1. Introduction

- Students are required to go through this introductory material on their own.
- Essential concepts will be discussed in Tutorial 1.

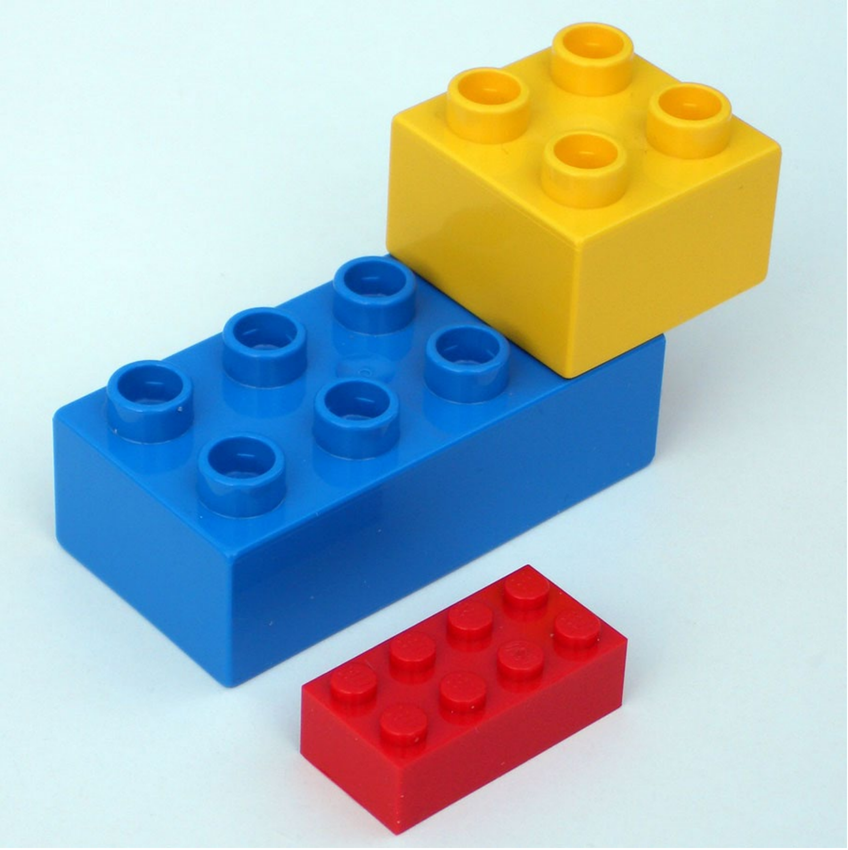
Quick links to each section

About Digital Design

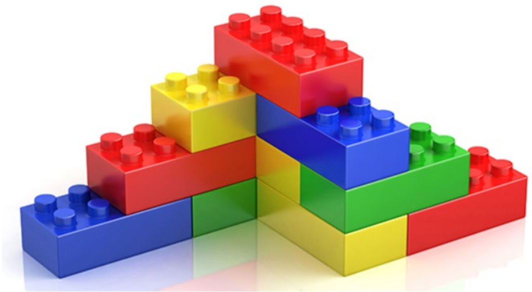
- Digital Design is also known as Logic Design, or Digital Electronics.
- Why should we learn it?

  - it provides the fundamentals of designing modern digital gadgets and computer systems, including medical equipment, smart phones, tablet PCs, laptops, security systems, etc.

Digital design is like playing with building blocks… YES, it can be fun!



You can create almost anything…
limited only by your imagination



A Successful Digital Designer should be competent in

- Debugging (troubleshoot systematically – not by trial-and-error)
- Business requirements & practices (documentation, specifications)
- Risk taking (in making design decisions)
- Communication (both directions: speak and listen)

You will appreciate all these when you embark on SC2079 Multidisciplinary Design Project (MDP)

Analog versus Digital

- Analog quantities happen in the nature around us, examples are time, temperature, light intensity, sound volume, etc.
- An analog quantity changes in a <u>continuous</u> manner over time (e.g. it gets bright gradually in the early morning).

- Digital quantities are countable, examples are
  - the number of people in a lecture theatre
  - the amount of school fee you pay
  - the number of AUs you need to obtain in order to graduate

Analog versus Digital

Analog:

The speaker volume can be increased or decreased by very small amount.

Digital:

The speaker volume can only be increased or decreased in steps.

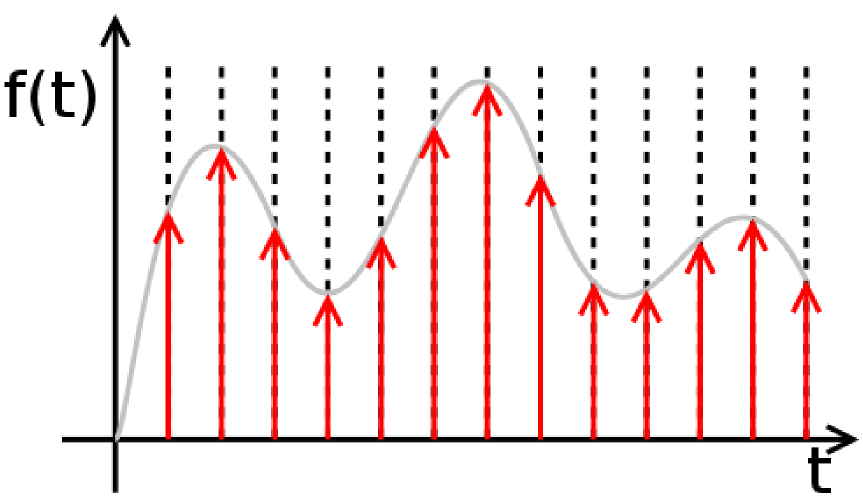
- A digital quantity changes in discrete steps.
- Analog quantities can be represented in digital format by using sampling and quantisation.

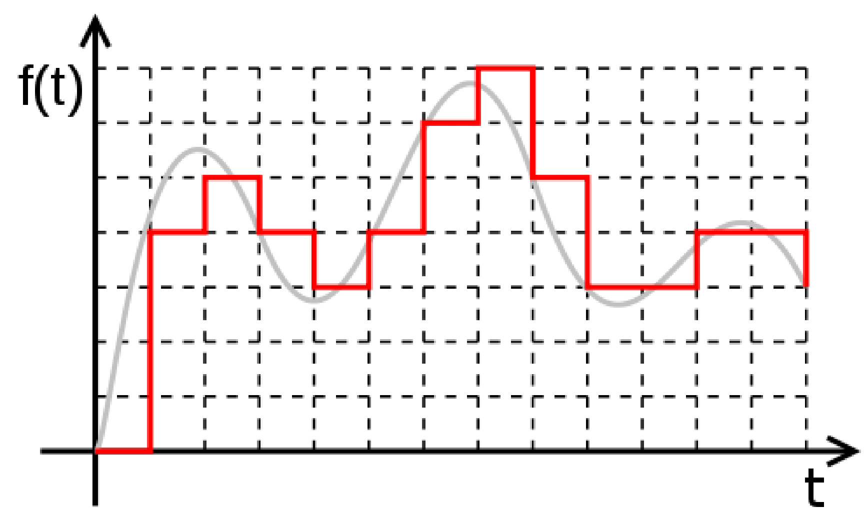
- Examples of analog quantities that are commonly digitised:
  - digital clock/watch (time is analog)
  - digital thermometer (temperature is analog)
  - digital camera (light intensity is analog)
  - digital audio/video content (light and sound intensities are analog)

f(t) is an analog signal continuously varying with time (gray curve)

Sampling f(t) at periodic intervals will generate the discrete time signal (red arrows)

Quantisation of the discrete time signal will produce the digital signal (red lines)





What we should be aware of Quantisation

- A range of analog values is lumped together and assigned a representative digital value. For example, 0V to 0.8V is assigned logic 0; 2V to 5V is assigned logic 1
- A many-to-one mapping (using the above example, 2V is mapped to 1, similarly 3V, 3.8V, 5V are also mapped to 1)
- A finite amount of precision is lost in the process (logic 1 can mean 2V; logic 1 can also mean 5V)
- See illustration on next page

Temperature range	Quantised value
20 <= temp < 21	20^oC
19 <= temp < 20	19^oC
18 <= temp < 19	18^oC
17 <= temp < 18	17^oC
16 <= temp < 17	16^oC
15 <= temp < 16	15^oC
14 <= temp < 15	14^oC
13 <= temp < 14	13^oC

Any temperature variation within each range cannot be distinguished in the digital representation

Advantages of Digital Techniques Over Analog Techniques

- Easier to design
- Information storage is easy
- Greater accuracy & precision
- Programmability
- Less susceptible to circuit noise
- VLSI (Very Large Scale Integration) technology

  - high speed
  - low cost
  - small size

Limitations of Digital Technique

- The real world is mainly analog in nature, hence there is a need to
  - convert analog inputs to digital form
  - process the digital information
  - convert the digital result back to analog form
- The advantages of digital techniques usually outweigh the additional time, complexity and expenses involved in ADC (analog-to-digital conversion) and DAC (digital-to-analog conversion)

Digital Number Systems

The decimal system is most commonly used in daily life because we have 10 fingers. But digital circuits prefer the binary system.

Number system	Symbols
Decimal	0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Binary	0, 1
Octal	0, 1, 2, 3, 4, 5, 6, 7
hexadecimal	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F

You will learn more in the self-study material 2a_number_systems.pdf

Electronic aspects

- In digital circuits, information is stored in binary digits
- A binary digit (commonly known as bit) has the value of 0 or 1
- In digital electronic circuits, the binary value is represented by electrical voltage or current
- Thus all digital gadgets require electrical power supply to work

- For example:

  0 volt – 0.8 volt may represent 0

  2 volts – 5 volts may represent 1
- The exact voltage level within each range is usually not important (e.g. 0.2 or 0.3 volt both represent 0)
- Usually more bits are required to represent useful information
- 4 bits make a nibble, e.g. 1001
- 8 bits make a byte, e.g. 1100 0101

Software aspects

- Modern digital design involves Computer-Aided Design (CAD) software tools
- Schematic entry: use a software tool to draw circuit connections diagrams
- HDL: use Hardware Description Language to describe the logic circuit (e.g. Verilog)
- Synthesizer: creates a circuit realisation based on the above inputs

- Simulator: predicts the electrical and functional behaviour of a circuit without actually building it
- Test bench: a software environment to test the simulated circuit’s functional and timing behaviour
- You will use some of these tools in the lab experiments
- Fig. 1.19 on the next page shows the typical design flow

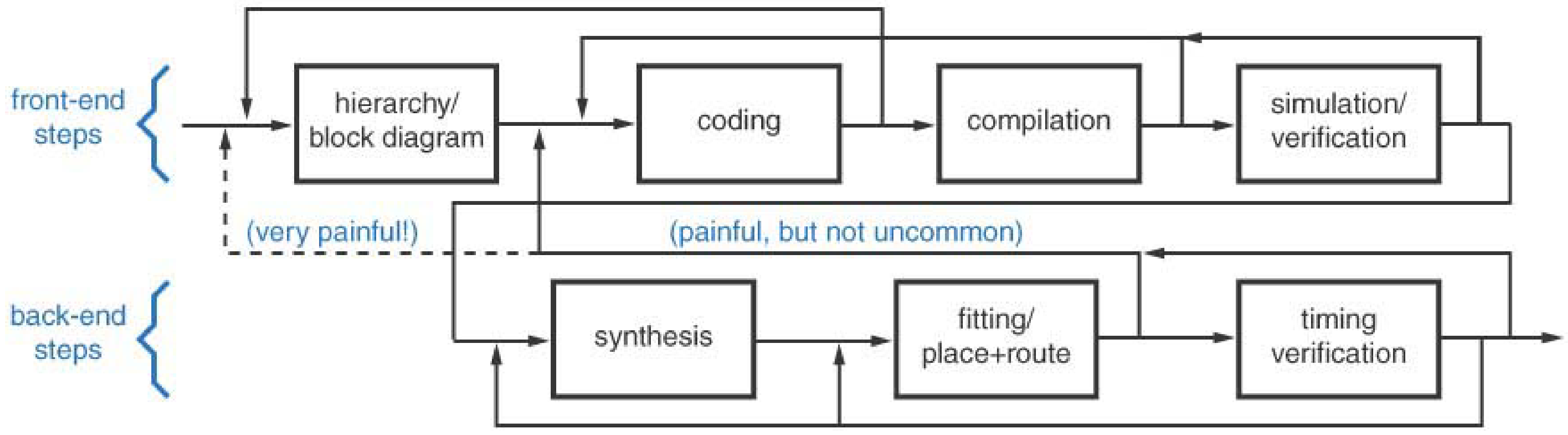
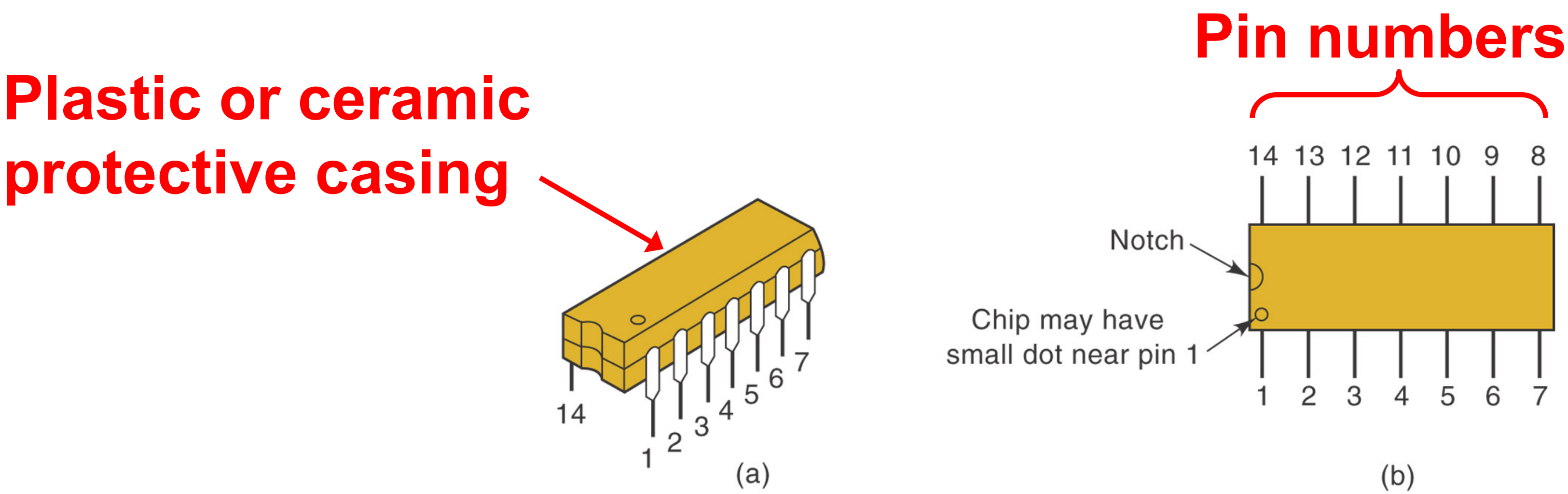
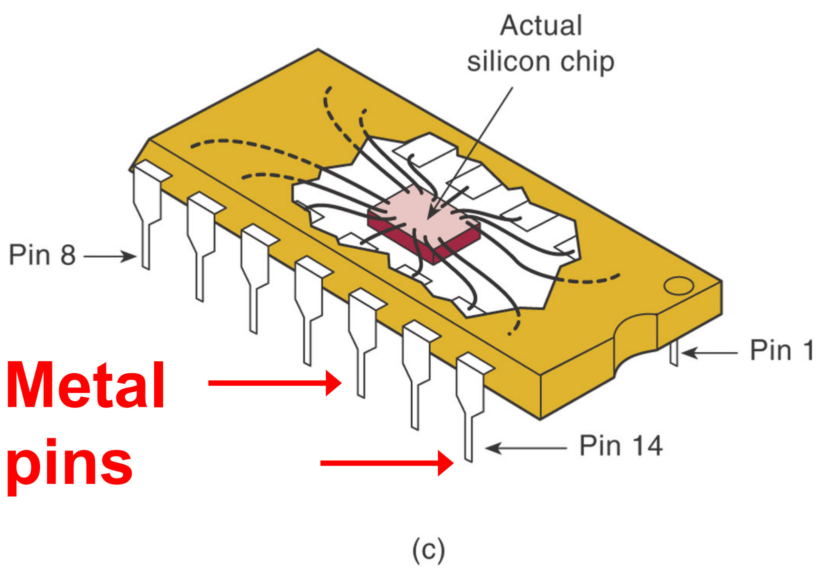


Fig. 1.19 HDL-based design flow

Integrated Logic Circuits

- Logic circuits are usually fabricated as Integrated Circuits (ICs) using various semiconductor technologies – see Fig. 4.29 on next page
- You will use some of these ICs in the lab experiments
- The circuit's logic can range from very simple to very complex





The logic is built into the silicon chip. The metal pins are for connections.

Figure 4.29: (Tocci 10th Ed) Dual-in-line Package

Programmable Logic Devices

- In some integrated circuits (ICs), the circuit's logic function can be easily changed, i.e. programmable
- This allows bugs to be fixed or circuit behaviour to be modified without physically replacing or rewiring the device
- An example is FPGA, Field-Programmable Gate Array
- You will be using it in the lab experiments

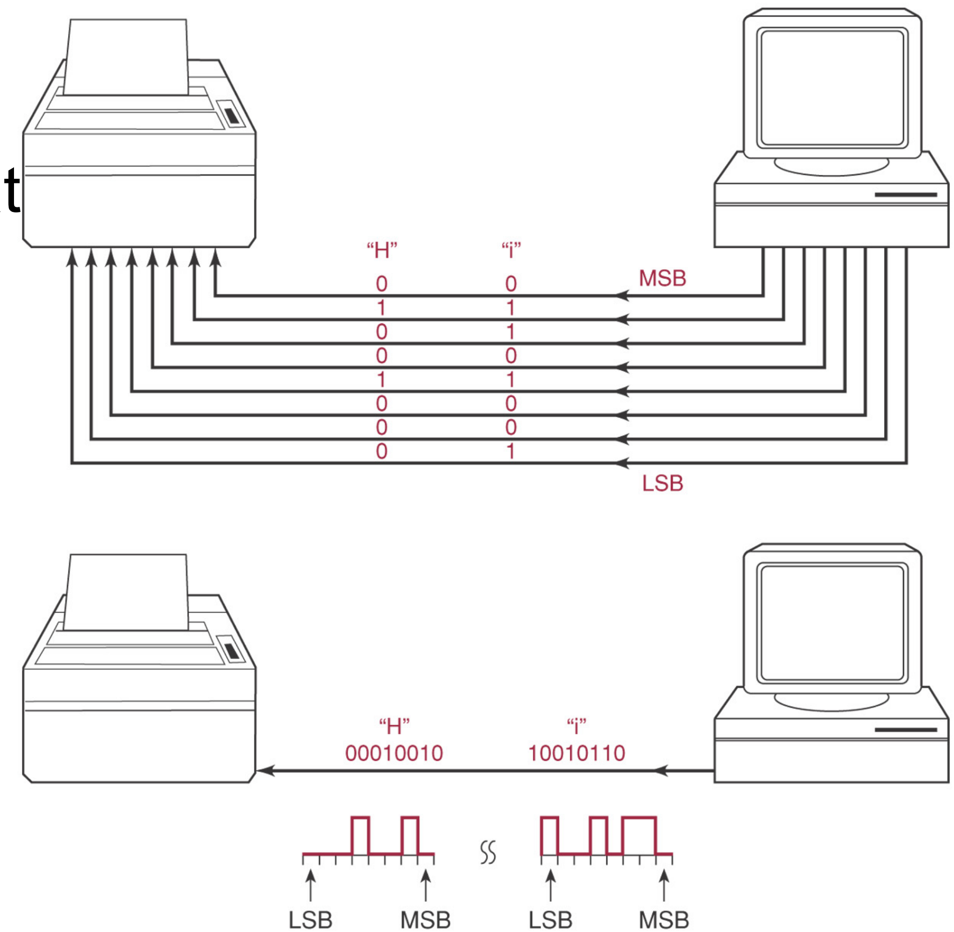
Digital Data transmission

- Data (in bits) can be transmitted from one device to another in 2 ways: serial or parallel
- Parallel: think 4 checkout counters at the supermarket. 4 customers can be served at the same time
- Serial: think 1 checkout counter at the supermarket. Only 1 customer can be served at any time
- Trade off is Simplicity/Cost versus Speed

  E.g. Fig. 1.10, Transmission of 8 bits of data

Parallel: all 8 bits transmitted at the same time

Serial: 8 bits transmitted one bit at a time



Advantage:

High speed

Advantage:

Low cost

Figure 1.10 (Tocci 10th Ed) Parallel and Serial Transfer

Example:

- 1 serial line to transmit 8 bits, say at 1 bit per millisecond. Total time taken to transmit is 8 milliseconds. But 1 serial line costs only, say $1 (low cost option).

- 8 parallel lines can transmit all 8 bits simultaneously in one millisecond. But 8 lines may cost $8 (high speed option).
- Data Transfer Methods - YouTube