

# CSCI 210: Computer Architecture

## Lecture 15: Digital Logic

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Slides from Cynthia Taylor

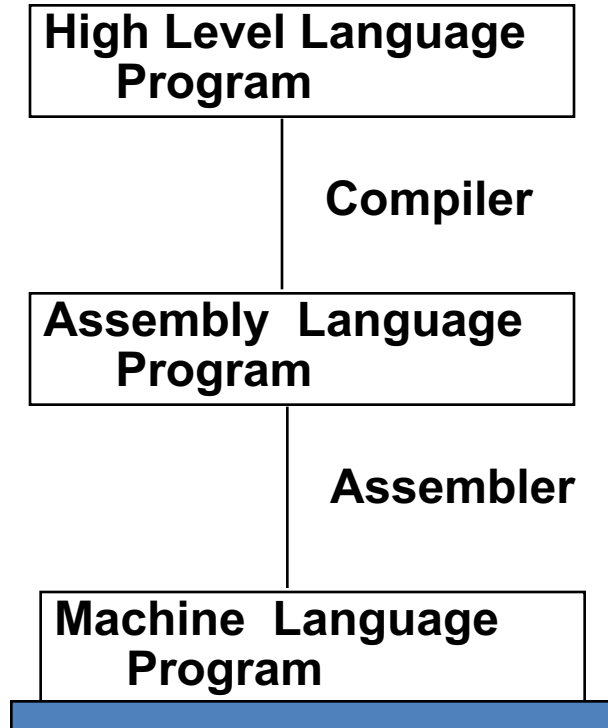
# Announcements

- Problem Set 4 due today
- Lab 3 due Sunday!
- Office Hours today 13:30 – 14:30 pm

# Creating the Universe from 1 and 0

- We have seen how to build programs from assembly
- Now we'll learn how we build assembly language instructions out of circuits

# Machine Interpretation



**Machine Interpretation**

```
temp = v[k];  
v[k] = v[k+1];  
v[k+1] = temp;
```

```
lw $15, 0($2)  
lw $16, 4($2)  
sw $16, 0($2)  
sw $15, 4($2)
```

```
10001100011000100000000000000000  
10001100111100100000000000000100  
10101100111100100000000000000000  
10101100011000100000000000000100
```

**Machine does something!**

A digital circuit is comprised of signals, gates, and wires.

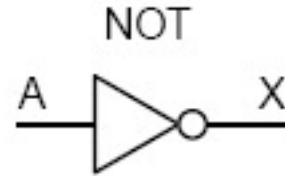
- Signals
  - Voltages applied to lines which generate electric current
- Binary signals are represented by different voltages:
  - 0: 0-1 volts
  - 1: 2-5 volts

A digital circuit is comprised of signals, gates, and wires.

- Gates
  - Devices which perform operations on signals corresponding to basic logic operations: and, or, not, nand, nor, xor
  - Made out of transistors
- Wires
  - Lines over which signals are transmitted between gates

# Representation of Logic Gates

- Symbol



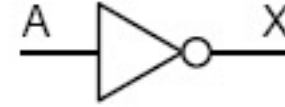
- Truth Table

A	X
0	1
1	0

- Algebraic Representation

$\bar{A}$

# Not

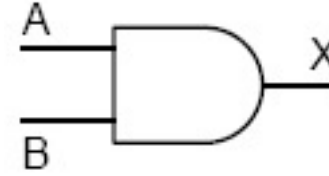


A	X
0	1
1	0

- Inverts the input
- Algebraic representation:  $\bar{A}$



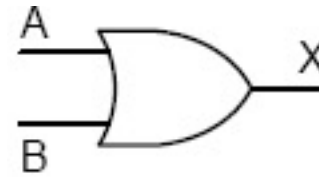
# And



A	B	X
0	0	0
0	1	0
1	0	0
1	1	1

- Algebraic representation:  $AB$  or  $A \cdot B$

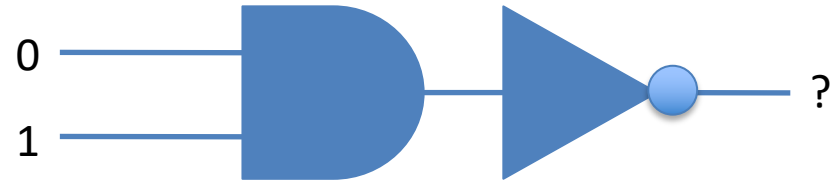
# Or



A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

- Algebraic representation:  $A+B$

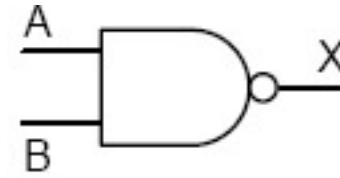
# And and Not



A. 0

B. 1

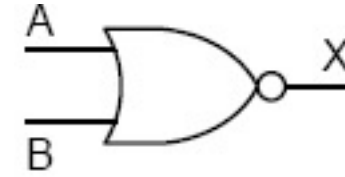
# Nand



A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

- Algebraic representation:  $\overline{(A \cdot B)}$

# Nor



A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

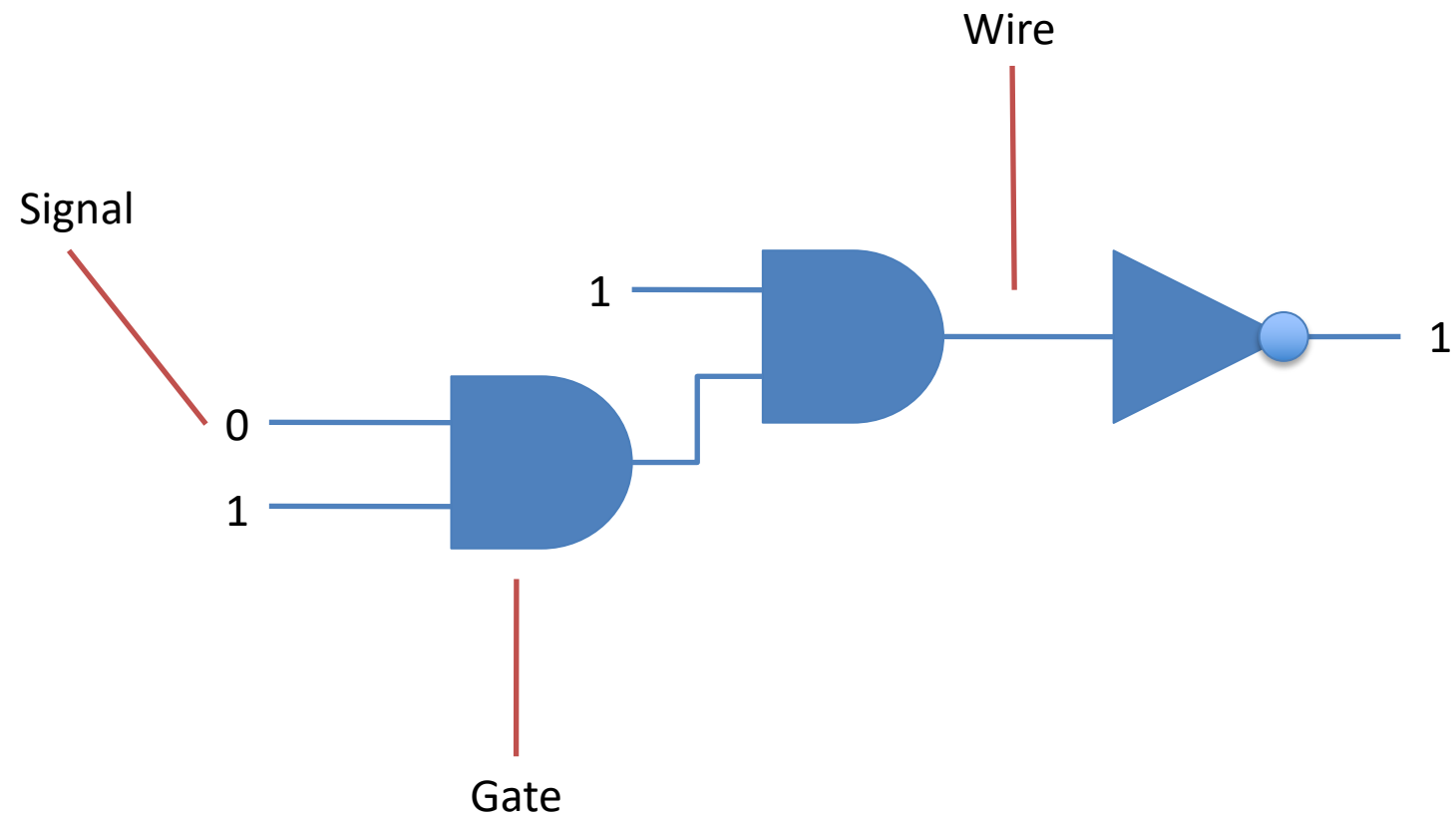
- Algebraic representation:  $\overline{(A + B)}$

# Xor

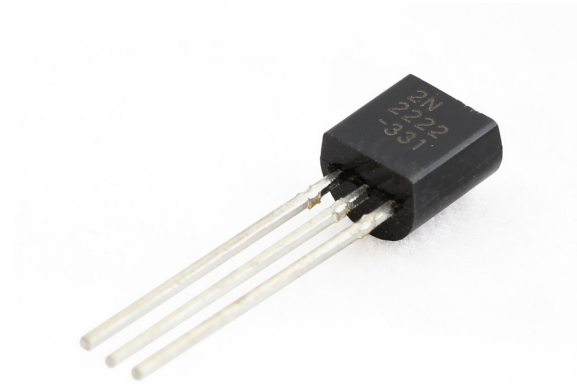
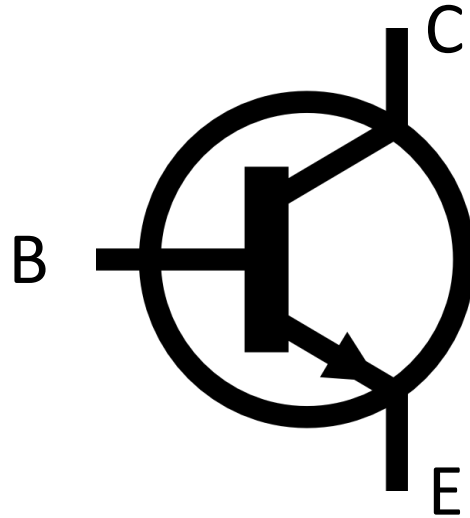


A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

- Algebraic representation:  $A \wedge B$  or  $A \oplus B$



# Our Friend the Transistor

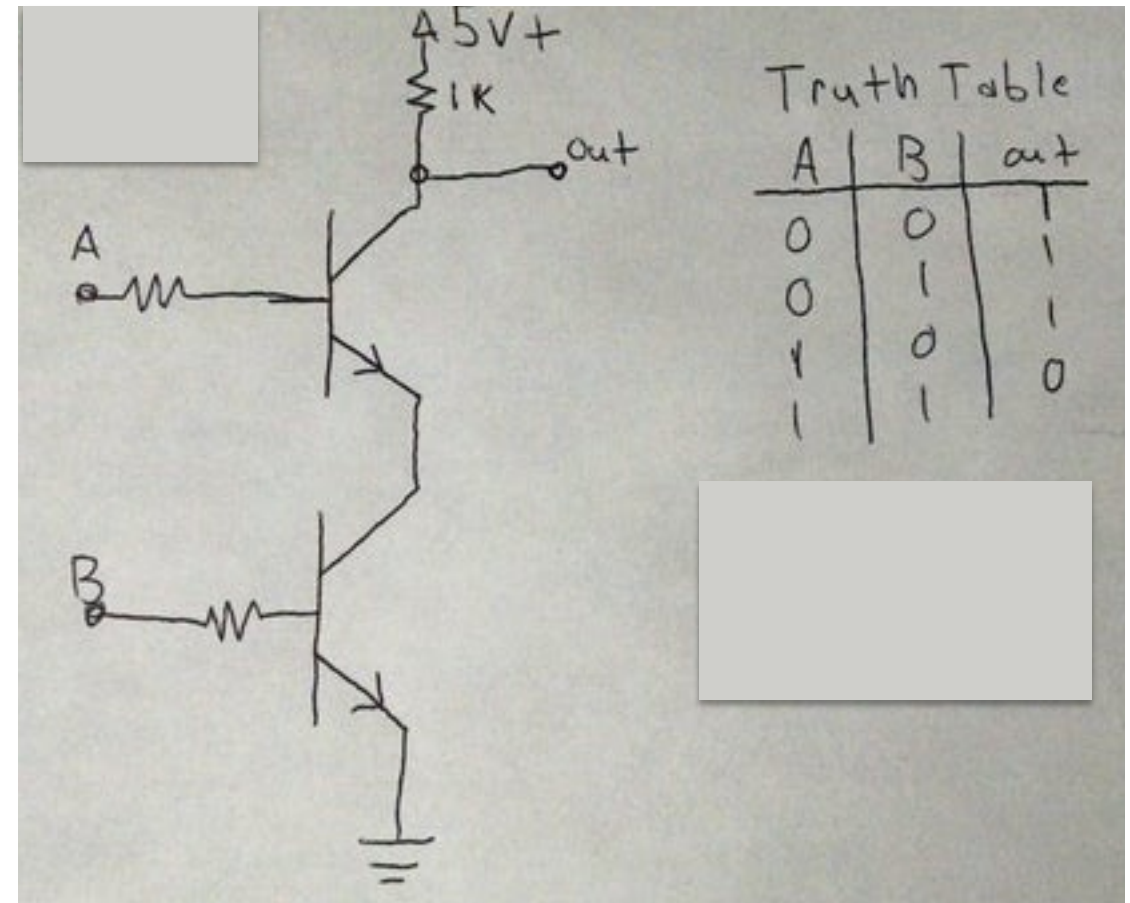


- The basic electronic component from which all gates are created; there are many types, this is an NPN transistor
- When the base (B) has a high voltage, current can flow from the collector (C) to the emitter (E)
- This creates an on/off switch



# Building gates out of switches

- Two inputs A and B
- One output out
- When A or B are 1, the other two electrodes (collector and emitter) are connected
- When A and B are both 1, out is connected to ground (logic value 0)
- When either A or B is 0, out is not connected to ground and current can flow from 5V to out

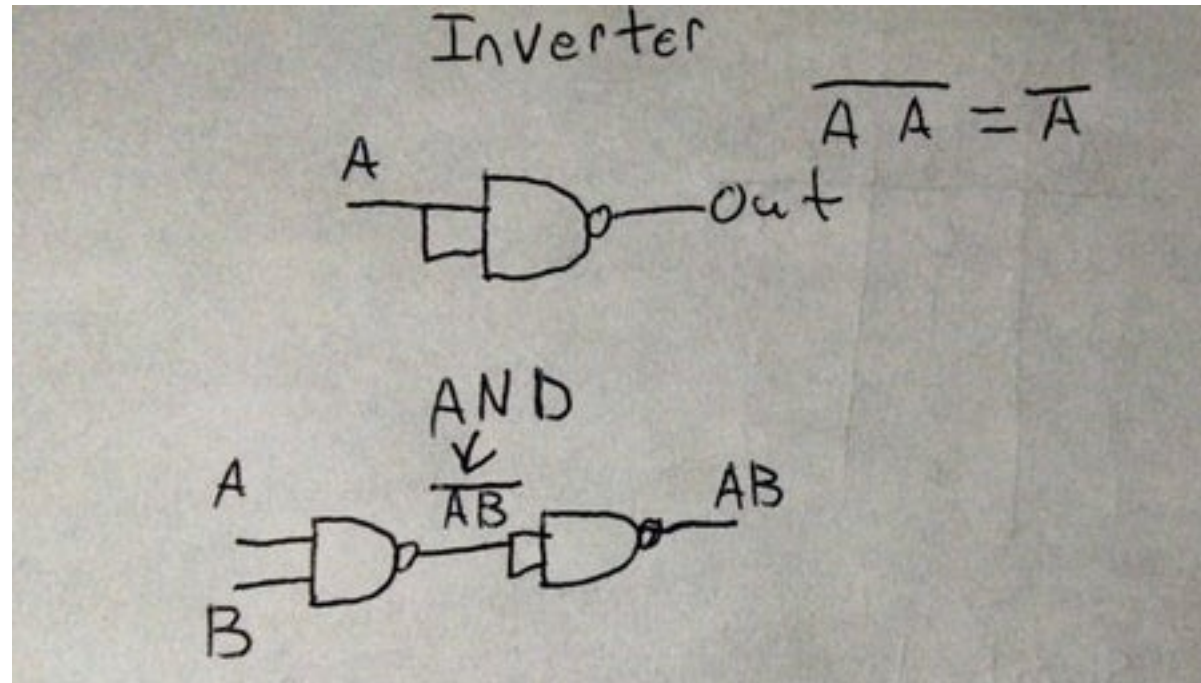


# What Gate Does This Match?

- If A and B are high voltage (logical 1), C will be low voltage (logical 0)
- Otherwise, C is high voltage

- A. AND
- B. OR
- C. NAND
- D. NOR

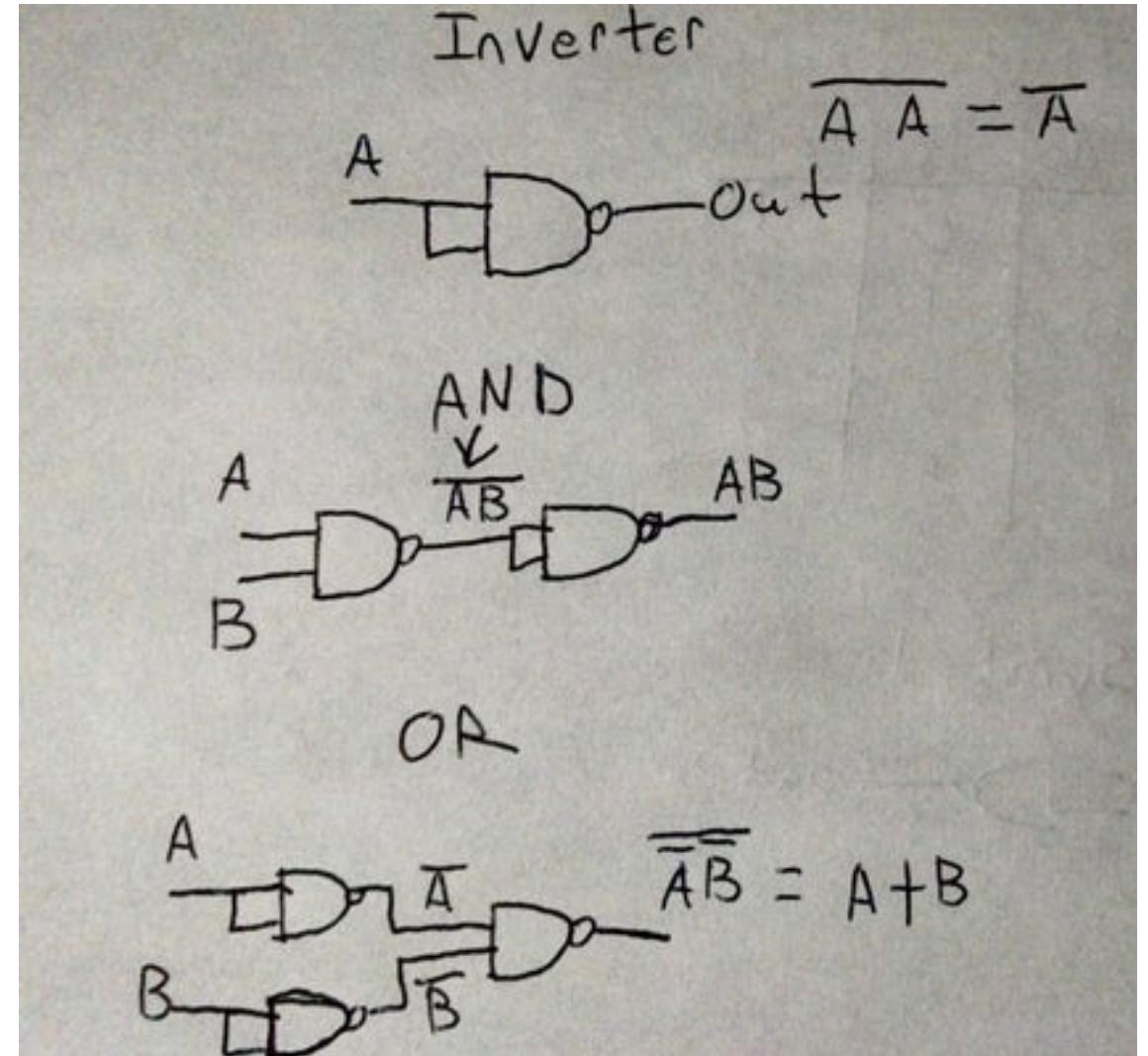
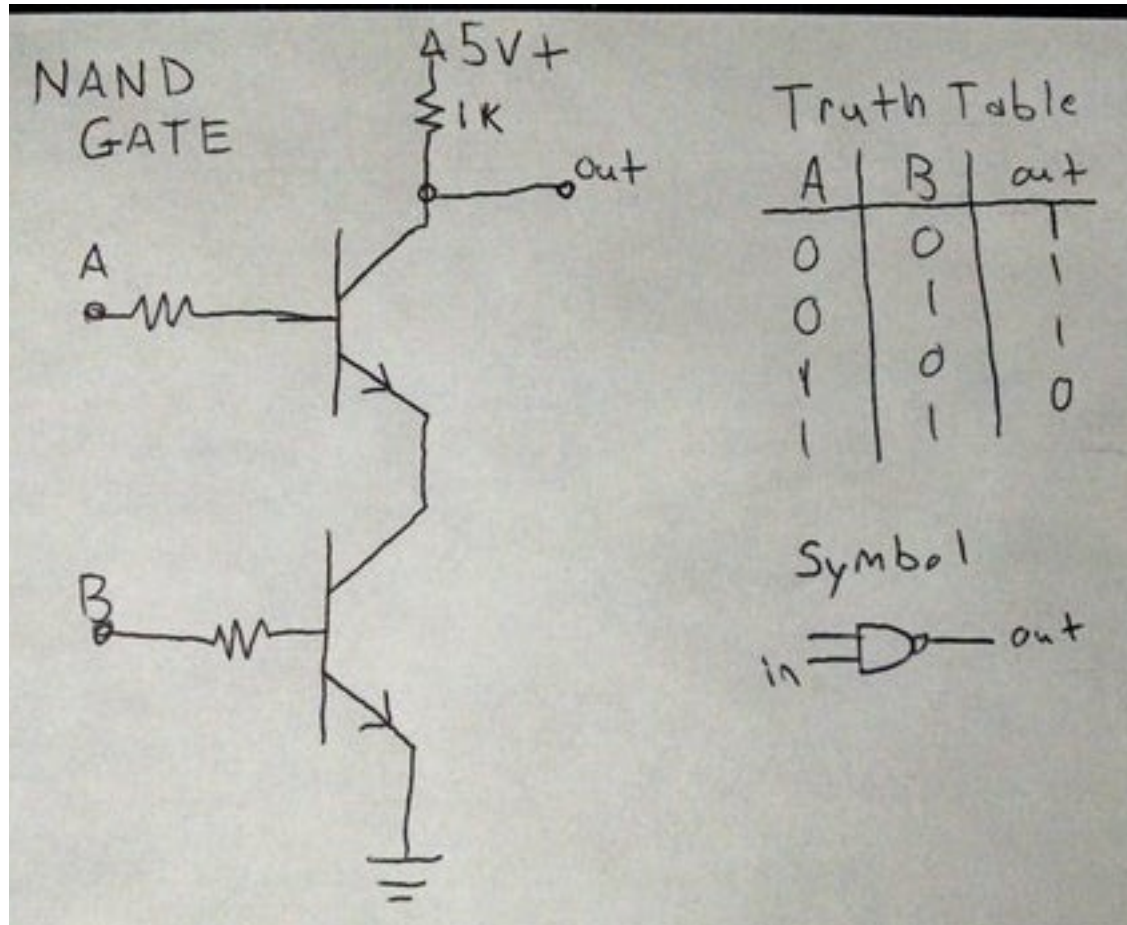
# All Other Gates Can Be Created From NAND



# Which is equivalent to $A \text{ OR } B$ ?

- A.  $A \text{ NAND } B$
- B.  $\text{NOT } (A \text{ NAND } B)$
- C.  $(\text{NOT } A) \text{ NAND } (\text{NOT } B)$
- D.  $\text{NOT } ((\text{NOT } A) \text{ NAND } (\text{NOT } B))$
- E. None of the above

# Putting them together



# All Other Gates Can Be Created from NOR

- You will show this in Problem Set 5

Which column completes the truth table for

$$F = \overline{X} \cdot (Y + Z) ?$$

X	Y	Z	A	B	C	D
0	0	0	0	0	1	1
0	0	1	1	1	1	1
0	1	0	1	1	1	1
0	1	1	1	1	1	1
1	0	0	0	0	0	0
1	0	1	0	1	0	1
1	1	0	0	1	0	1
1	1	1	0	1	0	1

Diagram:  $F = \overline{X} \cdot (Y + Z)$



$$F = \overline{A} + (B(AC + \overline{A}\overline{B}))$$

Truth Table

A	B	C	$AC$	$\overline{A}\overline{B}$	$B(AC + \overline{A}\overline{B})$	$F$
0	0	0				
0	0	1				
0	1	0				
0	1	1				
1	0	0				
1	0	1				
1	1	0				
1	1	1				

# Reading

- Next lecture: Boolean Algebra
  - 3.3
- Problem Set 4 due today
- Lab 3 due Sunday