EEE104 – Digital Electronics (I)

Lecture 1

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This Module

Textbooks:

T. Floyd, *Digital Fundamentals*, 10th Edition, Pearson Education/Science Press, 2011, ISBN 9787030318534

Reference Book:

R. J. Tocci, et al, *Digital Systems: Principles and Applications*, 10th Edition, Pearson/China Machine Press, 2006, ISBN 9787111193401

This Module

Assessment:

Final exam (80%), Assignments (10%), Lab (10%)

Module Leaders: Dr. Ming Xu (EE518)

Instructors: Dr. Ming Xu, Dr. Filbert Juwono, and Dr. Jiangmin Gu

TAs: TBD

In This Session

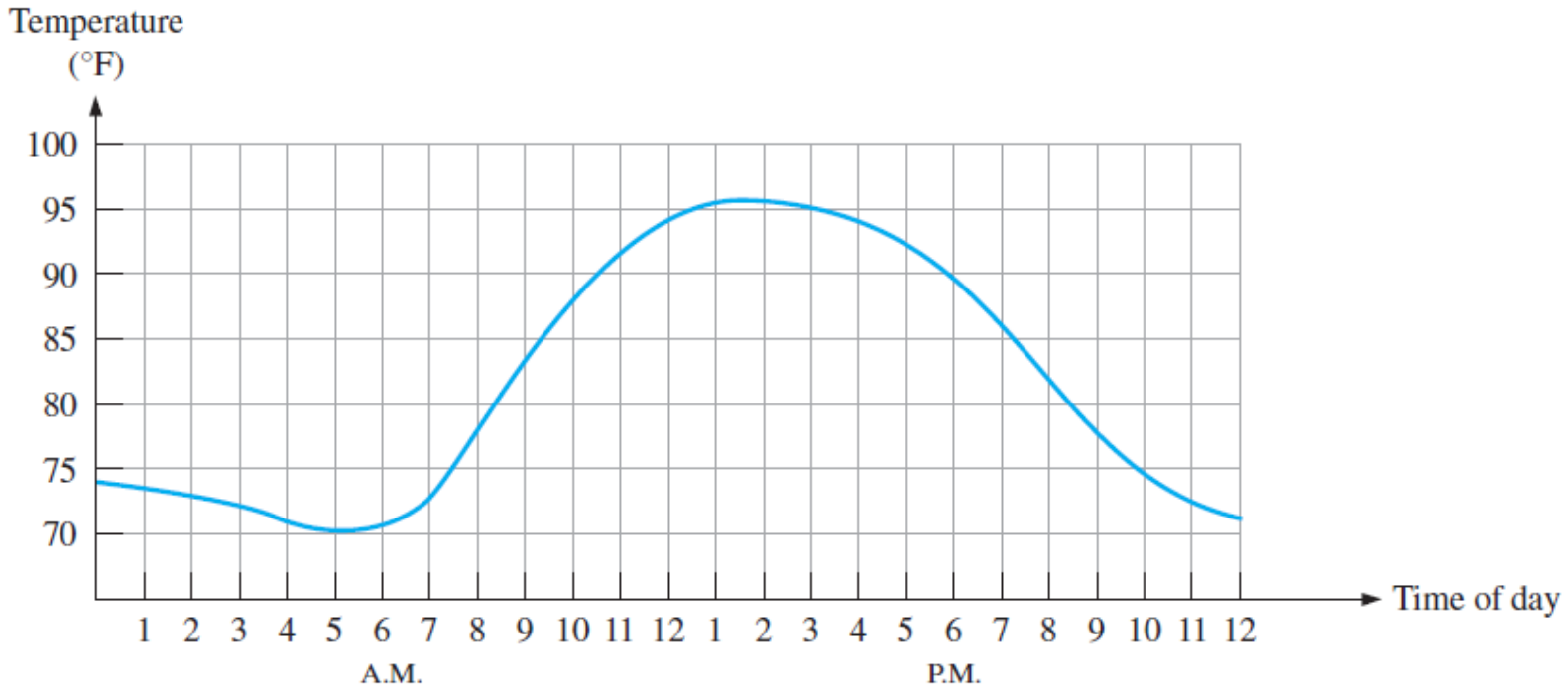
- Analog and digital quantities.
- Bits, Logic Levels, and Digital Waveforms

Digital and Analog Quantities

- Analog = continuous
- Digital = discrete
- Example:
  - An analog clock, whose hands move smoothly and continuously.
  - A digital clock, whose digits jump from one value to the next.

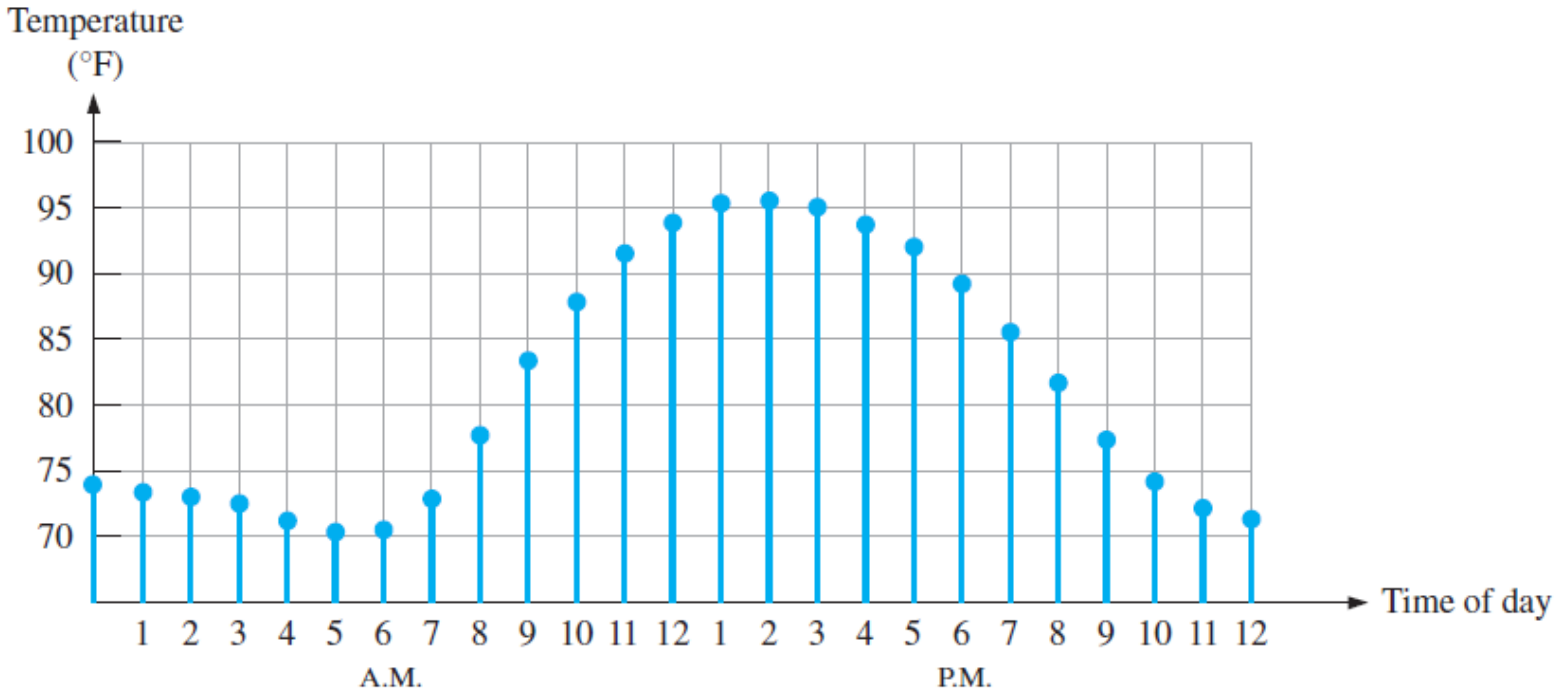
Digital and Analog Quantities

- **Analog** quantities have **continuous** values

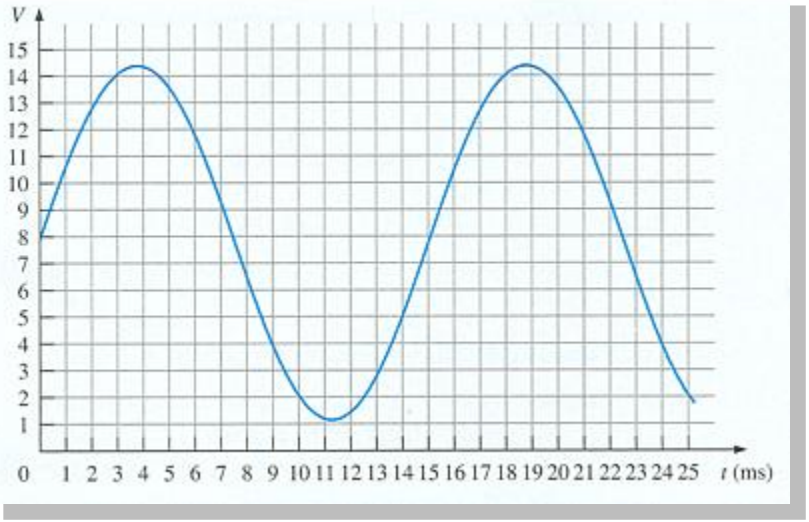


Digital and Analog Quantities

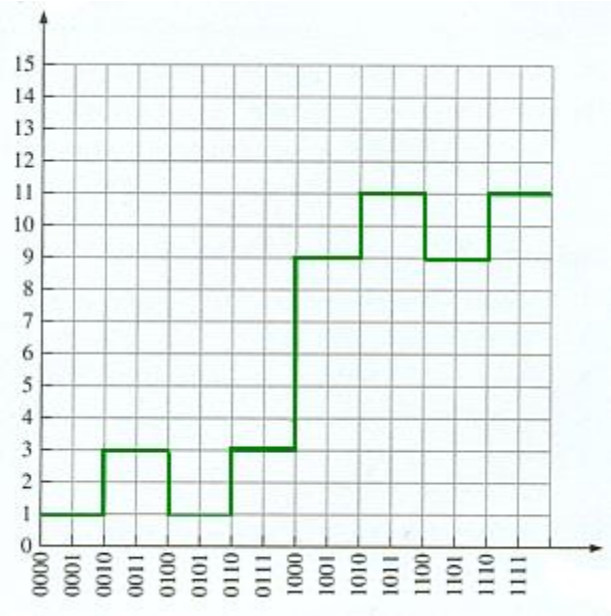
- **Digital** quantities have **discrete** sets of values, e.g. discrete time points (via sampling) and discrete values (via digitalization).



Digital and Analog Quantities



Analog quantities have continuous values



Digital quantities have discrete sets of values

Digital and Analog Quantities

Types of electronic devices or instruments:

- Analog
- Digital
- Combination analog and digital

Interfacing With the Analog World

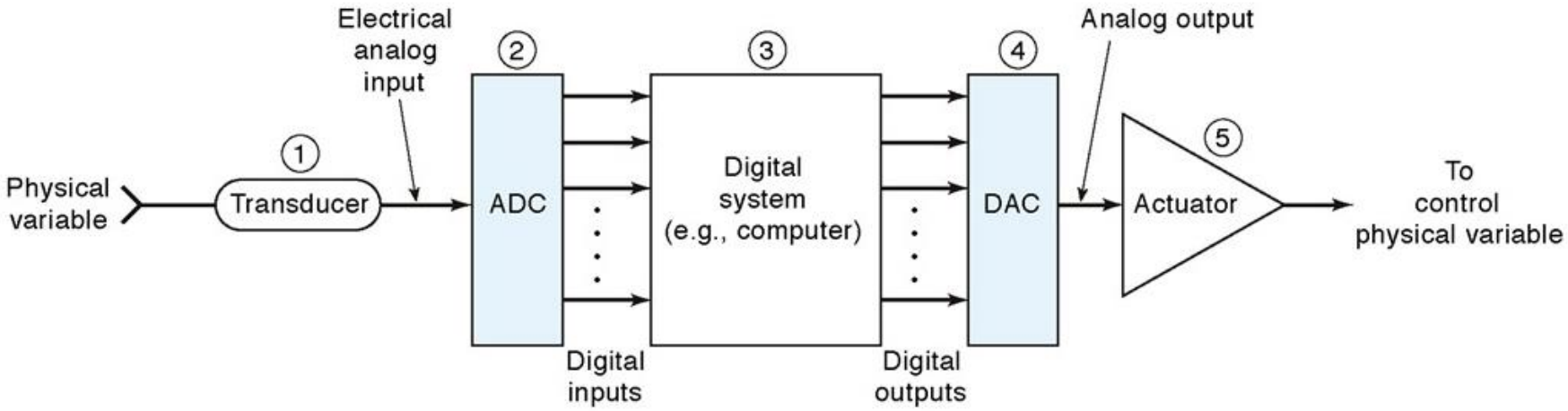
① Transducer: converts physical variables to electrical ones.

② ADC: converts analog inputs to digital ones.

③ Digital System: processes digital inputs

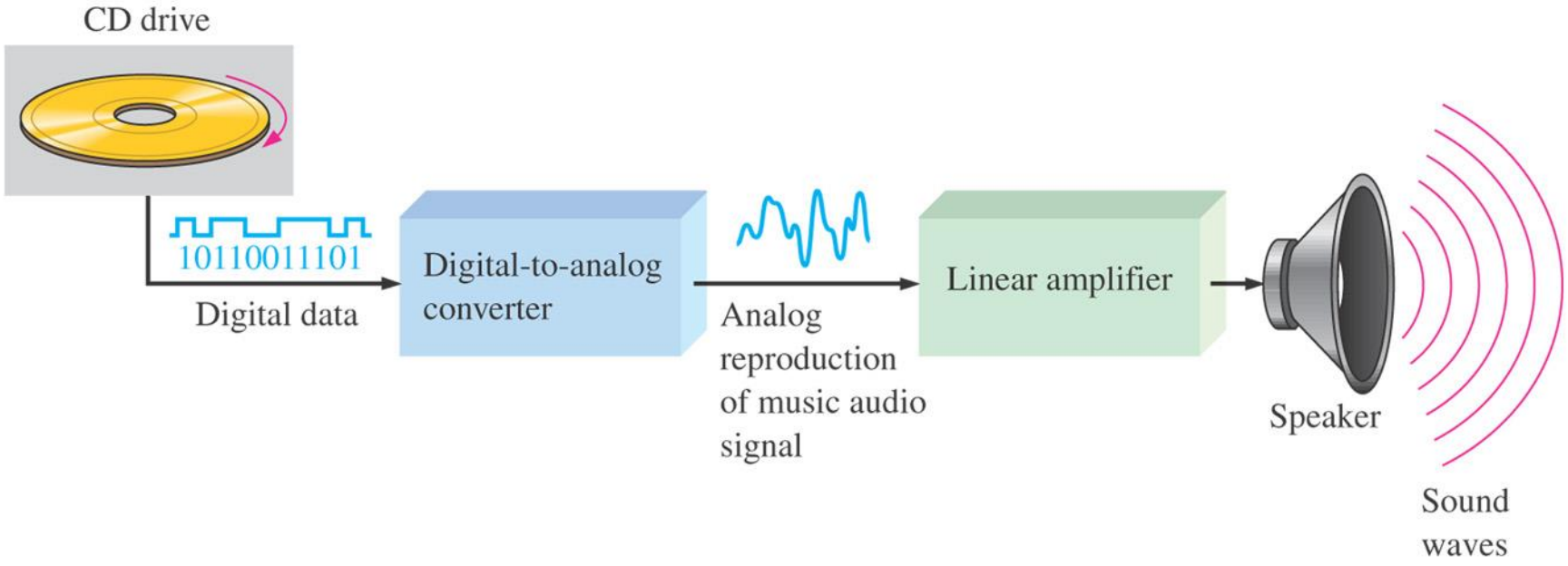
④ DAC: converts digital outputs to analog outputs

⑤ Actuator: controls physical variables

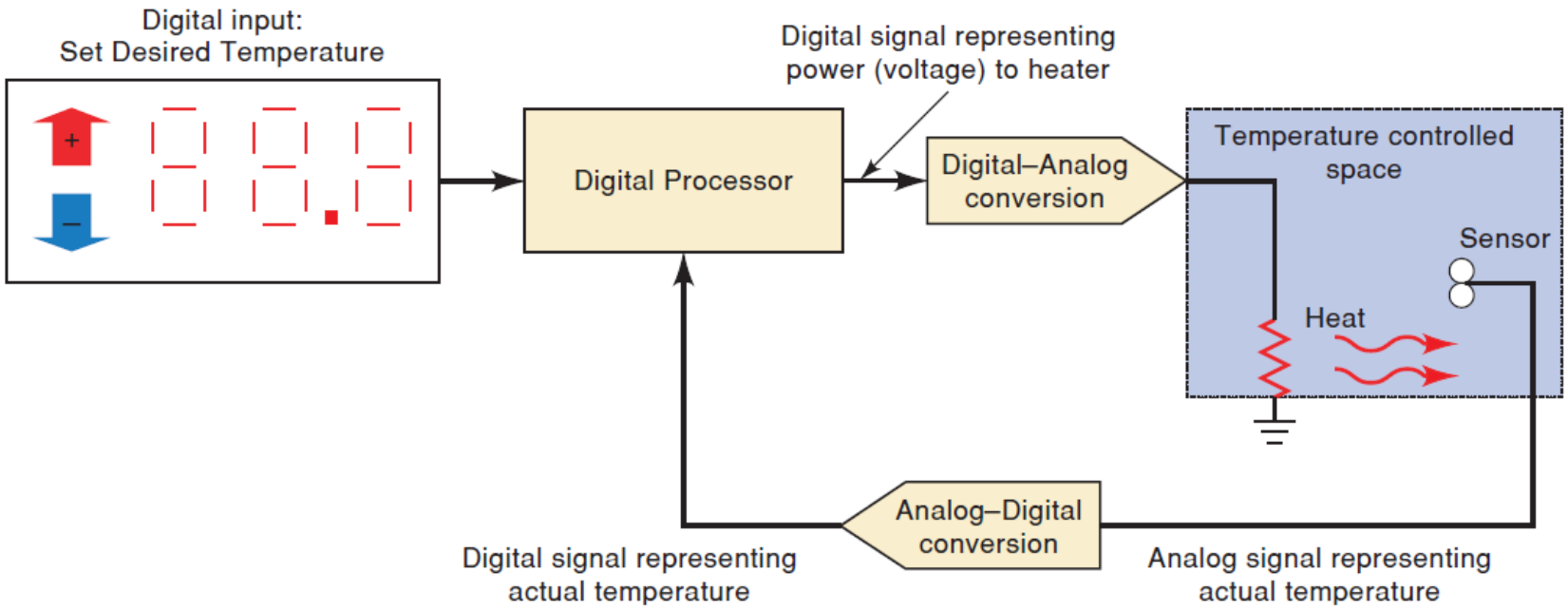


Digital and Analog Quantities

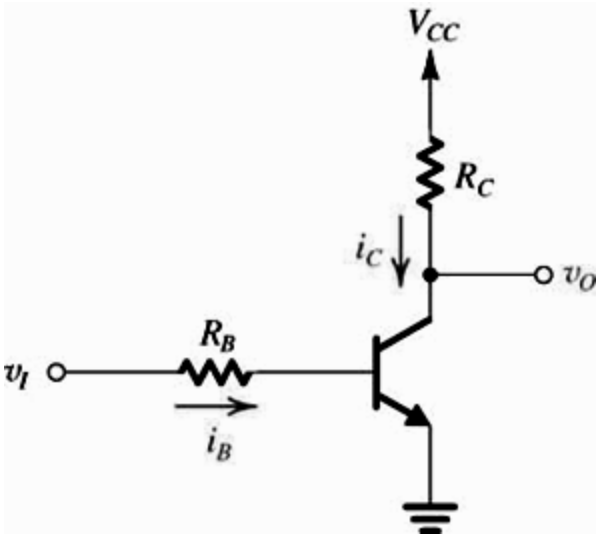
- An **analog** system contains devices that manipulate analog quantities, e.g. audio amplifiers.
- A **digital** system contains devices that manipulate digital quantities, e.g. digital audio and video equipment, computers.



Digital and Analog Quantities



Digital and Analog Quantities



When a BJT is used as a digital circuit, it operates between the cutoff and saturation modes.

1. If v_I is at a value close to V_{CC} (logic "1"), the BJT is saturated; $v_O = V_{CEsat} \cong 0.2$ V (logic "0").
2. If v_I is at a value close to ground (logic "0"), the BJT is cut off; $v_O = V_{CC}$ (logic "1").
3. This is a logic inverter, the simplest digital circuit.

Digital and Analog Quantities

Advantages of Digital Techniques

1. **Easier to design**. The range (HIGH or LOW), rather than the exact values of voltages, is important.
2. **Information storage is easy**. Billions of bits of information can be stored in a small space.
3. **Accuracy and precision are easier to maintain**. They will not be degraded by the effects of temperature and humidity.

Digital and Analog Quantities

Advantages of Digital Techniques

4. **Its operation can be programmed**, i.e. controlled by a set of stored instructions.
5. **Less affected by noise**, as long as the noise is not large enough to convert a HIGH signal to by LOW or vice versa.
6. **More digital circuitry can be fabricated on IC chips**. In analog circuitry high-value capacitors, inductors and transformers cannot be economically integrated.

Digital and Analog Quantities

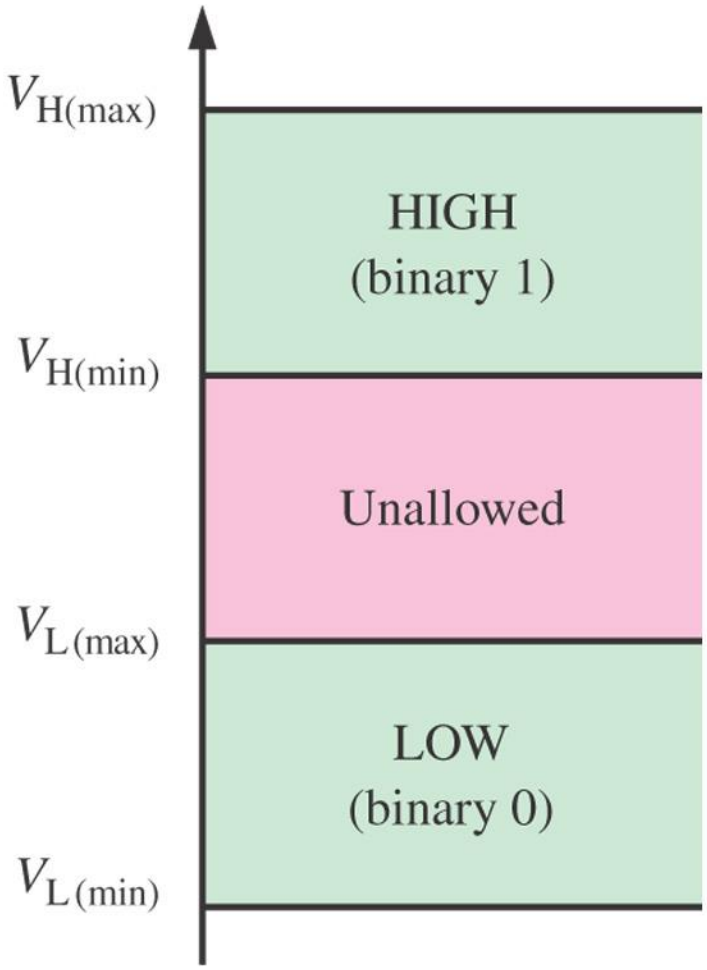
Limitations of Digital Techniques

- **The real world is analog**. We have to convert the analogy input to digital form, and after processing it convert the digital output to analog form.
- **Processing digitized signals takes time**. The more precise the numbers need to be, the longer it takes to process them.

Bits, Logic Levels, and Digital Waveforms

- The conventional numbering system uses ten digits: 0-9.
- In digital circuits, there are only two possible states: **HIGH** and **LOW**, corresponding to two different voltage levels, or open and closed switches.
- So the binary numbering system is used, which has just two digits: **0** and **1,** called **bits** (binary digits). **LOW = 0** and **HIGH = 1.**

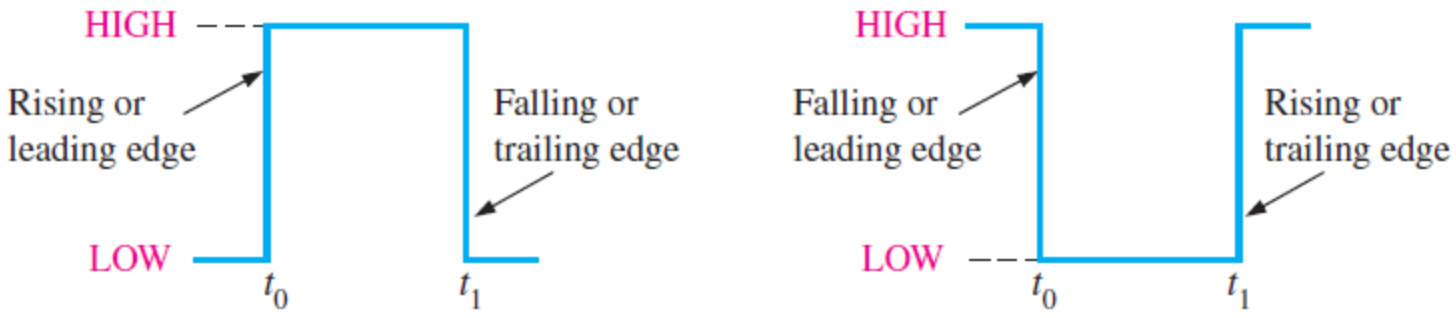
Bits, Logic Levels, and Digital Waveforms



- The voltages used to represent a 1 and a 0 are called **logic levels**.
- Each corresponds to a range of voltages.
- For TTL digital circuits , the high values range from 2 V to 5 V, and the low values range from 0 V to 0.8 V.

Bits, Logic Levels, and Digital Waveforms

- A **digital waveform** is a graph of voltage versus time.
- To represent an analog signal in digital form, multiple waveforms are required, each corresponds to one bit of a multi-bit binary number.
- An ideal **digital pulse**



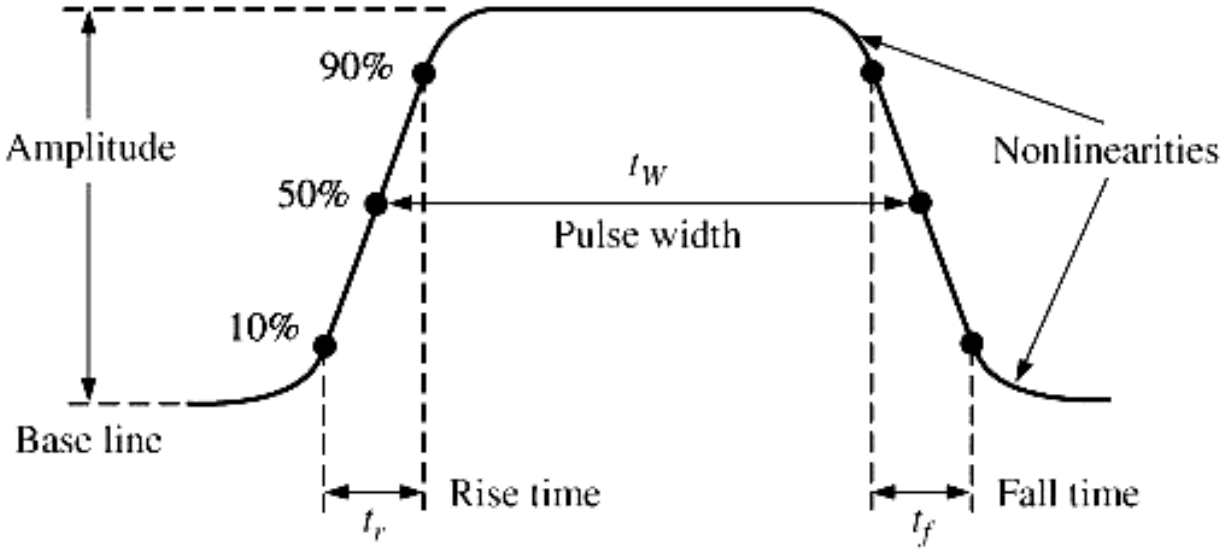
(a) Positive–going pulse

(b) Negative–going pulse

Bits, Logic Levels, and Digital Waveforms

A nonideal digital pulse

- **Rise time** (t_r) – time from 10% to 90% of the pulse magnitude
- **Pulse width** (t_w) – time between 50% points.
- **Fall time** (t_f) – time from 90% to 10% of the pulse magnitude

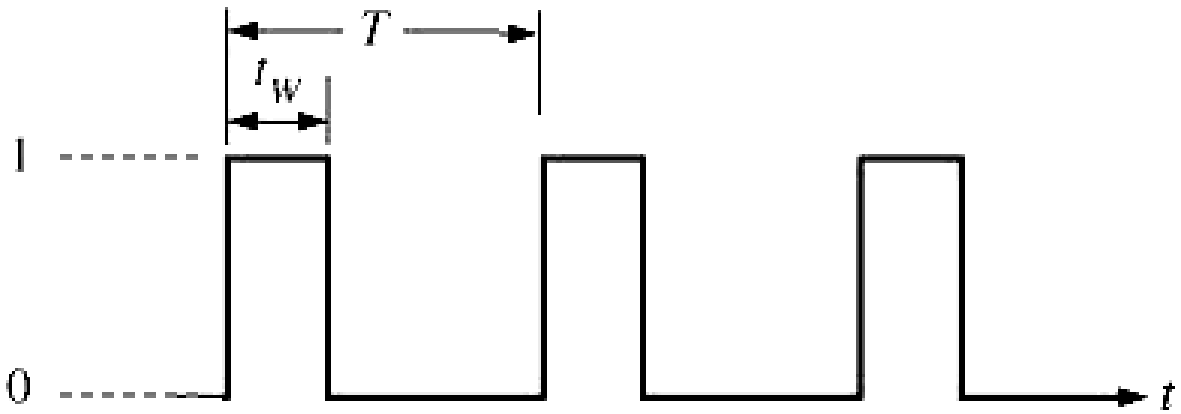


Bits, Logic Levels, and Digital Waveforms

A periodic waveform repeats itself at a fixed interval.

- T = **period** of the waveform
- f = **frequency** of the waveform

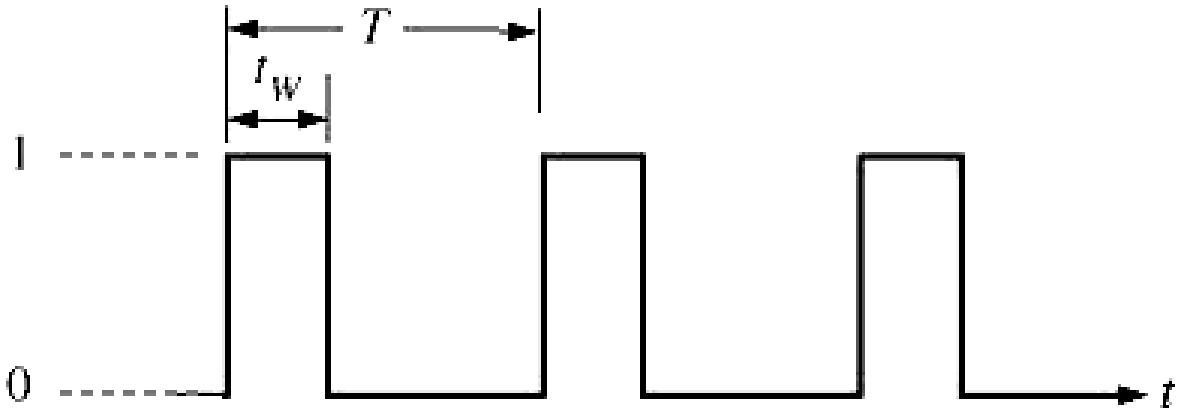
$$\mathbf{f = \frac{1}{T}}$$



Bits, Logic Levels, and Digital Waveforms

The **duty cycle** of a binary waveform is defined as:

$$\textbf{Duty cycle} = \left(\frac{\mathbf{t_w}}{\mathbf{T}}\right)\mathbf{100\%}$$



Bits, Logic Levels, and Digital Waveforms

- Digital waveforms are often synchronized with a periodic waveform called the **clock**.
- A **timing diagram** is used to show the relationship of multiple waveforms.