EE40: Introduction to Microelectronic Circuits

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Course Material

- ✓Main reference
  - ✓http://www-inst.eecs.berkeley.edu/~ee40
- ✓Textbook (s)
  - ✓Electrical Engineering Principles and Applications by Allan R. Hambley.
- ✓Reader available at Copy Central, 2483 Hearst Avenue
- ✓Publications
  - ✓Selected pubs posted on the web

Course Organization

- ✓ Lectures: 3 x week (20 total)
- ✓ Labs
  - ✓ Experimenting and verifying
  - ✓ Building a complete system: mixer, tone control, amplifier, power supply, control
- ✓ Discussion sessions
  - ✓ More examples, exercise, exams preparation
- ✓ Homework
  - ✓ Weekly, for a better understanding
- ✓ Exams
  - ✓ 2 midterms, 1 final
- ✓ Grade
  - ✓ HW: 10%, LAB: 10%, MID: 20%, FINAL: 40%

Table of contents

- ✓ Circuit components
  - ✓ Resistor, Dependent sources, Operational amplifier
- ✓ Circuit Analysis
  - ✓ Node, Loop/Mesh, Equivalent circuits
  - ✓ First order circuit
- ✓ Active devices
  - ✓ CMOS transistor
- ✓ Digital Circuits
  - ✓ Logic gates, Boolean algebra
  - ✓ Gates design
  - ✓ Minimization
- ✓ Extra Topics

CAD for electronic circuits

Prerequisites

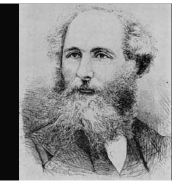
- ✓ Math 1B
- ✓ Physics 7B

Lecture 1

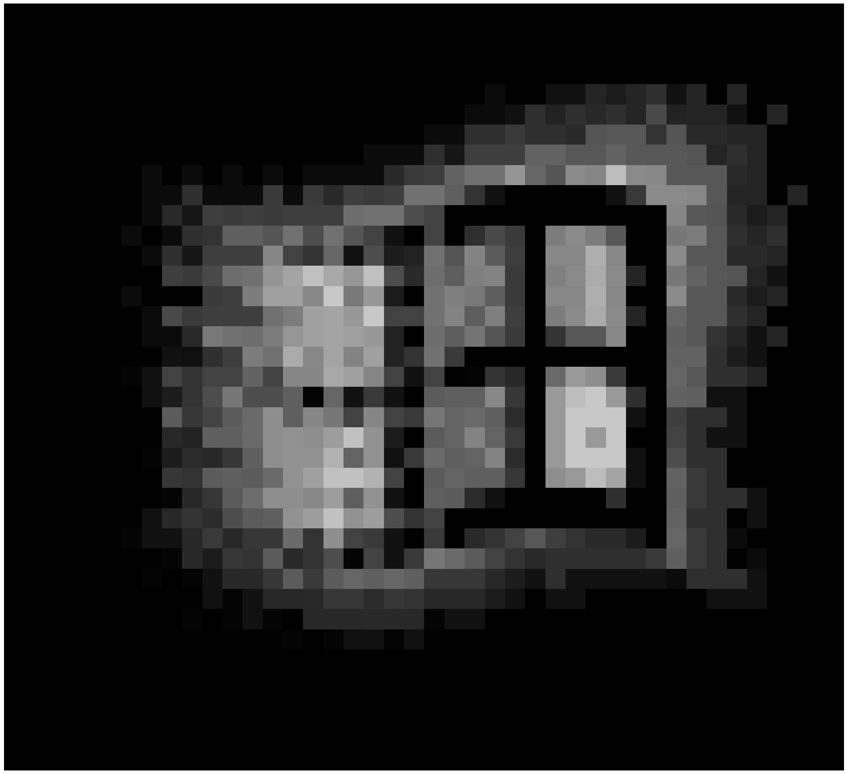
- ✓Illustrates the historical background
  - ✓Electricity
  - ✓Transistor
  - ✓Monolithic integration
  - ✓Moore’s law

- ✓Introduces signals: Analog and Digital

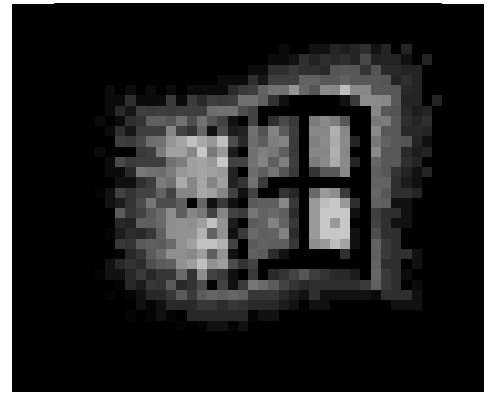
History of EE: Electricity



Hans Christian Oersted 's Experiment (1820)



Michael Faraday's Experiment (1831)



(Source: Molecular Expression)

Maxwell's Equations (1831)

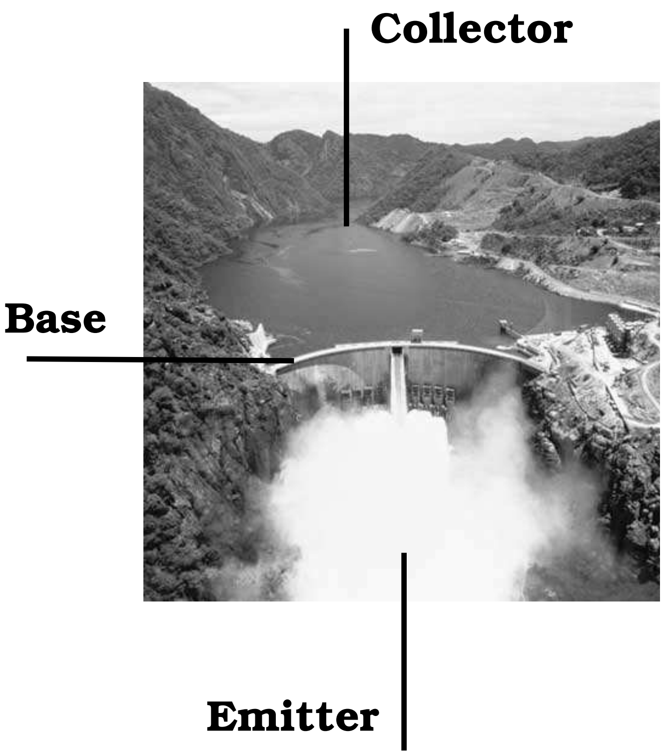
$$\nabla \cdot \mathbf{E} = 4\pi\rho$$

$$\nabla \times \mathbf{E} = -\frac{1}{c}\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{B} = \frac{4\pi}{c}\mathbf{J} + \frac{1}{c}\frac{\partial \mathbf{E}}{\partial t},$$

History of EE: Transistor



J. Bardeen,W. Brattain and W. Shockley, 1939-1947

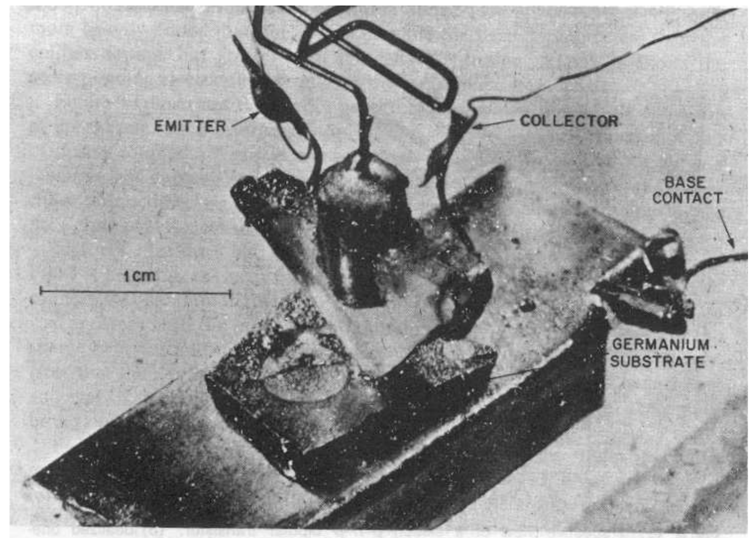
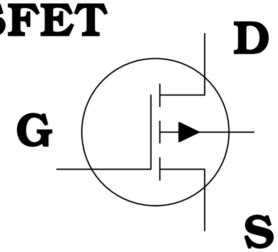
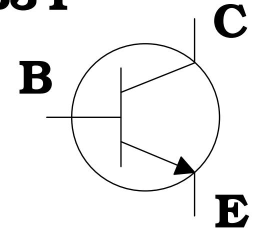


Fig. 1 The first transistor.[1]

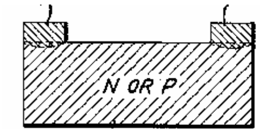
MOSFET



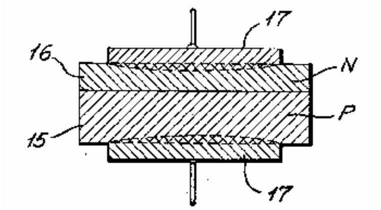
BJT



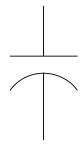
History of EE: Integration

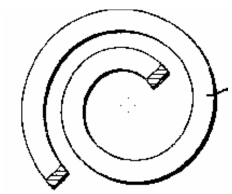


Resistor

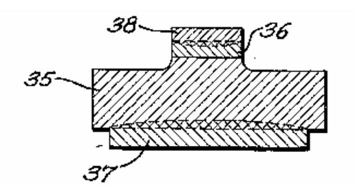


Capacitor

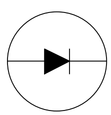


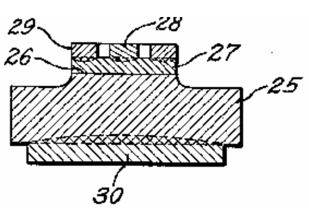


Inductor

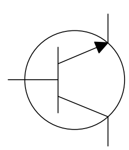


Diode



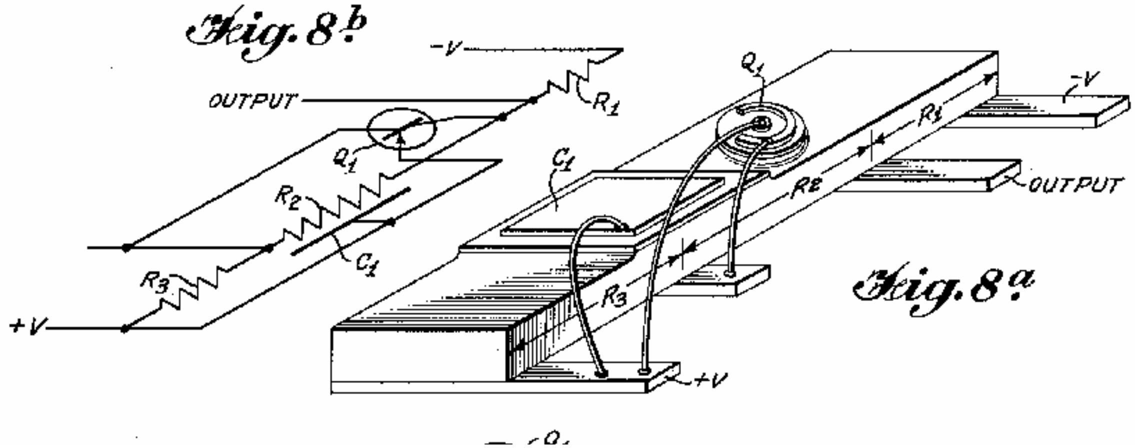


Transistor

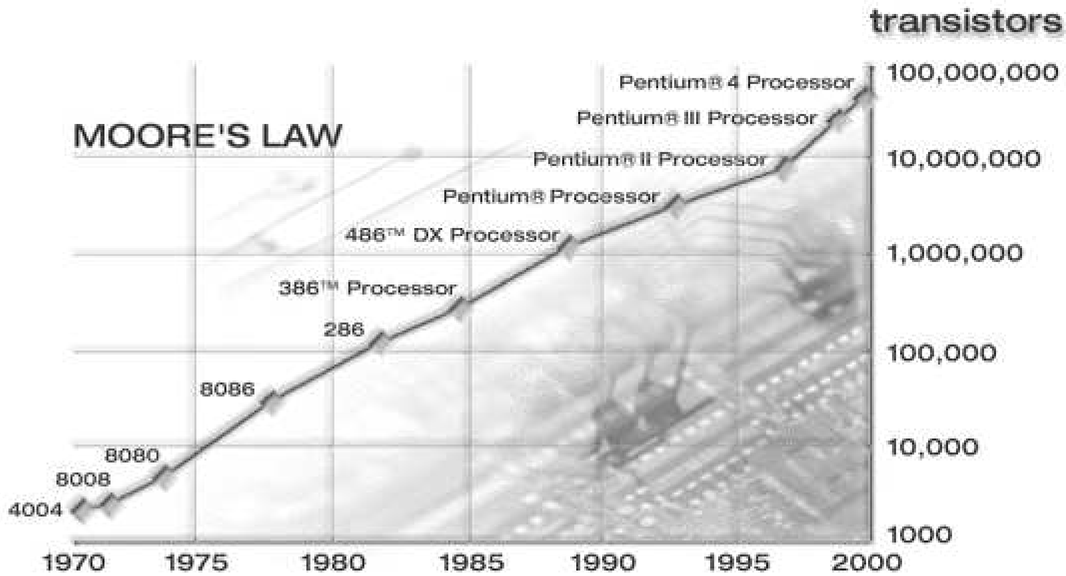


Jack S. Kilby (1958)

Monolithic (one piece) circuits: built form a silicon substrate



Today's Chips: Moore's Law



Gordon Moore, 1965

Number of transistor per square inch doubles approximately every18 months

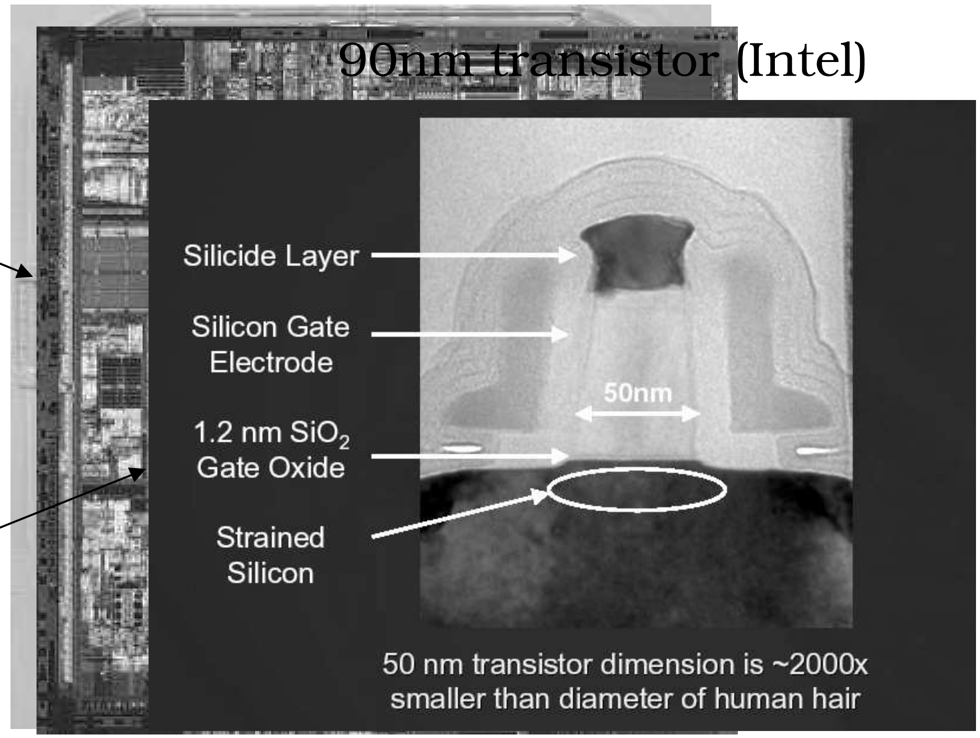
- ✓ Implications
  - ✓ Cost per device halves every 18 months
  - ✓ More transistors on the same area, more complex and powerful chips
  - ✓ Future chips are very hard to design!!!
  - ✓ Fabrication cost is becoming prohibitive

Today's Chips: An Example

300mm wafer, 90nm

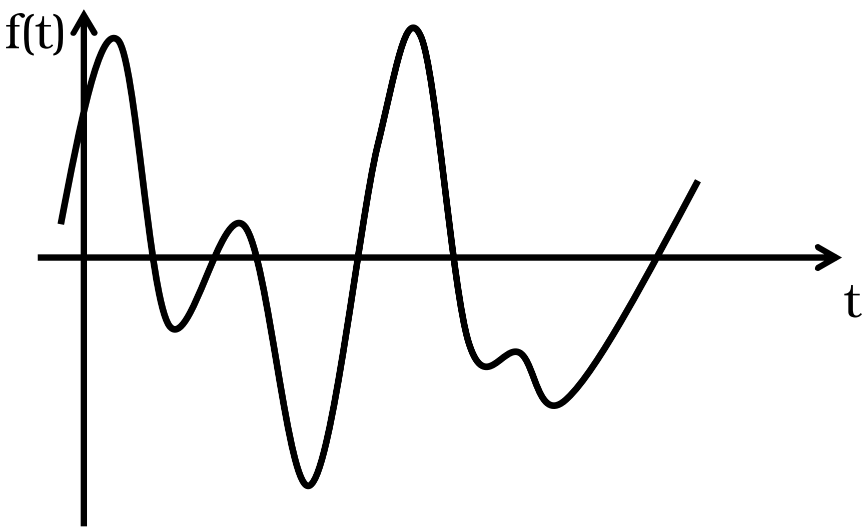
P4 2.4 Ghz, 1.5V, 131mm^2

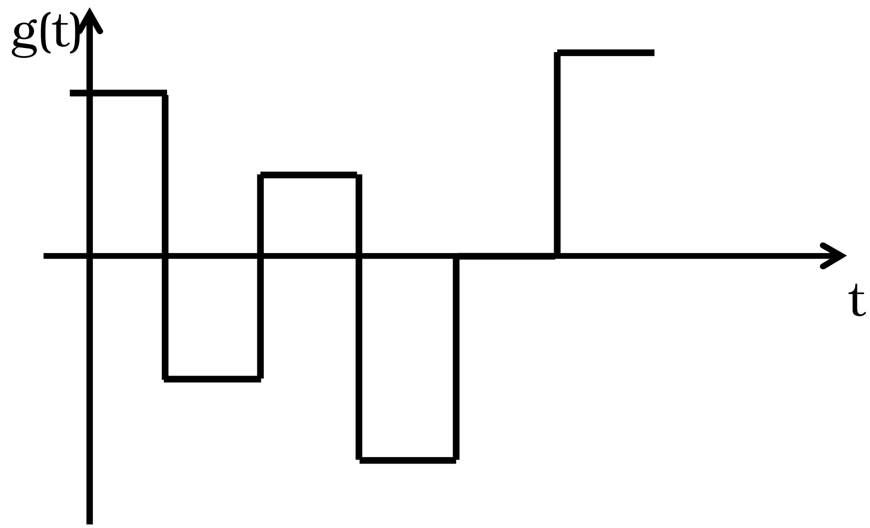
90nm transistor (Intel)



Hair size (1024px)

Signals: Analog vs. Digital



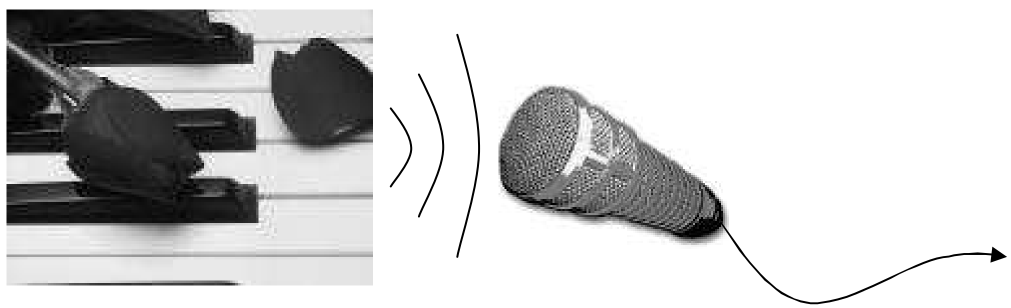


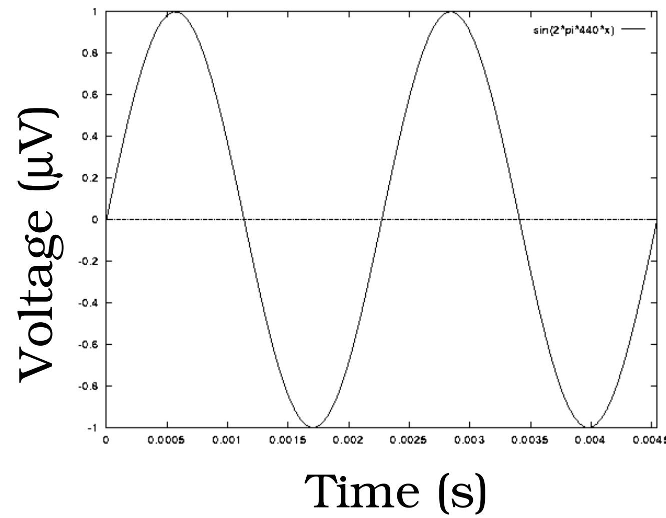
Analog: Analogous to some physical quantity

Digital: can be represented using a finite number of digits

Example of Analog Signal

A (440Hz) piano key stroke

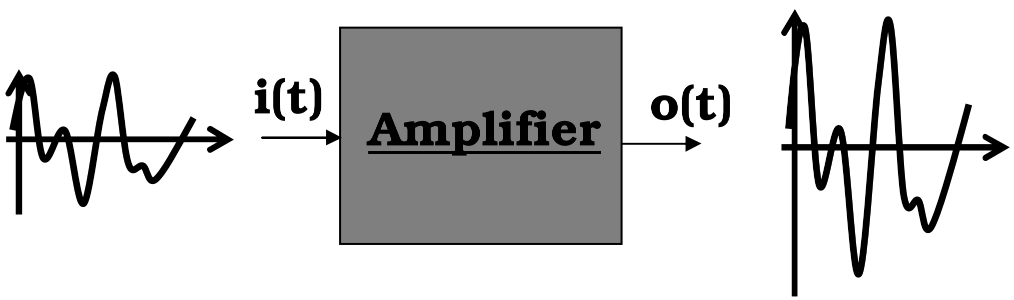




- ✓Properties:
  - ✓Dynamic range: maxV – minV
  - ✓Frequency: number of cycles in one second

Analog Circuits

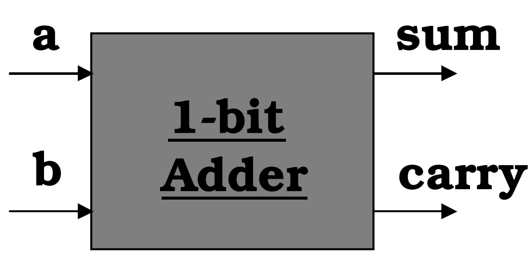
- ✓ It is an electronic subsystem which operates entirely on analog signals



o(t) = K i(t)

Digital Circuits

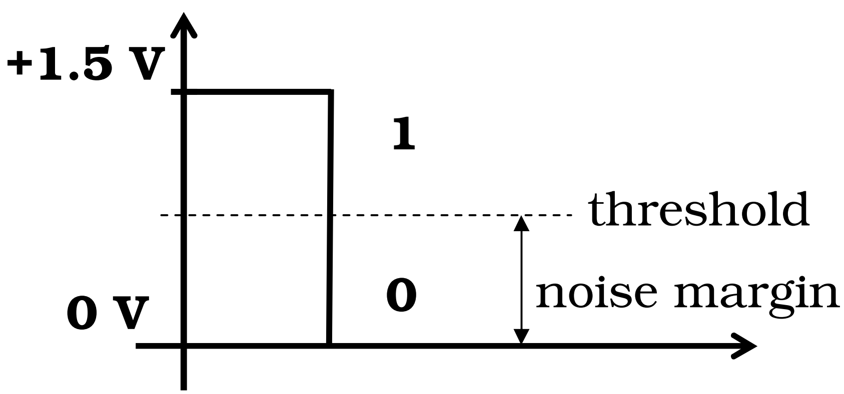
- ✓ It is an electronic subsystem which operates entirely on numbers (using, for instance, binary representation)

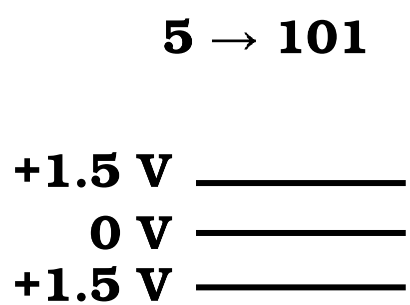


a	b	sum	carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Encoding of Digital Signals

- ✓We use binary digits
  - ✓Two values: {**0** , **1**}
- ✓Positional system
- ✓Encoded by two voltage levels
  - ✓ **+1.5 V → 1 , 0 V → 0**





Why Digital?

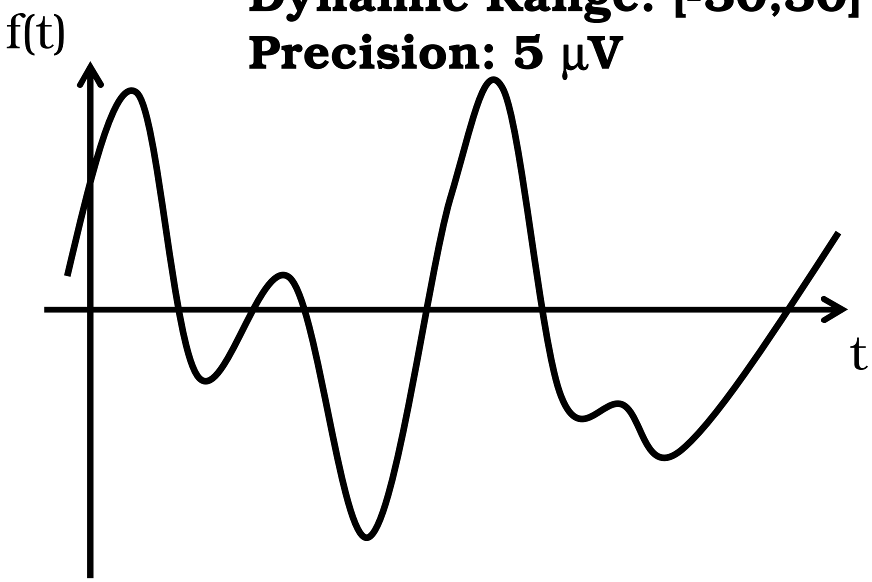
- ✓ Digital signals are easy and cheap to store
- ✓ Digital signals are insensible to noise
- ✓ Boolean algebra can be used to represent, manipulate, minimize logic functions
- ✓ Digital signal processing is easier and relatively less expensive than analog signal processing

Digital Representation of Analog Signals

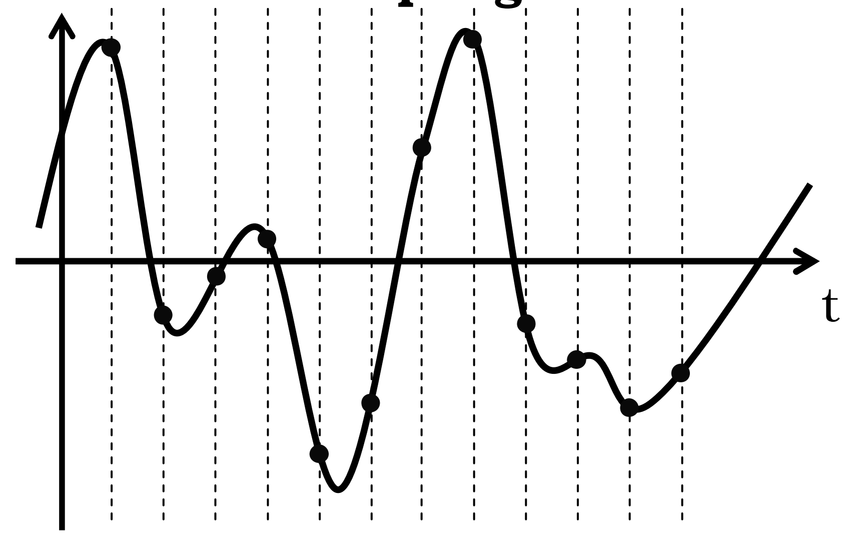
- ✓ Problem: represent f(t) using a finite number of binary digits
- ✓ Example: A key stroke using 6 bits
  - ✓ Only 64 possible values, hence not all values can be represented
- ✓ Quantization error: due to finite number of digits
- ✓ Time sampling: time is continuous but we want a finite sequence of numbers

Digital Representation of Analog Signals

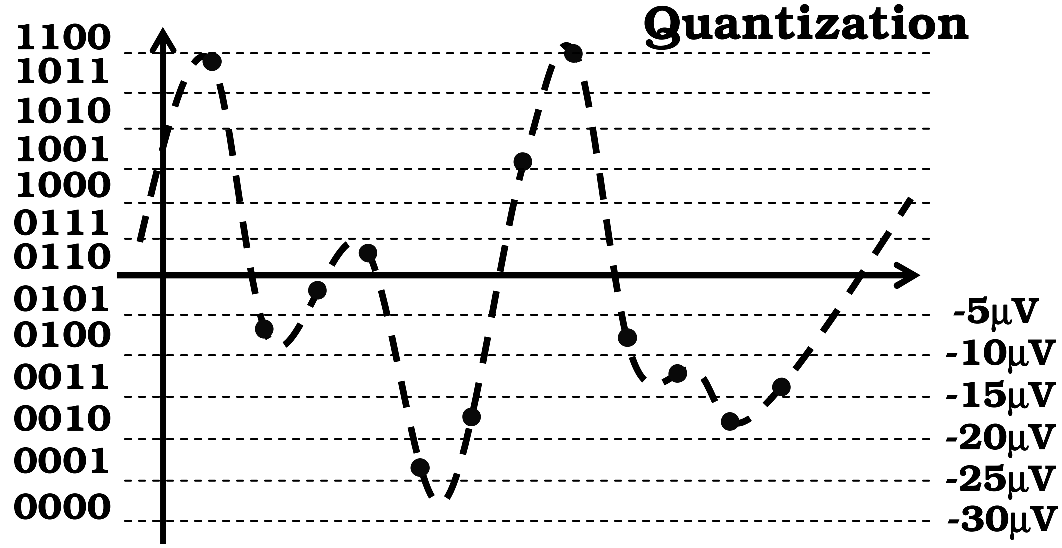
Dynamic Range: [-30,30] μV
Precision: 5 μV



Sampling



Quantization



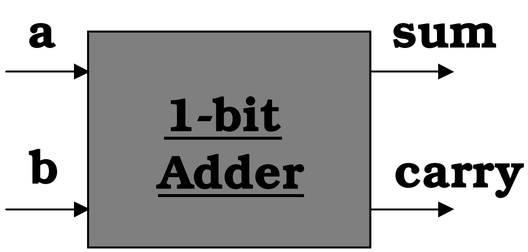
Result ←

1011
0100
0101
0110
0001
0010
1001
1100
0100
0011
0010
0011

Digital Representation of Logic Functions

- Boolean Algebra:
  - Variables can take values **0 or 1** (true or false)
  - Operators on variables:
    - a AND b $a \cdot b$
    - a OR b $a+b$
    - NOT b $\overline{b}$
- Any logic expression can be built using these basic logic functions
- Example: exclusive OR

Full Adder Example



a	b	sum	carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Summary

- ✓Analog signals are representation of physical quantities
- ✓Digital signals are less sensible to noise than analog signals
- ✓Digital signals can represent analog signals with arbitrary precision (at the expense of digital circuit cost)
- ✓Boolean algebra is a powerful mathematical tool for manipulating digital circuits