Digital logic design (DLD)

Instructor

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INTRODUCTION

The term digital is derived from how operations are performed, by counting digits. For many years, applications of digital electronics were confined to computer systems.

Today, digital technology is applied in a wide range of areas in addition to computers.

Digital techniques are used in applications such as television, communications systems, radar, navigation and guidance systems, military systems, medical instrumentation, industrial process control, and consumer electronics.

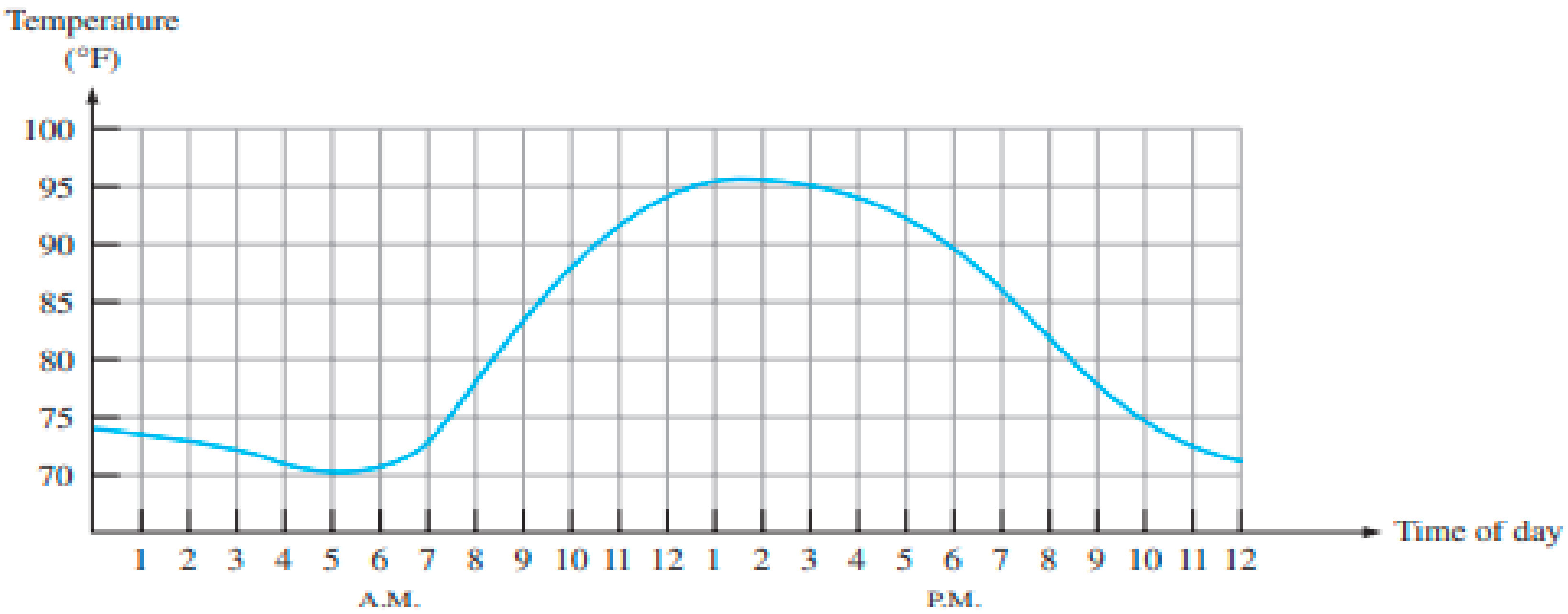
Over the years, digital technology has progressed from vacuum-tube circuits to discrete transistors to complex integrated circuits, many of which contain millions of transistors, and many of which are programmable.

Digital and Analog Quantities

- Electronic circuits can be divided into two categories, digital and analog.

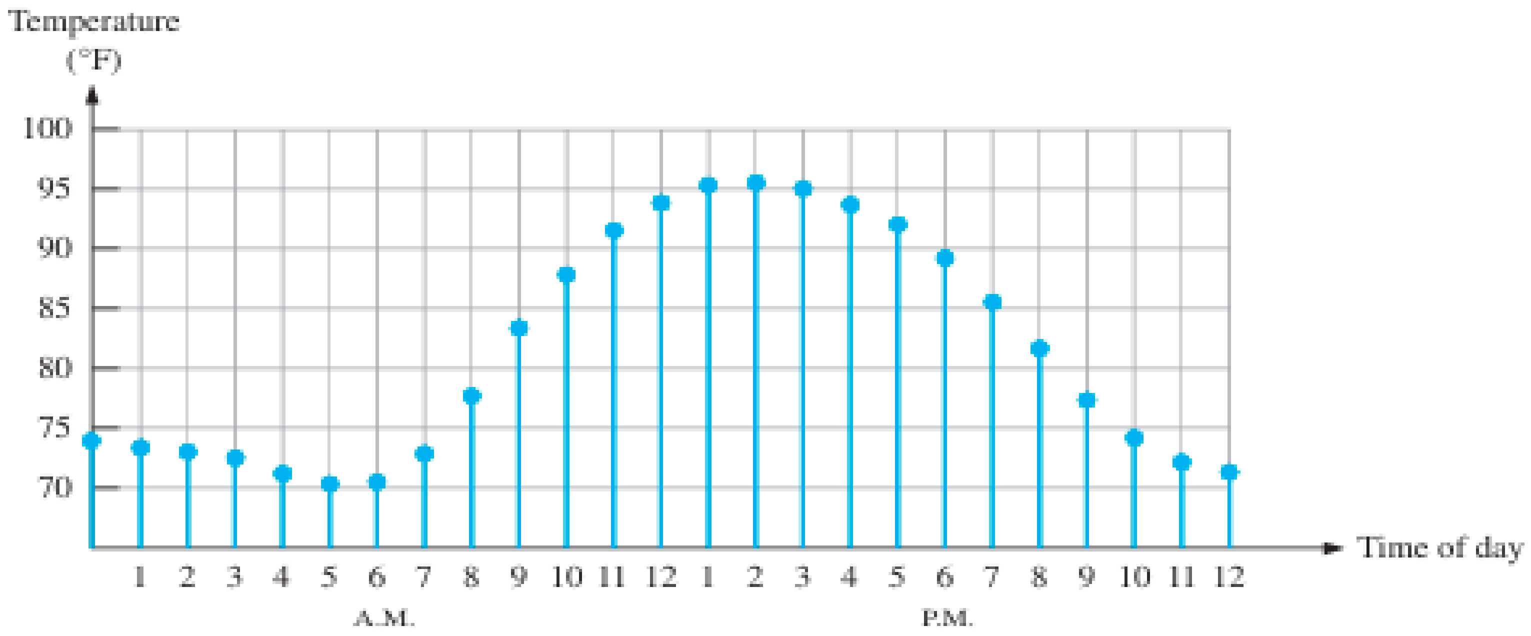
(1) Analog electronics involves quantities with continuous values.

- An analog quantity is one having continuous values. Most things that can be measured quantitatively occur in nature in analog form. For example, the air temperature changes over a continuous range of values. During a given day, the temperature does not go from 70 to 71 instantaneously; it takes on all the infinite values in between. Examples of analog quantities are time, pressure, distance, and sound.



(2) Digital quantities. A digital quantity is one having a discrete set of values.

Rather than graphing the temperature continuously, suppose you just take a temperature reading every hour. Now you have sampled values representing the temperature at discrete points in time (every hour) over 24 hours.



Analog Circuit Everyday Examples (Continuous signals)

1. **Volume knob on a radio** – Smoothly changes loudness.
2. **Old landline telephone** – Voice signal travels as an analog wave.
3. **Speedometer in older cars** – Needle moves smoothly with speed.
4. **Thermostat in old AC systems** – Adjusts cooling continuously.
5. **FM/AM radio tuner** – Dial changes frequency smoothly.
6. **Analog wall clock** – Hands move continuously.
7. **Dimmer for ceiling fan speed** – Smoothly adjusts motor speed.
8. **Vinyl record player** – Plays grooves as continuous audio.
9. **CCTV camera with analog output** – Sends continuous video signal.
10. **Electric guitar (before digital effects)** – Signal from strings is analog.

Digital Circuit Everyday Examples (Binary / discrete signals)

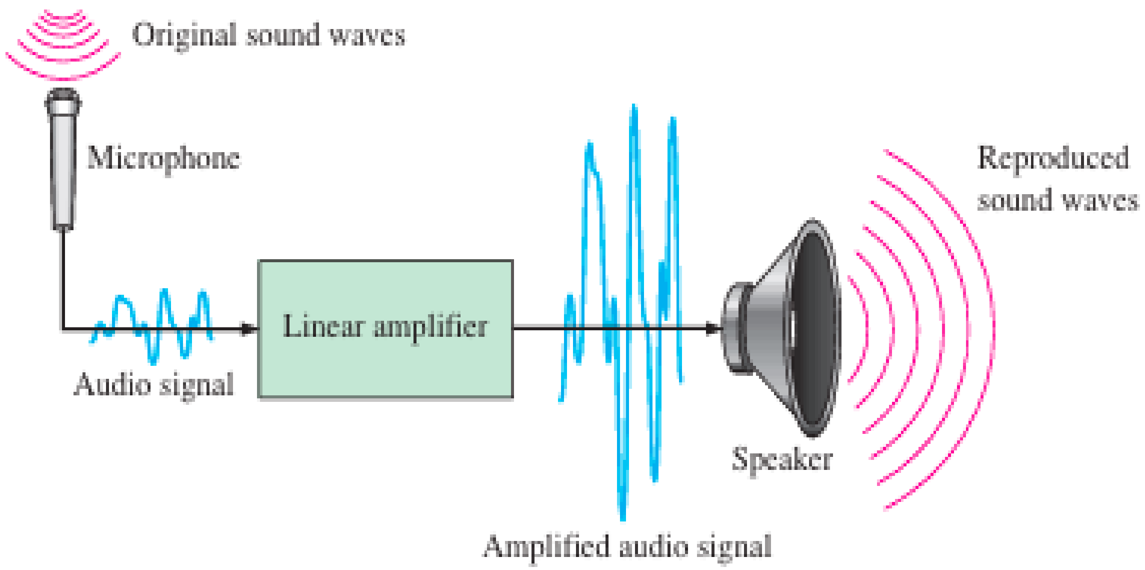
1. **Digital alarm clock** – Displays time in digits, changes in steps.
2. **Calculator** – Processes numbers using 0s and 1s.
3. **Microwave oven control panel** – Takes input in digital form.
4. **Digital wristwatch** – Shows exact numbers, no moving hands.
5. **Automatic washing machine** – Programmed cycles controlled by microcontrollers.
6. **Smartphone** – Internally processes data in binary.
7. **LED traffic lights** – Controlled digitally, either ON or OFF.
8. **Digital thermometer** – Shows temperature as numbers, no mercury column.
9. **Bluetooth speaker control buttons** – Send digital commands.
10. **Digital cameras** – Convert light into binary pixel data.

The Digital Advantage

- Digital representation has certain advantages over analog representation in electronics applications. Digital data can be processed and transmitted more efficiently and reliably than analog data.
- Also, digital data has a great advantage when storage is necessary. For example, music, when converted to digital form, can be stored more compactly and reproduced with greater accuracy and clarity than is possible when it is in analog form. Noise (unwanted voltage fluctuations) does not affect digital data nearly as much as it does analog signals.

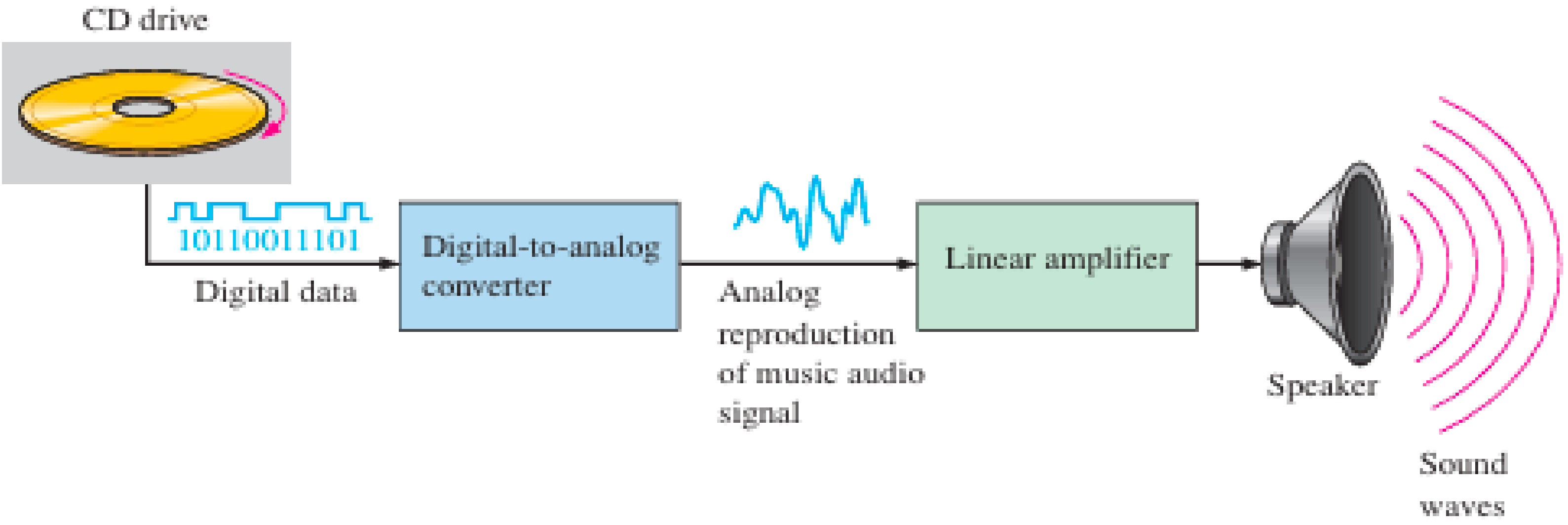
Analog System

- A public address system, used to amplify sound so that it can be heard by a large audience, is one simple example of an application of analog electronics.
- Sound waves, which are analog in nature, are picked up by a microphone and converted to a small analog voltage called the audio signal. This voltage varies continuously as the volume and frequency of the sound change and is applied to the input of a linear amplifier. The output of the amplifier, which is an increased reproduction of the input voltage, goes to the speaker(s). The speaker changes the amplified audio signal back to sound waves that have a much greater volume than the original sound waves picked up by the microphone.



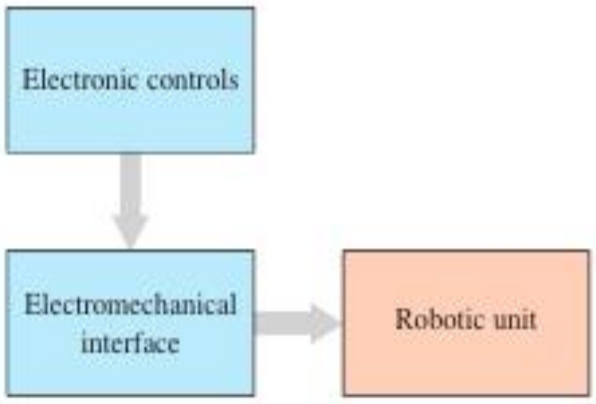
A System Using Digital and Analog Methods

- The compact disc (CD) player is an example of a system in which both digital and analog circuits are used.
- Music in digital form is stored on a compact disc. A laser diode optical system picks up the digital data from the rotating disk and transfers it to the digital-to-analog converter (DAC). The DAC changes the digital data into an analog signal that is an electrical reproduction of the original music. This signal is amplified and sent to the speaker for you to enjoy.
- When the music was originally recorded on the CD, a process, essentially the reverse of the one described here, using an analog-to-digital converter (ADC) was used.



MechatronIcs

- Both digital and analog electronics are used in the control of various mechanical systems.
- The interdisciplinary field that comprises both mechanical and electronic components is known as mechatronics.
- Mechatronic systems are found in homes, industry, and transportation. Most home appliances consist of both mechanical and electronic components. Electronics controls the operation of a washing machine in terms of water flow, temperature, and type of cycle. Manufacturing industries rely heavily on mechatronics for process control and assembly. In automotive and other types of manufacturing, robotic arms perform precision welding, painting, and other functions on the assembly line. Automobiles themselves are mechatronic machines; a digital computer controls functions such as braking, engine parameters, fuel flow, safety features, and monitoring.



(a) Mechatronic system block diagram

(b) Robotic arm

(c) Automotive assembly line

The movement of the arm in any quadrant and to any specified position is accomplished with some type of digital control, such as a microcontroller.

Binary Digits, Logic Levels

Binary Digit (Bit):

- The smallest unit of digital information.
- Can be **0** or **1**.

Logic Levels:

- Represent binary digits with voltages.
- Example (for TTL logic):
  - Logic 0 → **0V (0 – 0.8 V)**
  - Logic 1 → **5V (2 – 5 V)**

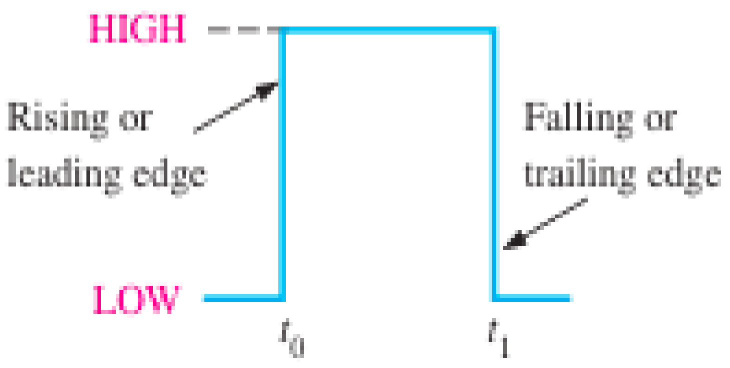
Computers and digital circuits use these two logic levels to process and store information.

Information Note

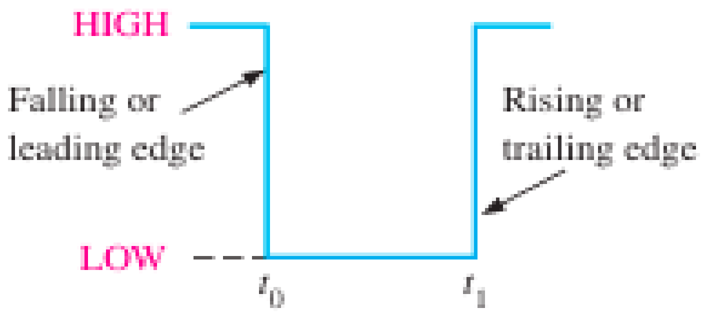
- The concept of a digital computer can be traced back to Charles Babbage, who developed a crude mechanical computation device in the 1830s.
- John Atanasoff was the first to apply electronic processing to digital computing in 1939.
- In 1946, an electronic digital computer called ENIAC was implemented with vacuum-tube circuits. Even though it took up an entire room, ENIAC didn’t have the computing power of your handheld calculator.

Digital Waveforms

- Digital signals change between two levels (0 and 1).
- Digital waveforms consist of voltage levels that are changing back and forth between the HIGH and LOW levels or states.
- Figure (a) shows that a single positive-going pulse is generated when the voltage (or current) goes from its normally LOW level to its HIGH level and then back to its LOW level.
- The negative-going pulse in Figure (b) is generated when the voltage goes from its normally HIGH level to its LOW level and back to its HIGH level. A digital waveform is made up of a series of pulses.



(a) Positive–going pulse



(b) Negative–going pulse

(a) Periodic Digital Waveform

Repeats after a fixed time interval.

Example: Clock signal used in computers.

Parameters:

Period (T): Time to complete one cycle.

Frequency (f): Number of cycles per second.

Duty Cycle: % of time signal remains HIGH in one cycle.

(b) Non-Periodic Digital Waveform

Does not repeat regularly.

Example: Keyboard input signal, Data transmission signals.

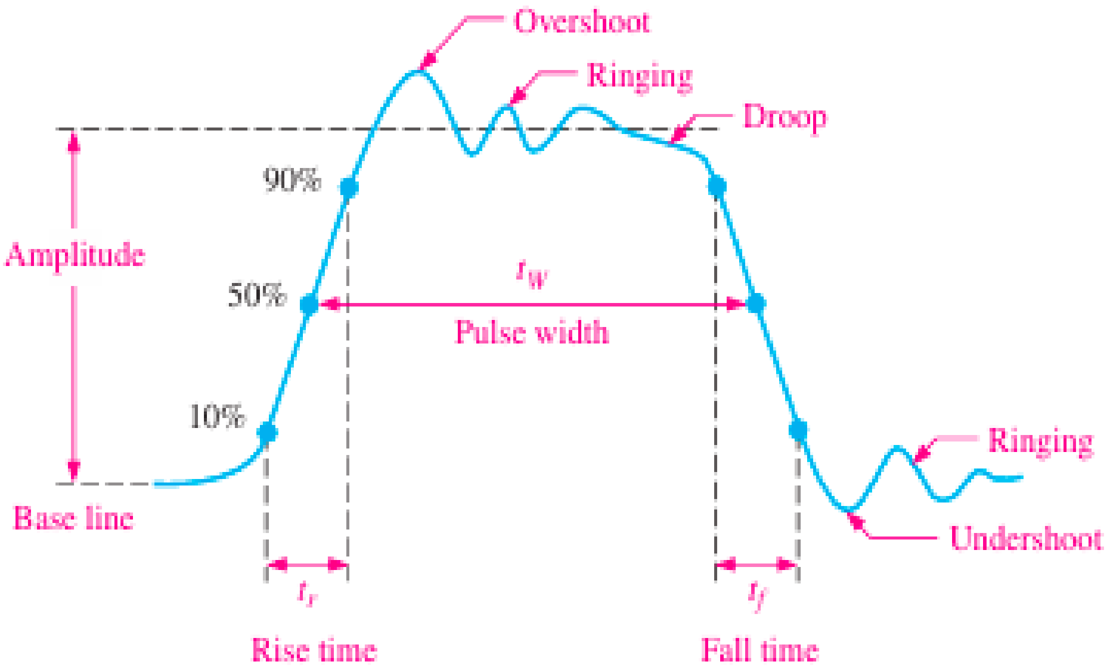
👉 Analogy:

Periodic = heartbeat (regular).

Non-periodic = speech pattern (irregular).

The Pulse

A pulse has two edges: a leading edge that occurs first at time t0 and a trailing edge that occurs last at time t1. For a positive-going pulse, the leading edge is a rising edge, and the trailing edge is a falling. The pulses in the Figure are ideal because the rising and falling edges are assumed to change in zero time (instantaneously). In practice, these transitions never occur instantaneously, although for most digital work, you can assume ideal pulses.



Nonideal pulse characteristics.

In reality, all pulses exhibit some or all of these characteristics. The overshoot and ringing are sometimes produced by stray inductive and capacitive effects. The droop can be caused by stray capacitive and circuit resistance, forming an RC circuit with a low time constant.