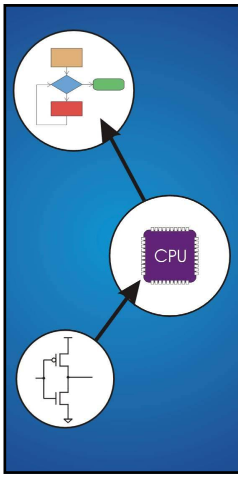
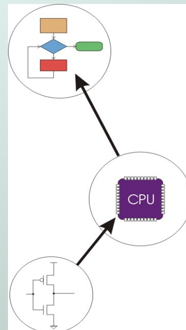


Chapter 3
Digital Logic Structures

Original slides from Gregory Byrd, North Carolina State University

Modified slides by Chris Wilcox, Colorado State University

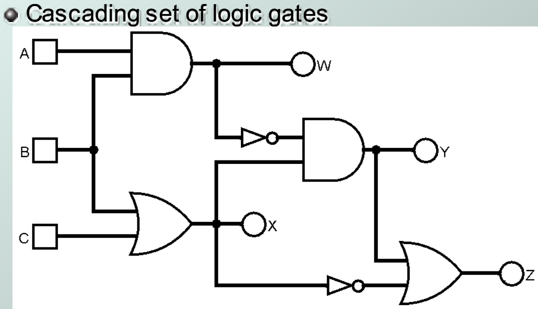
Computing Layers



- Problems
- Algorithms
- Language
- Instruction Set Architecture
- Microarchitecture
- Circuits ←
- Devices

Combinational Logic

- Cascading set of logic gates



What is the truth table?

Truth Table (from circuit)

- Truth table for circuit on previous slide

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

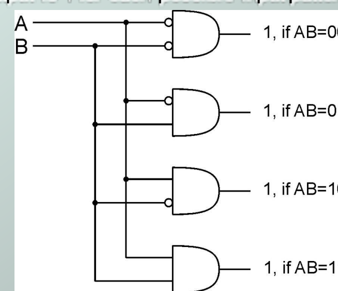
Logisim Simulator

- Logic simulator: allows interactive design and layout of circuits with AND, OR, and NOT gates
- Simulator web page (linked on class web page)
  http://ozark.hendrix.edu/~burch/logisi
- Overview, tutorial, downloads, etc.
- Windows or Linux operating systems
- Logisim demonstration

Decoder

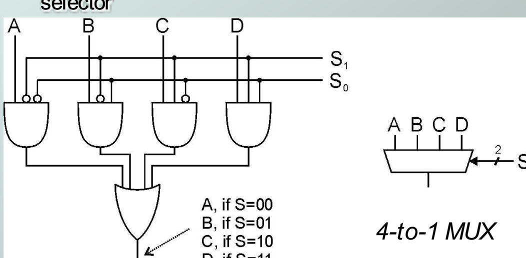
- *n* inputs, 2^n outputs
  - exactly one output is 1 for each possible input pattern

2-bit decoder



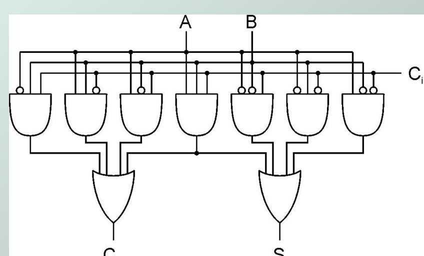
Multiplexer (MUX)

- *n*-bit selector and 2^n inputs, one output
  - output equals one of the inputs, depending on selector



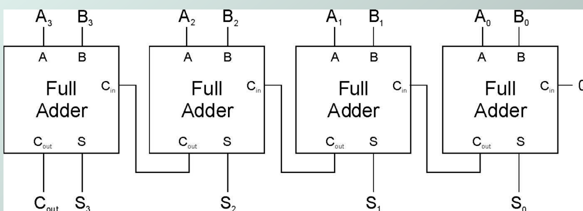
Full Adder

- Add two bits and carry-in, produce one-bit sum and carry-out.



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

Four-bit Adder



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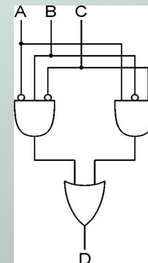
Logical Completeness

- Can implement ANY truth table with combo of AND, OR, NOT gates.

A	B	C	D
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	0



1. AND combinations that yield a "1" in the truth table.
2. OR the results of the AND gates.

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Truth Table (to circuit)

- How do we design a circuit for this?

A	B	C	X	Y
0	0	0	1	0
0	0	1	0	1
0	1	0	1	0
0	1	1	0	1
1	0	0	0	0
1	0	1	0	1
1	1	0	1	0
1	1	1	1	1

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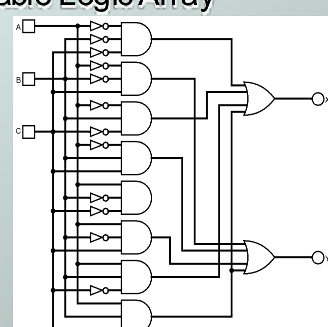
Programmable Logic Array

- Front end is decoder for inputs
- Back end defines the outputs
- Any truth table can be built
- Not necessarily minimal circuit!

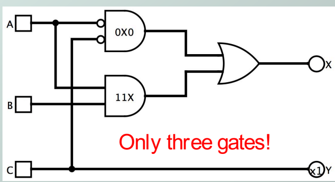


Requires (at least) ten gates.

Circuit Minimization

- Gate array design has one unused AND gate.
- Boolean logic lets us reduce even further:
  - X = $\overline{ABC}$ + $\overline{A}B\overline{C}$ + $AB\overline{C}$ + ABC =
    = $\overline{AC}$ + AB
  - Y = $\overline{AB}C$ + $\overline{A}BC$ + $A\overline{B}C$ + ABC = C

A	B	C	X	Y
0	0	0	1	0
0	0	1	0	1
0	1	0	1	0
0	1	1	0	1
1	0	0	0	0
1	0	1	0	1
1	1	0	1	0
1	1	1	1	1



Looking Ahead: C Structures

- Useful for data structures

```
struct student
{
    char *lastName;
    char *firstName;
    Date birthDate;
    …
};
struct student s;
s.lastname = (char *)malloc(80);
strcpy(s.lastname, "Smith");
```


Looking Ahead: Dynamic Memory

- Static versus dynamic memory allocation:

```
// static allocation
char name[80];
strcpy(name, "Smith");
printf("Name: %s\n", name);
// dynamic allocation
char *name = (char *)malloc(80);
strcpy(name, "Smith");
printf("Name: %s\n", name);
free(name);
```


Looking Ahead: String Tokens

- How to extract tokens from a string:

```
char *token = strtok(string, " \t");
while (token != null)
{
    tokens[numTokens] = (char *)
            malloc(strlen(token)+1);
    strcpy(tokens[numTokens], token);
    token = strtok(NULL, " \t");
    numTokens++;
}
```