Chapter 1

Design Concepts

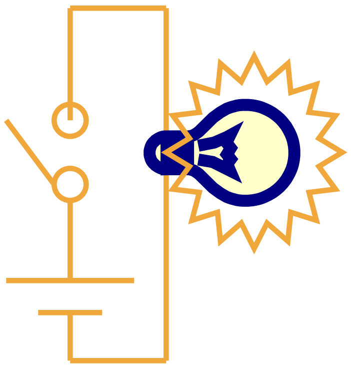
Contents

- Digital Design
- Design of Digital Hardware System
- Design Process
- Binary Number

DIGITAL DESIGN

Digital Design

- *Design of digital electronics circuits* that are within digital hardware in many digital devices, including computer
- Circuits are often called *Logics.*
  - Why?
- What is *Digital*?



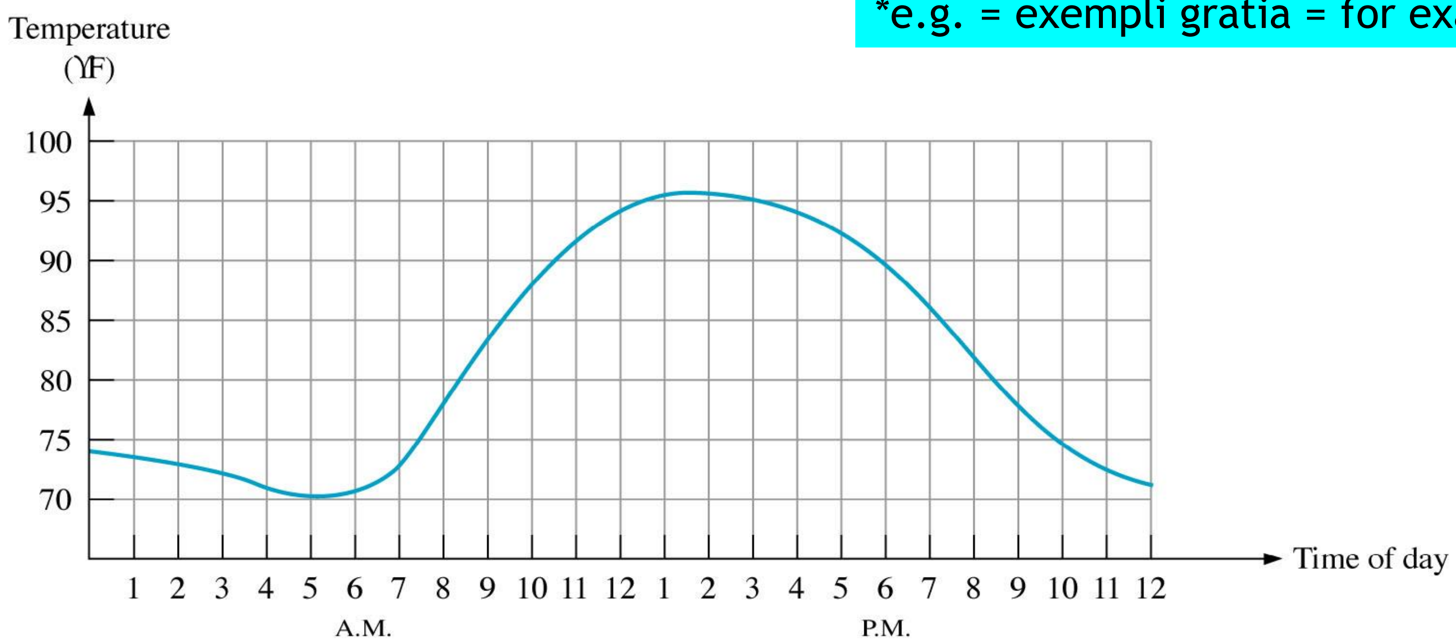
Definition of the "Digital"

- Digit:
  - A human finger or toe
  - 0, 1, 2, 3, … , 9 in Arabic number system
- Digital:
  - countable by human fingers
  - We use the term "digital" synonymous to "discrete".

Analog signal

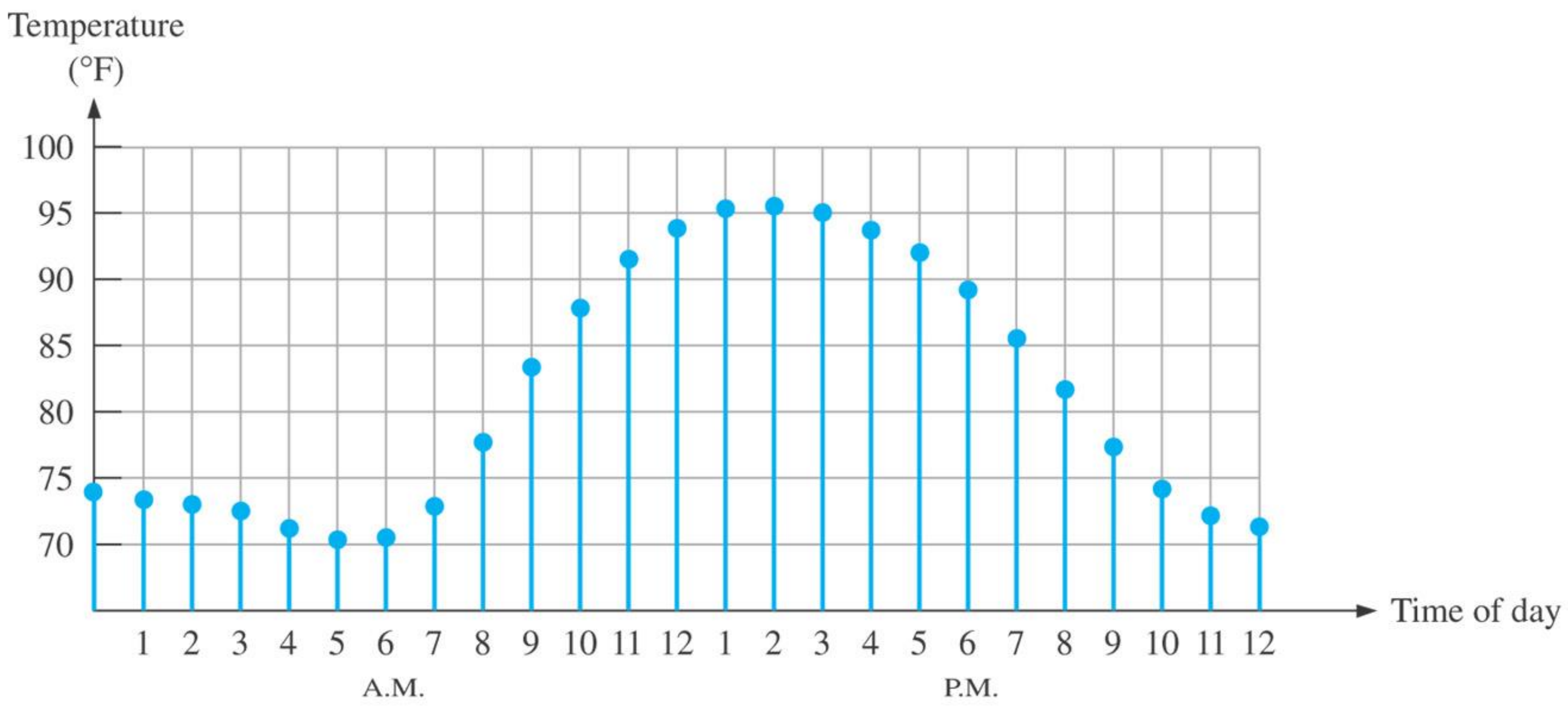
- An analog signal has continuous values.
  - e.g. sound, voice, video
- Most things that can be measured in nature appear in analog;
  - e.g. Temperature during a day

*e.g. = exempli gratia = for example



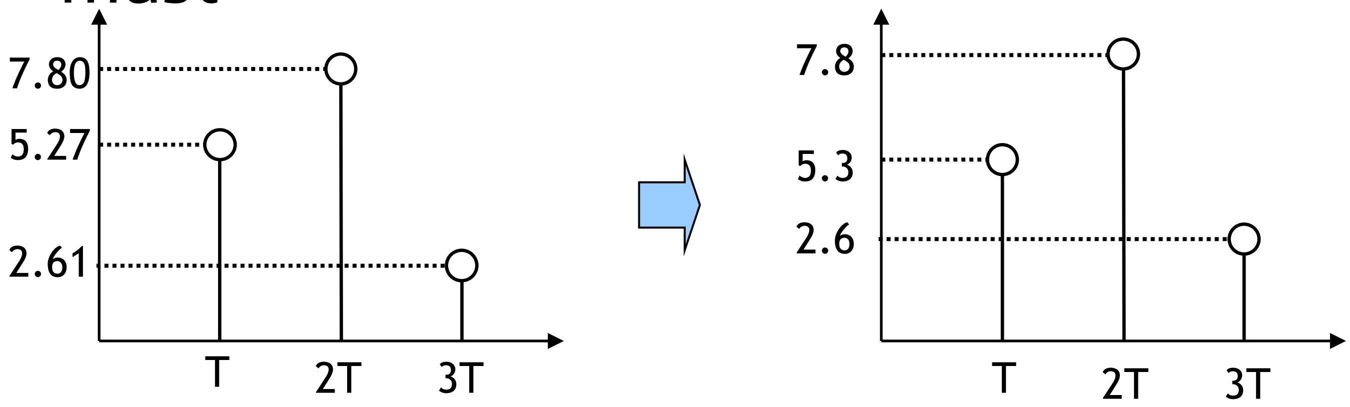
How to convert analog signal into digital signal

- 1st step: Sampling of an analog signal
  - makes a discrete-time signal



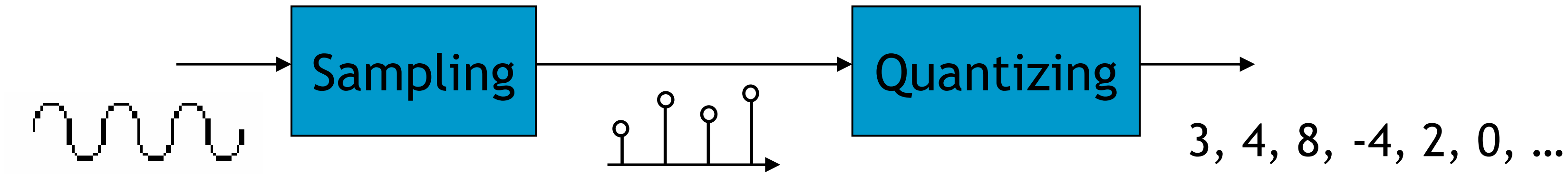
How to convert analog signal into digital signal

- 2^{nd} step: Quantizing sampled data
  - Using a limited number of bits to describe the sampled data precision, a quantizing is a must



Analog to digital conversion

- Sampling & Quantization
  - Digital representation of an analog data is possible through *sampling* & *quantization*



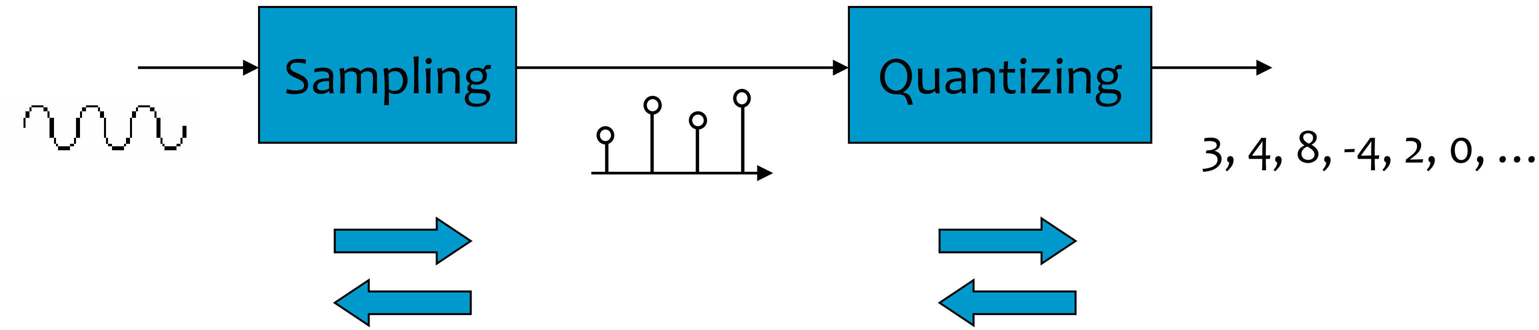
Sampling theorem

- The sampling theorem:
  - If a data is sampled
    - at regular intervals of time
    - and at a rate higher than twice the highest data frequency,
  - the samples contain all the information of the origin al data.

Nyquist rate $f_s \geq 2f_m$

- Example
  - Human hearing: max frequency 20k Hertz
  - If sampled more than 40k Hertz, then the sample ha s all the information.
  - CD player: 44.1K Hertz sampling frequency.

Sampling theorem & Quantization Error



- If sample frequently enough, a perfect restoration of original analog data from the sequence is possible

- Perfect restoration of the original sequence is not possible because of Quantization error

CD: 44.1 kHz, 2 channels at 16 bits per channel or 2 × 16 bit per sample (1411.2 k bits/sec)

MP3: 44.1 kHz, 128k bits per second, or 192k b/sec

Examples of Audio Coding

- cd (compact disc)
  - PCM (Pulse Coded Modulation): 16bit/44.1kHz (16bit/channel x 44.1 x 10^3 (1/sec) x 2 channel = 1411.2kbps)
  - CD ripping: waveform audio format (.wav)
  - 무손실압축: FLAC (free lossless audio coding), ALAC (apple lossless audio coding), (.ape)
  - 손실압축: MP3 (56kbps, 196kbps)

- sacd (super audio cd)
  - 24bit/192kHz (24 x 192 x 10^3 x 2 = 9213kbps = 9.213mbps)

- dsd (direct stream digital)
  - PDM (Pulse Density Modulation): 1bit 2.8224mHz (dsd64), 1bit 5.6448mHz (dsd128)
  - 32bit/768kHz (32 x 768 x 10^3 x 2 = 49152kbps = 49.152mbps)
  - 확장자: .dff, .dsf

Digital advantages

- Advantages of digital representation
  - Data Processing: more efficient
  - Data Transmission: more reliable
  - Data Storage: more compact
- A copy can be exactly the same as the original → Information sharing
- Digital, in our everyday life, is synonymous with “Sharing”
- This is how life has evolved.

DESIGN OF DIGITAL HARDWARE SYSTEM

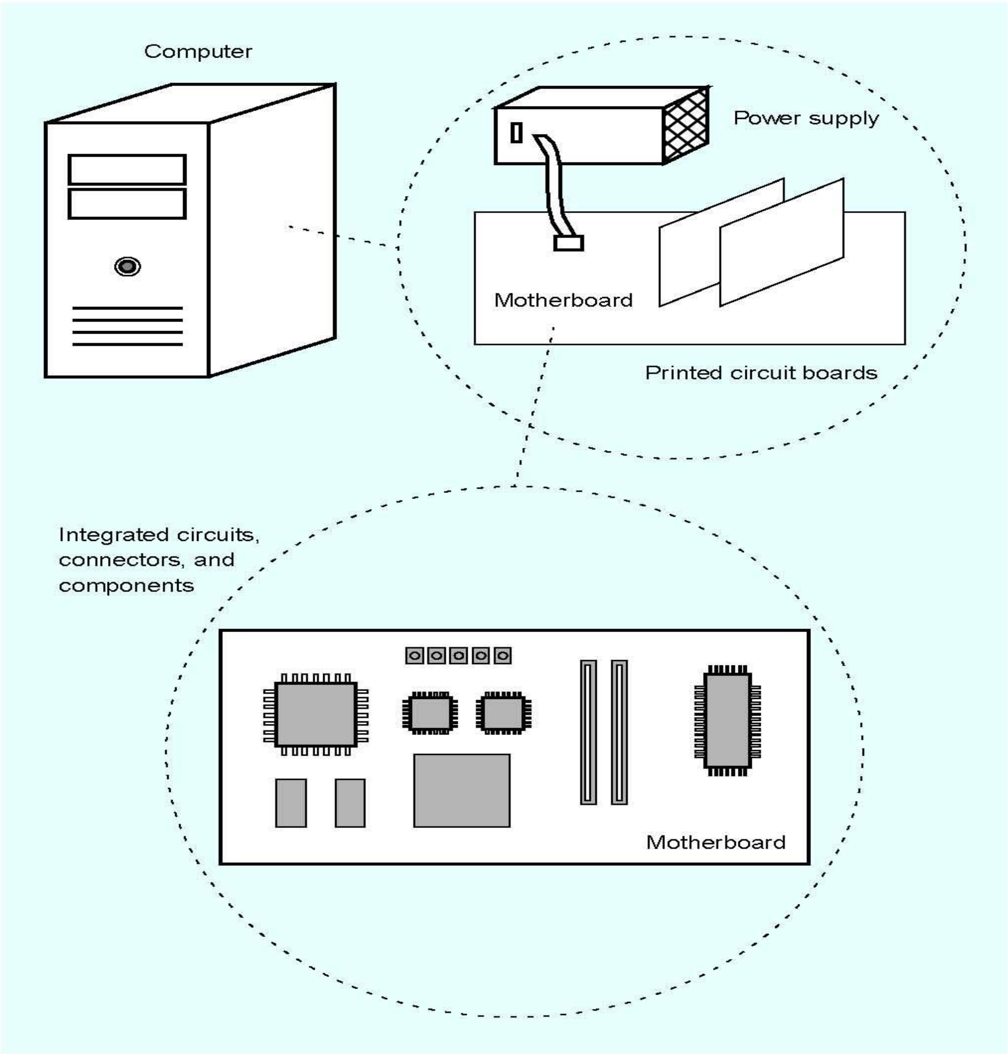


Figure 1.5. A digital hardware system (Part *a*).

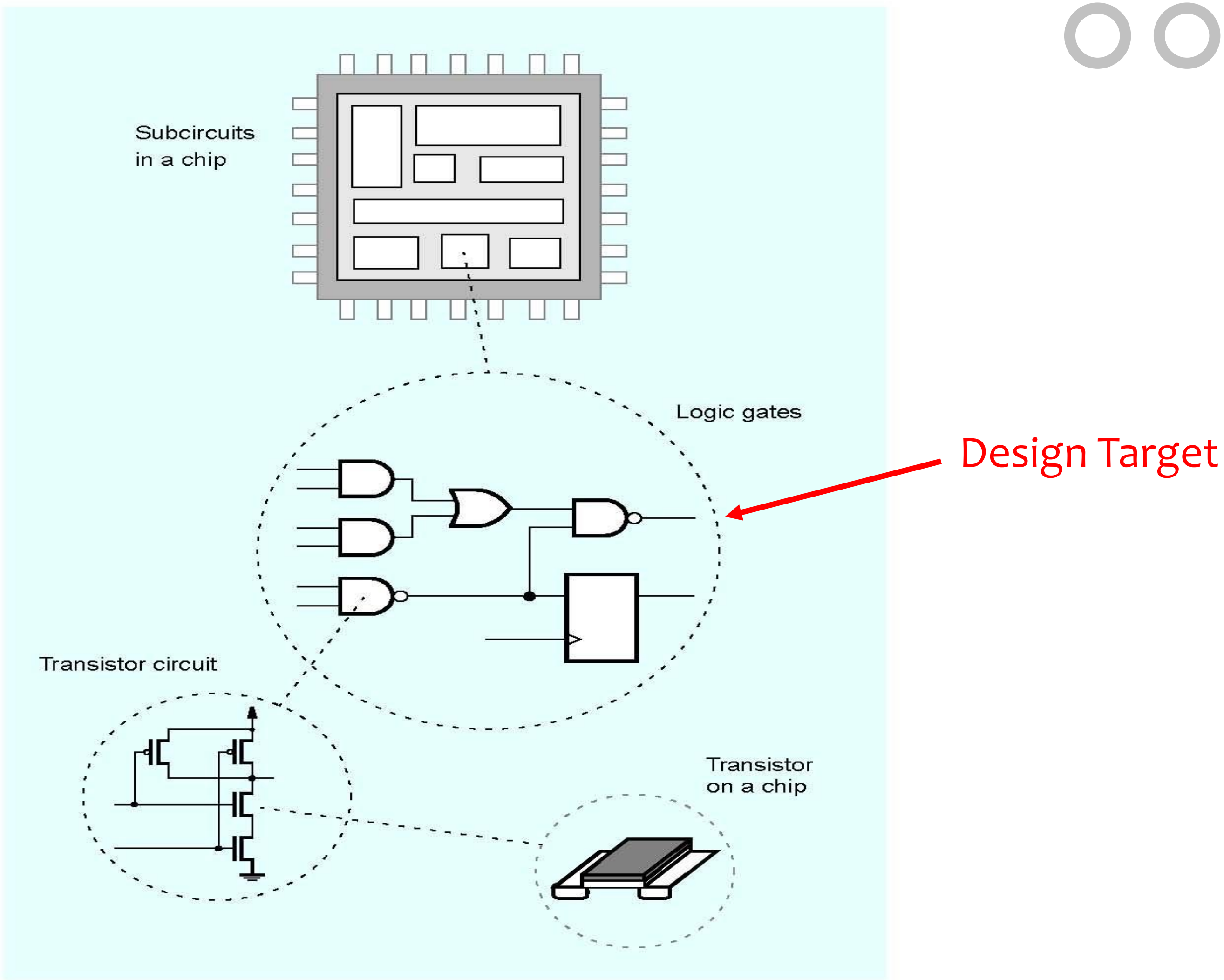


Figure 1.5. A digital hardware system (Part *b*).

Digital Hardware System

- Computer : Power supply, PCBs (printed circuit boards, mother board), storage units (Hard disk, Solid state disk, DVD, CD-ROM etc.)
- Mother board : CPU, storage (ROM/RAM), I/O interface, plugged-in slots
- Chip : sub-circuits (logic gates)

Digital Hardware Components

- Standard Chip
  - Popular for building logic circuits until the early 1980s
  - Drawback: fixed functionality, inefficient space
- Programmable Logic Devices
  - FPGA (field-programmable gate array)
- Custom-Designed Chips
  - Custom or semi-custom design
  - ASIC (application specific integrated circuits)

DESIGN PROCESS

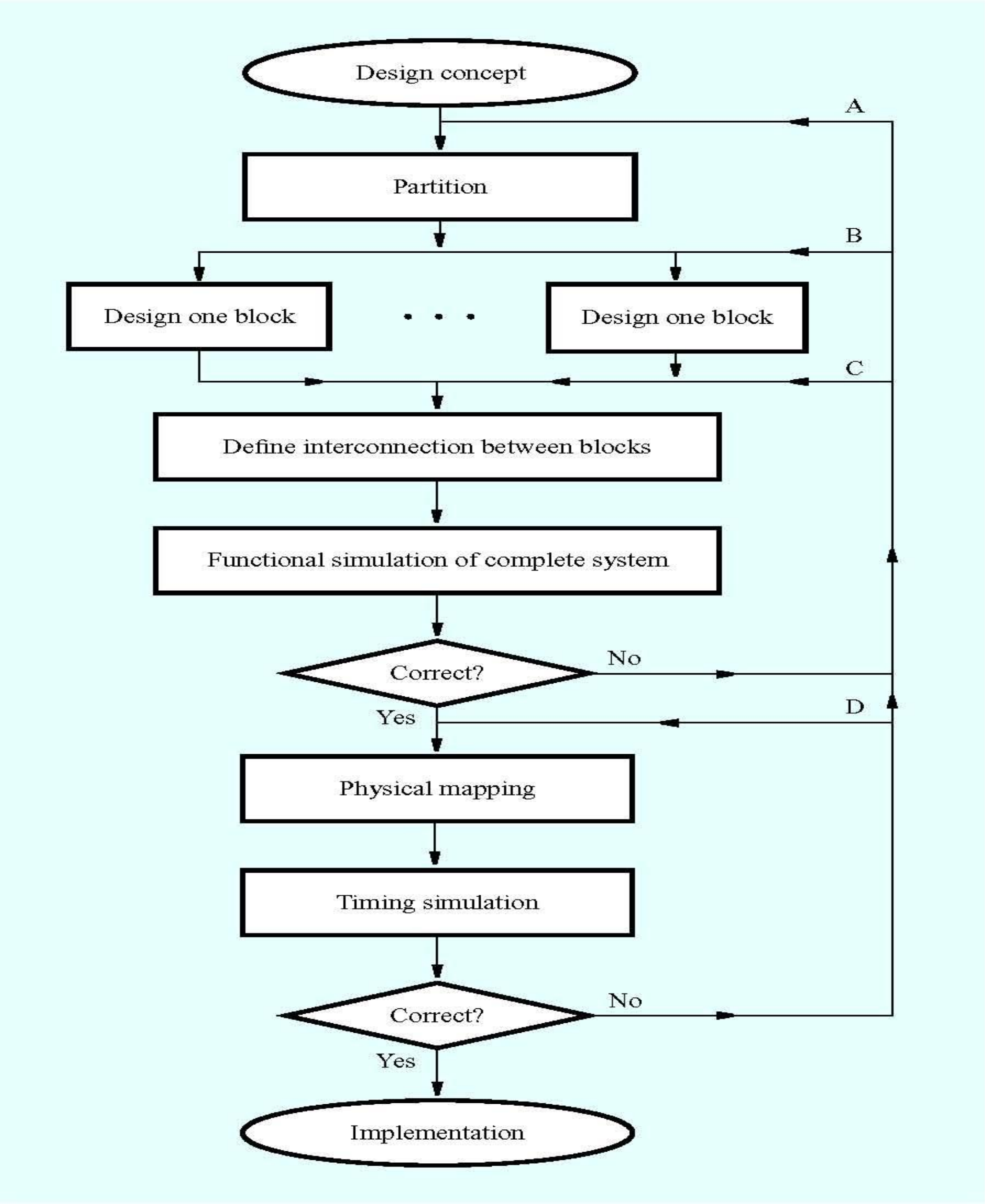


Figure 1.7. Design flow for logic circuits.

BINARY NUMBER

Binary Number

- $a_5a_4a_3a_2a_1a_0.a_{-1}a_{-2}a_{-3}$
  $= a_nr^n+a_{n-1}r^{n-1}+\ldots+a_2r^2+a_1r+a_0+a_{-1}r^{-1}+a_{-2}r^{-2}+\ldots+a_{-m}r^{-m}$

$7392 = 7 \times 10^3 + 3 \times 10^2 + 9 \times 10^1 + 2 \times 10^0$

$(11010.11)_2 = 1\times2^4+1\times2^3+0\times2^2+1\times2^1+0\times2^0+1\times2^{-1}+1\times2^{-2}$

$= (26.75)_{10}$

a_i : coefficient

r : base

2^{10} = 1Kilo

2^{20} = 1Mega

2^{30} = 1Giga

Table 1-1
Powers of Two

n	2^n	n	2^n	n	2^n
0	1	8	256	16	65,536
1	2	9	512	17	131,072
2	4	10	1,024	18	262,144
3	8	11	2,048	19	524,288
4	16	12	4,096	20	1,048,576
5	32	13	8,192	21	2,097,152
6	64	14	16,384	22	4,194,304
7	128	15	32,768	23	8,388,608

Number Base Conversions

- Ex 1-1) Convert decimal 41 to binary.

	Integer Quotient		Remainder	Coefficient
41/2 =	20	+	½	$a_0 = 1$
20/2 =	10	+	0	$a_1 = 0$
10/2 =	5	+	0	$a_2 = 0$
5/2 =	2	+	½	$a_3 = 1$
2/2 =	1	+	0	$a_4 = 0$
1/2 =	0	+	½	$a_5 = 1$

Integer	Remainder
41	
20	1
10	0
5	0
2	1
1	0
0	1

Answer

=101001

answer : $(41)_{10} = (a_5a_4a_3a_2a_1a_0)_2 = (101001)_2$

Number Base Conversions

- Ex 1-2) Convert decimal 153 to octal.

$$\begin{array}{r|l} 153 & \\ 19 & 1 \\ 2 & 3 \\ 0 & 2 \end{array} = (231)_8$$

- Ex 1-3) Convert $(0.6875)_{10}$ to binary.

		Integer		Fraction	Coefficient
1.3750=	0.6875*2 =	1	+	0.3750	$a_{-1} = 1$
	0.3750*2 =	0	+	0.7500	$a_{-2} = 0$
	0.7500*2 =	1	+	0.5000	$a_{-3} = 1$
	0.5000*2 =	1	+	0.0000	$a_{-4} = 1$

Answer: $(0.6875)_{10} = (0.a_{-1}a_{-2}a_{-3}a_{-4})_2 = (0.1011)_2$

Summary

- The target scope of the digital design is the gate level design for a semiconductor chip.
- Analog to digital conversion (ADC) consists of the sampling and the quantizing process.
- The important process of design flow contains the functional simulation and the timing simulation.
- Digital system is based on the binary number system.