Integrated Circuits

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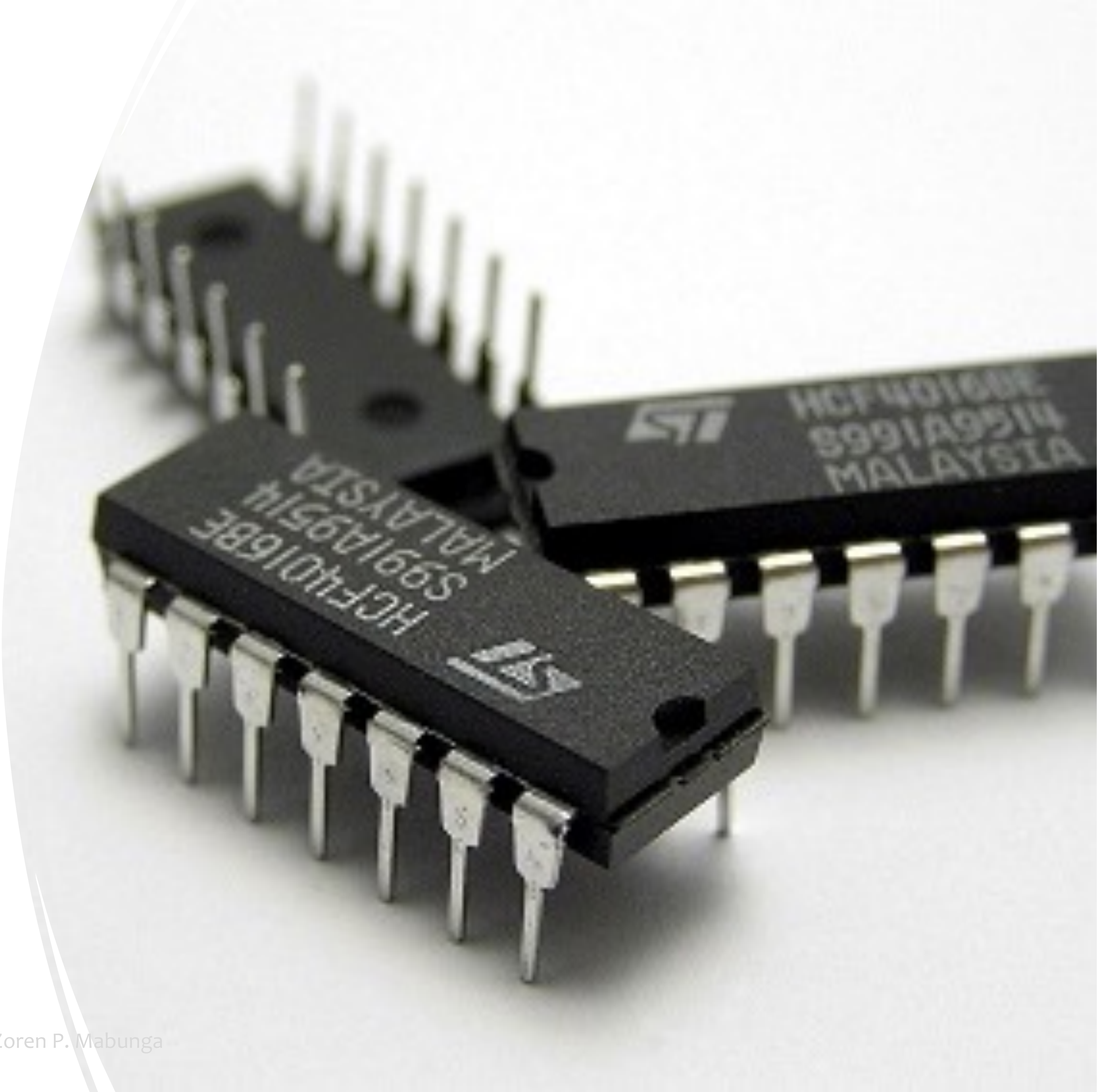
Digital ICs

- Digital ICs are a collection of resistors, diodes, and transistors fabricated on a single piece of semiconductor material called a substrate, commonly referred to as a chip.



Digital IC types

Complexity (Level of Integration)	Number of Gates
Small-scale integration(SSI)	<10
Medium-scale integration(MSI)	10 to 99
Large-scale integration(LSI)	100 to 9999
Very large-scale integration(VLSI)	10,000 to 99,999
Ultra large-scale integration(ULSI)	100,000 to 999,999
Giga-scale integration (GSI)	1,000,000 or more

Bipolar and Unipolar Digital ICs

- Categorized according to the principal type of electronic component used in their circuitry.
- Bipolar ICs are those that are made using the bipolar junction transistor (PNP or NPN)
- Unipolar ICs are those that use the unipolar field-effect transistors (P-channel and N-channel MOSFETs).

Digital IC Families

1. TTL – a logic family that has been use for a long time
   - common in SSI and MSI chips
2. ECL - has an advantage in systems requiring high speed of operation
3. MOS – suitable for circuits with high component density
4. CMOS – preferable in systems requiring low power consumption
5. DTL - obselete

TTL Family

TTL Series	Prefix	Example IC
Standard TTL	74	7404 (hex inverter)
Schottky TTL	74S	74S04
Low-power Schottky TTL	74LS	74LS04
Advanced Schottky TTL	74AS	74AS04
Advanced low-power Schottky TTL	74ALS	74ALS04

CMOS Family

CMOS Series	Prefix	Example IC
Metal-gate CMOS	40	4001
Metal-gate, pin-compatible with TTL	74C	74C02
Silicon-gate, pin-compatible with TTL, high-speed	74HC	74HC02
Silicon-gate, high-speed, pin-compatible and electrically compatible with TTL	74HCT	74HCT02
Advanced-performance CMOS, not pin or electrically compatible with TTL	74AC	74AC02
Advanced-performance CMOS, not pin but electrically compatible with TTL	74ACT	74ACT02

Power and Ground

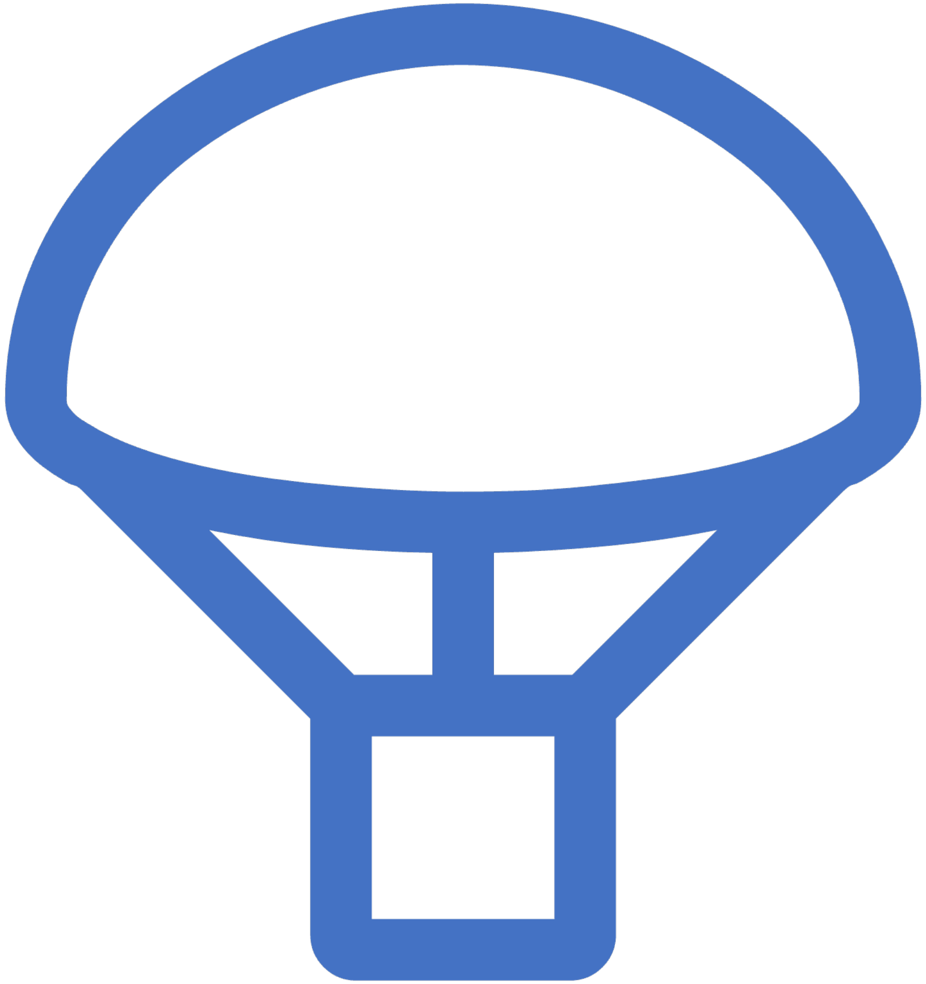
- To use digital IC, it is necessary to make proper connection to the IC pins.
- Power: labeled V_{cc} for the TTL circuit, labeled V_{DD} for CMOS circuit.
- Ground

Logic-level Voltage Ranges

- For TTL devices, V_{CC} is normally 5V.
- For CMOS circuits, V_{DD} can range from 3-18V.
- For TTL, logic 0 : 0-0.8V, logic 1:2-5V
- For CMOS, logic 0 : 0-1.5V, logic 1:3.5-5V

Unconnected Inputs

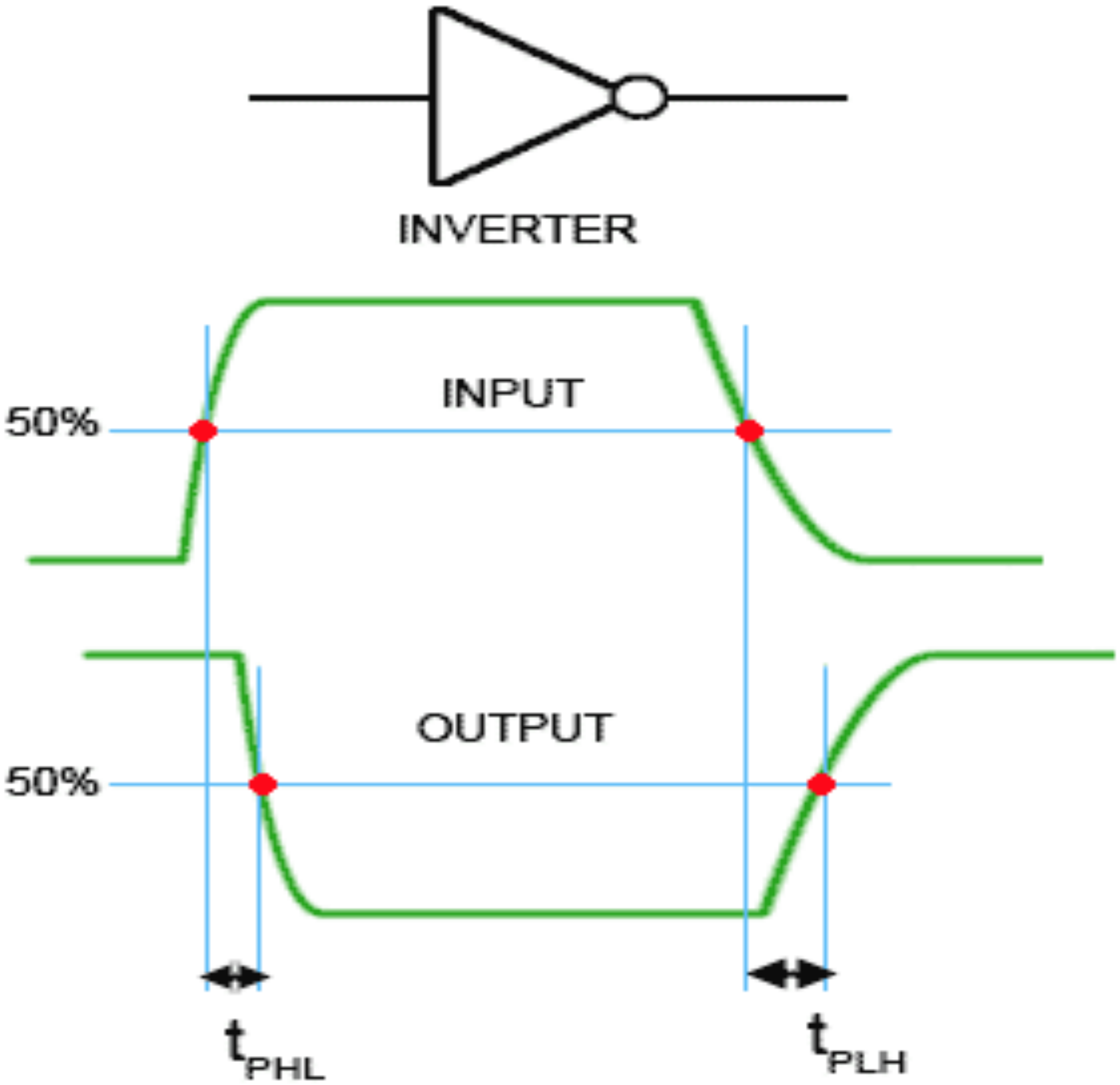
- Also called floating inputs.
- A floating TTL input acts like a logic 1.
- A CMOS input cannot be left floating.

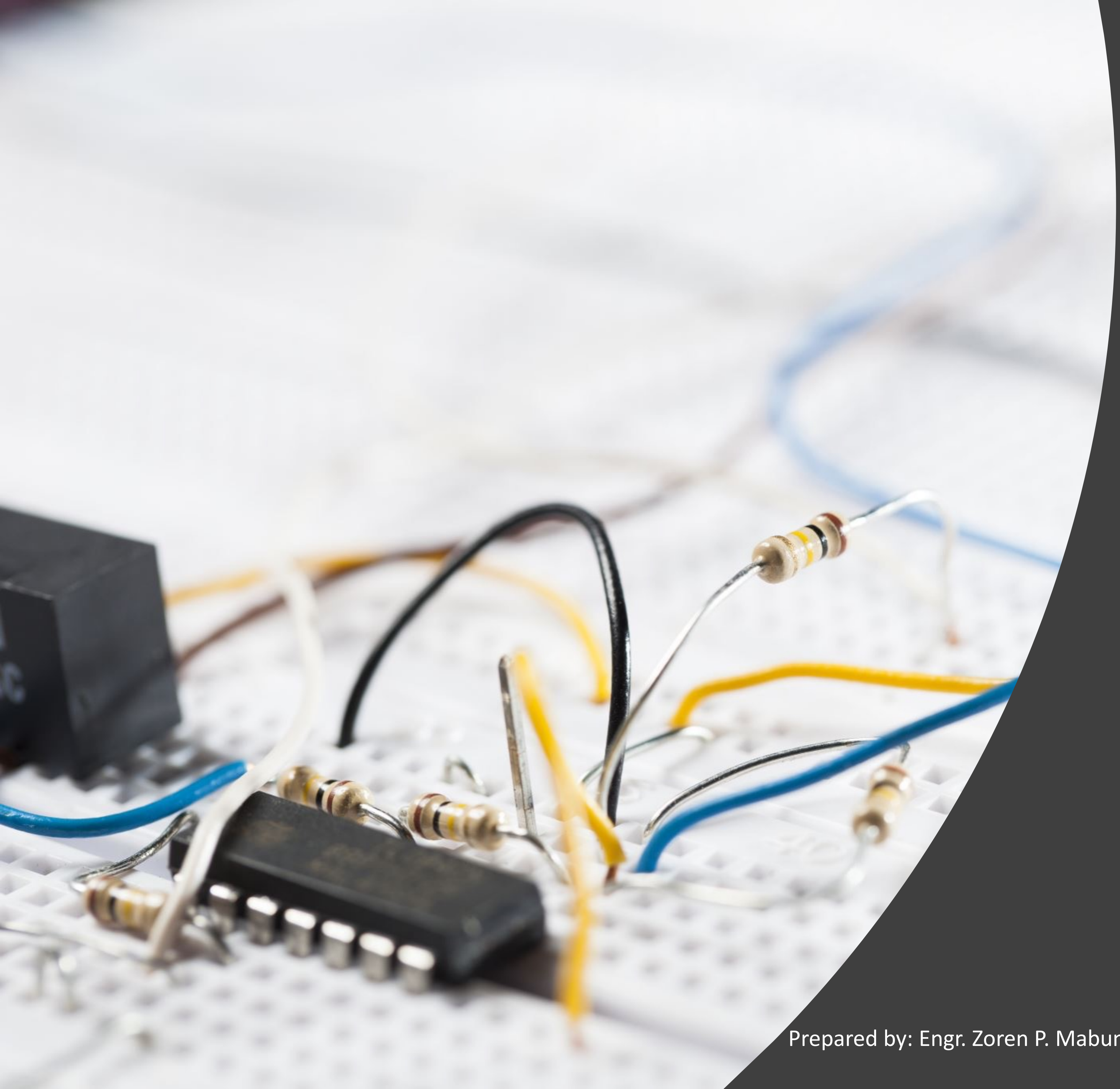


Important Parameters

1. **Fan-in** – the number of inputs available on a gate
2. **Fan-out** – the number of standard loads driven by a gate output
3. **Noise Margin** – maximum extent noise voltage added to an input signal that does not cause an undesirable change in the circuit output.
4. **Propagation Delay** – The time required for a change in the value of a signal to propagate from an input to an output
5. **Power Dissipation** – the amount of power drawn from the power supply and consumed by the gate

Propagation Delay Illustration





Combinational Logic Circuits

Prepared by: Engr. Zoren P. Mabunga

Combinational Logic Circuits

- A **combinational logic circuit** is consists of input variables, logic gates and output variables.
- This type of logic circuit reacts to values of the signals at their inputs and produce the output signal.

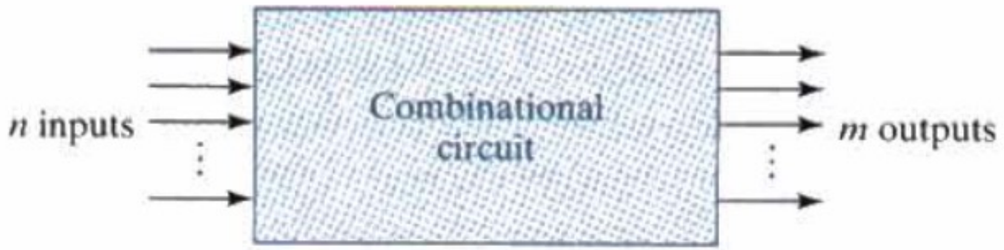


FIGURE 4.1
Block diagram of combinational circuit

Half-Adder

- This circuit needs two binary inputs and two binary outputs.
- The input variables designate the augend and addend bits
- The output variables produce the sum and carry

Table 4.3
Half Adder

x	y	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

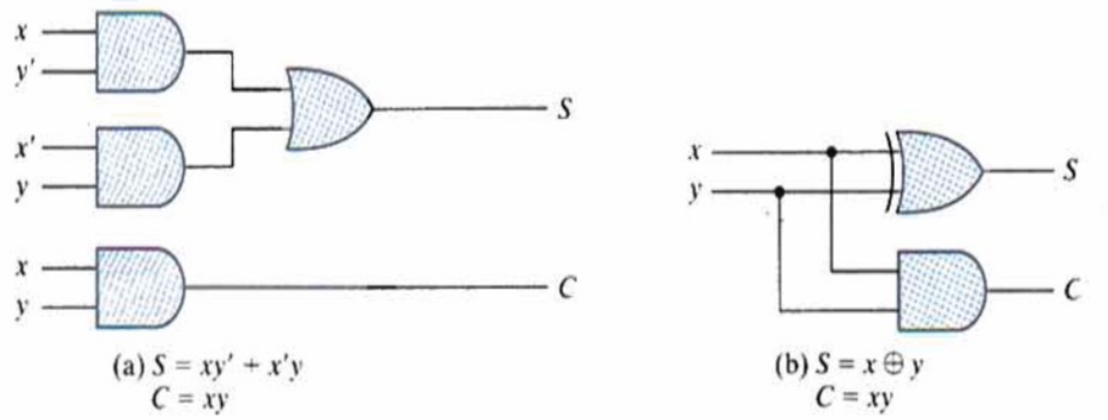


FIGURE 4.5
Implementation of half adder

Full Adder

- A full adder is a combinational logic circuit that performs the arithmetic sum of 3 bits.

Table 4.4
Full Adder

x	y	z	C	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

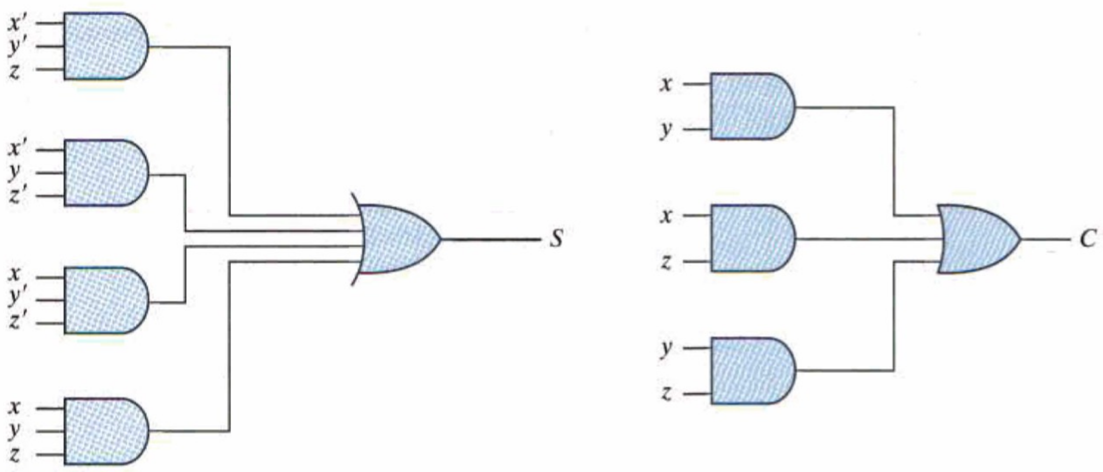


FIGURE 4.7
Implementation of full adder in sum-of-products form

Binary Adder

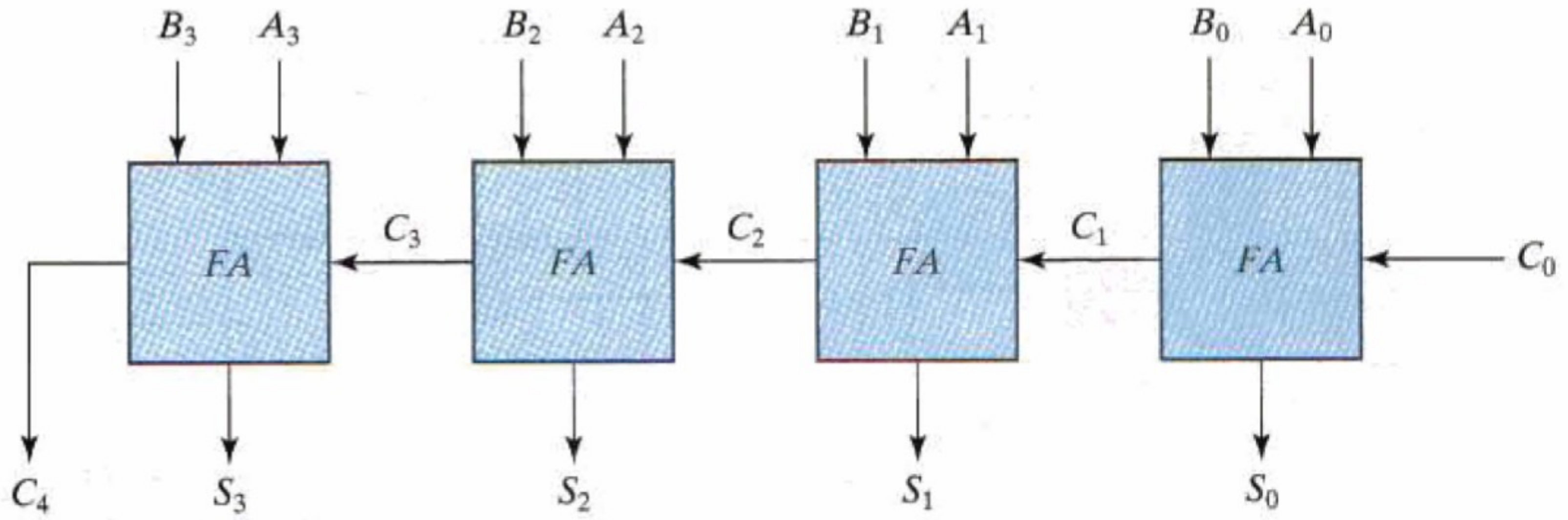
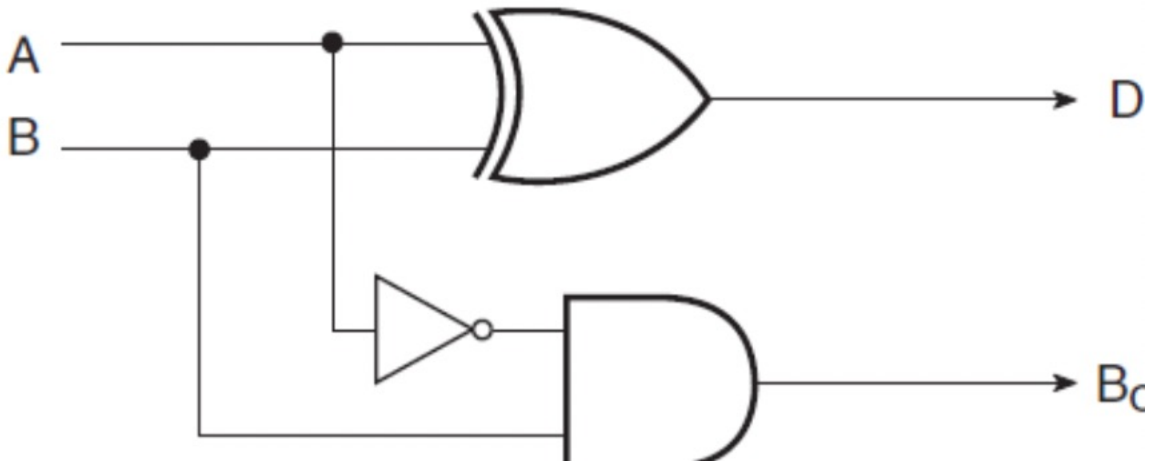


FIGURE 4.9
Four-bit adder

Half Subtractor

- A half subtractor is a combinational logic circuit intended to subtract two single bits and generate two outputs (borrow and difference).

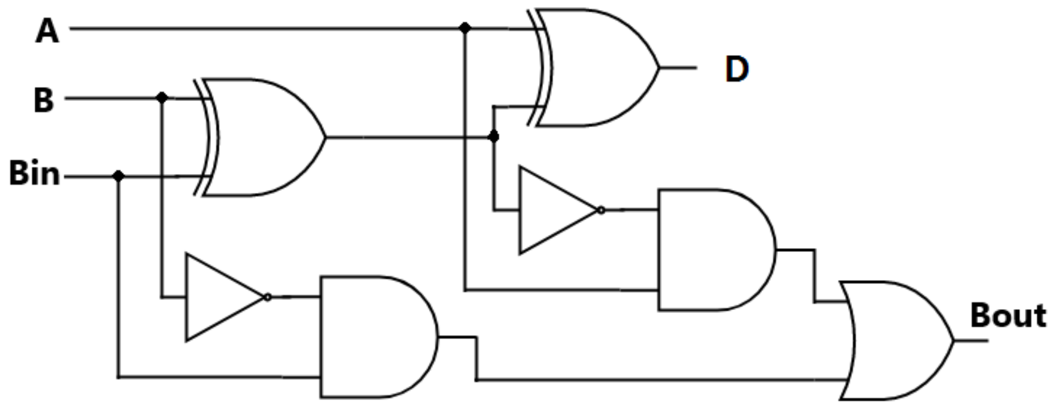
Inputs		Outputs	
A	B	Diff	Borrow
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0



Full Subtractor

- A full subtractor is a combinational logic circuit that delivers the subtraction of two bits, one is minuend, and the other is subtrahend considering the borrow of the earlier adjacent lower minuend bit.

Inputs			Outputs	
A	B	$Borrow_{in}$	Diff	Borrow
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1



Decoders

- A **decoder** is a combinational circuit that converts binary information from *n* input lines to a maximum of 2^n unique output lines.

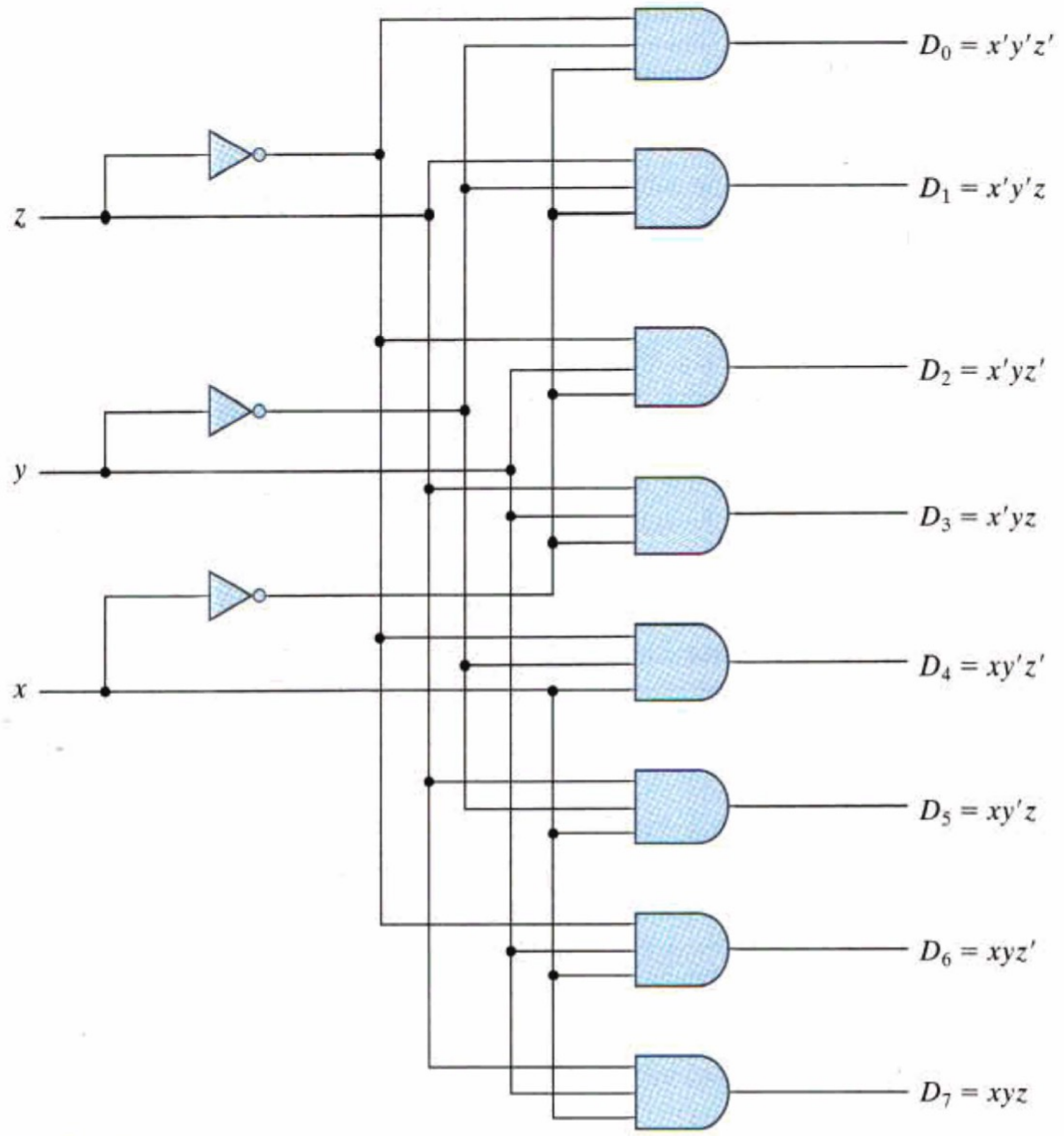
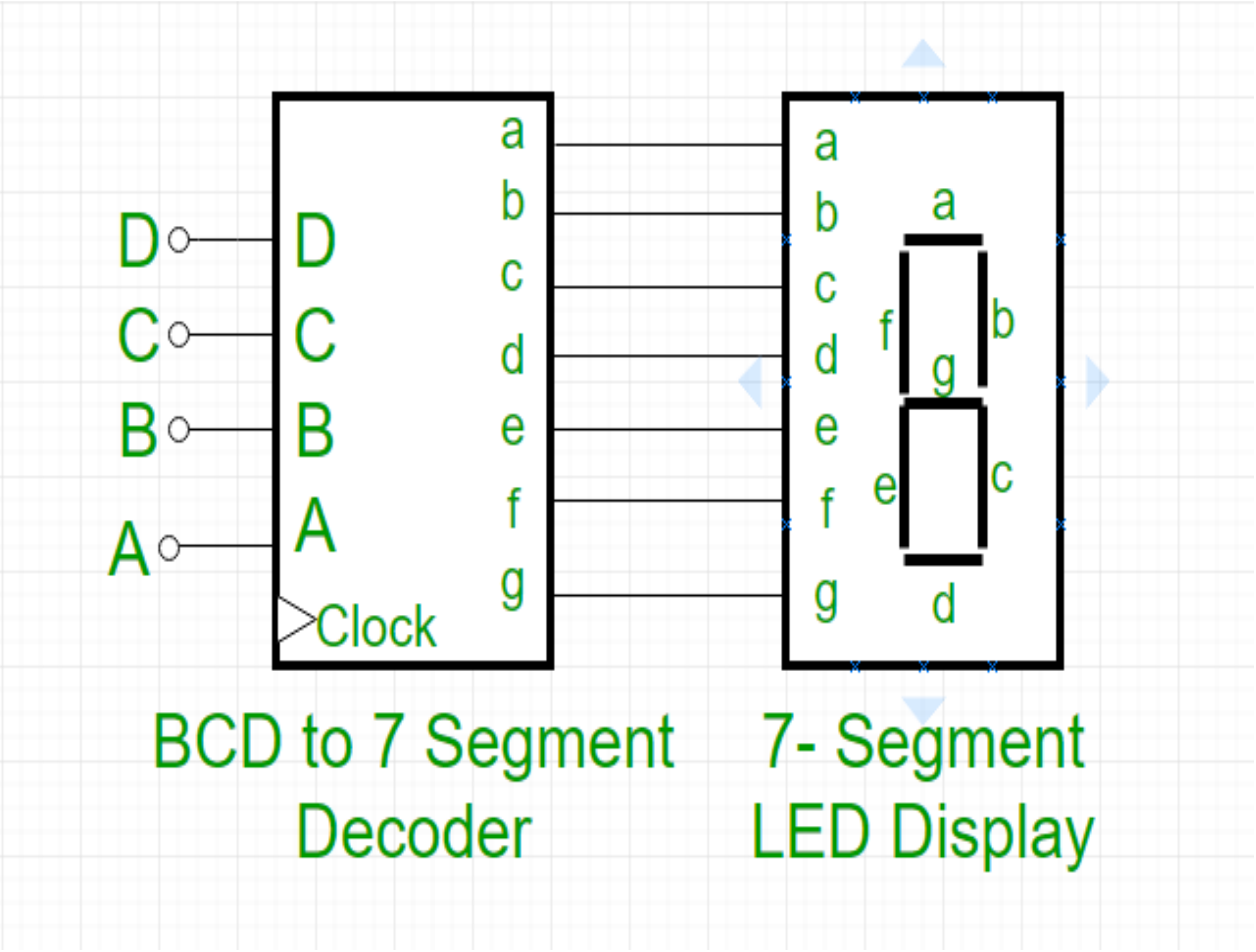


FIGURE 4.18
Three-to-eight-line decoder

BCD to 7-segment Decoder



Encoders

- the opposite of decoders
- it converts *m*-bit input code to a *n*-bit output code with $n \leq m \leq 2^n$ such that each valid code word produces a unique output code

Example

- Octal-to-Binary Encoder

TABLE 3-7
Truth Table for Octal-to-Binary Encoder

Inputs								Outputs		
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	A_2	A_1	A_0
0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0	0	1
0	0	0	0	0	1	0	0	0	1	0
0	0	0	0	1	0	0	0	0	1	1
0	0	0	1	0	0	0	0	1	0	0
0	0	1	0	0	0	0	0	1	0	1
0	1	0	0	0	0	0	0	1	1	0
1	0	0	0	0	0	0	0	1	1	1

Multiplexers

- A multiplexer selects information from an input line and directs the information to an output line
- A typical multiplexer has n control inputs (S_{n-1}, … S_0) called *selection inputs*, 2^n information inputs (I_{2^n-1}, … , I_0), and one output Y
- A multiplexer can be designed to have m information inputs with $m < 2^n$ as well as n selection inputs

2-to-1-Line Multiplexer

Since $2 = 2^1$, $n = 1$

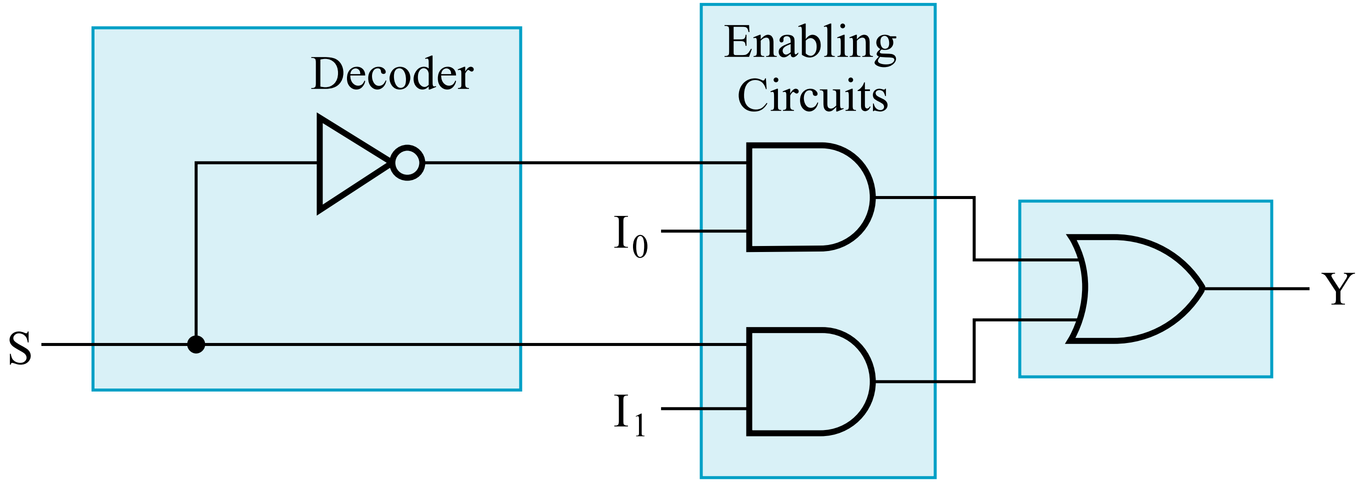
The single selection variable S has two values:

- $S = 0$ selects input I_0
- $S = 1$ selects input I_1

The equation:

$$Y = \quad I_0 + SI_1$$

The circuit:

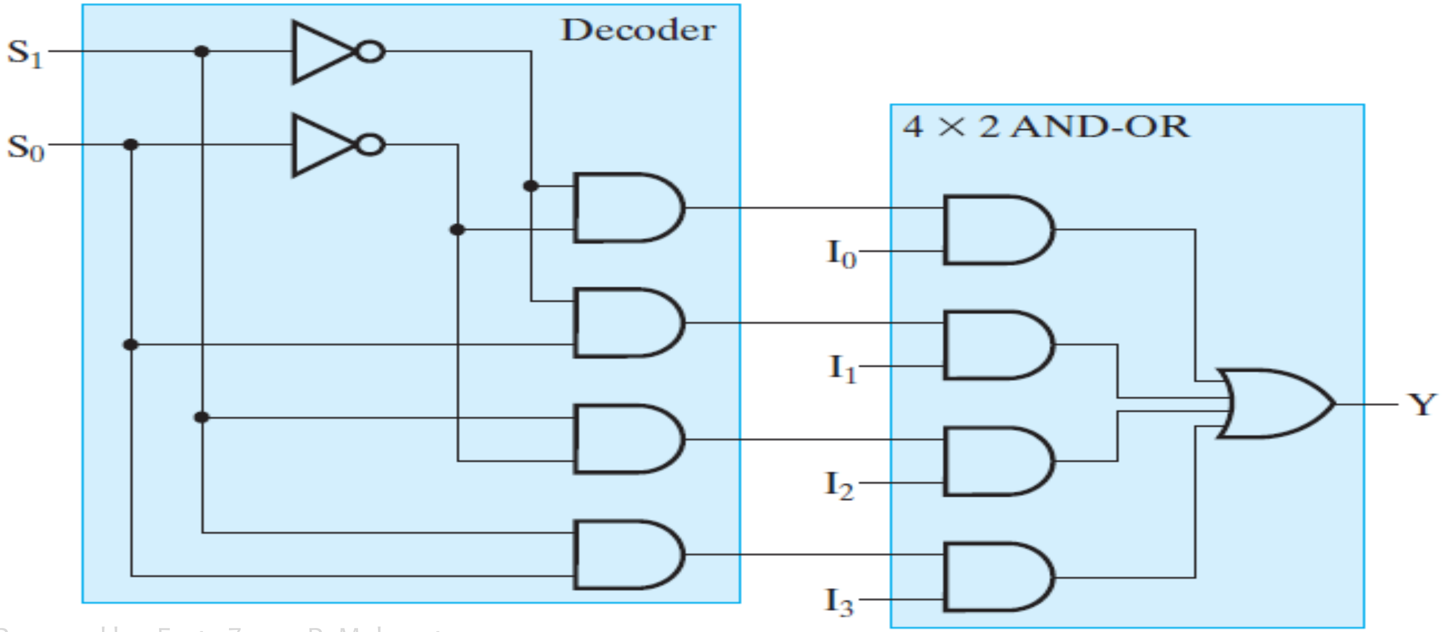


4-to-1-line Multiplexer

- 2-to-2^2-line decoder
- $2^2 \times 2$ AND-OR

TABLE 3-10
Condensed Truth Table for 4-to-1-Line Multiplexer

S_1	S_0	Y
0	0	I_0
0	1	I_1
1	0	I_2
1	1	I_3



Sample MCQs

1. BCD input 1000 is fed to a 7-segment display through a BCD to 7 segment decoder/driver. The segments which will lit up are

a) a,b,d

b) a,b,c

c) All

d) a,b,g,c,d

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Sample MCQs

2. The output of a half adder is

a) SUM

b) CARRY

c) SUM and CARRY

d) None of the above

Sample MCQs

2. The output of a half adder is

a) SUM

b) CARRY

c) SUM and CARRY

d) None of the above

Sample MCQs

3. Which device has one input and many outputs?

a) Multiplexer
b) Demultiplexer
c) Counter
d) Flip-flop

Sample MCQs

3. Which device has one input and many outputs?

a) Multiplexer

b) Demultiplexer

c) Counter

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Sample MCQs

4. A 4 : 1 multiplexer requires ___________ data select line.

a) 1

b) 2

c) 3

d) 4

Sample MCQs

4. A 4 : 1 multiplexer requires ___________ data select line.

a) 1

b) 2

c) 3

d) 4

Sample MCQs

5. In digital circuits Schottky transistors are preferred over normal transistors because of their:

a) Lower propagation delay

b) Lower power dissipation

c) Higher propagation delay

d) Higher power dissipation

Sample MCQs

5. In digital circuits Schottky transistors are preferred over normal transistors because of their:

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Sample MCQs

6. Which of the following finds application in pocket calculators?

a) TTL

b) CMOS

c) ECL

d) Both a and c

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