Chapter 2

Logic Functions and Gates

Basic Logic Functions

- Three Basic Logic Functions
  - AND
  - OR
  - NOT
- Other functions can be created from these

Logic Function Representation

- Logic functions can be represented:
  - Algebraically
  - Using truth tables
  - Using electronic circuits

Algebraic Representation

- Uses Boolean algebra
- Boolean variables have two states (binary)
- Boolean operators include:
  - AND
  - OR
  - NOT

Truth Table Representation

- Defines the output of a function for every possible combination of inputs
- A system with n inputs has 2^n possible combinations

Electronic Circuit Representation

- Uses logic *gates* to perform Boolean algebraic functions
- Gates can be represented by schematic symbols
- Symbols can be either distinctive-shape or rectangular-outline

Distinctive Shape Schematic Symbols

- Uses different graphic representations for different logic functions
- Uses a bubble (a small circle) to indicate a logical inversion

Rectangular-Outline Schematic Symbols

- All functions are shown in rectangular form with the logic function indicated by standard notation inside the rectangle
- The notation specifying the logic function is called the qualifying symbol
- Inversion is indicated by a 1/2 arrowhead

NOT Function

- One input and one output
- The output is the opposite logic level of the input
- The output is the complement of the input

NOT Function Boolean Representation

- Inversion is indicated by a bar over the signal to be inverted

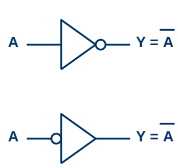
$$Y = \overline{A}$$

Truth Table

A	Y
0	1
1	0

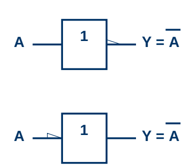
NOT Function Electronic Circuit

- Called a *NOT gate* or, more usually, an *Inverter*
- Distinctive-shape symbol uses a triangle with inversion bubble



NOT Function Electronic Circuit

- Rectangular symbol uses “1” and the inversion half arrowhead (IEEE std. 91-1984)



AND Function

- Two or more inputs, one output
- Output is HIGH only when all of the inputs are HIGH
- Output is LOW whenever any input is LOW
- *Logical Product*

AND Boolean Representation

- AND symbol is "•" or nothing at all

  Y = A • B

  Y = AB

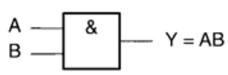
Truth Table

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

AND Function Electronic Circuit

- Called an *AND gate*
- Distinctive-shape symbol uses AND designation
- Rectangular-shape symbol use "&" as designator

a. Distinctive-shape



b. Rectangular-outline

OR Function

- Two or more inputs, one output
- Output is HIGH whenever one or more input is HIGH
- Output is LOW only when all of the inputs are LOW
- *Logical Sum*

OR Boolean Representation

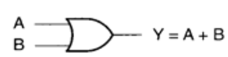
- OR symbol is "+"
- Y = A + B

Truth Table

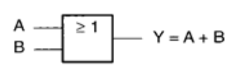
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

OR Function Electronic Circuit

- Called an *OR gate*
- Distinctive-shape symbol uses OR designation
- Rectangular-shape symbol uses "≥" as designator



a. Distinctive-shape



b. Rectangular-outline

Active Level

- The logic level defined as "ON" for a circuit
- When a logic HIGH is "ON", the signal is ***active-HIGH***
- When a logic LOW is "ON", the signal is ***active-LOW***
  - ***Indicated by a bubble at the output terminal of the logic function***

NAND Function

- Generated by inverting the output of the AND function
- Output is HIGH whenever any input is LOW
- Output is LOW only when all inputs are HIGH

NAND Boolean Representation

- Uses AND with an inversion overbar

$Y = \overline{A \bullet B}$

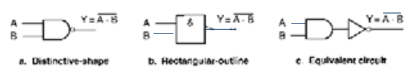
$Y = \overline{AB}$

Truth Table

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

NAND Function Electronic Circuit

- Called a ***NAND gate***
- Uses the AND symbol with inversion on the output



NOR Function

- Generated by inverting the output of the OR function
- Output is HIGH only when all inputs are LOW
- Outputs is LOW whenever any input is HIGH

NOR Boolean Representation

- Uses OR with an inversion overbar

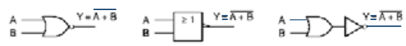
$Y = \overline{A + B}$

Truth Table

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

NOR Function Electronic Circuit

- Called a *NOR gate*
- Uses OR symbol with inversion on the output



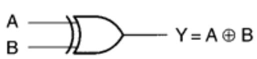
a. Distinctive-shape b. Rectangular-outline c. Equivalent circuit

Exclusive OR Gate

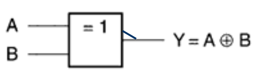
- Two inputs, one output
- Output is HIGH when one, and only one, input is HIGH
- Output is LOW when both inputs are equal – both HIGH or both LOW
- $Y = A \oplus B = A\overline{B} + \overline{A}B$

Exclusive OR Gate Electronic Circuit

- Called an *XOR gate*



a. Distinctive-shape



b. Rectangular-outline

Truth Table

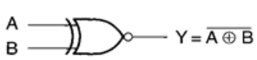
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Exclusive NOR Gate

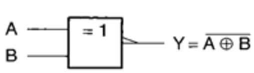
- Two inputs, one output
- Output is HIGH when both inputs are equal – both HIGH or both LOW
- Output is LOW when one, and only one, input is HIGH

Exclusive NOR Gate Electronic Circuit

- Called an *XNOR gate*



a. Distinctive-shape



b. Rectangular-outline

Truth Table

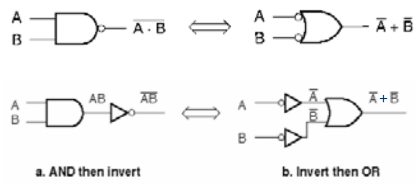
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

Gate Equivalence - NAND

- A NAND gate can be represented by an AND gate with inverted output
- A NAND gate can be represented by an OR gate with inverted inputs

$Y = \overline{AB}$

Gate Equivalence - NAND



Gate Equivalence - NOR

- A NOR gate can be represented by an OR gate with inverted output
- A NOR gate can be represented by an AND gate with inverted inputs
- EXERCISE

Gate Equivalence – DeMorgan Forms

- Change an AND function to an OR function and an OR function to an AND function
- Invert the inputs
- Invert the outputs

DeMorgan's Theorems

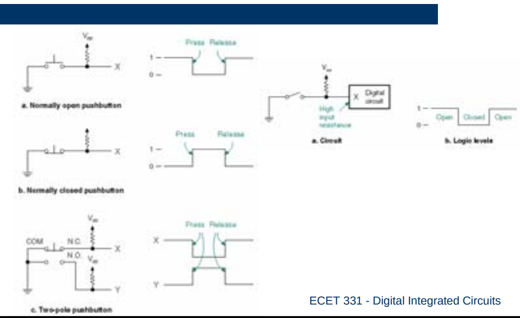
$$\overline{A \bullet B} = \overline{A} + \overline{B}$$

$$\overline{A + B} = \overline{A} \bullet \overline{B}$$

Logic Switches

- Can be used to create logic voltages for circuit inputs
- Provides a logic HIGH or LOW depending on switch position
- Commonly used switches include
  - normally-open pushbutton
  - normally-closed pushbutton
  - single-pole single-throw
  - single-pole double-throw

Logic Switches



Light Emitting Diodes (LEDs)

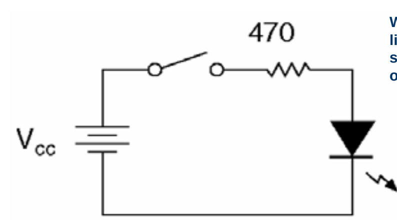
- Conducts current in one direction and only illuminates when it is conducting
- Can be used to monitor outputs of a logic circuit
- Provide a visual indication of a logic state
- Can be wired to display active-HIGH or active-LOW

LEDs

LED Operation

- Lights when current flows from anode to cathode
- Use a resistor to avoid burning out the LED with too much current

LED Circuit



Will the LED light when the switch is open or closed?

Logic Gate Enable

- The input to a gate that allows the output to respond to other inputs
- A logic LOW for an OR or NOR gate, a logic HIGH for an AND or NAND gate

Logic Gate Inhibit

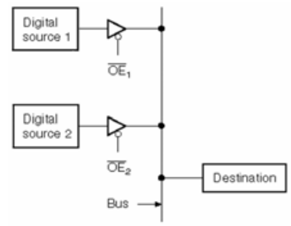
- The input to a gate that forces the output to ignore any other input
- A logic HIGH for an OR or NOR gate, a logic LOW for an AND or NAND gate

Tristate Buffer

- Three output states, HIGH, LOW and high-impedance
- Requires a separate input to control which output state is selected

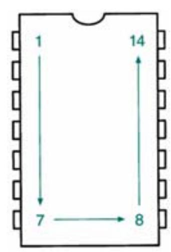
Tristate Buffer Applications

- Used to connect multiple outputs together
- Used in controlling the operation of buses

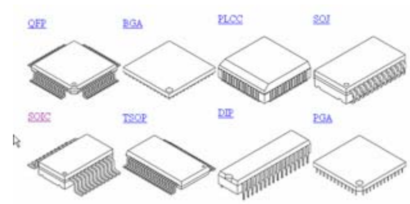


Integrated Circuit Packages

- Integrated Circuits (ICs) contain many devices in a single package
- Several packaging options are available
- One common package is called dual-in-line package (DIP)



Other IC Packages



Source: www.adapters.com

Integrated Circuit Technology

- One common form is transistor-transistor logic, called TTL
- The other common form is Complementary Metal-Oxide Semiconductor, called CMOS

Integrated Circuit Designation

- Standard form is 74XXNN
  - XX is the logic family designation
  - NN identifies the specific logic function
- See textbook, p. 57

Terms

- SSI, MSI, LSI, VLSI
  - Small, Medium, Large, or Very Large scale Integration depending on the number of gates in an IC package (<12, 12-100, 100-10k, >10k gates)
- Through-hole
  - IC packages which are mounted on circuit boards by inserting pins through holes in the board and soldering them in place
- SMT
  - Surface Mount Technology – A system of mounting ICs to the surface of a circuit board rather than through-hole