Computer Abstractions and Technology

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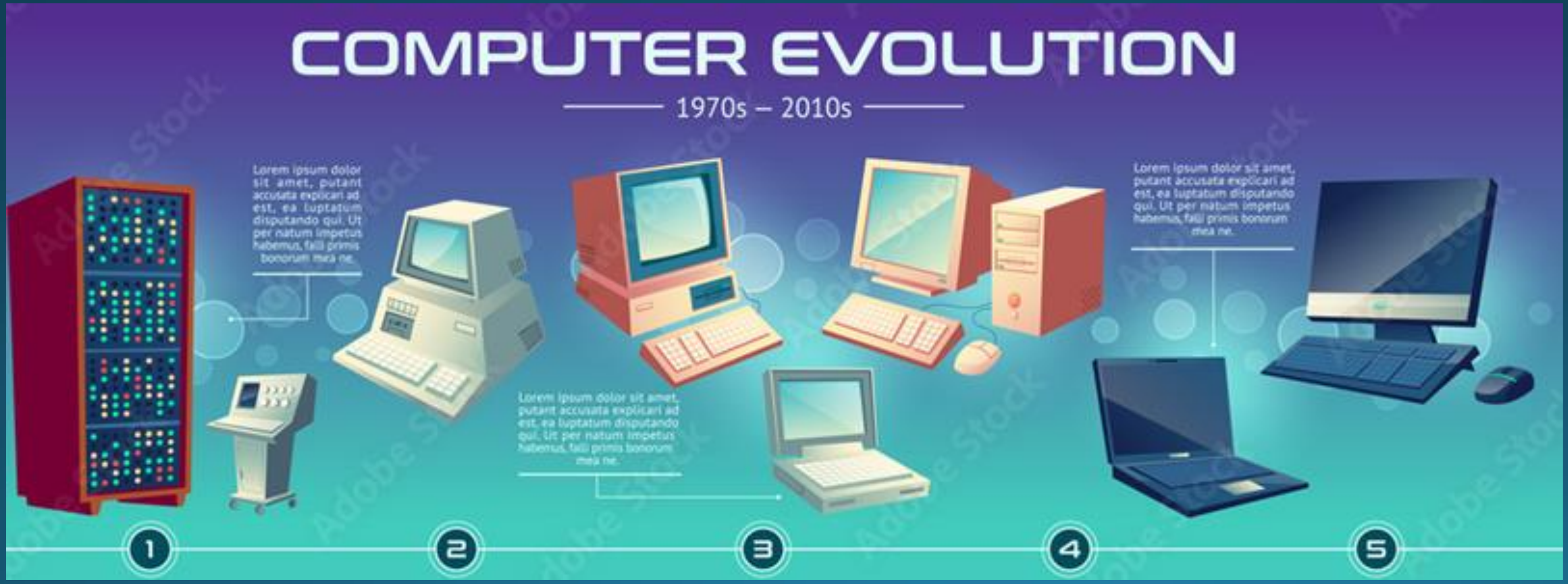
Revolution

- In the last 30-40 years,
  - A number of new computers has been introduced
  - Each time, an older set of computers has contributed to revolutionize and create a new set of computers
  - The revolution caused a set of computers to either short lived or a relatively long lived if it appears a better set



Once, Computer science fiction

- Until a few years ago,
  - Computers in automobiles:
    - Today, computers reduce pollution, improve fuel efficiency via engine controls
  - Cell phones:
    - Today, more than half of the planet have mobile phones
  - Human genome project:
    - Today, analysis of your own genome can allow personalized medical care
  - World Wide Web:
    - Today, the web has replaced libraries and newspapers
  - Search engines:
    - Today, many people rely on search engines for a large part of their lives

Growth of Marker in Post-PC Era

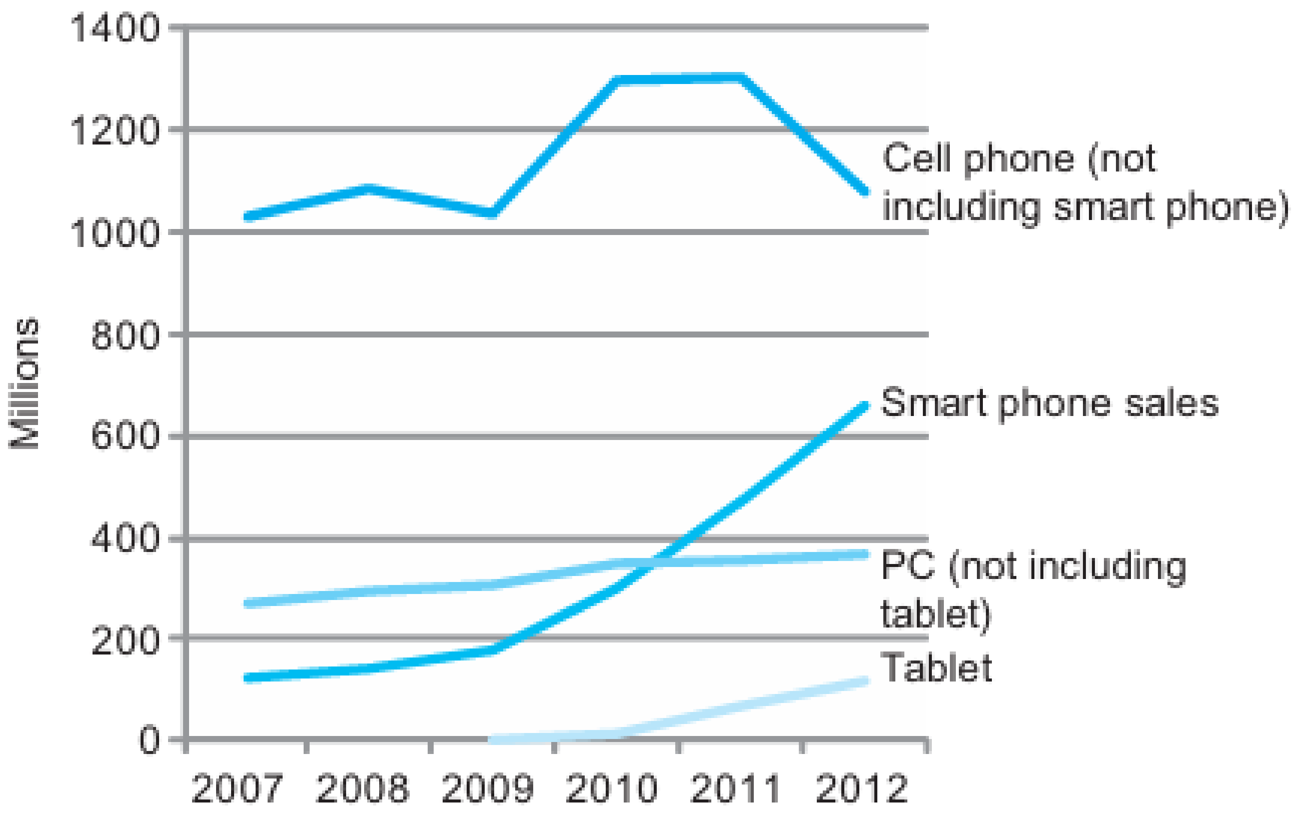


FIGURE 1.2 The number manufactured per year of tablets and smart phones, which reflect the PostPC era, versus personal computers and traditional cell phones. Smart phones represent the recent growth in the cell phone industry, and they passed PCs in 2011. Tablets are the fastest growing category, nearly doubling between 2011 and 2012. Recent PCs and traditional cell phone categories are relatively flat or declining.

Internet of Things (IoT) /Embedded Computers

- Examples
  - microwaves,
  - washing machines,
  - most printers,
  - networking switches, and
  - all automobiles

- Internet of Things (IoT)
  - Embedded computers that are connected to the Internet, typically, wirelessly
- Embedded computers include
  - **8-bit to 32-bit processors** that may cost one penny
  - high-end 64-bit processors **for cars and network switches** that cost $100.

Under the Covers

- Five classic components
  - The Processor
  - The Memory
  - The Input
  - The Output
  - The Datapath

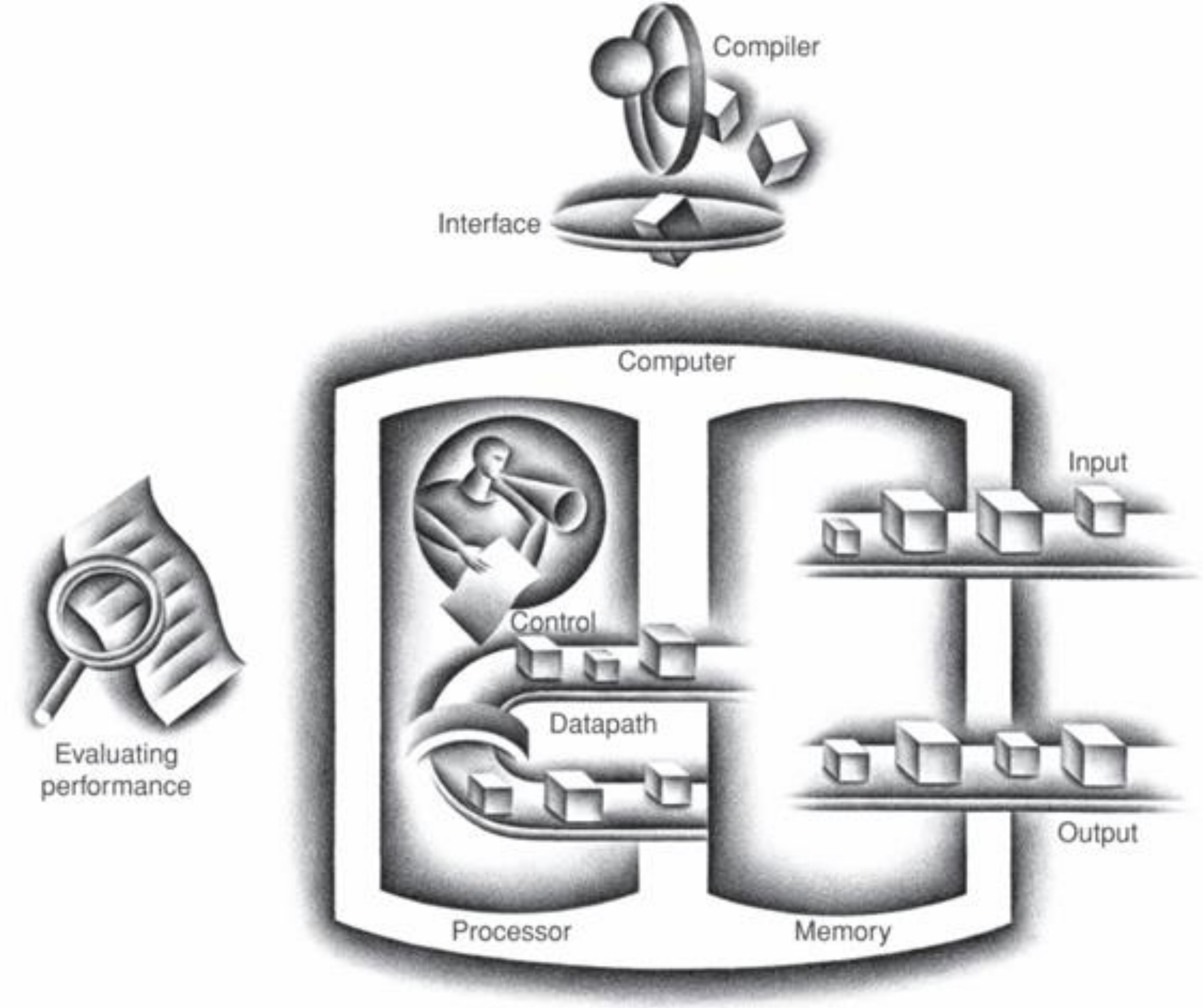
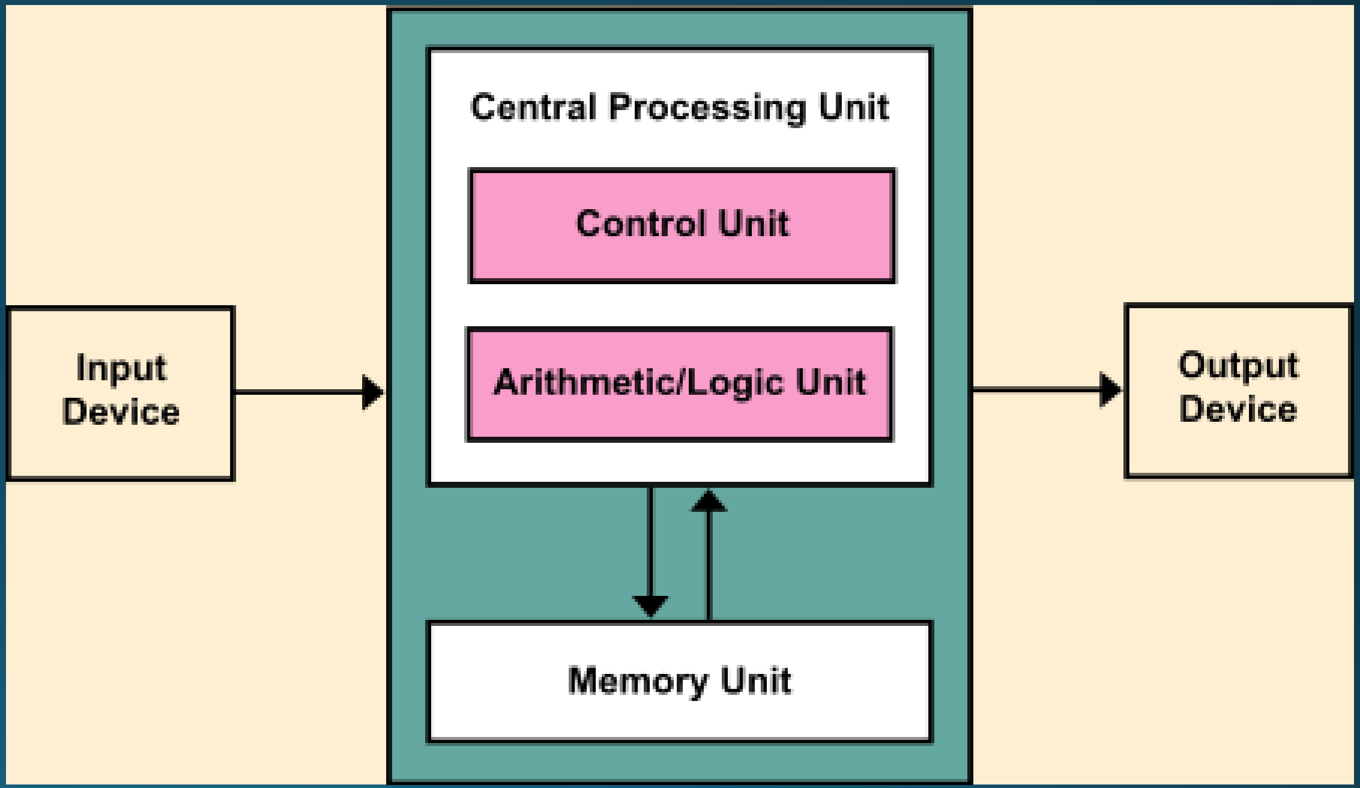


FIGURE 1.5 The organization of a computer, showing the five classic components. The processor gets instructions and data from memory. Input writes data to memory, and output reads data from memory. Control sends the signals that determine the operations of the datapath, memory, input, and output.

Von Neumann architecture

- Based on
  - a 1945 description by John von Neumann
- Four main components
  - CPU,
  - Memory,
  - Input Device,
  - Output Device
- One of the Basic principles
  - an instruction fetch and a data operation cannot occur at the same time (since they share a common bus)
  - This is called as stored-program computer



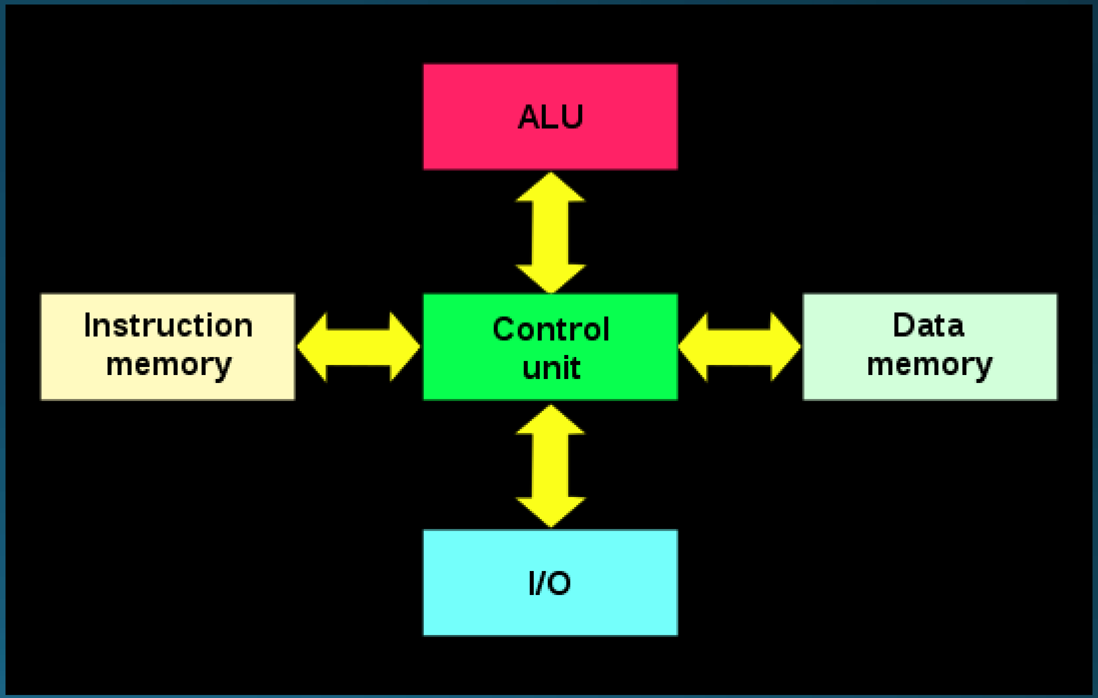
Simpler than in a **Harvard architecture** machine

Harvard architecture

- Separate storage and separate signal pathways for instructions and data

- The CPU can both read an instruction and perform a data memory access at the same time even without a cache

- **Instruction address zero** might identify a twenty-four-bit value,
  - while **data address zero** might indicate an eight-bit byte that is not part of that twenty-four-bit value



Technologies for Building Processors and Memory

- Electronic technology
  - drives the design of a better computer
- Started in 1951 with **Vacuum tube**
  - Forms baseline performance

Year	Technology used in computers	Relative performance/unit cost
1951	Vacuum tube	1
1965	Transistor	35
1975	Integrated circuit	900
1995	Very large-scale integrated circuit	2,400,000
2013	Ultra large-scale integrated circuit	250,000,000,000

FIGURE 1.10 Relative performance per unit cost of technologies used in computers over time. Source: Computer Museum, Boston, with 2013 extrapolated by the authors. See Section 1.12.

Manufacturing Process of Pentium 4 Chips

- The manufacture of a chip begins with **silicon**
  - a substance found in sand
- Silicon does not conduct electricity well
  - So, it is called a **semiconductor**.
- With a **special chemical process,**
  - it is possible to add materials to silicon

a tiny area in silicon

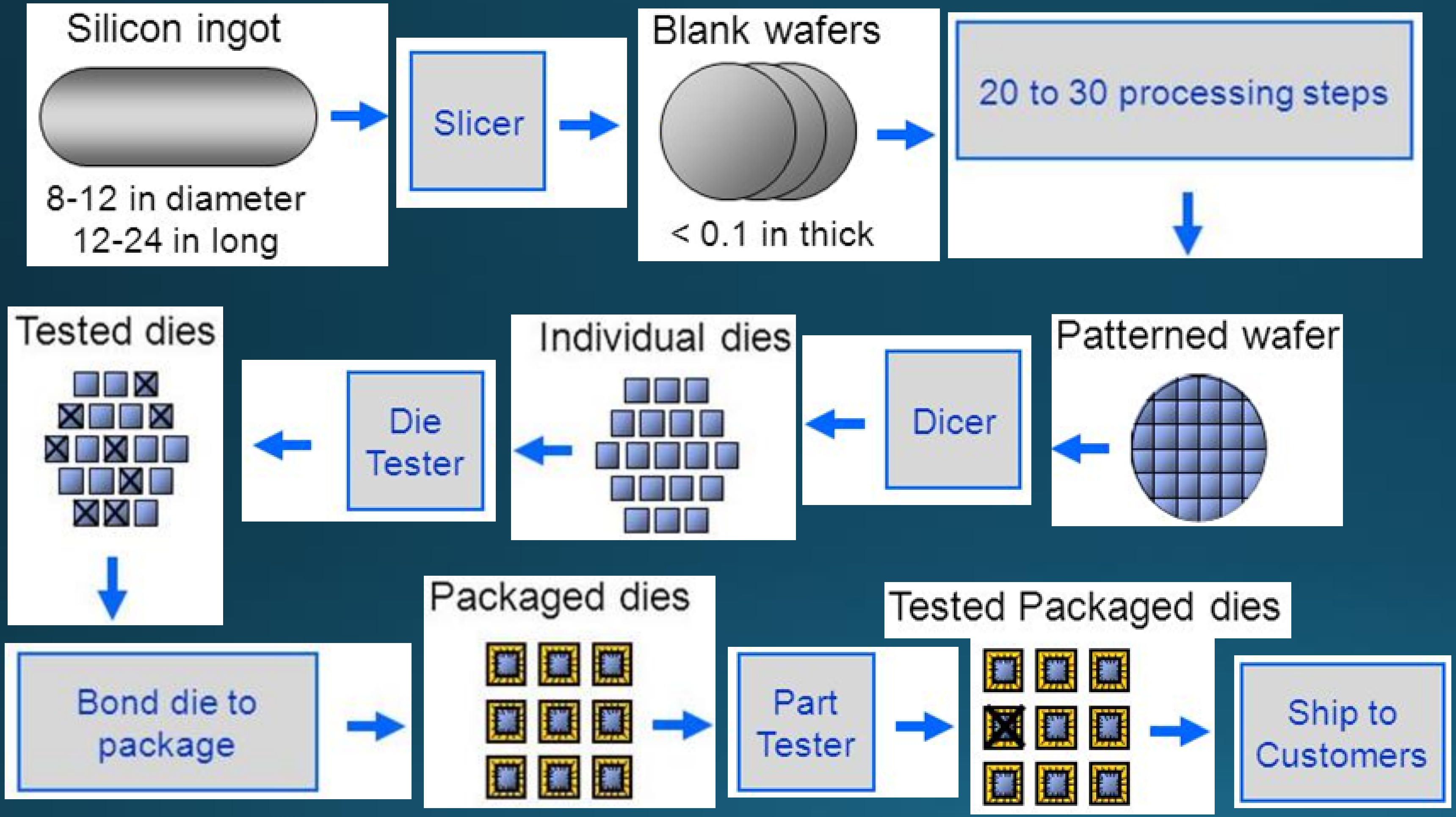
transforms into

Excellent **conductors**	Excellent **insulators**	**conduct** *or* **insulate**
using either copper or aluminum wire	using **plastic sheathing** or glass	as a switch

Manufacturing Process of Pentium 4 Chips

- **Transistors** fall in the last category
- A **VLSI** circuit is
  - billions of **combinations of conductors, insulators, and switches** manufactured in a single, small package

Chip Manufacturing Process



silicon crystal ingot A rod composed of a silicon crystal that is between 6 and 12 inches in diameter and about 12 to 24 inches long.

wafer A slice from a silicon ingot no more than 0.1 inch thick, used to create chips.

die The individual rectangular sections that are cut from a wafer, more informally known as chips.

The chip manufacturing process

- After being sliced from the silicon ingot,
  - blank wafers are put through 20 to 40 steps to create patterned wafers
- These patterned wafers are
  - then tested with a wafer tester and a map of the good parts is made.
- Then, the wafers are diced into dies
- For example, one wafer produced 20 dies, of which 17 passed testing.
  - *X* means the die is bad.
- These good dies are
  - then bonded into packages and tested one more time before shipping the packaged parts to customers.
  - For example, one bad packaged part was found in this final test.

Wafer of Intel Pentium 4

FIGURE 1.15 An 8-inch (200-mm) diameter wafer containing Intel Pentium 4 processors.

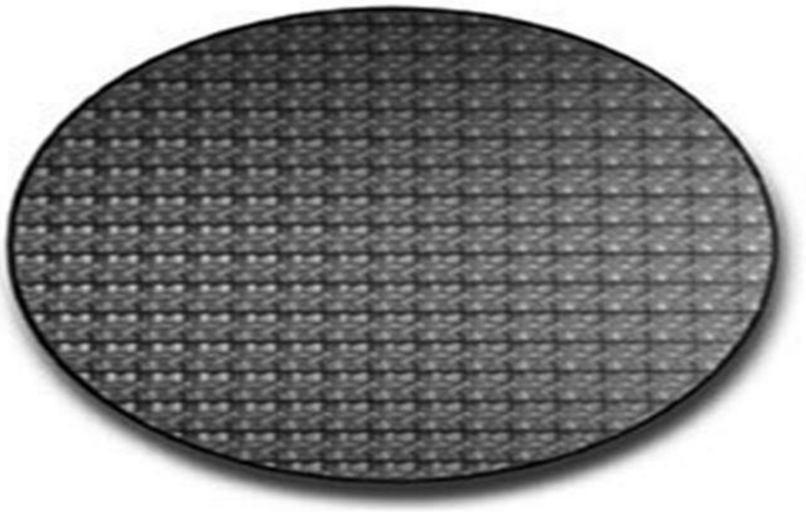
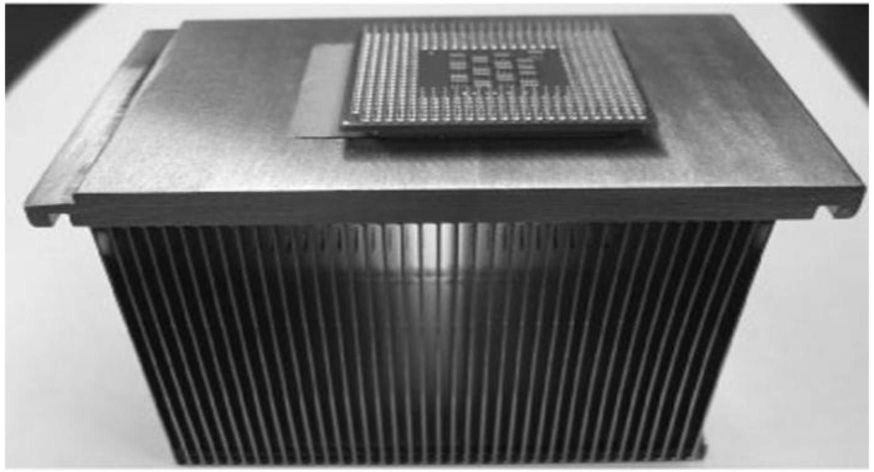


FIGURE 1.16

An Intel Pentium 4 (3.06 GHz) mounted on top of its heat sink, which is designed to remove the 82 watts generated within the die.



Wafer of Intel Core i7

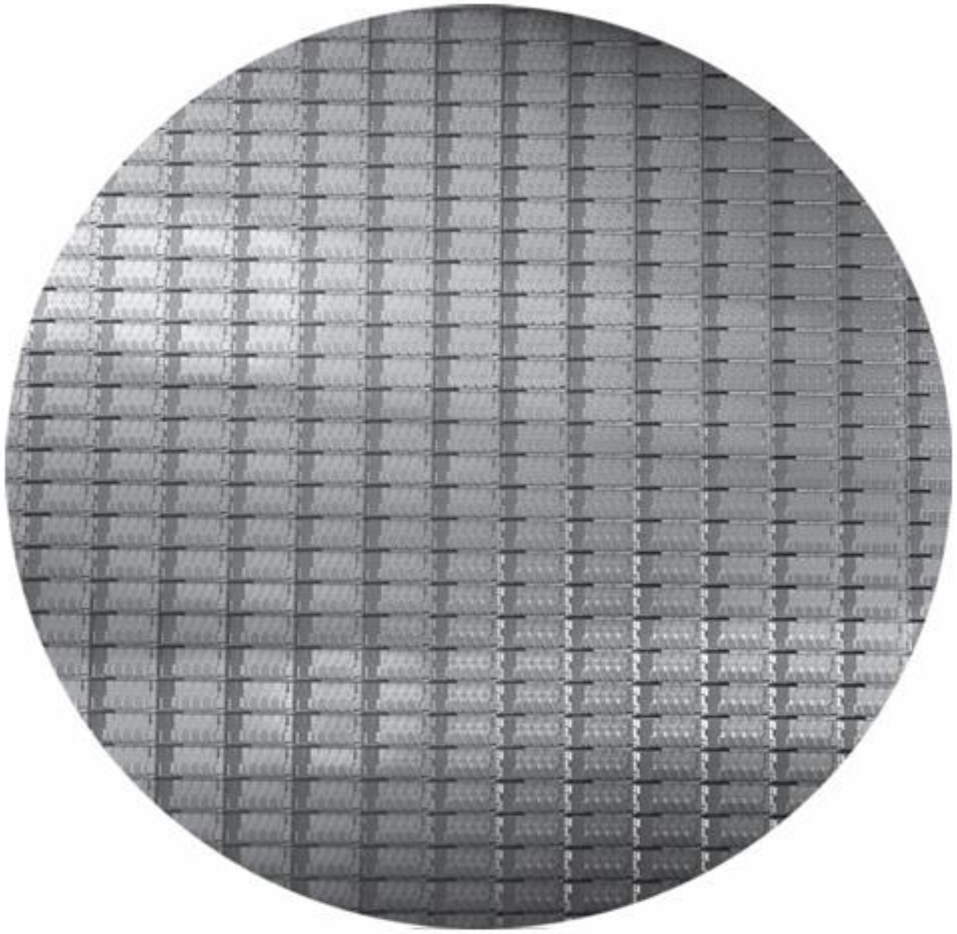


FIGURE 1.13 A 12-inch (300 mm) wafer of Intel Core i7 (Courtesy Intel). The number of dies on this 300 mm (12 inch) wafer at 100% yield is 280, each 20.7 by 10.5 mm. The several dozen partially rounded chips at the boundaries of the wafer are useless; they are included because it's easier to create the masks used to pattern the silicon. This die uses a 32-nanometer technology, which means that the smallest features are approximately 32 nm in size, although they are typically somewhat smaller than the actual feature size, which refers to the size of the transistors as "drawn" versus the final manufactured size.

The cost of an integrated circuit

- Expressed using three equations:

$$\text{Cost per die} = \frac{\text{Cost per wafer}}{\text{Dies per wafer} \times \text{yield}}$$

$$\text{Dies per wafer} \approx \frac{\text{Wafer area}}{\text{Die area}}$$

$$\text{Yield} = \frac{1}{(1 + (\text{Defects per area} \times \text{Die area}/2))^2}$$

Yield The percentage of good dies from the total number of dies on the wafer.

- Q1. Assume a 15 cm diameter wafer has a cost of 12, contains 84 dies, and has 0.020 defects/cm². Assume a 20 cm diameter wafer has a cost of 15, contains 100 dies, and has 0.031 defects/cm².
- a. Find the yield for both wafers.

$$\text{Yield} = \frac{1}{(1 + (\text{Defects per area} \times \text{Die area}/2))^2}$$

$$\text{die area}_{15cm} = \text{wafer area/dies per wafer} = \text{pi}*7.5^2 / 84 = 2.10 \text{ cm}^2$$

$$\text{yield}_{15cm} = 1/(1+(0.020*2.10/2))^2 = 0.9593$$

$$\text{die area}_{20cm} = \text{wafer area/dies per wafer} = \text{pi}*10^2/100 = 3.14 \text{ cm}^2$$

$$\text{yield}_{20cm} = 1/(1+(0.031*3.14/2))^2 = 0.9093$$

- Q1. Assume a 15 cm diameter wafer has a cost of 12, contains 84 dies, and has 0.020 defects/cm². Assume a 20 cm diameter wafer has a cost of 15, contains 100 dies, and has 0.031 defects/cm².
- a. Find the yield for both wafers.
- b. Find the cost per die for both wafers.

$$\text{Cost per die} = \frac{\text{Cost per wafer}}{\text{Dies per wafer} \times \text{yield}}$$

$$\text{cost/die}_{15cm} = 12/(84*0.9593) = 0.1489$$

$$\text{cost/die}_{20cm} = 15/(100*0.9093) = 0.1650$$

- Q1. Assume a 15 cm diameter wafer has a cost of 12, contains 84 dies, and has 0.020 defects/cm². Assume a 20 cm diameter wafer has a cost of 15, contains 100 dies, and has 0.031 defects/cm².
- a. Find the yield for both wafers.
- b. Find the cost per die for both wafers.
- c. If the number of dies per wafer is increased by 10% and the defects per area unit increases by 15%, find the die area and yield.

$$\text{die area}_{15cm} = \text{wafer area/dies per wafer} = \text{pi}*7.5^2/(84*1.1) = 1.91\ \text{cm}^2$$

$$\text{yield}_{15cm} = 1/(1 + (0.020*1.15*1.91/2))^2 = 0.9575$$

$$\text{die area}_{20cm} = \text{wafer area/dies per wafer} = \text{pi}*10^2/(100*1.1) = 2.86\ \text{cm}^2$$

$$\text{yield}_{20cm} = 1/(1 + (0.03*1.15*2.86/2))^2 = 0.9082$$

- Q1. Assume a 15 cm diameter wafer has a cost of 12, contains 84 dies, and has 0.020 defects/cm². Assume a 20 cm diameter wafer has a cost of 15, contains 100 dies, and has 0.031 defects/cm².
- a. Find the yield for both wafers.
- b. Find the cost per die for both wafers.
- c. If the number of dies per wafer is increased by 10% and the defects per area unit increases by 15%, find the die area and yield.
- d. Assume a fabrication process improves the yield from 0.92 to 0.95. Find the defects per area unit for each version of the technology given a die area of 200 mm².

$$\text{Yield} = \frac{1}{(1 + (\text{Defects per area} \times \text{Die area}/2))^2}$$

defects per $\text{area}_{0.92}$ = (1–y^.5)/(y^.5*die_area/2) = (1−0.92^.5)/(0.92^.5*2/2) = 0.043 defects/cm²

defects per $\text{area}_{0.95}$ = (1–y^.5)/(y^.5*die_area/2) = (1−0.95^.5)/(0.95^.5*2/2) = 0.026 defects/cm²

Thank You