Principles of Computer Science I

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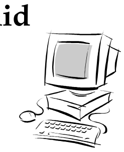
CSC 120A - Fall 2004

Lecture Unit 6



Computers and Electricity

- Computers represent data using voltage levels along wires
- Signal of 0 to 2 volts is considered "low" and interpreted as binary "0"
- Signal of 2 to 5 volts is "high" and interpreted as binary "1"
- Gate: device that performs a basic operation on electrical signals
  - One or more inputs
  - Single output
- Circuit: combination of gates that perform more complicated task
  - Arithmetic operations
  - Storing values

Describing Gates and Circuits

- Three notations, different but equally expressive
- Boolean expressions
  - Form of algebra invented by George Boole (English mathematician, b. 1815)
  - Mathematical notation for expressing logical functions
- Logic diagrams
  - Graphical representation of circuit
  - Each gate has a specific graphical symbol
  - Gates connected by wires to visually represent logic of entire circuit
- Truth tables
  - List of all possible input combinations for gate/circuit along with corresponding output

Basic Gates

- NOT *(inverter)*

Boolean Expression: X = A'

Logic Diagram Symbol:

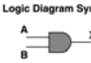
Truth Table

A	X
0	1
1	0

- AND

Boolean Expression: X = A · B

Logic Diagram Symbol:



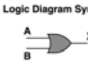
Truth Table

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

- OR

Boolean Expression: X = A + B

Logic Diagram Symbol:



Truth Table

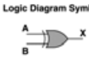
A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

Other Basic Gates

- XOR

Boolean Expression: X = A ⊕ B

Logic Diagram Symbol:



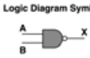
Truth Table

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

- NAND

Boolean Expression: X = (A · B)'

Logic Diagram Symbol:



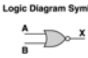
Truth Table

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

- NOR

Boolean Expression: X = (A + B)'

Logic Diagram Symbol:



Truth Table

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

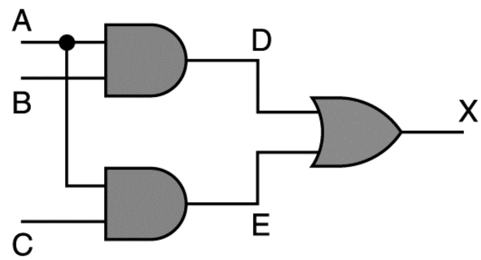
Constructing Gates

- Gates can be designed to have three or more inputs
- Gates use one or more transistors to map input to output
- A transistor is a device that acts, depending on the voltage level of an input signal, either as a wire that conducts electricity or as a resistor that blocks the flow of electricity
  - Invented 1947, Bell Labs; revolutionized technology
  - Made of semiconductor material-- neither particularly good conductor of electricity, such as copper, nor particularly good insulator, such as rubber
  - Replaced vacuum tubes, which gave off great deal of heat and often failed, requiring replacement

Circuits

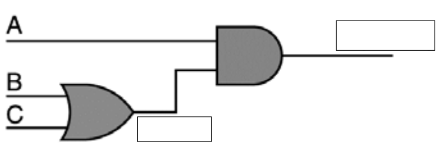
- Two general categories
  - In a combinational circuit, the input values explicitly determine the output
  - In a sequential circuit, the output is a function of the input values as well as the existing state of the circuit
- As with gates, we can describe the operations of circuits using three notations
  - Boolean expressions
  - Logic diagrams
  - Truth tables

A Combinational Circuit



- Boolean expression…
- Truth table…

Another Combinational Circuit



- Boolean expression…
- Truth table…
- Compare the two circuits, Boolean expressions

Boolean Algebra

- Allows us to apply provable mathematical principles to help us design logical circuits
- Properties:

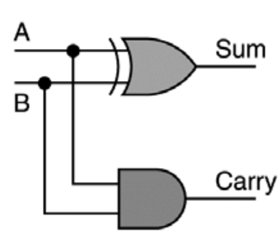
Property	AND	OR
Commutative	AB = BA	A + B = B + A
Associative	(AB)C = A(BC)	(A + B) + C = A + (B + C)
Distributive	A(B + C) = (AB) + (AC)	A + (BC) = (A + B)(A + C)
Identity	A1 = A	A + 0 = A
Complement	A(A') = 0	A + (A') = 1
DeMorgan's law	(AB)' = A' OR B'	(A + B)' = A'B'

Adders

- At the digital logic level, addition is performed in binary
- Addition operations are carried out by special circuits called, appropriately, adders
- The result of adding two binary digits could produce a *carry value*
- Recall that 1 + 1 = 10 in base two
- A circuit that computes the sum of two bits and produces the correct carry bit is called a *half adder*

Half Adder

A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1



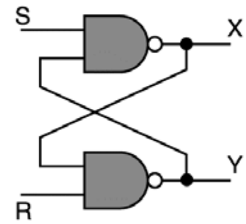
sum = $A \oplus B$
carry = AB

Full Adder

- A circuit called a full adder takes the carry-in value into account

Circuits as Memory

- Digital circuits can be used to store information
- These circuits form a sequential circuit, because the output of the circuit is also used as input to the circuit
- Example: The value of X at any point in time is considered to be the current state of the circuit

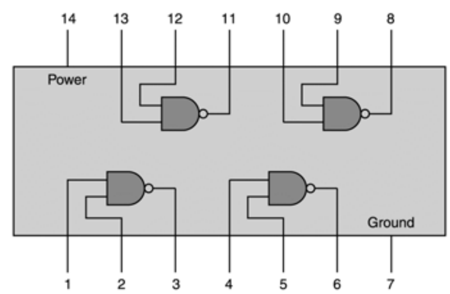


Integrated Circuits (Chips)

- Piece of silicon on which multiple gates have been embedded
- Silicon pieces are mounted on a plastic or ceramic package with pins along the edges
  - Can be soldered onto circuit boards or inserted into appropriate sockets
- Classified by number of gates:

Abbreviation	Name	Number of Gates
SSI	Small-Scale Integration	1 to 10
MSI	Medium-Scale Integration	10 to 100
LSI	Large-Scale Integration	100 to 100,000
VLSI	Very-Large-Scale Integration	more than 100,000

An SSI Chip

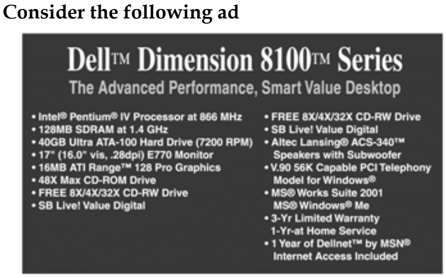


CPU Chips

- The most important integrated circuit in any computer is the Central Processing Unit, or CPU
- Each CPU chip has a large number of pins through which essentially all communication in a computer system occurs

Computer Components

- Consider the following ad



- What does it all mean?

Sizes in Perspective

Power of 10	Power of 2	Value of Power of 2	Prefix	Abbreviation	Derivation
10^{-12}			pico	p	Spanish for little
10^{-9}			nano	n	Greek for dwarf
10^{-6}			micro	μ	Greek for small
10^{-3}			milli	m	Latin for thousand
10^{3}	2^{10}	1024	kilo	K	Greek for thousandth
10^{6}	2^{20}	1,048,576	mega	M	Greek for large
10^{9}	2^{30}	1,073,741,824	giga	G	Greek for giant
10^{12}	2^{40}	not enough room	tera	T	Greek for monster
10^{15}	2^{50}	not enough room	peta	P	Greek prefix for five

Jargon

- MHz – megahertz / GHz – gigahertz
  - Hertz = cycles per second
- SDRAM – static dynamic random access memory (main memory): 128 x 2^{20} bytes
  - Can be accessed at 1.4GHz (cycles per second)
- Disk drive:
  - Ultra ATA-100 – type of interface/transfers data at 100MB/second
  - Spins at 7200 revolutions per minute
- Monitor
  - 16″ visible, .28 dot pitch
- CDROM, CD-RW
  - ROM – read-only-memory
  - DVD: digital versatile disk
- Sound card, speakers
- Modem
  - 56K: 56,000 bytes per second
- Software, services…