Chapter # 2: Two-Level Combinational Logic

Section 2.5 -- Practical Matters
Practical Matters

- Underlying technologies used to implement digital functions, how logic gates are combined into integrated circuit packages, and the standard techniques for documenting logic schematics.
Technology Metrics -- Faster gates consume more power, generate more heat, cannot be packaged as densely, and are more sensitive to noise problems

Gate Delay -- time delay between a change in the input that causes a change in output

Degree of Integration -- area required to implement a given function in the underlying technology.
SSI -- small scale integrated circuit -- package containing up to 10 logic gates
MSI -- medium scale IC -- up to 100 gates
VLSI -- very large scale IC -- thousands of gates

Power dissipation -- gates consume power as they perform their logic functions, generating heat that must be dissipated

Noise Margin -- maximum voltage that can be added to or subtracted from the logic voltages and still have the circuit interpret the voltage as the correct logic values.
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Fan Out -- Ease with which gates can be composed into more complex functions

Driving Capability -- Discrete gates are usually placed with other gates in ready to use packages. Speed of communication between packaged components.

Comparison between Bipolar and MOS technologies

<table>
<thead>
<tr>
<th>Metric</th>
<th>Bipolar</th>
<th>MOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate delay</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Integration</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Power</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Noise</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Cost</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Fan-out</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>Drive</td>
<td>Good</td>
<td>Low</td>
</tr>
</tbody>
</table>
TTL Packaged Logic

- TTL is a family of packaged logic components that enjoys widespread use in industry

- TTL IC package typically contains several logic gates. TI 74-series components provide the standard numbering scheme used by industry

- Ex. 7400 -- NAND gate -- contains four 2-input NAND gates
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Subfamilies of TTL

- All subfamilies implement the same logic functions but represent different trade-offs between speed of operation and power consumed
- The faster the component, the more power it consumes

<table>
<thead>
<tr>
<th>Subfamily</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>74XX</td>
<td>Standard TTL components</td>
</tr>
<tr>
<td>74HXX</td>
<td>High speed TTL components. One-third faster and twice as much power as standard</td>
</tr>
<tr>
<td>74LXX</td>
<td>Low power. 1/10 of power and 4 times the delay as standard</td>
</tr>
<tr>
<td>74SXX</td>
<td>Schottky TTL. Faster and uses same power as H-TTL</td>
</tr>
<tr>
<td>74LSXX</td>
<td>Low-power schottky. As Fast and uses 20% of power as standard</td>
</tr>
<tr>
<td>74 ASXX</td>
<td>Twice speed and Comparable power consumption as S-TTL</td>
</tr>
<tr>
<td>74 ALSXX</td>
<td>Less power and high speed than LS</td>
</tr>
</tbody>
</table>
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Speed-Power Product

Delay through the gate multiplied by the power it consumes. The smaller the better.

High speed system is desirable but components are more expensive and system consumes more power.

Higher power consumption system runs hotter and needs more expensive cooling and power supplies.

Ex. TTL (9 ns x 10 mW = 90)
LSTTL (9 ns x 2 mW = 18)
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Polarization and Bubbles

A signal with positive (.H) polarity is asserted at a high voltage level.

A signal with negative (.L) polarity is asserted at a low voltage level.

A bubble on a logic symbol indicates that an input or output is inverted.

An input with a bubble means that the input signal is to be asserted low.

A bubble output is asserted when its voltage is low.

Bubbled input should almost always match a bubbled output or another signal that is specified as being asserted active low.
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Polarization and Bubbles

Incorrect bubble matching

Correct bubble matching

5 active high input signals are ANDed together
Chapter # 3: Multi-Level Combinational Logic

Section 3.5 -- Practical Matters
Elements of the Data Sheet

- English language description
- Function / truth table
- Logic schematics
- Boolean expression
- Package pin-out
- Transistor schematics
- Absolute maximum ratings
- Recommended operating conditions
- Electrical characteristics
- Switching characteristics
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Simple Performance Characteristics

• **Typical Propagation Delay**
  – Take average of typical low-high and high-to-low propagation delays
  – Ex. 74LS00 -- 9.5 ns
  – Conservative design always uses the maximum propagation delays

• **Power Consumption (steady-state)**
  – Multiply gate current in holding outputs high or low by the power supply voltage
  – Nominal power supply voltage is 5V
  – Current $I_{CCH}$, $I_{CCL}$
  – Ex. 74LS00 (per package)
    \[
    \frac{I_{CCH} + I_{CCL}}{2} \times V_{CC} = \frac{0.8\, mA + 2.4\, mA}{2} \times 5V = 8\, mW
    \]
  – Divide by 4 to compute per gate

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Simple Performance Characteristics

- **Fan Out**
  - Typical TTL output can drive only a finite number of inputs before the output signal levels become degraded and are no longer recognized as good logic 0’s or 1’s.
  - (Absolute value of) \( I_{OH} \) of the driving gate must exceed the sum of the \( I_{IH} \) values of the inputs that the gate is driving
  - \( I_{OL} \) of the gate must exceed the (absolute value of) sum of the \( I_{IL} \) values of the inputs to which it is connected
  - Ex. 74LS00
    - \( I_{IH} = 20 \, \mu A \)
    - \( I_{OH} = -0.4 \, mA \)
    - LS NAND gate can drive 20 similar gates to a logic 1
    - \( I_{IL} = -0.36 \, mA \)
    - \( I_{OL} = 8 \, mA \)
    - LS NAND gate can drive 22 similar gates to a logic 0
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Inputs and Outputs with Switches and LEDs

- **Single pole / single throw switches**
  - Has two point connections to the outside
  - Switch can make or break the connection between these two points

![Diagram of single pole switches with LEDs showing high and low states.]
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Inputs and Outputs with Switches and LEDs

• Single pole / double throw
  – Three connections to the outside
  – Possible to selectively connect one of two of the connections to the third connection
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Inputs and Outputs with Switches and LEDs

• **Light emitting diode (LED)**
  - electronic elements that emit light whenever a current flows across them
  - Two connections: anode and cathode
  - Cathode is usually longer lead or lead closest to the flatside of LEDs plastic housing
  - Illuminated when anode voltage exceeds cathode voltage by a certain threshold
  - Unidirectional element
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Inputs and Outputs with Switches and LEDs

- **Current-limiting resistor -- resistor between LED and power supply**
- **Value of current limiting resistor**
  - Size resistor so that current across it comes closest but does not exceed $I_{OL}$ value for the gate that will drive the LED
  - Ex. 7404 Inverter gate
  
  $I_{OL} = 16\, \text{mA}$
  
  $R = V/I = 5\, \text{V} / 15\, \text{mA} = 333\, \Omega$

  Necessary resistance $= 330\, \Omega$

![Diagram of LED driven by a TTL gate](image)
Hardcopies of pages from Data Book will be available in front of Dr. Butler’s office.

p. 3-11 (b,c,d)
p. 3-13 (b,c)
p. 3-14 (b)