Decoders

Lecture by

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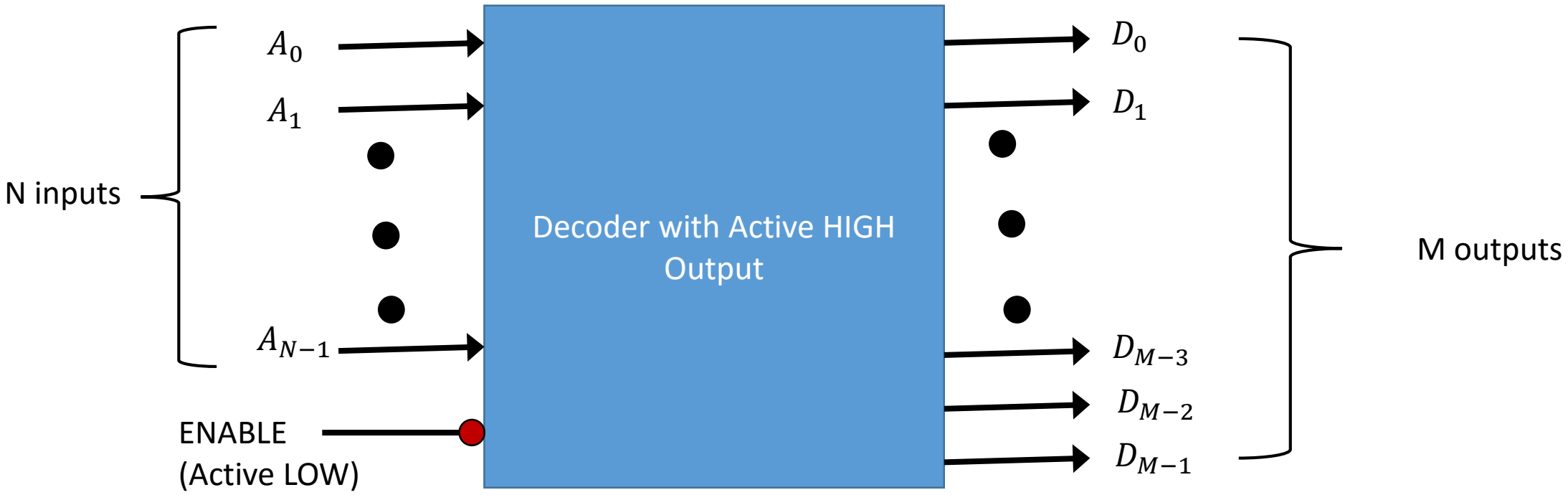
Outline

- 2-to-4-line Decoder
- 3-to-8-line Decoder
- Implementation of Boolean functions using Decoder
- 4-to-16 Decoder using 3-to-8 Decoders

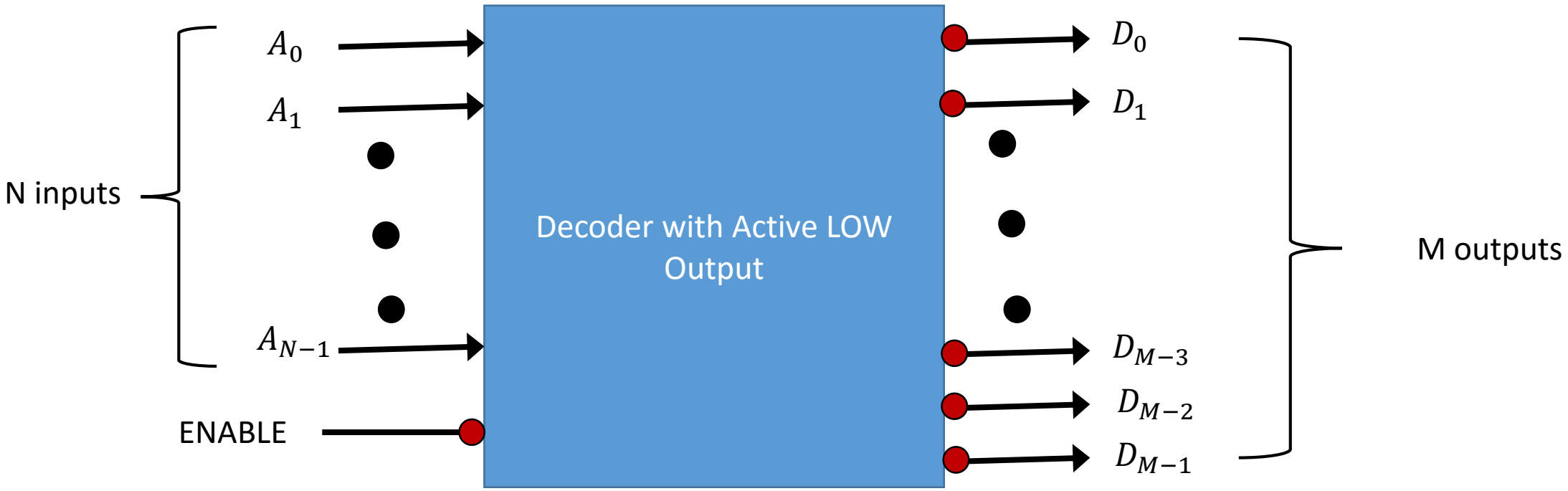
What is a decoder?

- A decoder is a logic circuit that converts an N-bit binary input code into M output lines such that only one output line is activated for each one of the possible combinations of inputs.
- Since each of the N inputs can be logic 0 or logic 1, there are 2^N possible input combinations or codes.
- For each of these input combinations, only one of the M outputs will be active (either HIGH or LOW) and the remaining output lines will be inactive (either LOW or HIGH).
- A decoder has an ENABLE input.

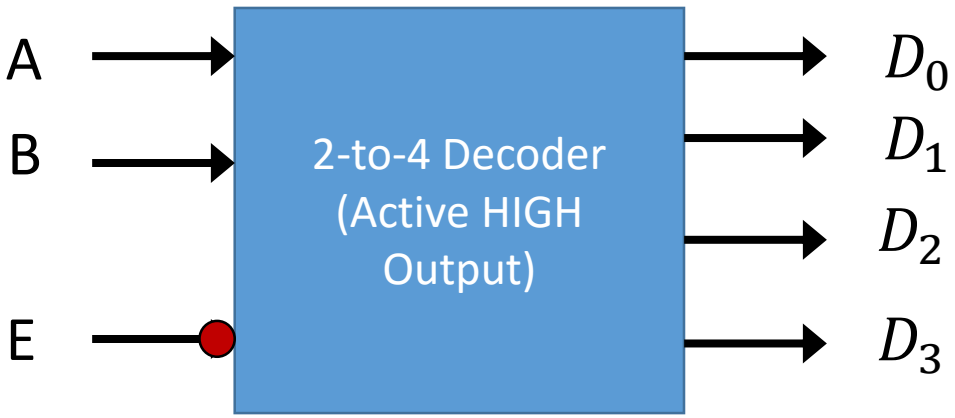
Decoder with Active HIGH Output Lines



Decoder with Active LOW Output Lines



2-to-4-line Decoder with Active HIGH Output



Functional block

Truth table

E	A	B	D_0	D_1	D_2	D_3
1	X	X	0	0	0	0
0	0	0	1	0	0	0
0	0	1	0	1	0	0
0	1	0	0	0	1	0
0	1	1	0	0	0	1

2-to-4-line Decoder with Active HIGH Output

Truth table

E	A	B	D_0	D_1	D_2	D_3
1	X	X	0	0	0	0
0	0	0	1	0	0	0
0	0	1	0	1	0	0
0	1	0	0	0	1	0
0	1	1	0	0	0	1

Logic expressions

$$D_0 = \bar{E}\,\bar{A}\,\bar{B}$$
$$D_1 = \bar{E}\,\bar{A}\,B$$
$$D_2 = \bar{E}\,A\,\bar{B}$$
$$D_3 = \bar{E}\,A\,B$$

2-to-4-line Decoder with Active HIGH Output

Logic expressions

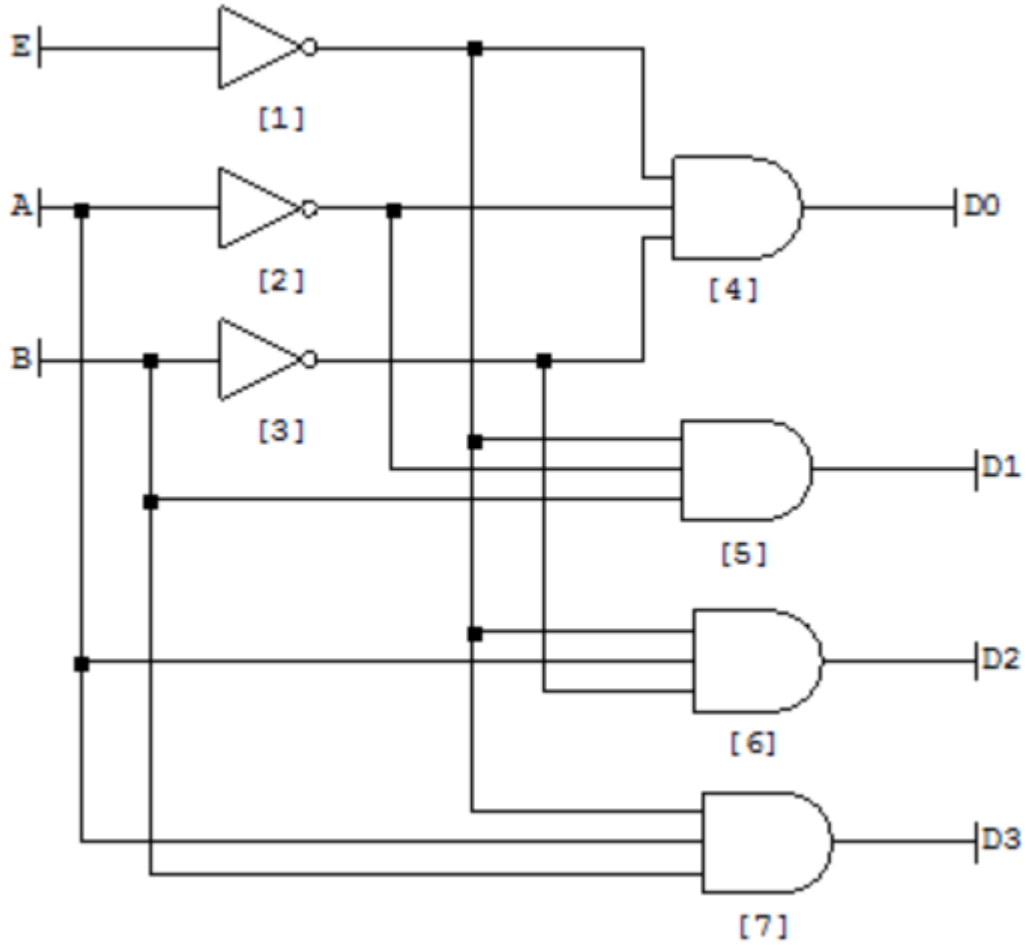
$$D_0 = \bar{E}\,\bar{A}\,\bar{B}$$

$$D_1 = \bar{E}\,\bar{A}\,B$$

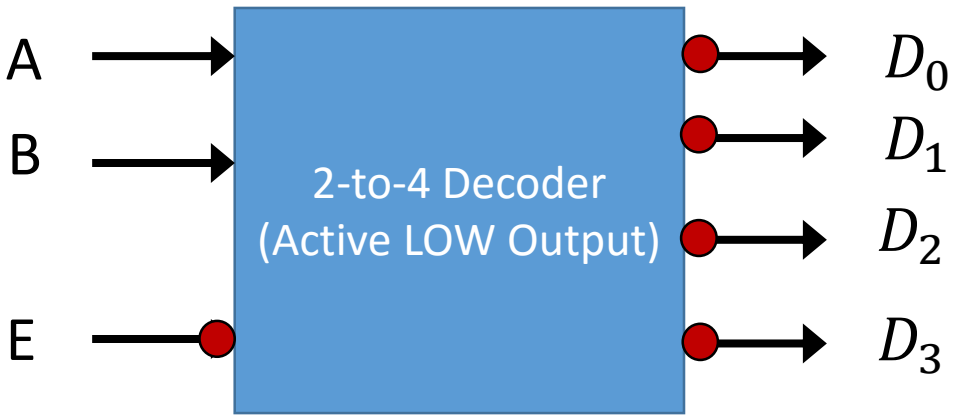
$$D_2 = \bar{E}\,A\,\bar{B}$$

$$D_3 = \bar{E}\,A\,B$$

Circuit Diagram



2-to-4-line Decoder with Active LOW Output



Functional block

Truth table

E	A	B	D_0	D_1	D_2	D_3
1	X	X	1	1	1	1
0	0	0	0	1	1	1
0	0	1	1	0	1	1
0	1	0	1	1	0	1
0	1	1	1	1	1	0

2-to-4-line Decoder with Active LOW Output

Truth table

E	A	B	D_0	D_1	D_2	D_3
1	X	X	1	1	1	1
0	0	0	0	1	1	1
0	0	1	1	0	1	1
0	1	0	1	1	0	1
0	1	1	1	1	1	0

Logic expressions

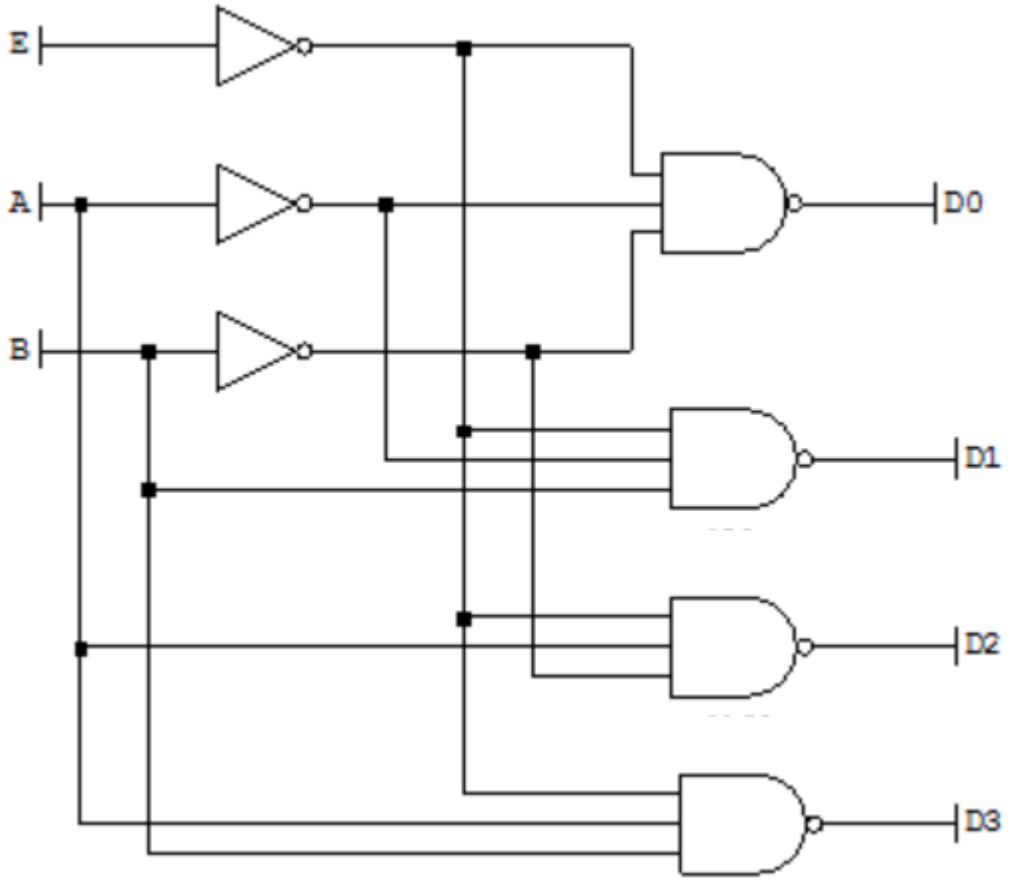
$$D_0 = \overline{\bar{E}\ \bar{A}\ \bar{B}}$$
$$D_1 = \overline{\bar{E}\ \bar{A}\ B}$$
$$D_2 = \overline{\bar{E}\ A\ \bar{B}}$$
$$D_3 = \overline{\bar{E}\ A\ B}$$

2-to-4-line Decoder with Active LOW Output

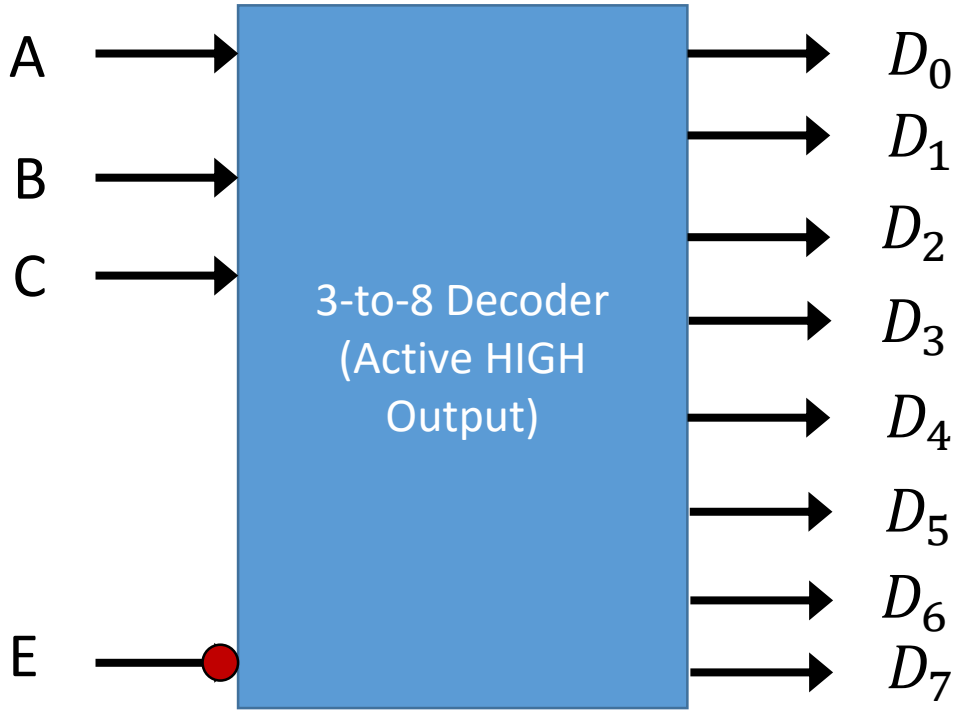
Logic expressions

$$D_0 = \overline{\bar{E}\ \bar{A}\ \bar{B}}$$
$$D_1 = \overline{\bar{E}\ \bar{A}\ B}$$
$$D_2 = \overline{\bar{E}\ A\ \bar{B}}$$
$$D_3 = \overline{\bar{E}\ A\ B}$$

Circuit Diagram

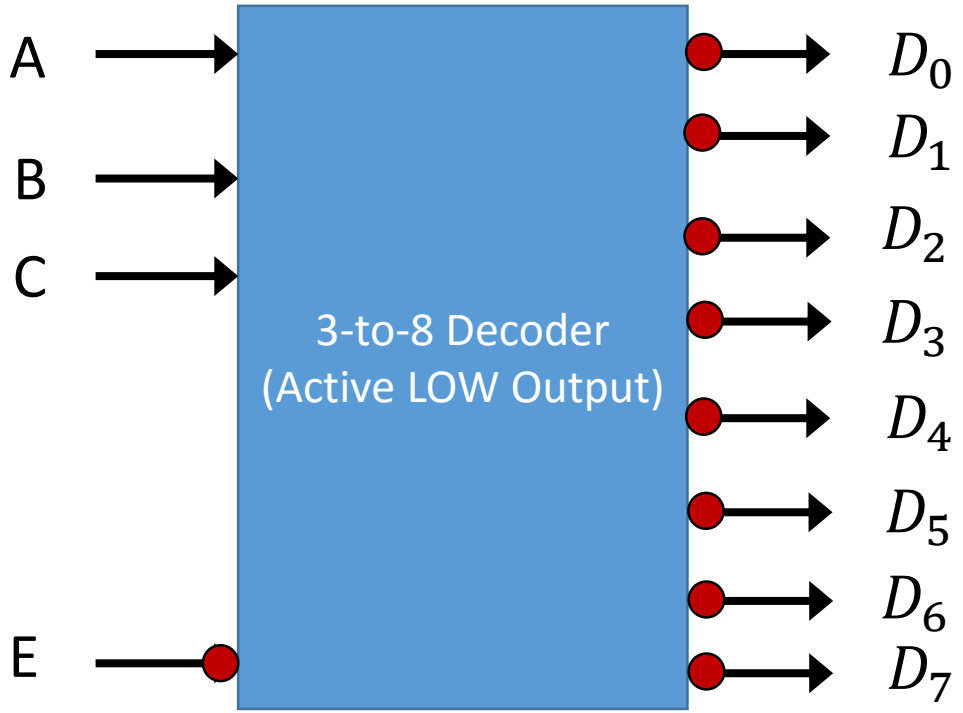


3-to-8 Line Decoder



Active HIGH

Output: 1 (active), 0 (inactive)



Active LOW

Output: 0 (active), 1 (inactive)

3-to-8 Line Decoder

Truth table

E	A	B	C	Active Output Line
1	X	X	X	None
0	0	0	0	$\boldsymbol{D_0}$
0	0	0	1	$\boldsymbol{D_1}$
0	0	1	0	$\boldsymbol{D_2}$
0	0	1	1	$\boldsymbol{D_3}$
0	1	0	0	$\boldsymbol{D_4}$
0	1	0	1	$\boldsymbol{D_5}$
0	1	1	0	$\boldsymbol{D_6}$
0	1	1	1	$\boldsymbol{D_7}$

Logic expressions

Active HIGH	Active LOW
$D_0 = \bar{E}\,\bar{A}\,\bar{B}\,\bar{C}$	$D_0 = \overline{\bar{E}\,\bar{A}\,\bar{B}\,\bar{C}}$
$D_1 = \bar{E}\,\bar{A}\,\bar{B}\,C$	$D_1 = \overline{\bar{E}\,\bar{A}\,\bar{B}\,C}$
$D_2 = \bar{E}\,\bar{A}\,B\bar{C}$	$D_2 = \overline{\bar{E}\,\bar{A}\,B\bar{C}}$
$D_3 = \bar{E}\,\bar{A}\,BC$	$D_3 = \overline{\bar{E}\,\bar{A}\,BC}$
$D_4 = \bar{E}\,A\bar{B}\,\bar{C}$	$D_4 = \overline{\bar{E}\,A\bar{B}\,\bar{C}}$
$D_5 = \bar{E}\,A\bar{B}C$	$D_5 = \overline{\bar{E}\,A\bar{B}C}$
$D_6 = \bar{E}\,AB\,\bar{C}$	$D_6 = \overline{\bar{E}\,AB\,\bar{C}}$
$D_7 = \bar{E}\,ABC$	$D_7 = \overline{\bar{E}\,ABC}$

Implementation of Boolean Functions using Decoders

Design Problems and Solutions

Design a Full Adder using 3-to-8 Decoder

- Step 1: Write the truth table of Full adder

Inputs			Sum	Carry
A	B	C_{in}	S	C_{out}
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Design a Full Adder using 3-to-8 Decoder

- Step 2: Assume 3-to-8 Decoder with Active HIGH output lines. Then, express the outputs S and C_{out} in terms of minterms.

Inputs			Sum	Carry
A	B	C_{in}	S	C_{out}
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

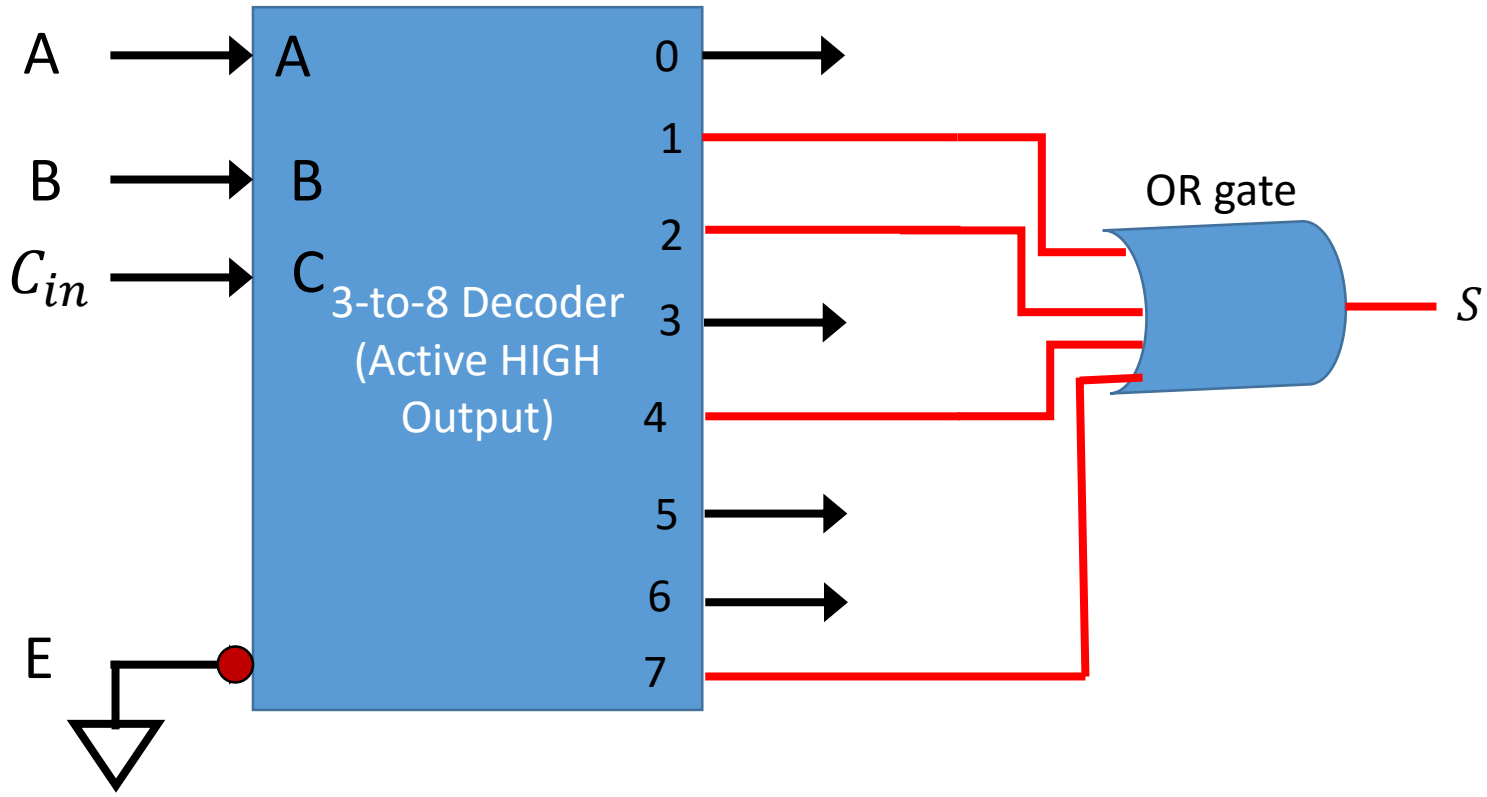
$$S = \sum m(1,2,4,7)$$

$$C_{out} = \sum m(3,5,6,7)$$

Design a Full Adder using 3-to-8 Decoder

- Step 3: Realize the output S using 3-to-8 decoder with Active HIGH output lines.

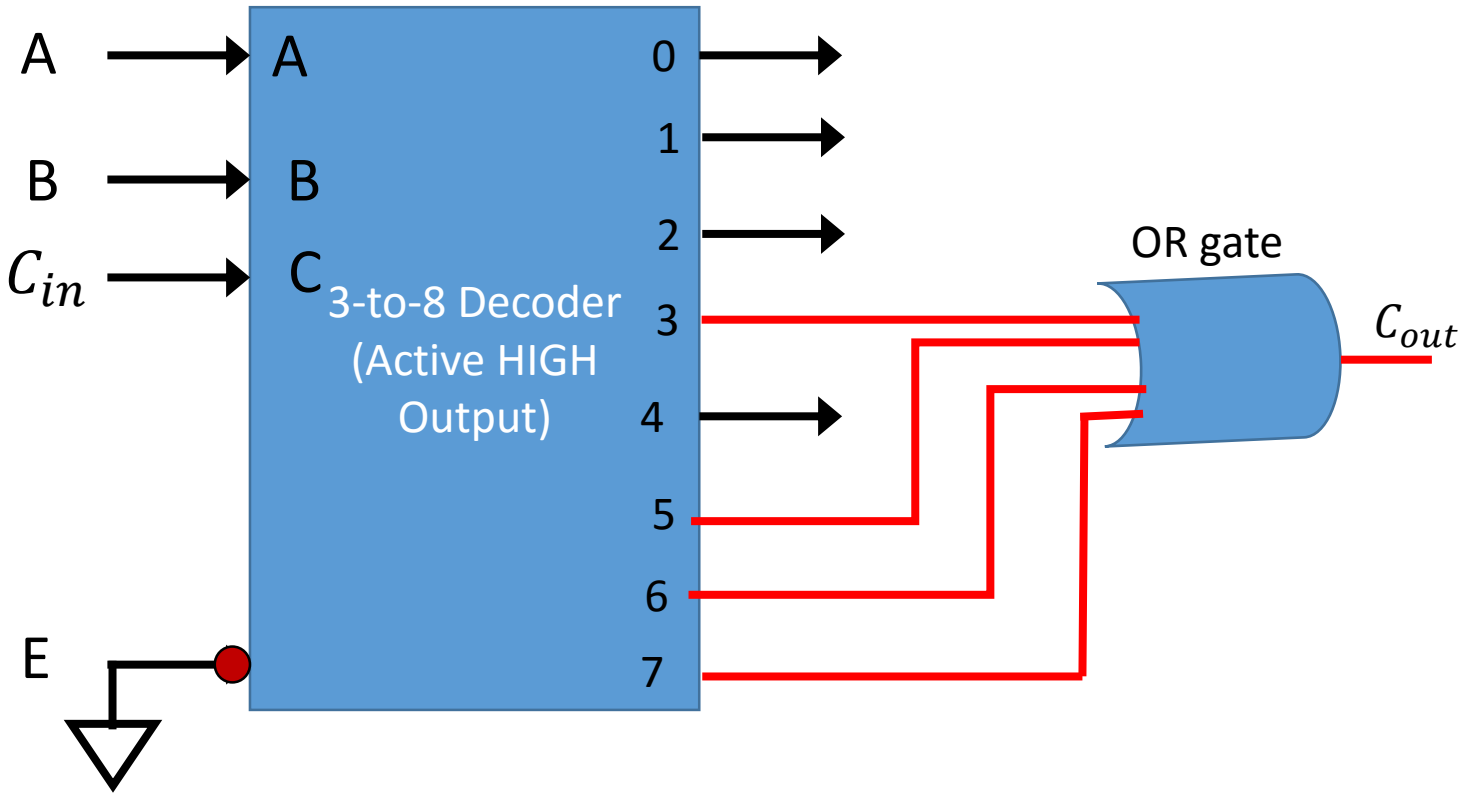
$$S = \sum m(1,2,4,7)$$



Design a Full Adder using 3-to-8 Decoder

- Step 4: Realize the output C_{out} using 3-to-8 decoder with Active HIGH output lines.

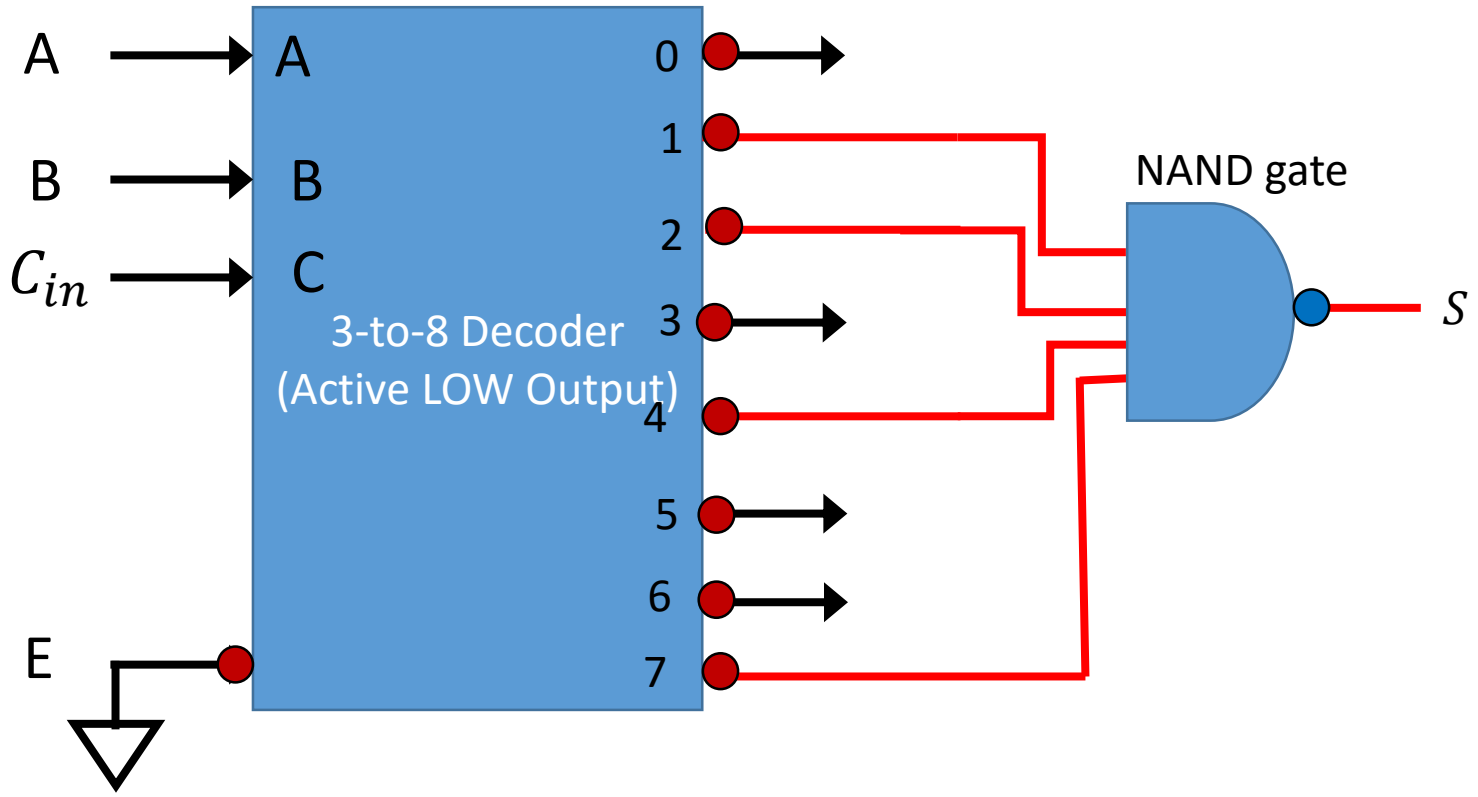
$$C_{out} = \sum m(3,5,6,7)$$



Design a Full Adder using 3-to-8 Decoder

- Step 3: Alternatively, we assume 3-to-8 Decoder with Active LOW output lines. Realize the output S using 3-to-8 decoder with Active LOW output lines.

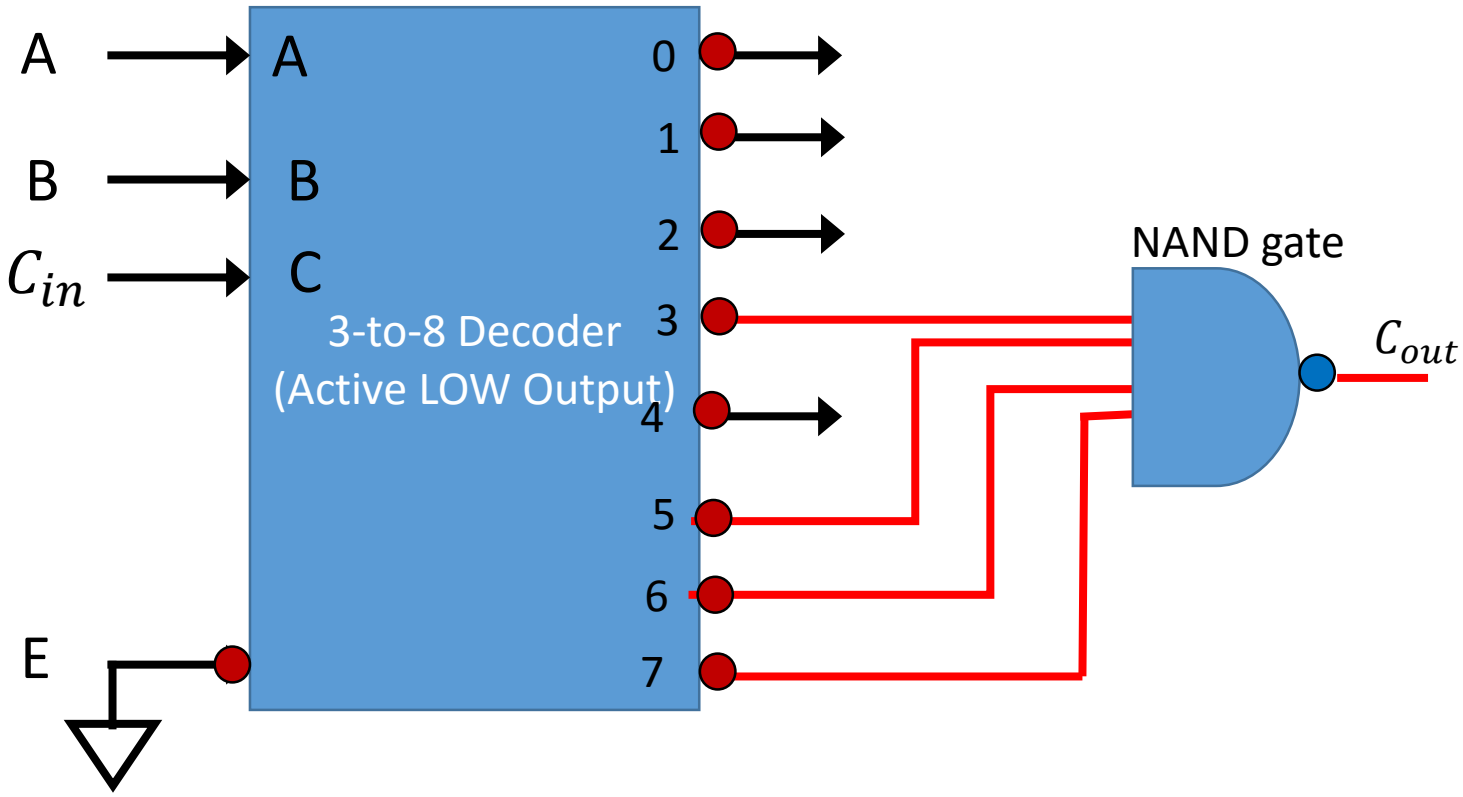
$$S = \sum m(1,2,4,7)$$



Design a Full Adder using 3-to-8 Decoder

- Step 4: Realize the output C_{out} using 3-to-8 decoder with Active LOW output lines.

$$C_{out} = \sum m(3,5,6,7)$$



Design a 1-bit Comparator using 2-to-4 Decoder

- Step 1: Write the truth table of 1-bit Comparator

A_0	B_0	L	E	G
0	0	0	1	0
0	1	1	0	0
1	0	0	0	1
1	1	0	1	0

Design a 1-bit Comparator using 2-to-4 Decoder

- Step 1: Write the truth table of 1-bit Comparator
- Step 2: Write the output expressions in terms of minterms.

A_0	B_0	L	E	G
0	0	0	1	0
0	1	1	0	0
1	0	0	0	1
1	1	0	1	0

$$L = \sum m(1)$$

$$E = \sum m(0,3)$$

$$G = \sum m(2)$$

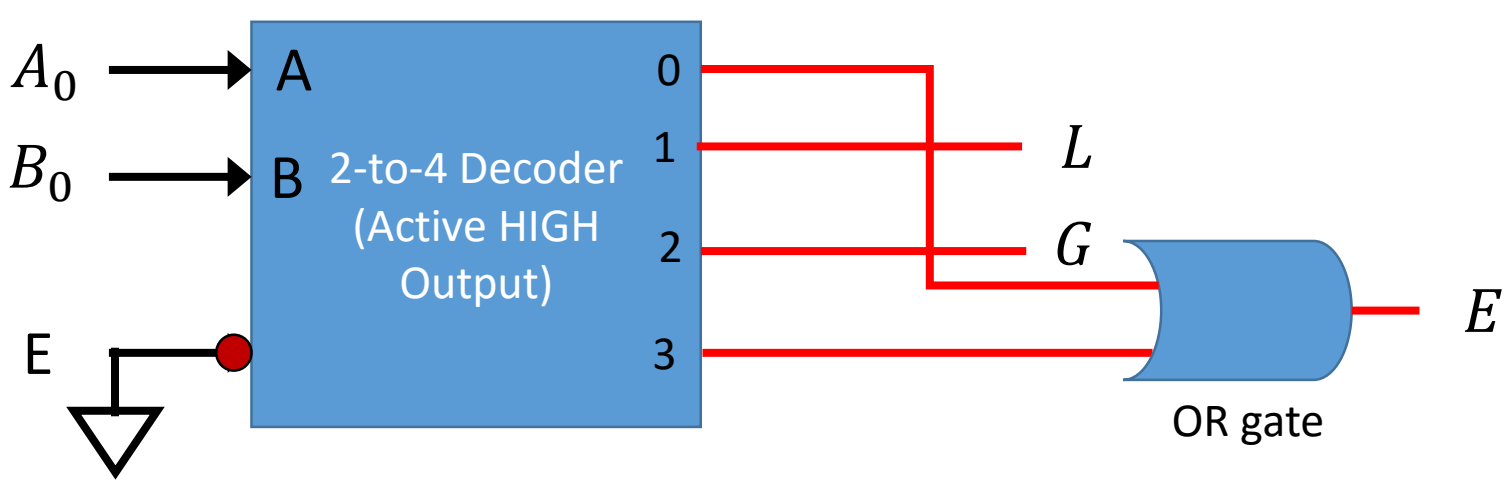
Design a 1-bit Comparator using 2-to-4 Decoder

- Step 1: Write the truth table of 1-bit Comparator
- Step 2: Write the output expressions in terms of minterms.
- Step 3: Draw the circuit (assume 2-to-4 Decoder with active HIGH output)

$$L = \sum m(1)$$

$$E = \sum m(0,3)$$

$$G = \sum m(2)$$



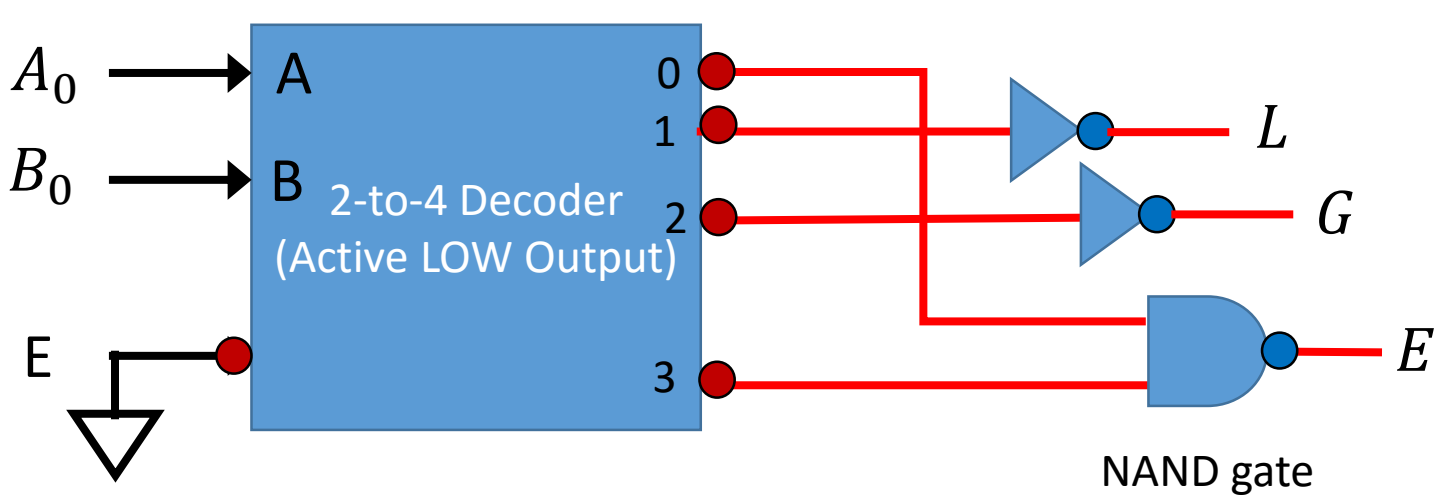
Design a 1-bit Comparator using 2-to-4 Decoder

- Step 1: Write the truth table of 1-bit Comparator
- Step 2: Write the output expressions in terms of minterms.
- Step 3: Draw the circuit (assume 2-to-4 Decoder with active LOW output)

$$L = \sum m(1)$$

$$E = \sum m(0,3)$$

$$G = \sum m(2)$$



Design Problem

- Design a combinational circuit with three inputs and one output. The output is 1 when the binary value of the inputs is an even number. Use 3-to-8 line decoder with active HIGH output lines.
- Solution: Step 1- Write the truth table

A	B	C	F
0	0	0	1
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	0

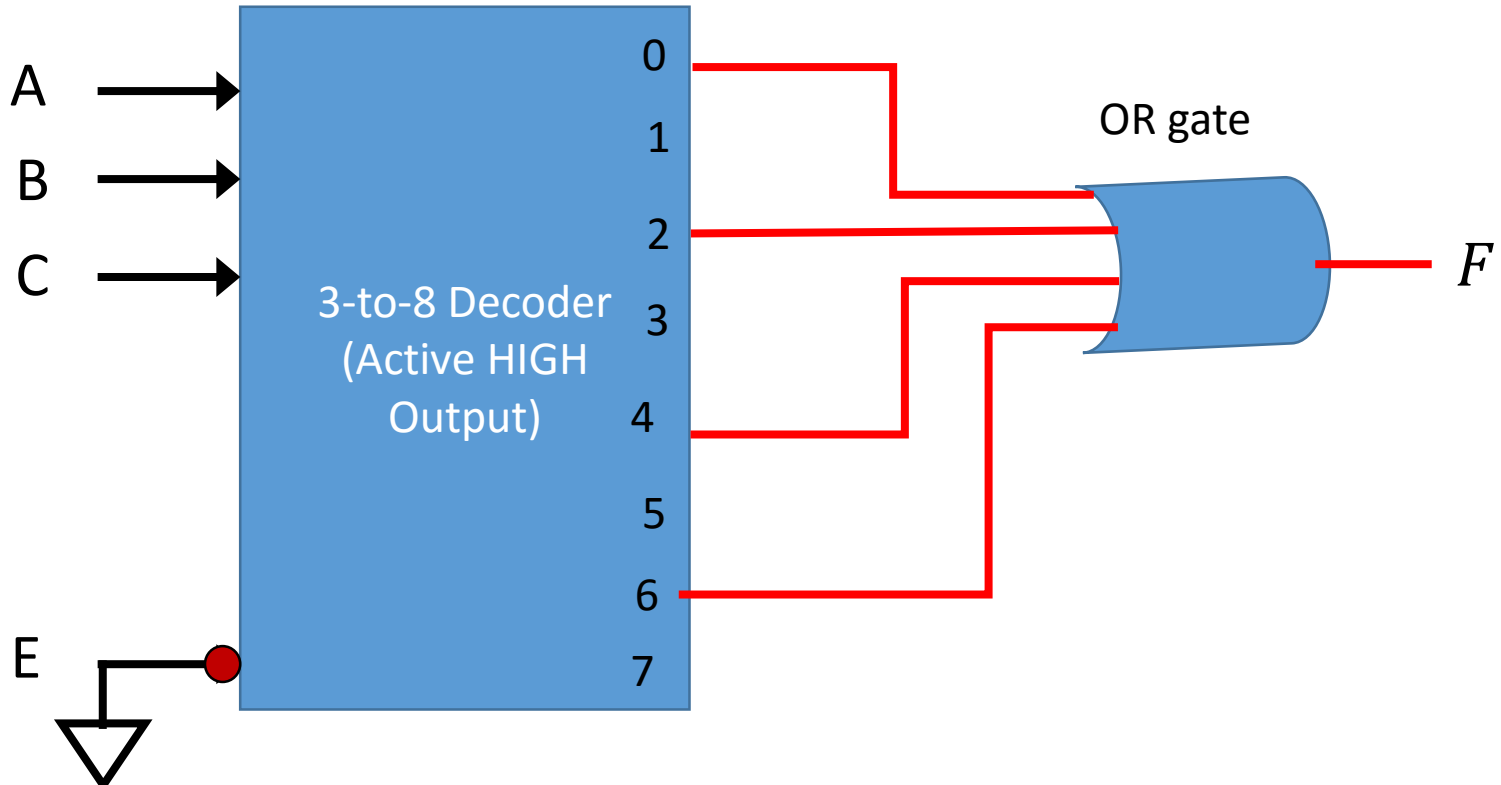
Step 2- Express F in terms of minterms

$$F = \sum m(0,2,4,6)$$

Design Problem

- Design a combinational circuit with three inputs and one output. The output is 1 when the binary value of the inputs is an even number. Use 3-to-8 line decoder with active HIGH output lines.
- Solution: Step 3- Draw the circuit

$$F = \sum m(0,2,4,6)$$



Design Problem

- Design a combinational circuit with three inputs, *x* , *y* , *z* and three outputs, *A, B* , *C* . When the binary input is 0, 1, 2, or 3, the binary output is one greater than the input. When the binary input is 4, 5, 6, or 7, the binary output is two less than the input. (Use 3:8 Decoder with active LOW output lines.)
- Solution: Step 1- write the truth table

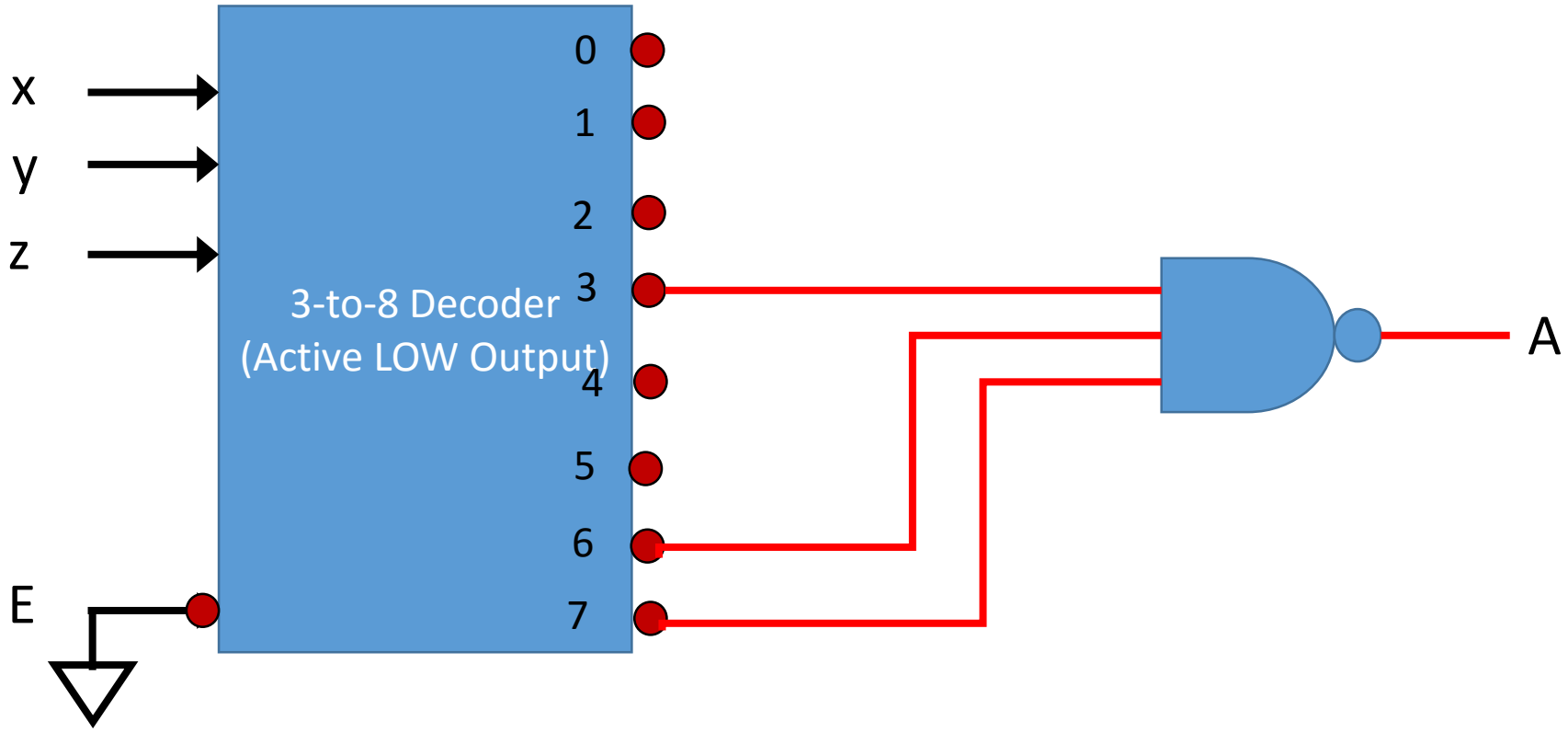
x	y	z	A	B	C
0	0	0	0	0	1
0	0	1	0	1	0
0	1	0	0	1	1
0	1	1	1	0	0
1	0	0	0	1	0
1	0	1	0	1	1
1	1	0	1	0	0
1	1	1	1	0	1

$$A = \sum m(3,6,7)$$

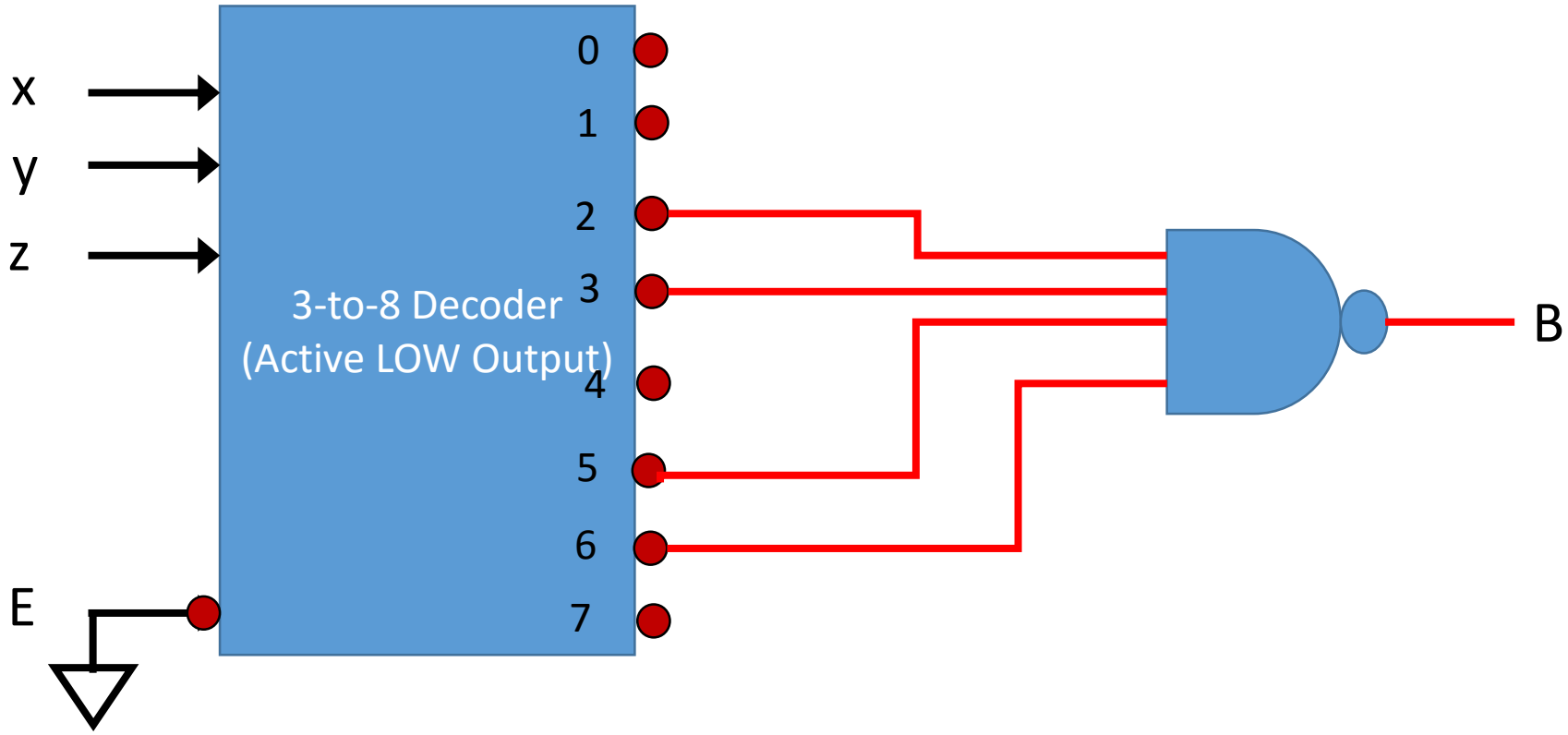
$$B = \sum m(2,3,5,6)$$

$$C = \sum m(0,2,5,7)$$

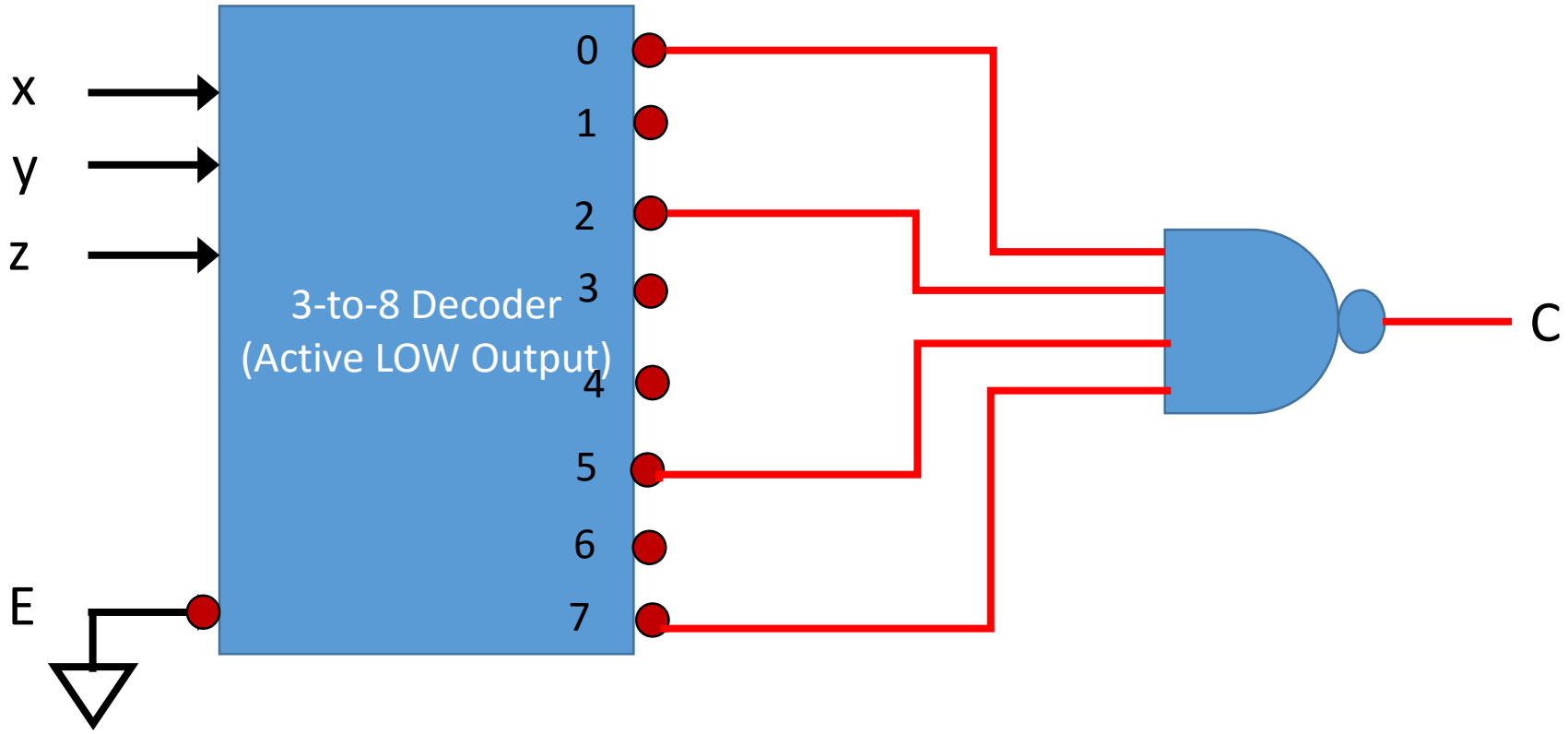
Draw the circuit



Draw the circuit



Draw the circuit



4-to-16 Line Decoder using 3-to-8 Line Decoder

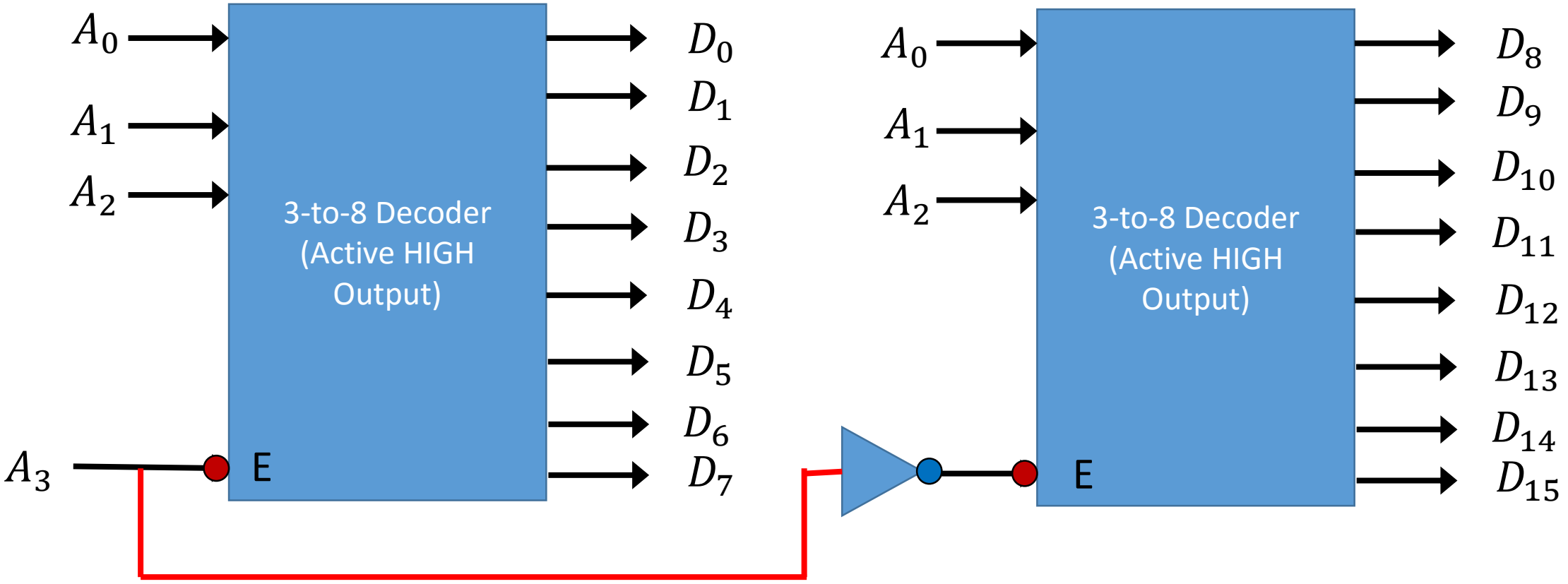
- Truth table of 4-to-16 Decoder

A_3	A_2	A_1	A_0	Active Output Line
0	0	0	0	D_0
0	0	0	1	D_1
0	0	1	0	D_2
0	0	1	1	D_3
0	1	0	0	D_4
0	1	0	1	D_5
0	1	1	0	D_6
0	1	1	1	D_7

A_3	A_2	A_1	A_0	Active Output Line
1	0	0	0	D_8
1	0	0	1	D_9
1	0	1	0	D_{10}
1	0	1	1	D_{11}
1	1	0	0	D_{12}
1	1	0	1	D_{13}
1	1	1	0	D_{14}
1	1	1	1	D_{15}

4-to-16 Line Decoder using 3-to-8 Line Decoder

- Logic circuit: Assume 3-to-8 line Decoder with active HIGH output



End