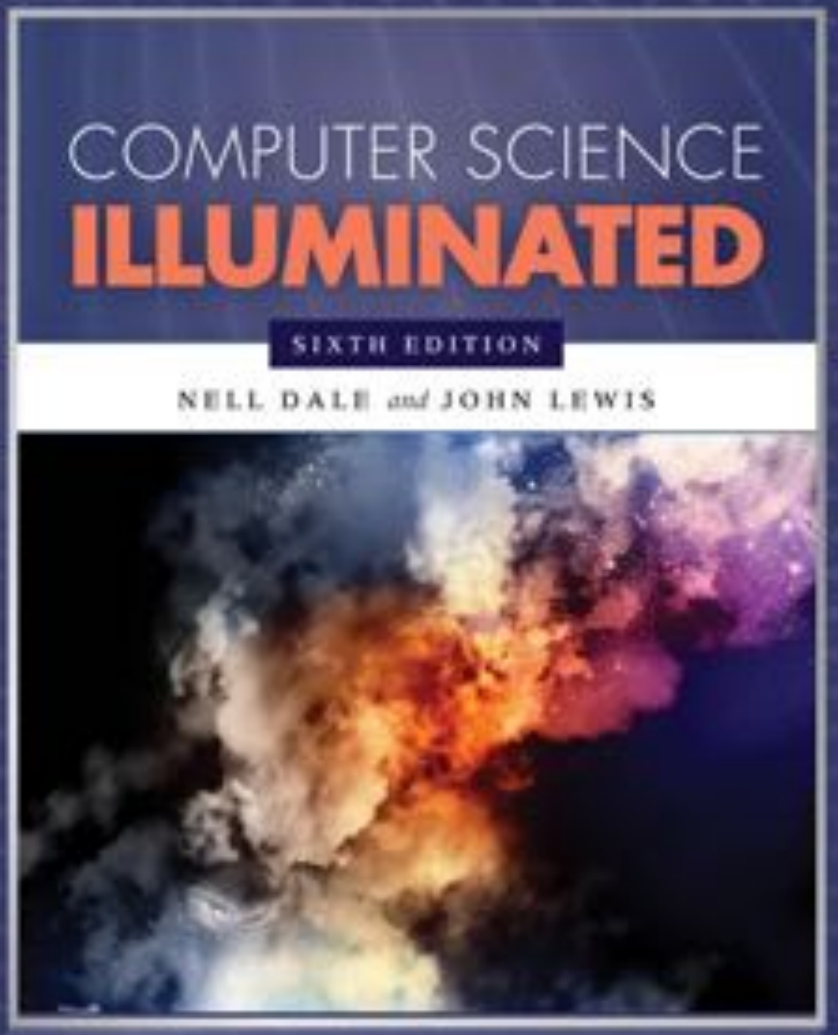
Chapter 4

Gates and Circuits



Chapter Goals

- Compare and contrast a half adder and a full adder
- Describe how a multiplexer works
- Explain how an S-R latch operates
- Describe the characteristics of the four generations of integrated circuits

Adders

At the digital logic level, addition is performed in binary

Addition operations are carried out by special circuits called, appropriately, **adders**

Adders

The result of adding two binary digits could produce a *carry value*

Recall that 1 + 1 = 10 in base two

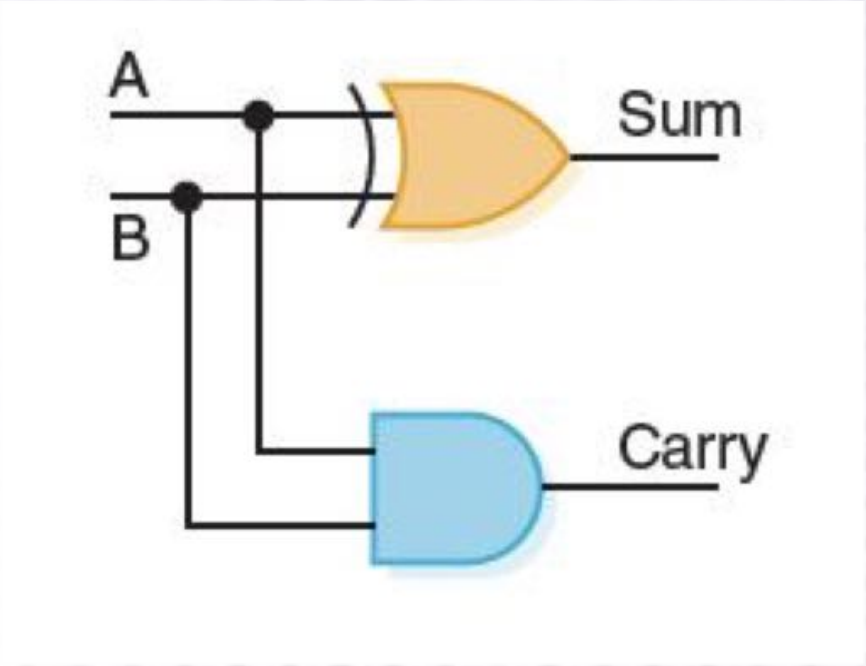
A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Truth table

Half adder

A circuit that computes the sum of two bits and produces the correct carry bit

Adders



Circuit diagram representing a half adder

Boolean expressions

$$\text{sum} = A \oplus B$$

$$\text{carry} = AB$$

Adders

Full adder

A circuit that takes the carry-in value into account

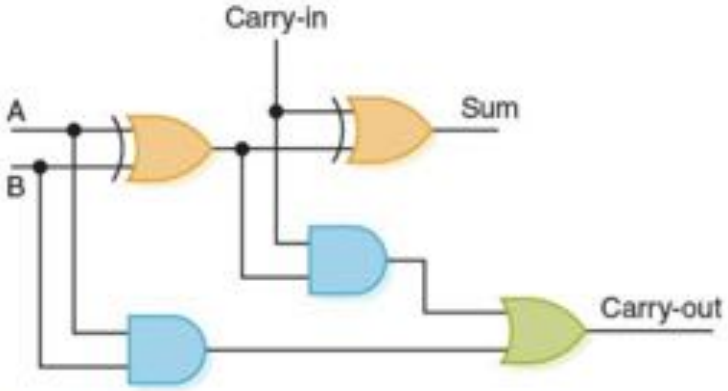


FIGURE 4.10 A full adder

Truth Table

A	B	Carry-in	Sum	Carry-out
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

Multiplexers

Multiplexer (or MUX)

A circuit that uses a few input control signals to determine which of several input data signals is routed to its output signal

Multiplexers

The control lines S0, S1, and S2 determine which of eight other input lines (D0 … D7) are routed to the output (F)

S0	S1	S2	F
0	0	0	D0
0	0	1	D1
0	1	0	D2
0	1	1	D3
1	0	0	D4
1	0	1	D5
1	1	0	D6
1	1	1	D7

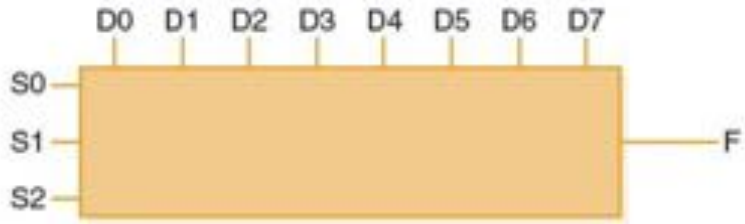


FIGURE 4.11 A block diagram of a multiplexer with three select control lines

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

Circuits as Memory

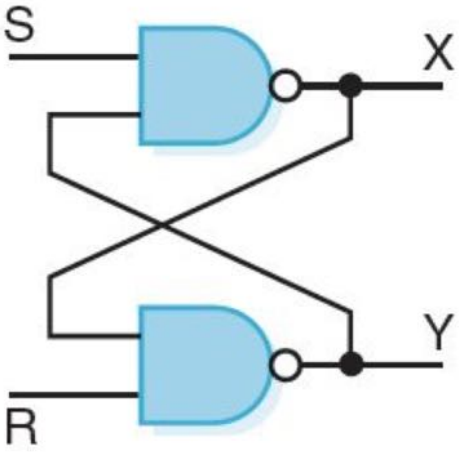


FIGURE 4.12 An S-R latch

An S-R latch stores a single binary digit (1 or 0)

There are several ways an S-R latch circuit can be designed using various kinds of gates

Circuits as Memory

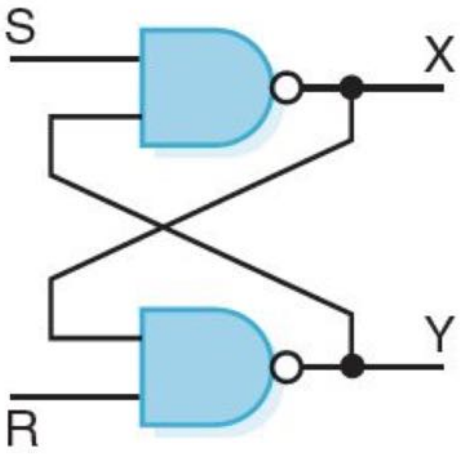


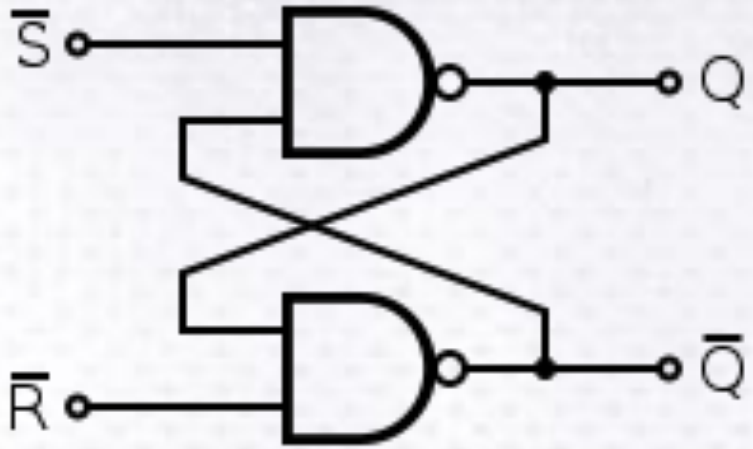
FIGURE 4.12 An S-R latch

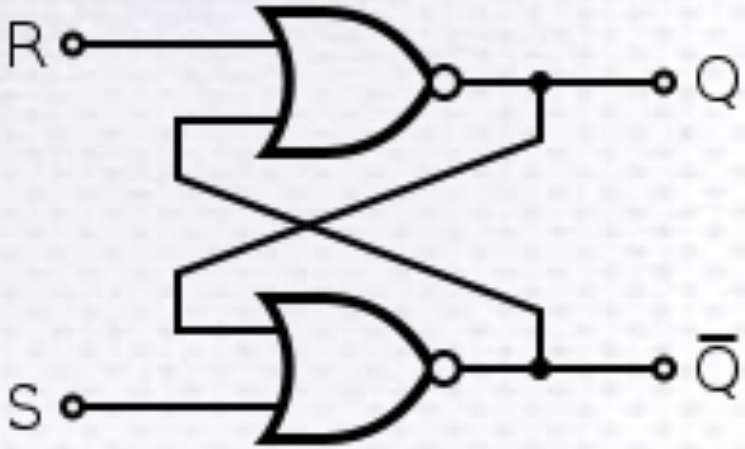
Assume that S and R are never both 0 at the same time

The design of this circuit guarantees that the two outputs X and Y are always complements of each other

The value of X at any point in time is considered to be the current state of the circuit

Therefore, if X is 1, the circuit is storing a 1; if X is 0, the circuit is storing a 0





Integrated Circuits

Integrated circuit (also called a *chip*)

A 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 that can be soldered onto circuit boards or inserted into appropriate sockets

Integrated Circuits

Historically, integrated circuits have been classified by the number of gates (or transistors) they contain

As of 2014, chips exist with over 20 billion transistors

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

Integrated Circuits

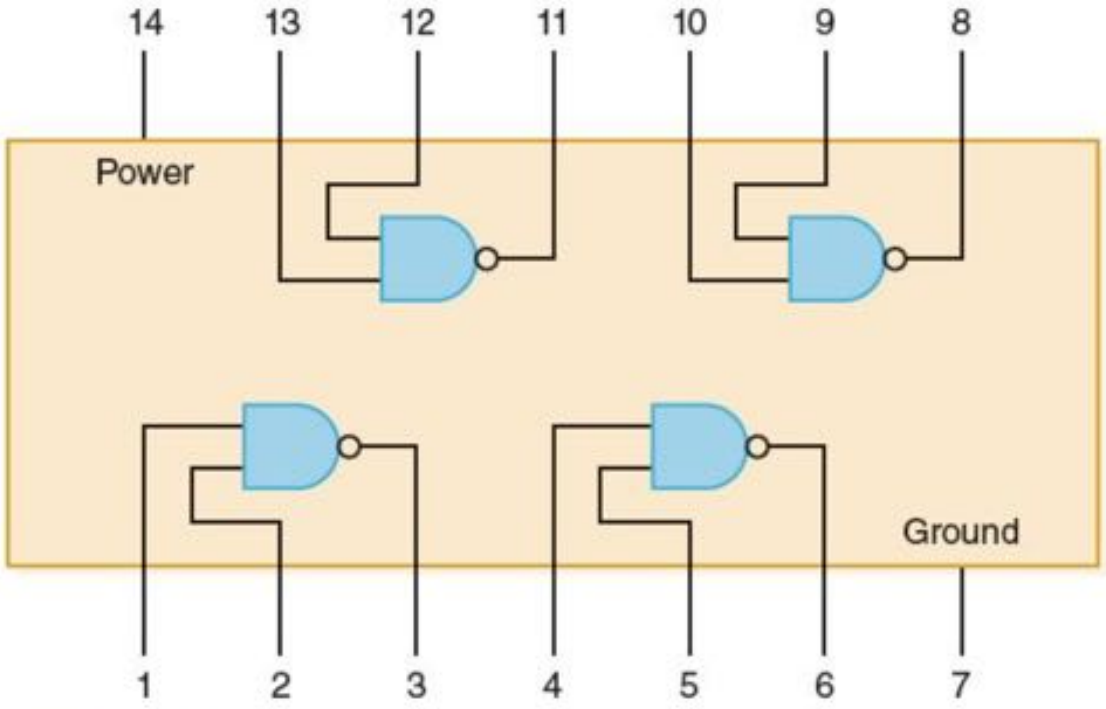


FIGURE 4.13 An SSI chip containing independent NAND gates

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

Ethical Issues

Codes of Ethics

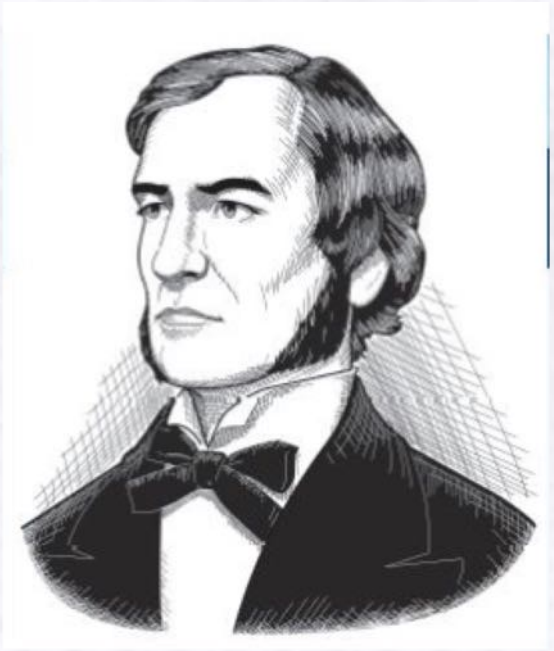
Which professional organization is more focused on the hardware side?

Which is more focused on the software side?

How are their codes of ethics alike?

How do they differ?

Who am I?



I didn't get much recognition at the time, but my book formed the basis for the development of digital computers. Can you name its contribution?

Do you know?

What is the name of the study of materials smaller than 100 nanometers?

What topic in computer science education is referred to as "the tenth strand"?

Who wrote about the fundamental problem of expressing thought by means of symbols?

What did Maurice Wilkes realize in 1949?

What two (or more) concepts can be referred to by the term "computer ethics"?