## Lecture 21: Combinational Circuits

- Integrated Circuits
- Combinational Circuits
  - Multiplexer
  - Demultiplexer
  - Decoder
  - Adders
  - ALU

## **Integrated Circuits**

- Circuits use modules that contain multiple gates packaged together, rather than individual gates.
- These are called Integrated Circuits (ICs, chips)
  - SSI (small scale integration): 1-10 gates/chip
  - MSI (medium scale integration): 10-100 gates/chip
  - LSI (large scale integration): 100 100,000 gates/chip
  - VLSI (very large scale integration): more than 100,000 gates/chip

• TTL example (older Tannenbaum)

#### Integrated Circuits, cont.

- Current technology could put 5 million NAND gates on a chip!
- But... that chip would need 15,000,002 pins.
- With standard pin spacing, an 18km long chip.
- Instead, circuits are designed with a high gate/pin ratio.



- Def: a set of interconnected gates whose output at any time is a function of the input at that time.
- The appearance of input is followed almost immediately by output, with only gate delays.

### Multiplexer (MUX)

- A circuit that goes from many inputs to one output.
- The select lines are used to pick one of the input lines to directly output to the output line.



#### MUX, cont.

- S1 and S0 are connected to AND gates in such a way that for any combination of S0 and S1, 3 of the AND gates will output 0
- The 4<sup>th</sup> AND gate will output the value of the selected input line.
- So, 3 inputs to the OR-gate will always be 0, and the output of the OR-gate will equal the value of the selected input gate.



## Demultiplexer

- Reverse of Multiplexer:
- Control lines choose which of the output lines will get the input bit (the rest of the output lines will get 0)



## Decoder

- A circuit that asserts one output line, depending on a pattern of input lines.
- In this circuit, inputs are the select lines. The line they select gets a one, all other lines get zero.



A B

0 0

0 1

1 0

1 1

carry

Sum Carry

0

0

0

1

sum

0

1

1

0

A + B

C S





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## Full-Adder

- For multiple-bit addition, need a full adder.
- Truth table:

A B	CarryIn	Sum	CarryOut
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



## Arithmetic Logic Units

- Most computers have a single circuit for performing AND, OR, and sum of two words.
- For n-bit words, built from n identical circuits or individual bit positions.
- These are known as 1-bit ALUs or bit slices.

# ALU

• Figure 3-19 from Tannenbaum.