Circuits

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CSC 120.02: Introduction to Computer Science

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Combinatorial and Sequential Circuits: Definitions

A *combinatorial circuit* is a circuit whose output is solely determined by its input values.

A *sequential circuit* is a circuit whose output is a function of input values and the current state of the circuit.
Combinatorial Circuits

Java expression:

```java
boolean A, B, C, X;
X = ((A && B) || (A && C));
```
Combinatorial Circuits (cont’d)

Java expression:

```java
boolean A, B, C, X;
X = A && (B || C);
```
## Properties of Boolean Algebra

<table>
<thead>
<tr>
<th>Property</th>
<th>AND</th>
<th>OR</th>
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<tbody>
<tr>
<td>Commutative</td>
<td>$A \cdot B = B \cdot A$</td>
<td>$A + B = B + A$</td>
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<tr>
<td>Associative</td>
<td>$(A \cdot B) \cdot C = A \cdot (B \cdot C)$</td>
<td>$(A + B) + C = A + (B + C)$</td>
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<td>Distributive</td>
<td>$A \cdot (B + C) = (A \cdot B) + (A \cdot C)$</td>
<td>$A + (B \cdot C) = (A + B) \cdot (A + C)$</td>
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<td>Identity</td>
<td>$A \cdot 1 = A$</td>
<td>$A + 0 = A$</td>
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<td>Complement</td>
<td>$A \cdot (A') = 0$</td>
<td>$A + (A') = 1$</td>
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<td>DeMorgan’s law</td>
<td>$(A \cdot B)' = (A') + (B')$</td>
<td>$(A + B)' = (A') \cdot (B')$</td>
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Half Adder

Problem with the Half Adder: No Carry-In
Full Adder

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>Carry-in</th>
<th>Sum</th>
<th>Carry-out</th>
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<tbody>
<tr>
<td>0</td>
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Multiplexer

A *multiplexer*, or a *mux*, is a circuit that takes several input signals and produces one output signal so that its output is equal to one of the inputs chosen based on the values of a few more special input signals called *select signals*, or *select control lines*.
A simple S-R flip-flop: (a) circuit; (b) symbol; (c) function table.
Circuits as Memory (cont’d)

Positive edge-triggered D flip-flop: (a) symbol; (b) function table.

\[ \begin{array}{c|c|c}
  \text{CLK} & D & Q \\
  \hline
  0 & 0 & 0 \\
  1 & 1 & 1 \\
  0 & x & \text{last } Q \\
  1 & x & \text{last } Q \\
\end{array} \]

\textit{D flip-flops} are grouped together into \textit{registers} to store multi-bit quantities in a computer.
Integrated Circuits (Chips)

SSI: Small-Scale Integration
MSI: Medium-Scale Integration
LSI: Large-Scale Integration
VLSI: Very-Large-Scale Integration

SSI: 1 to 10 gates
MSI: 10 to 100 gates
LSI: 100 to 100,000 gates
VLSI: more than 100,000 gates