# NEC 304

# STLD

## Lecture 15
***Magnitude Comparators and Multiplexers***

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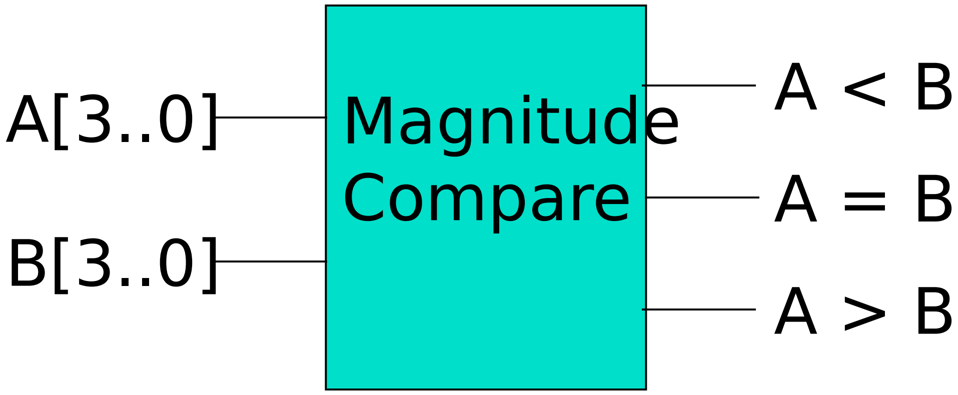
## Overview

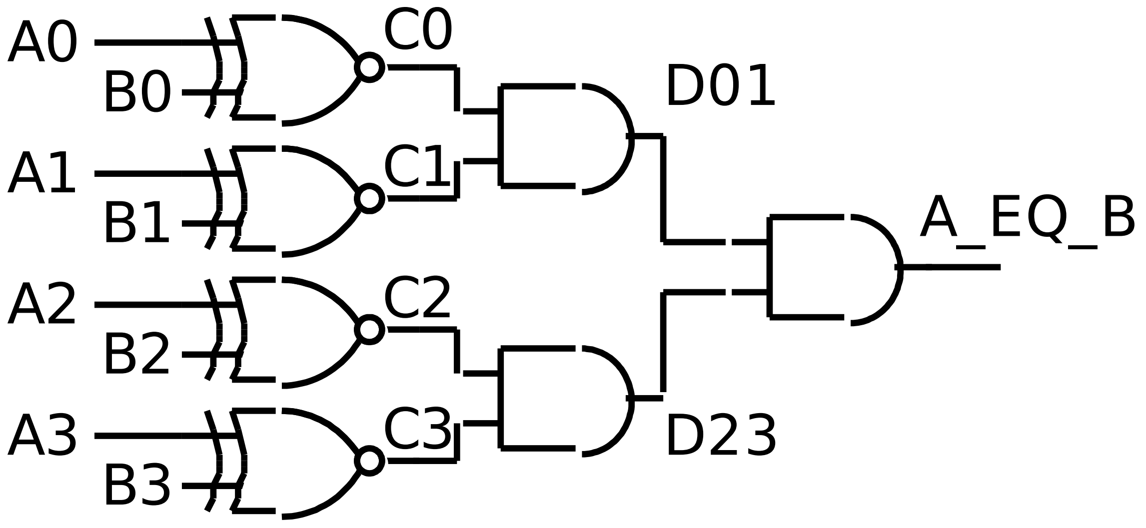
- Discussion of two digital building blocks
- Magnitude comparators
  - Compare two multi-bit binary numbers
  - Create a single bit comparator
  - Use repetitive pattern
- Multiplexers
  - Select one out of several bits
  - Some inputs used for selection
  - Also can be used to implement logic

# Magnitude Comparator

- The comparison of two numbers
  - outputs: A>B, A=B, A<B
- Design Approaches
  - the truth table
    - $2^{2n}$ entries - too cumbersome for large n
  - use inherent regularity of the problem
    - reduce design efforts
    - reduce human errors



# Magnitude Comparator

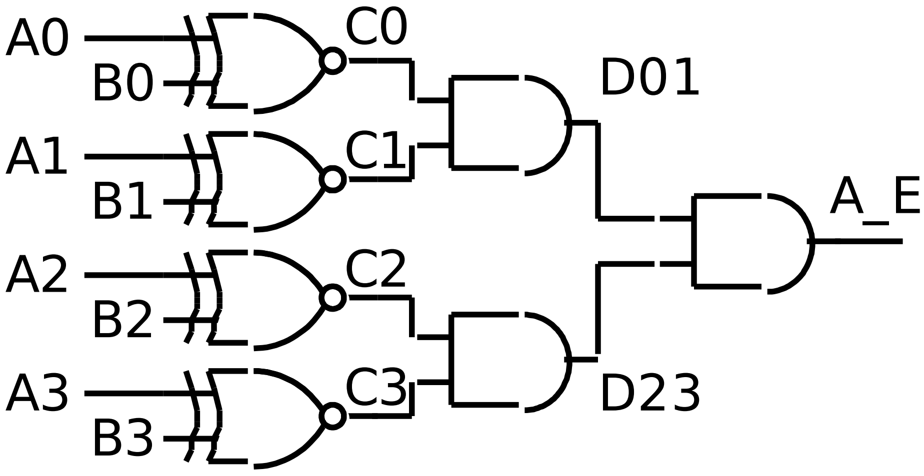



How can we find A > B?

How many rows would a truth table have?

$$2^8 = 256$$

# Magnitude Comparator




Find A > B

If A = 1001 and
B = 0111
is A > B?
Why?

Because A3 > B3
i.e. A3 . B3’ = 1

Therefore, one term in the logic equation for A > B is A3 . B3’

## Magnitude Comparator

If A = 1010 and
B = 1001
is A > B?
Why?

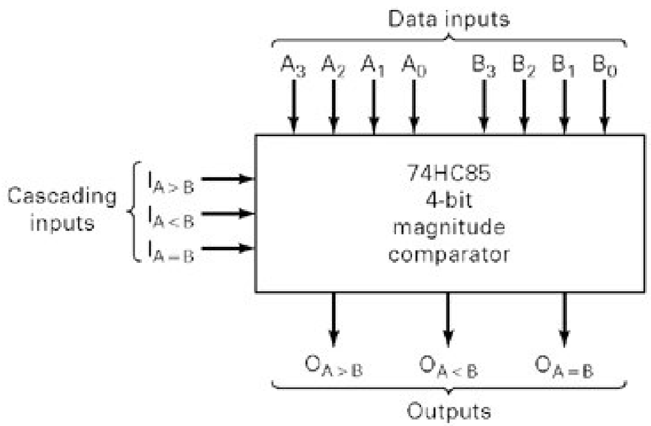
$A > B = A3 . B3'$
$+ C3 . A2 . B2'$
$+ \ldots..$

Because A3 = B3 and
A2 = B2 and
A1 > B1
i.e. C3 = 1 and C2 = 1 and
A1 . B1' = 1

Therefore, the next term in the logic equation for A > B is
C3 . C2 . A1 . B1'

# Magnitude Comparison

- **Algorithm -> logic**
  - **$A = A_3A_2A_1A_0$ ; $B = B_3B_2B_1B_0$**
  - **$A=B$ if $A_3=B_3$, $A_2=B_2$, $A_1=B_1$and $A_1=B_1$**
- **Test each bit:**
  - **equality: $x_i= A_iB_i+A_i'B_i'$**
  - **$(A=B) = x_3x_2x_1x_0$**
- **More difficult to test less than/greater than**
  - **$(A>B) = A_3B_3'+x_3A_2B_2'+x_3x_2A_1B_1'+x_3x_2x_1 A_0B_0'$**
  - **$(A<B) = A_3'B_3+x_3A_2'B_2+x_3x_2A_1'B_1+x_3x_2x_1 A_0'B_0$**
  - **Start comparisons from high-order bits**
- **Implementation**
  - **$x_i = (A_iB_i'+A_i'B_i)'$**



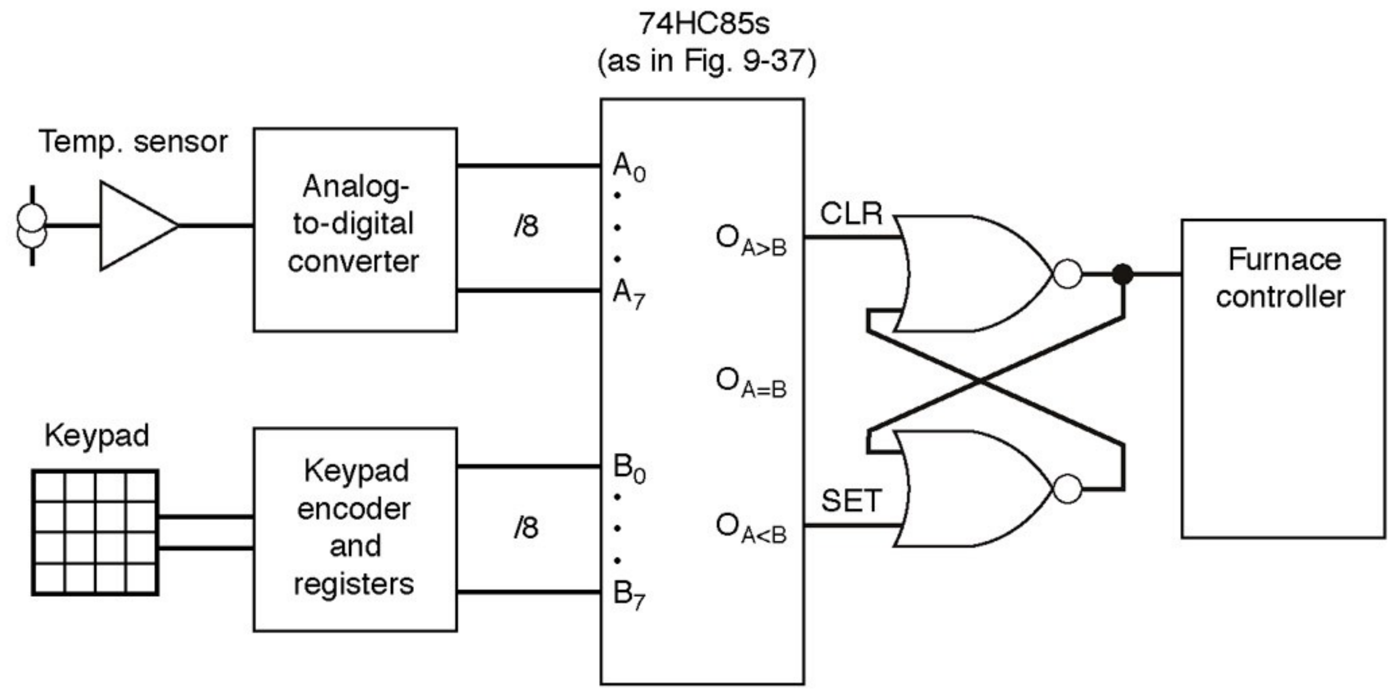

TRUTH TABLE

| COMPARING INPUTS | | | | CASCADING INPUTS | | | OUTPUTS | | |
|---|---|---|---|---|---|---|---|---|---|
| $A_3, B_3$ | $A_2, B_2$ | $A_1, B_1$ | $A_0, B_0$ | $I_{A>B}$ | $I_{A<B}$ | $I_{A=B}$ | $O_{A>B}$ | $O_{A<B}$ | $O_{A=B}$ |
| $A_3>B_3$ | X | X | X | X | X | X | H | L | L |
| $A_3<B_3$ | X | X | X | X | X | X | L | H | L |
| $A_3=B_3$ | $A_2>B_2$ | X | X | X | X | X | H | L | L |
| $A_3=B_3$ | $A_2<B_2$ | X | X | X | X | X | L | H | L |
| $A_3=B_3$ | $A_2=B_2$ | $A_1>B_1$ | X | X | X | X | H | L | L |
| $A_3=B_3$ | $A_2=B_2$ | $A_1<B_1$ | X | X | X | X | L | H | L |
| $A_3=B_3$ | $A_2=B_2$ | $A_1=B_1$ | $A_0>B_0$ | X | X | X | H | L | L |
| $A_3=B_3$ | $A_2=B_2$ | $A_1=B_1$ | $A_0<B_0$ | X | X | X | L | H | L |
| $A_3=B_3$ | $A_2=B_2$ | $A_1=B_1$ | $A_0=B_0$ | H | L | L | H | L | L |
| $A_3=B_3$ | $A_2=B_2$ | $A_1=B_1$ | $A_0=B_0$ | L | H | L | L | H | L |
| $A_3=B_3$ | $A_2=B_2$ | $A_1=B_1$ | $A_0=B_0$ | X | X | H | L | L | H |
| $A_3=B_3$ | $A_2=B_2$ | $A_1=B_1$ | $A_0=B_0$ | L | L | L | H | H | L |
| $A_3=B_3$ | $A_2=B_2$ | $A_1=B_1$ | $A_0=B_0$ | H | H | L | L | L | L |

H = HIGH Voltage Level
L = LOW Voltage Level
X = Immaterial

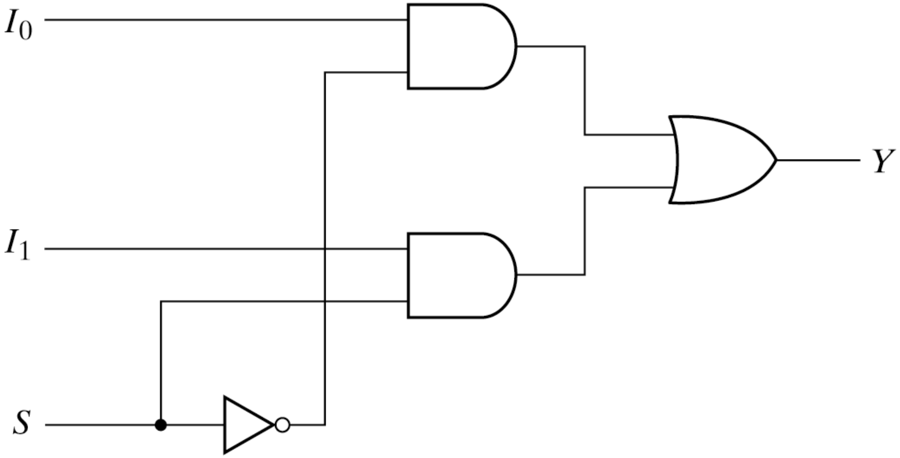
# Magnitude Comparator

- **Real-world application**
  - **Thermostat controller**

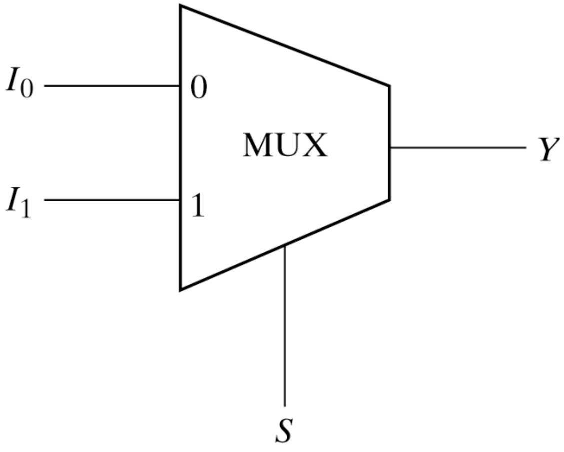


# Multiplexers

- Select an input value with one or more select bits
- Use for transmitting data
- Allows for conditional transfer of data
- Sometimes called a mux



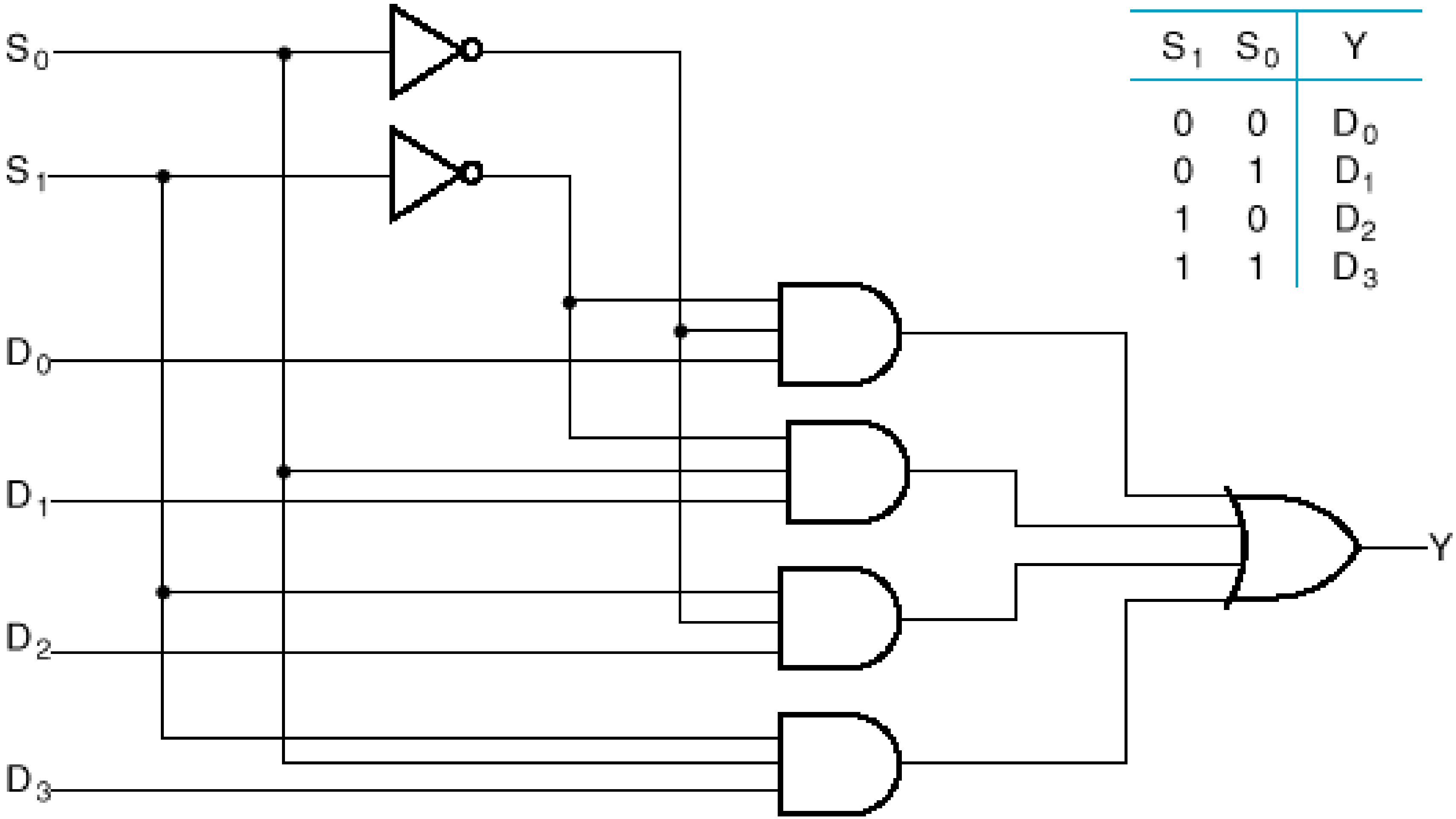

(a) Logic diagram




(b) Block diagram

Fig. 4-24 2-to-1-Line Multiplexer

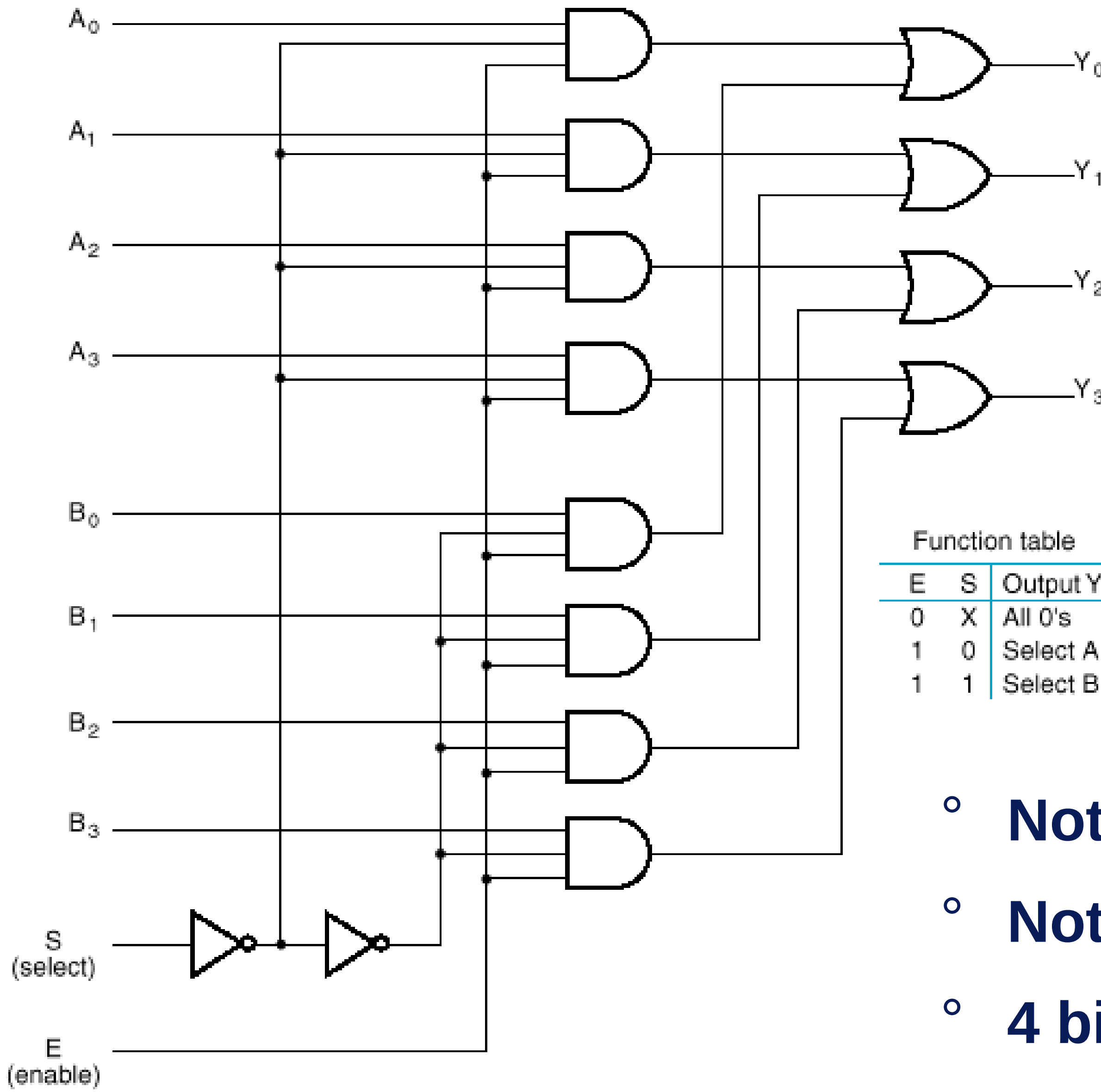
# 4– to– 1- Line Multiplexer




Function table

| $S_1$ | $S_0$ | Y |
|---|---|---|
| 0 | 0 | $D_0$ |
| 0 | 1 | $D_1$ |
| 1 | 0 | $D_2$ |
| 1 | 1 | $D_3$ |

# Quadruple 2–to–1-Line Multiplexer




Function table

| E | S | Output Y |
|---|---|---|
| 0 | X | All 0's |
| 1 | 0 | Select A |
| 1 | 1 | Select B |

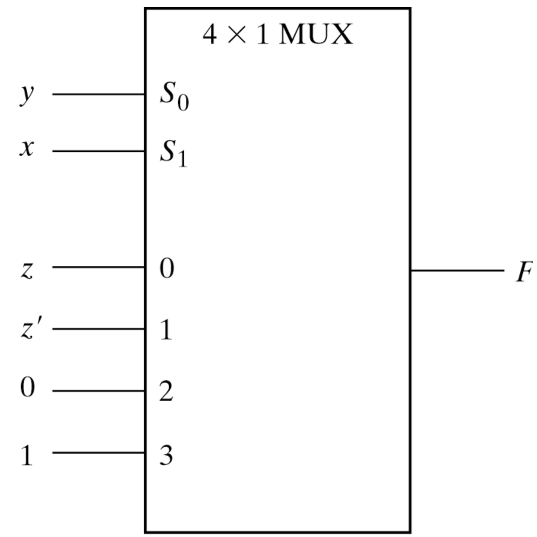
- Notice enable bit
- Notice select bit
- 4 bit inputs

# Multiplexer as combinational modules

- Connect input variables to select inputs of multiplexer *(n-1 for n variables)*
- Set data inputs to multiplexer equal to values of function for corresponding assignment of select variables
- Using a variable at data inputs reduces size of the multiplexer

| $x$ | $y$ | $z$ | $F$ | |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | $F = z$ |
| 0 | 0 | 1 | 1 | |
| 0 | 1 | 0 | 1 | $F = z'$ |
| 0 | 1 | 1 | 0 | |
| 1 | 0 | 0 | 0 | $F = 0$ |
| 1 | 0 | 1 | 0 | |
| 1 | 1 | 0 | 1 | $F = 1$ |
| 1 | 1 | 1 | 1 | |

(a) Truth table

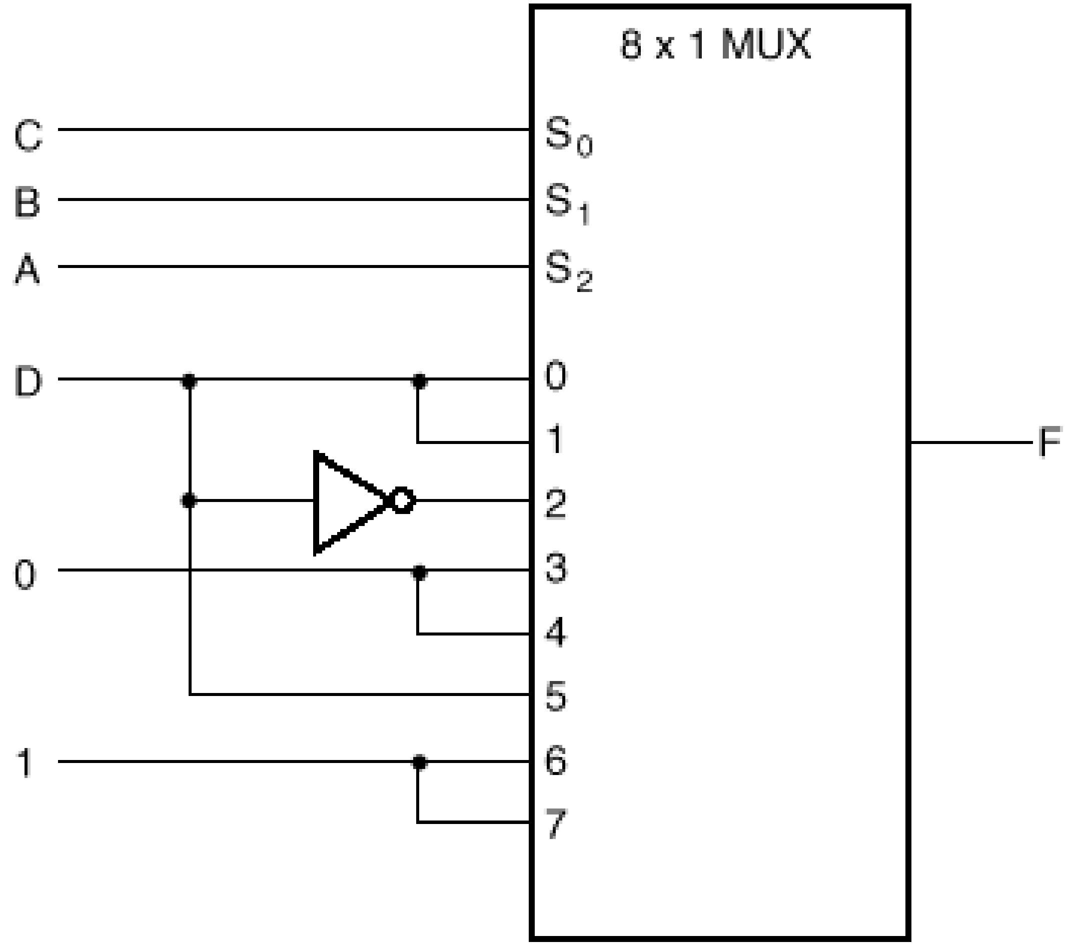



(b) Multiplexer implementation

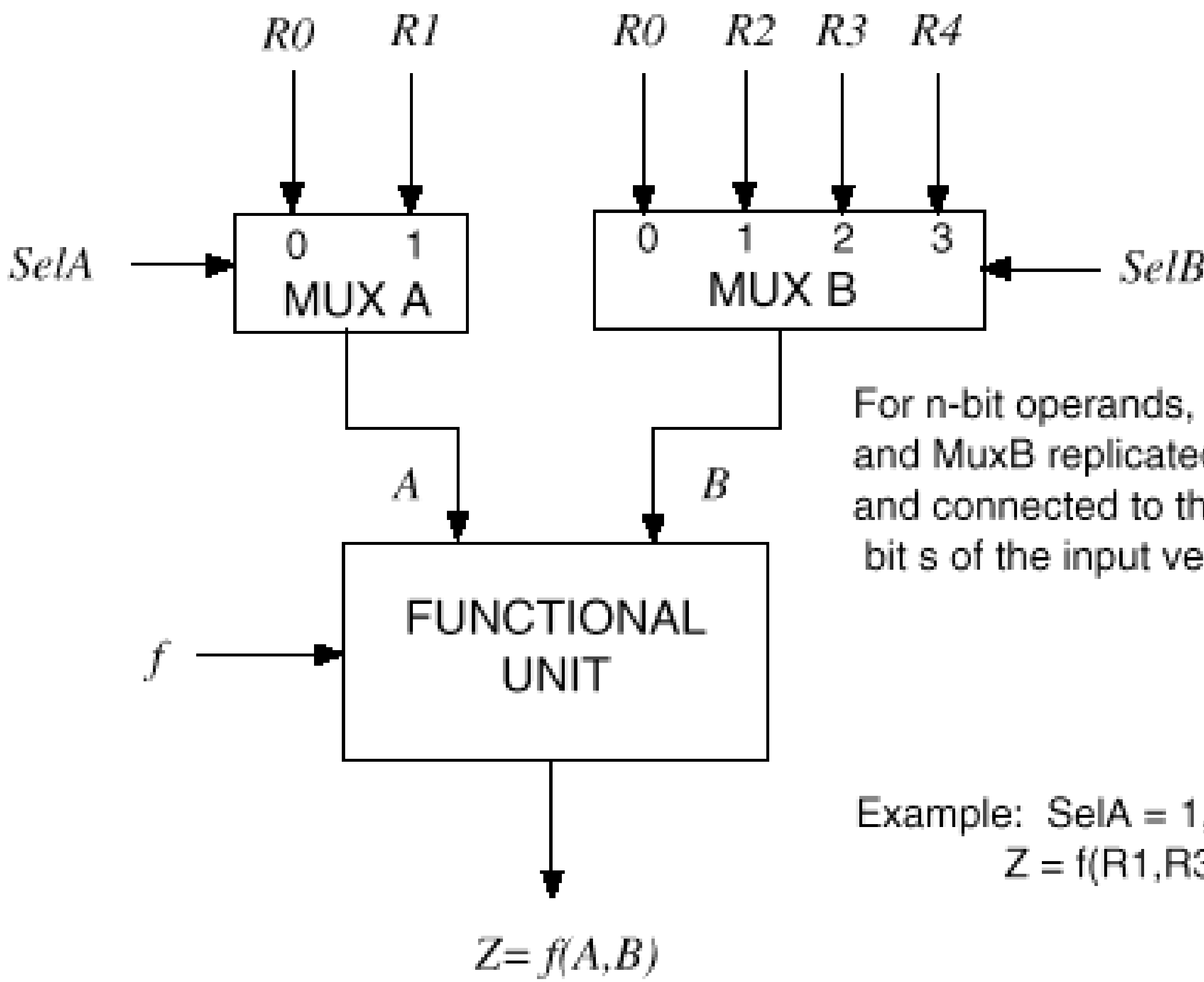
Fig. 4-27 Implementing a Boolean Function with a Multiplexer

# Implementing a Four- Input Function with a Multiplexer

| A | B | C | D | F | |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | F = D |
| 0 | 0 | 0 | 1 | 1 | |
| 0 | 0 | 1 | 0 | 0 | F = D |
| 0 | 0 | 1 | 1 | 1 | |
| 0 | 1 | 0 | 0 | 1 | F = $\overline{D}$ |
| 0 | 1 | 0 | 1 | 0 | |
| 0 | 1 | 1 | 0 | 0 | F = 0 |
| 0 | 1 | 1 | 1 | 0 | |
| 1 | 0 | 0 | 0 | 0 | F = 0 |
| 1 | 0 | 0 | 1 | 0 | |
| 1 | 0 | 1 | 0 | 0 | F = D |
| 1 | 0 | 1 | 1 | 1 | |
| 1 | 1 | 0 | 0 | 1 | F = 1 |
| 1 | 1 | 0 | 1 | 1 | |
| 1 | 1 | 1 | 0 | 1 | F = 1 |
| 1 | 1 | 1 | 1 | 1 | |



# Typical multiplexer uses



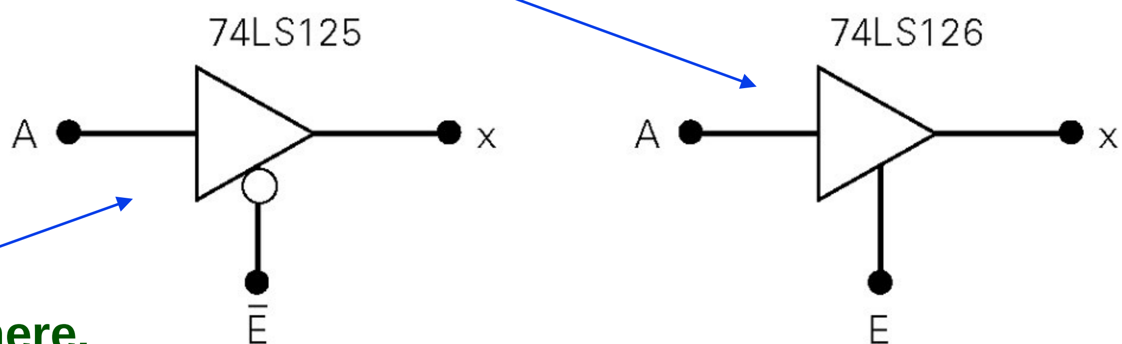

For n-bit operands, Mux A and MuxB replicated n times and connected to the corresponding bit s of the input vectors.

Example: SelA = 1, SelB = 2
Z = f(R1,R3)

Figure 9.21: Multiplexer example of use.

# Three-state gates

- **A multiplexer can be constructed with three-state gates**
- **Output state: 0, 1, and high-impedance (open ckts)**
- **If the select input (E) is 0, the three-state gate has no output**




**Opposite true here,**

**No output if $\bar{E}$ is 1**

| $\bar{E}$ | x |
|---|---|
| 0 | A |
| 1 | Hi-Z |

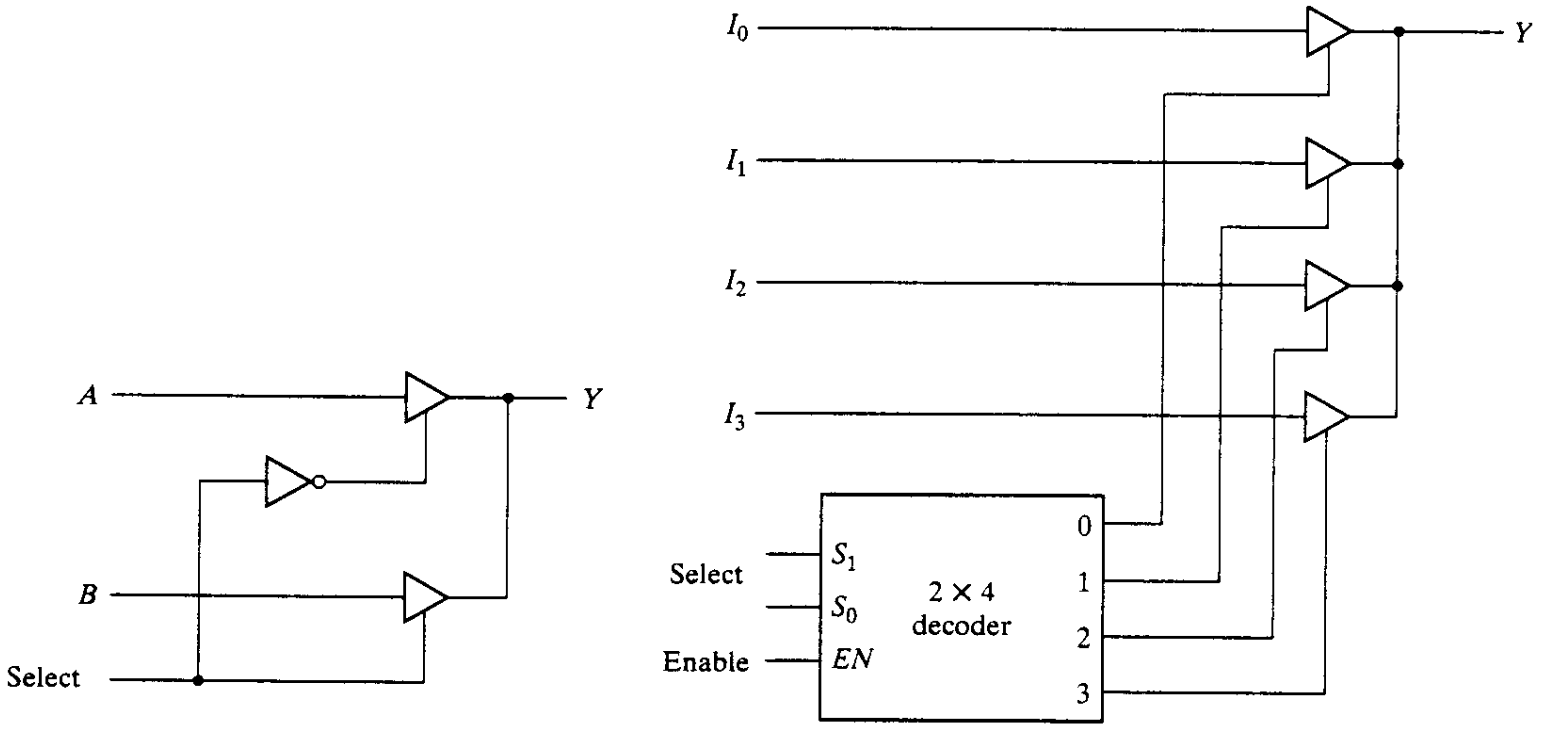
(a)

| E | x |
|---|---|
| 0 | Hi-Z |
| 1 | A |

(b)

# Three-state gates

- A multiplexer can be constructed with three-state gates
- Output state: 0, 1, and high-impedance (open ckts)
- If the select input is low, the three-state gate has no output




(a) 2-to-1- line mux

(b) 4 - to - 1 line mux

# Summary

- Magnitude comparators allow for data comparison
  - Can be built using and-or gates
- Greater/less than requires more hardware than equality
- Multiplexers are fundamental digital components
  - Can be used for logic
  - Useful for datapaths
  - Scalable
- Tristate buffers have three types of outputs
  - 0, 1, high-impedence (Z)
  - Useful for datapaths