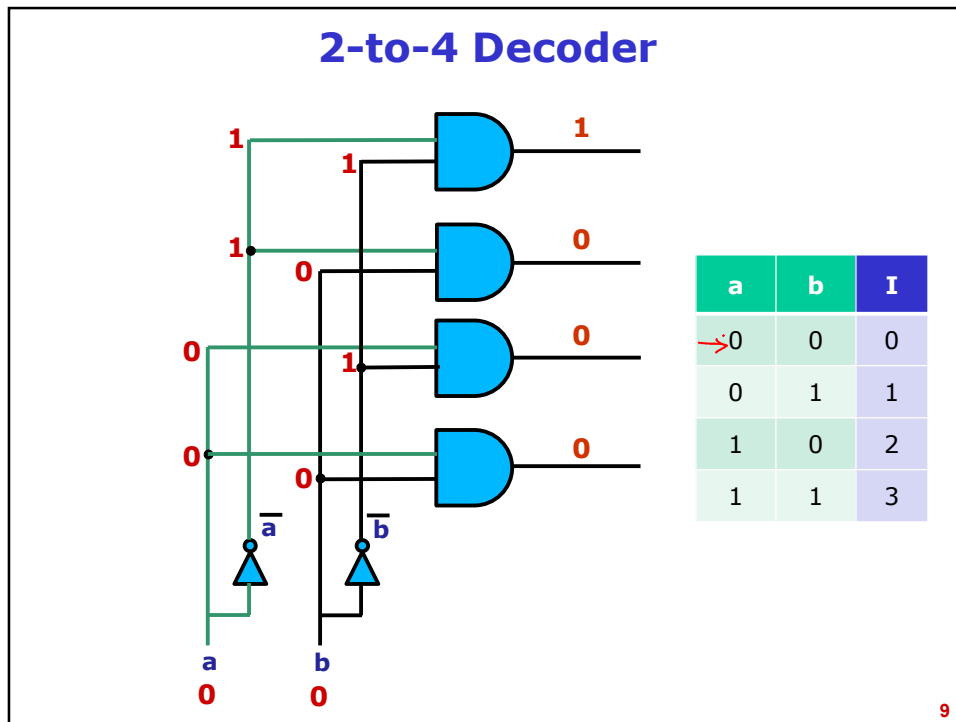
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## 2-to-4 Decoder

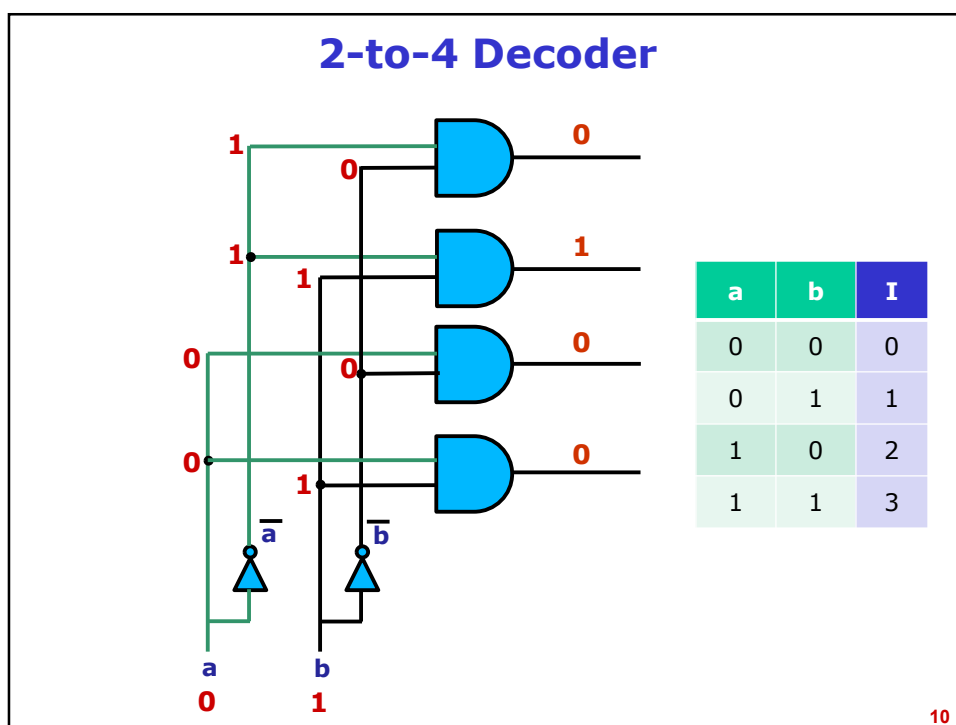
	<u>a</u>	<u>b</u>	<del>I</del>
→ 0	0	0	0 ✓
→ 0	0	1	1 ✓
→ 1	1	0	2 ✓
→ 1	1	1	3 ✓

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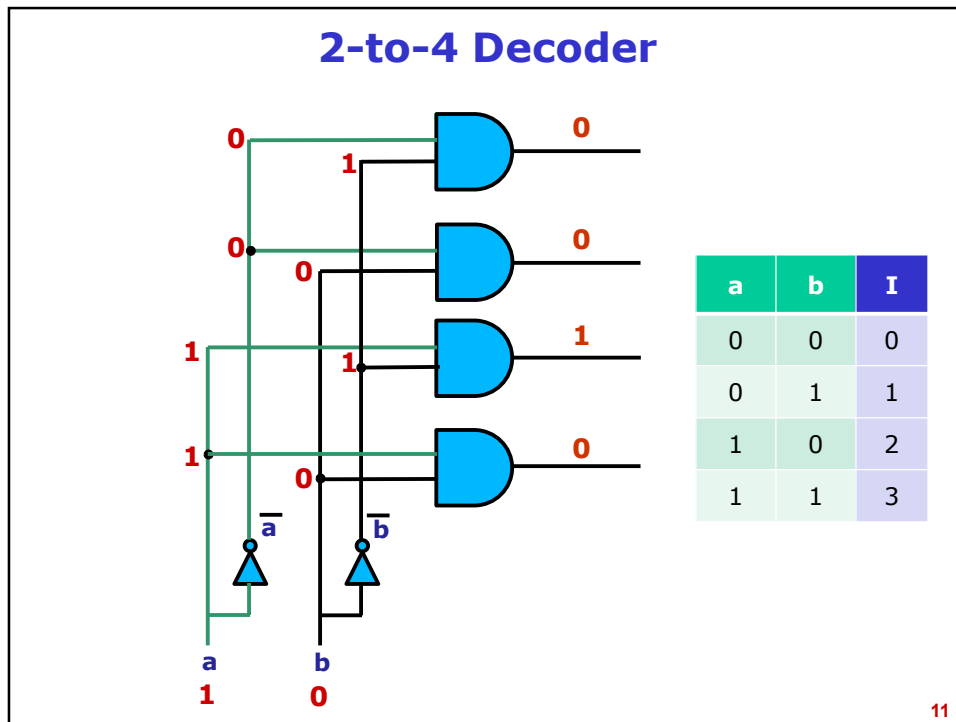
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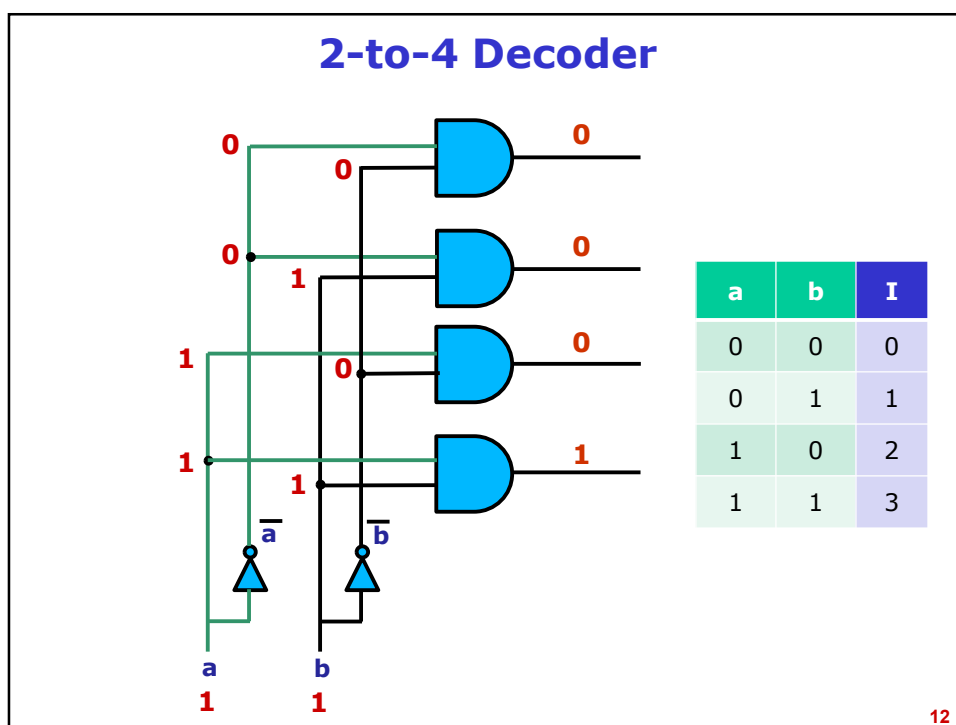
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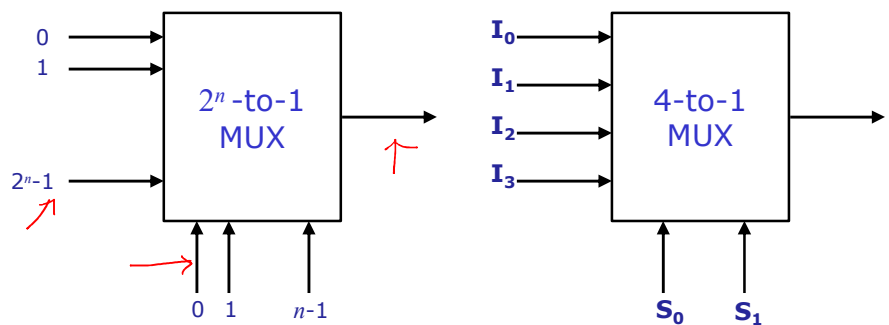
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## Multiplexers

- ✓ Multiplexer is a circuit with  $2^n$  data inputs and one data output and  $n$  control lines to select one of the data inputs
- The selected input is gated (i.e. routed) to the output



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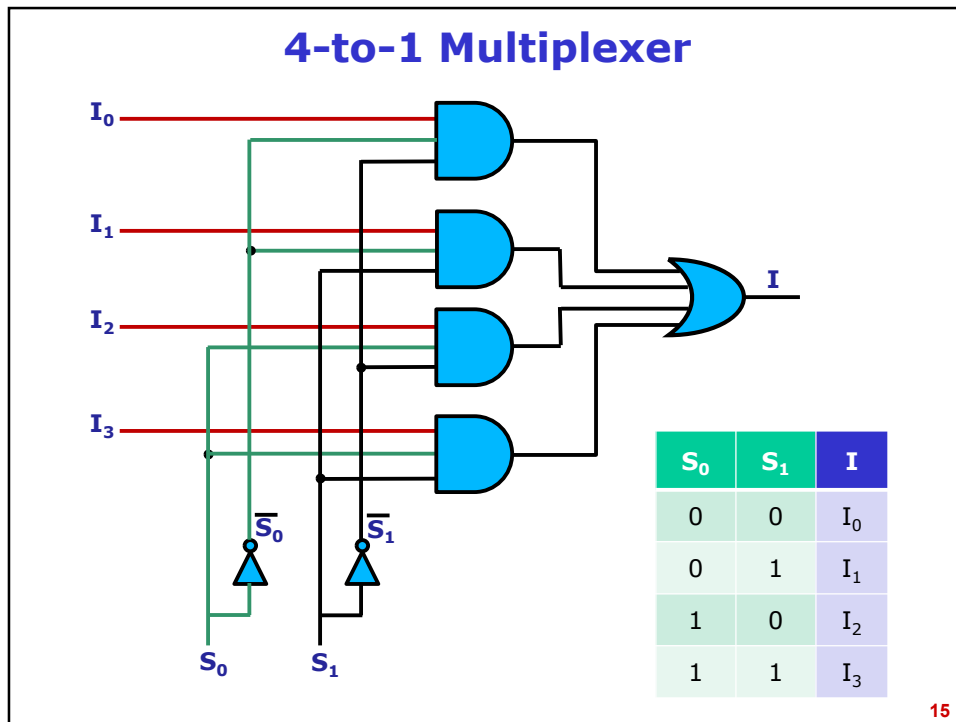
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## 4-to-1 Multiplexer

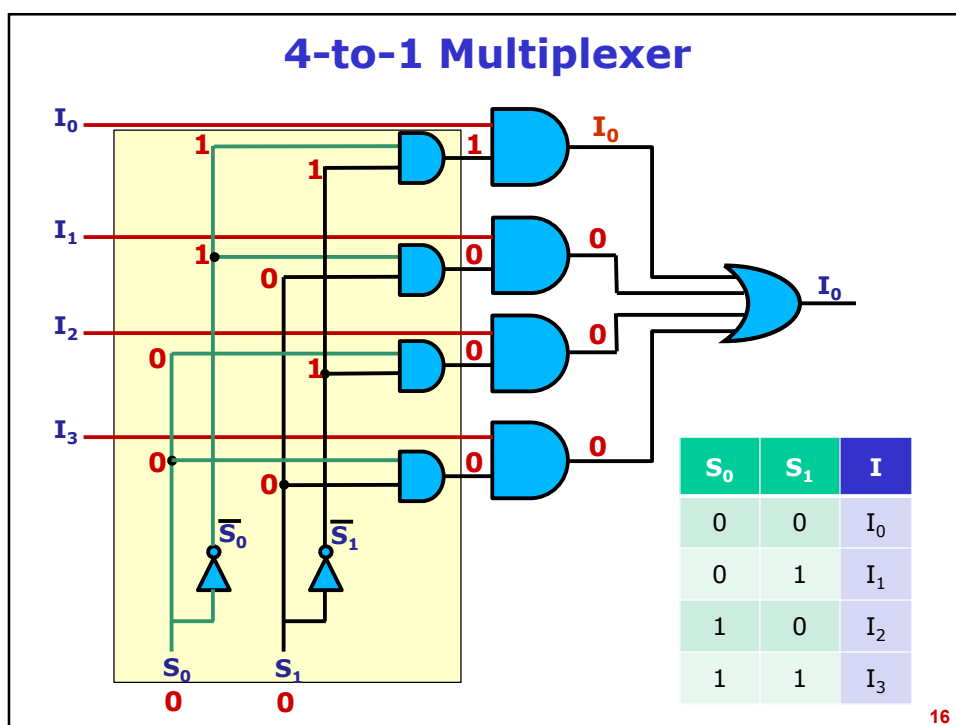
$S_0$	$S_1$	$I$
0	0	$I_0$
0	1	$I_1$
1	0	$I_2$
1	1	$I_3$

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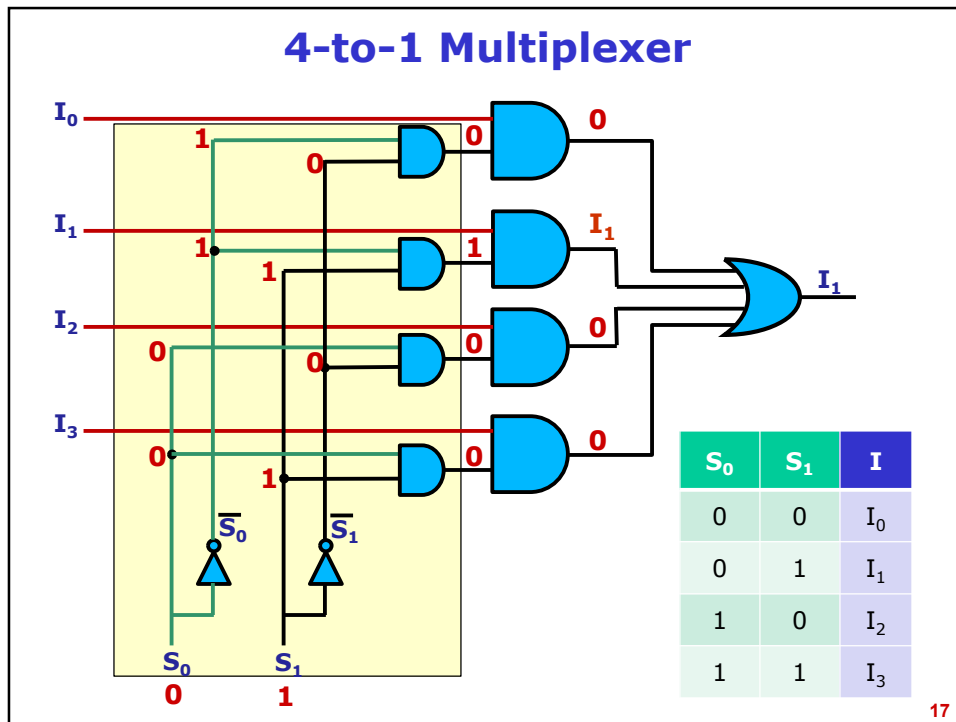


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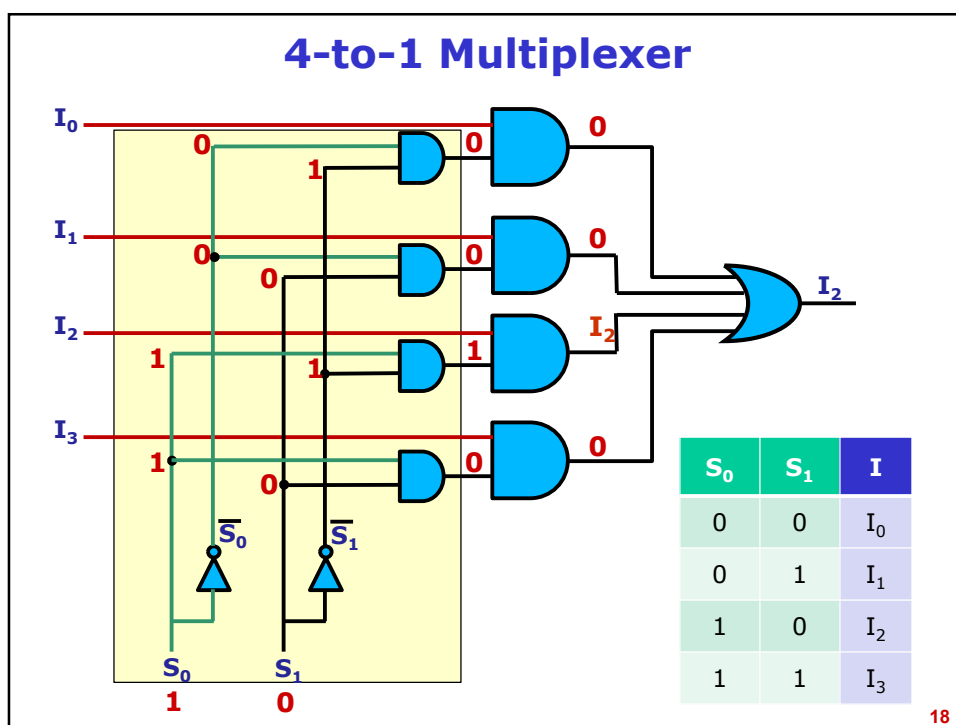


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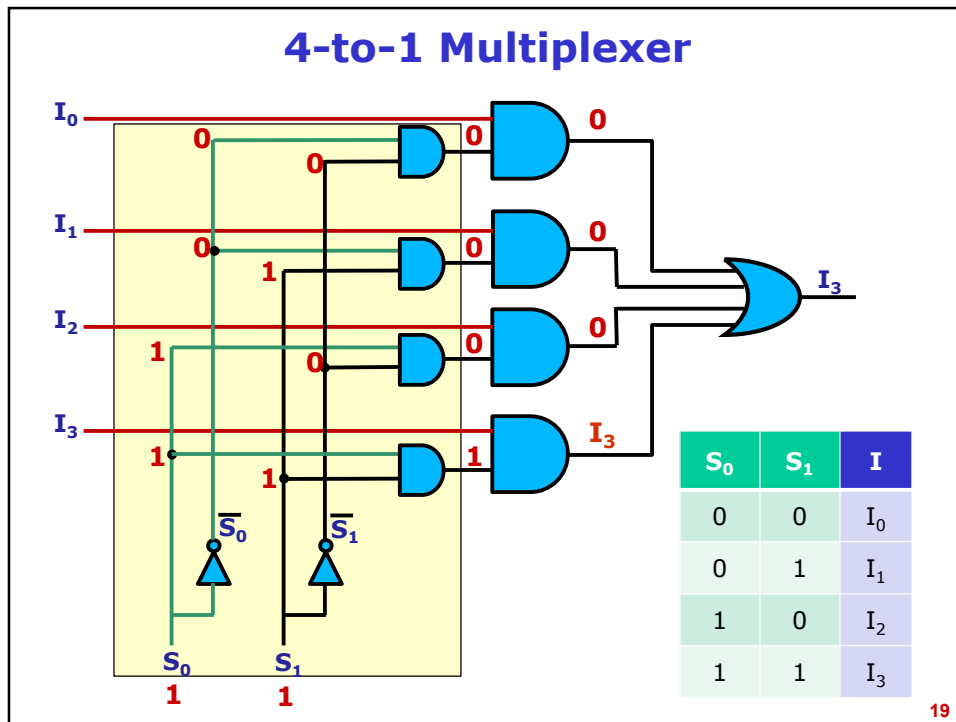




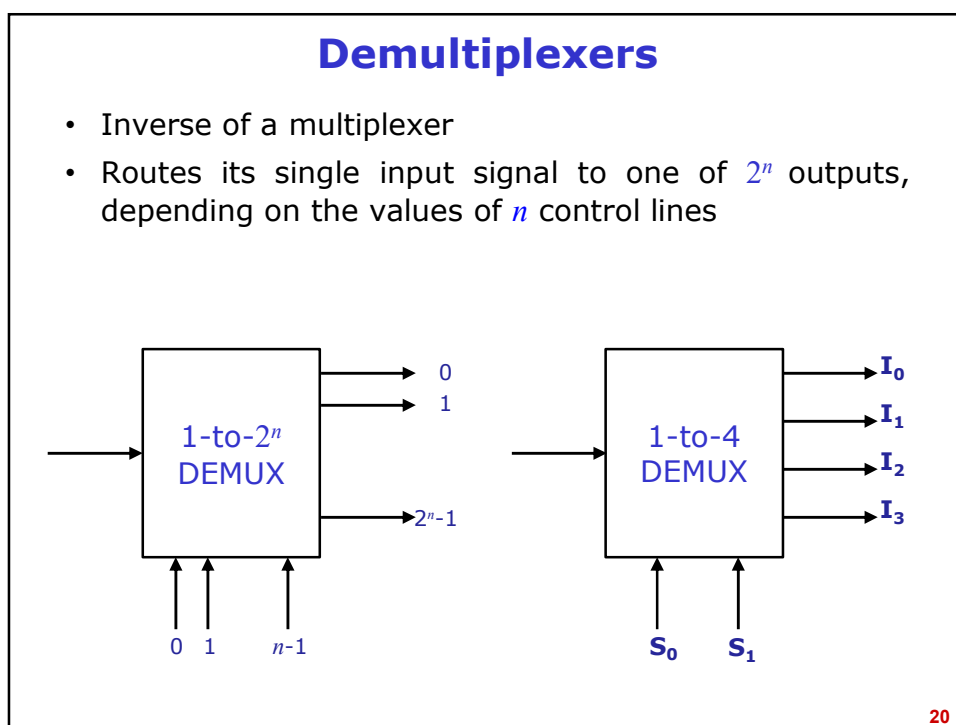
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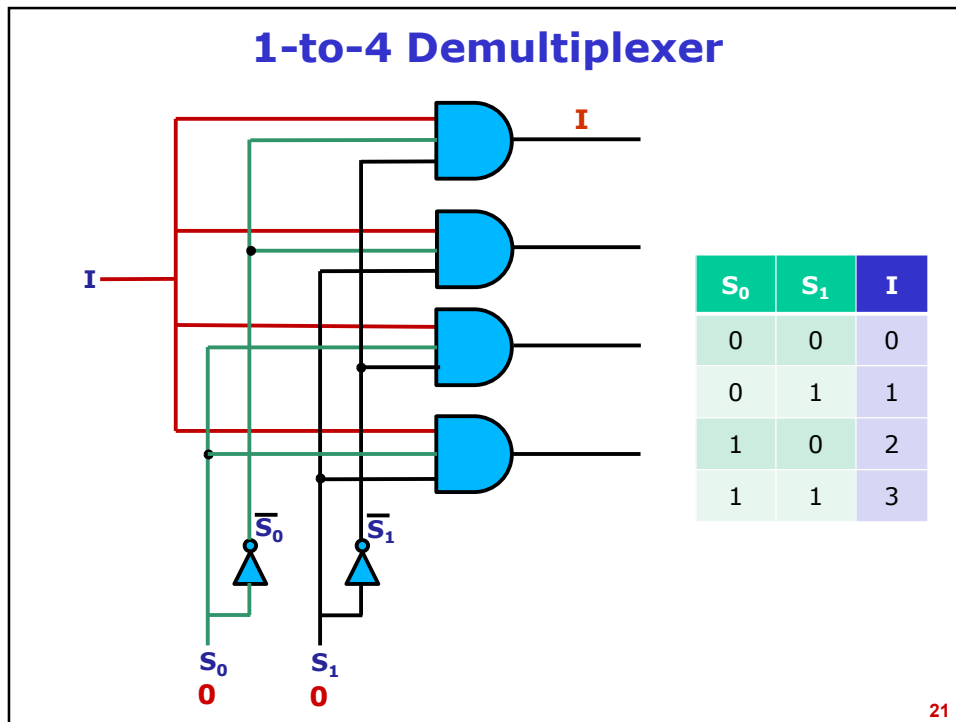
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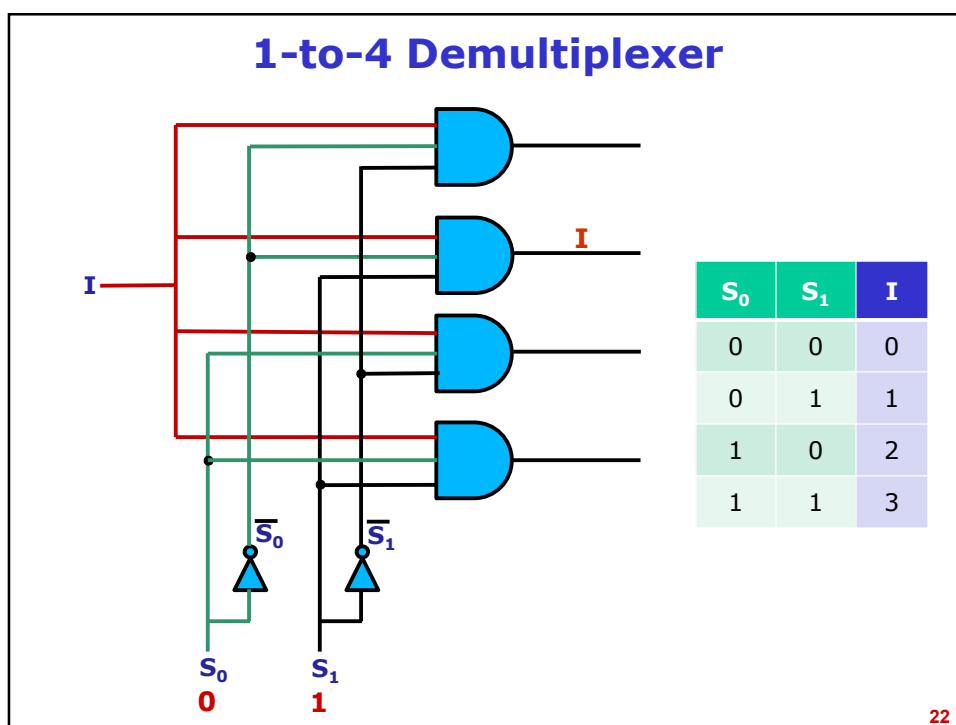
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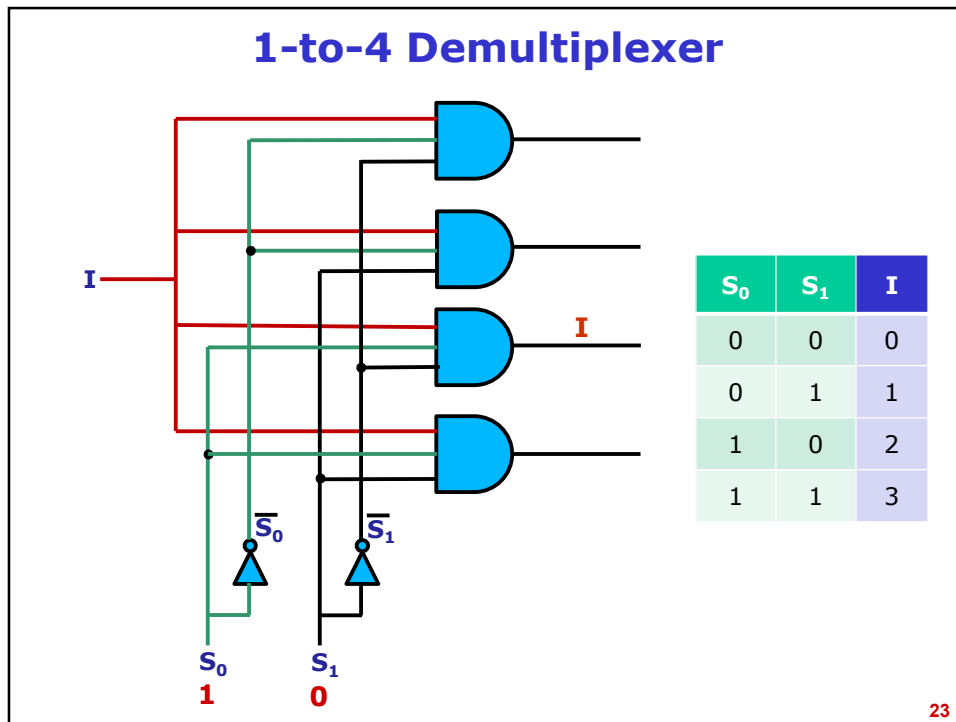
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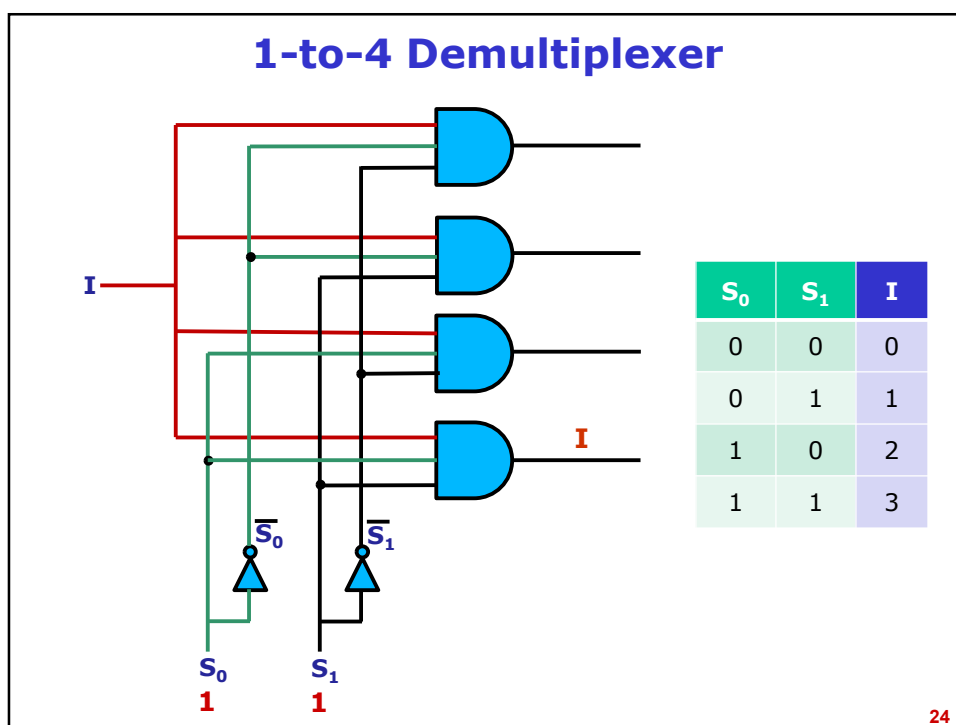
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## Comparator

- ✓ Compares two input words
- ✓ Produces 1 if they are equal and 0 if they are not

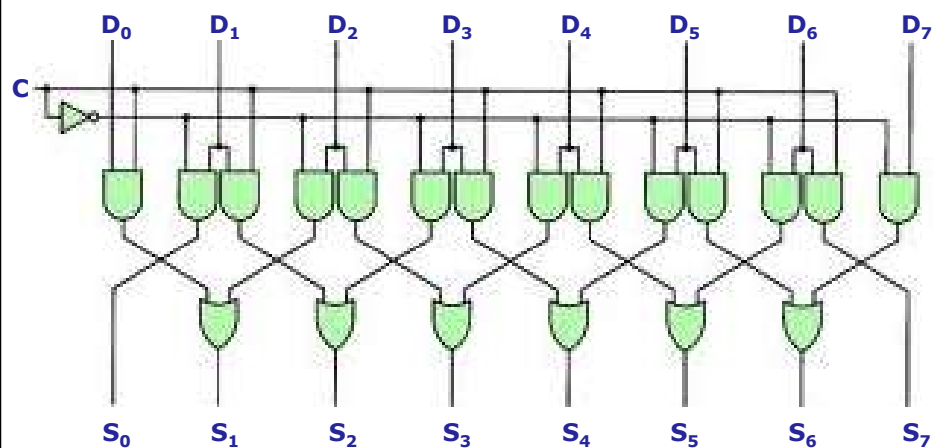
## Shifter

- ✓ Circuit that shifts the bits 1 bit left or right
- **Example:**
  - ✓ 8-bit shifter that shifts one bit left or right
  - It contain
    - ✓ 8-bit input line
    - ✓ 8-bit output line
    - One control line, C
      - It determine the direction of shift
      - ✓ C=0: shift left
      - ✓ C=1: shift right ←

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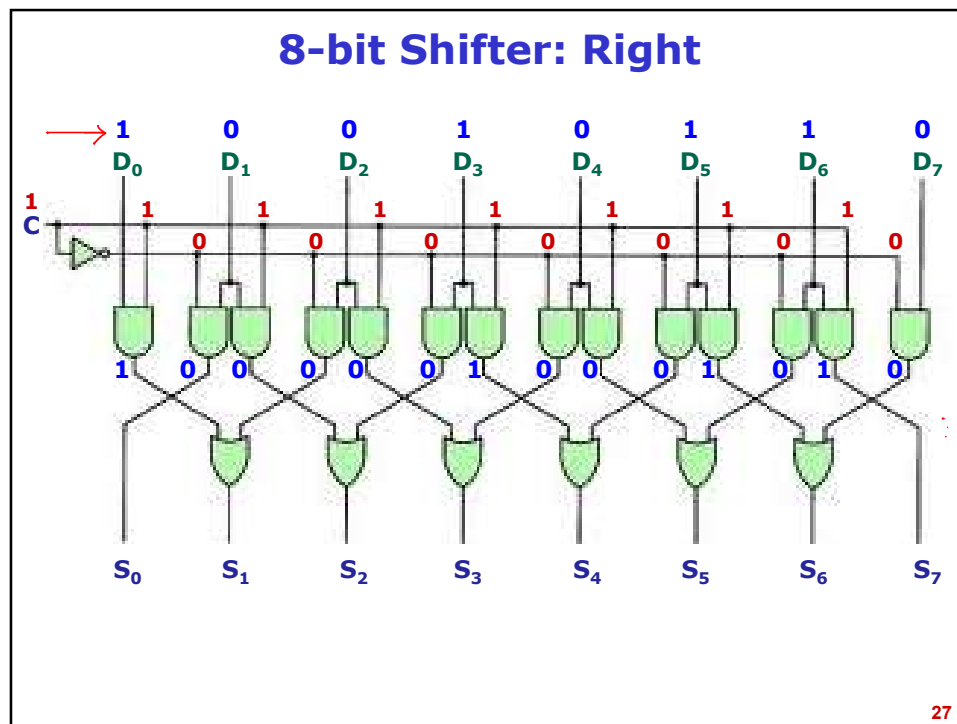
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## 8-bit Shifter

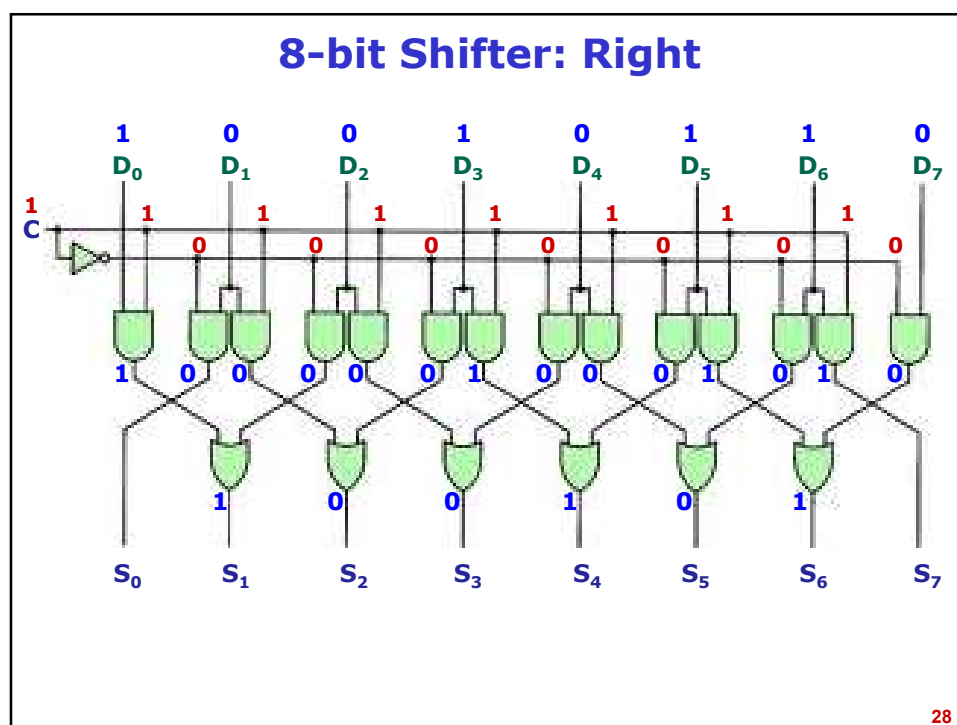


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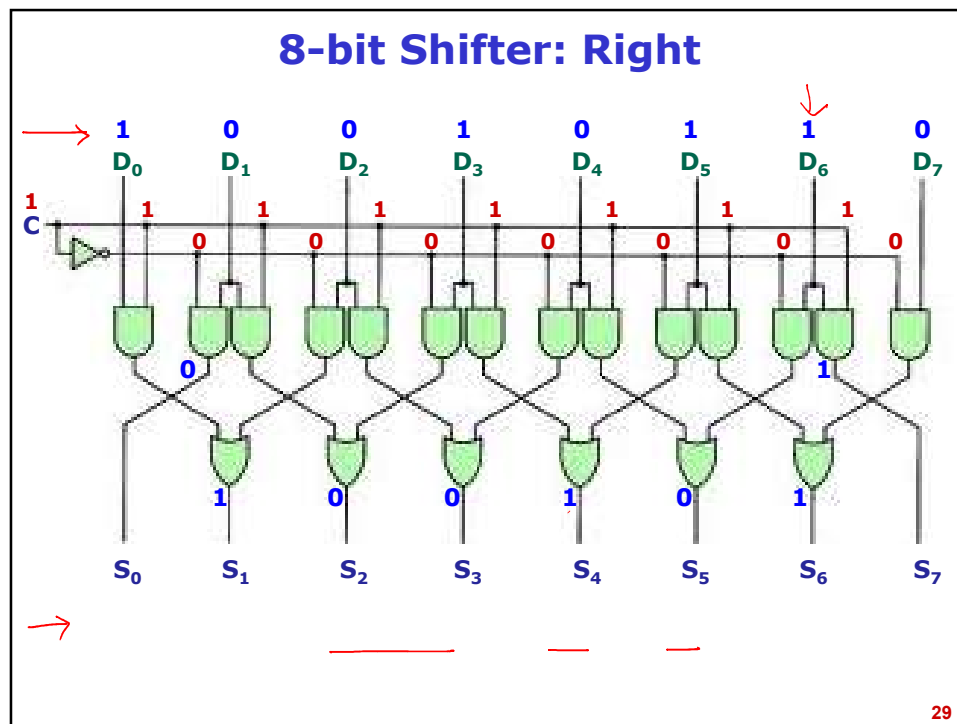
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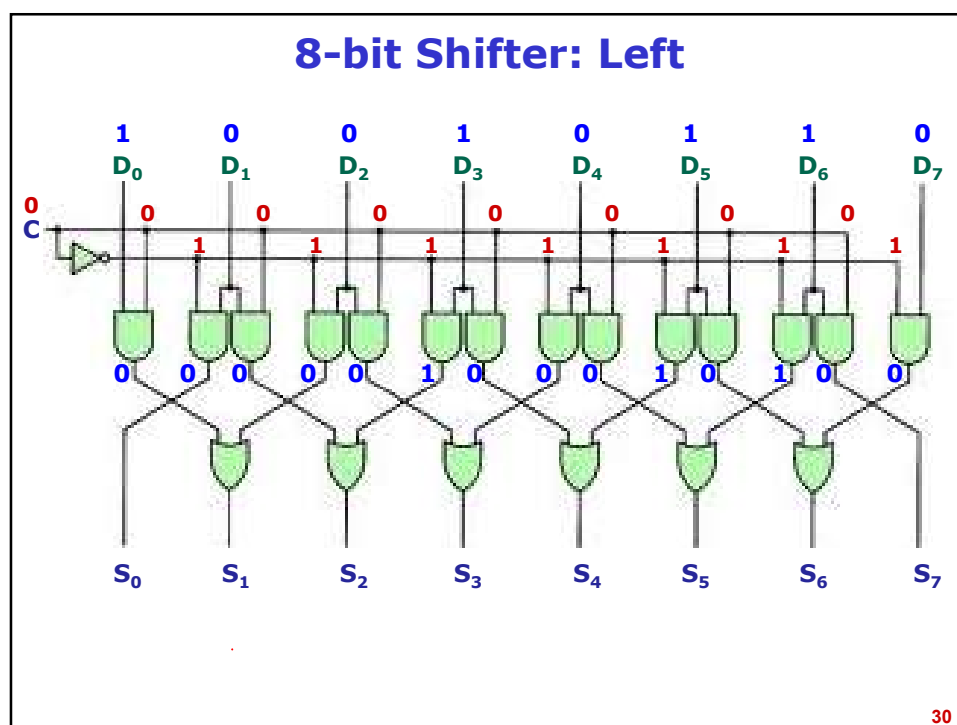
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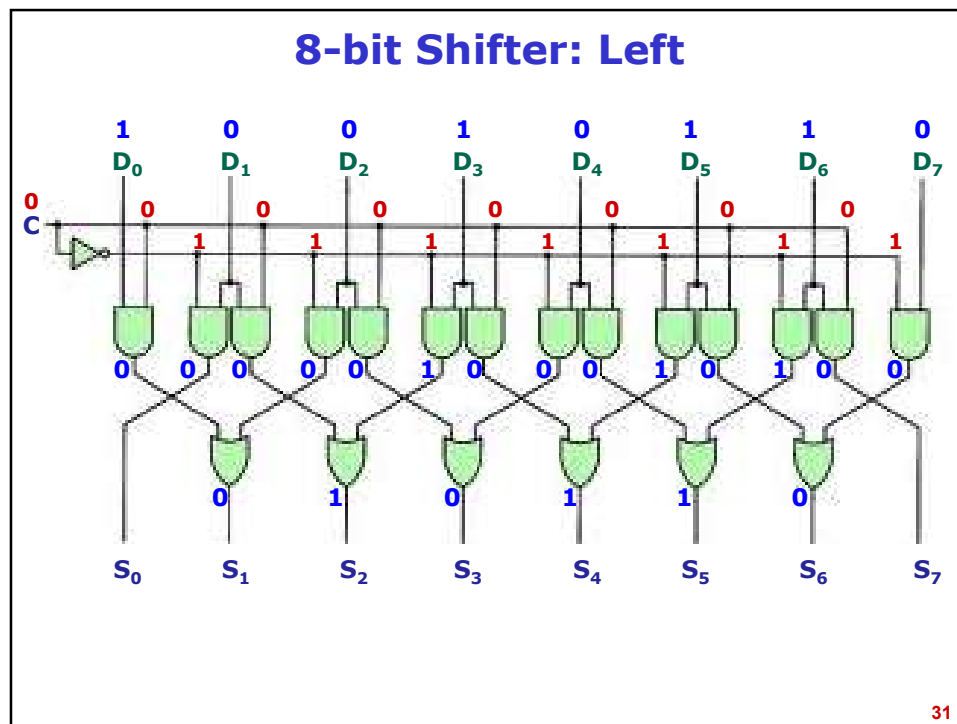
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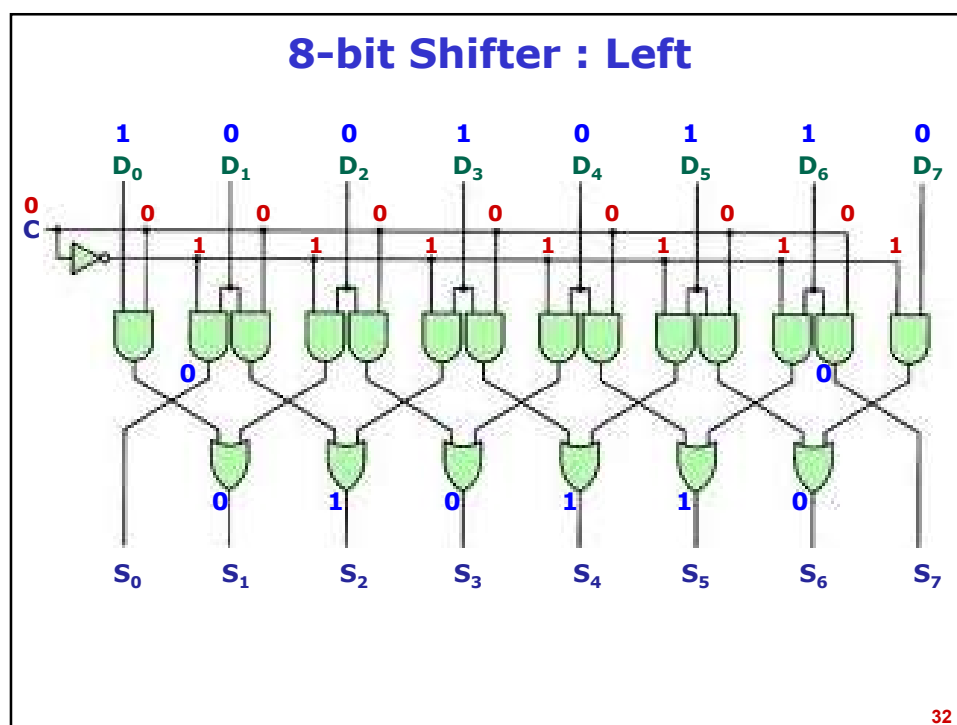
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# Sequential Circuits

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- – **Driven by a clock**
- ✓ – **Flip-flops**

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## Reference

- ~~Carl Hamacher, Zvonko Vranesic and Safwat Zaky, "Computer Organization", 5<sup>th</sup> Edition, Tata McGraw Hill, 2002~~

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## Thank You

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