Outline

•Computer generations and technology

•Cost of Integrated Circuits

Computer Generations

Generation	Dates	Technology	Principal new Product
1	1950-1959	Vacuum Tubes	Commercial Electronic Computer
2	1960-1968	Transistors	Cheaper Computers
3	1969-1977	Integrated Circuit	Minicomputer
4	1978-?	LSI and VLSI	PC and workstations

Fig. 1.29 Page 42

Each generation is about 8-10 years long except the fourth

Technology

Year	Technology used	Relative Performance/Unit Cost
1951	Vacuum Tube	1
1965	Transistor	35
1975	Integrated Circuit (IC)	900
1995	VLSI	2,400,000

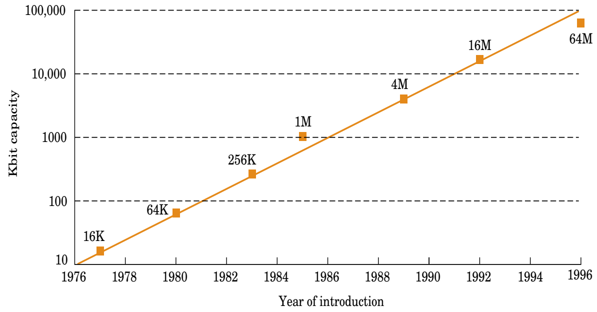
Fig. 1.13 Page 22

Transistor	On/Off switch controlled by electricity
IC	combine dozens to hundreds of transistors into a single chip
VLSI	Very-Large Scale Integrated circuit (millions of transistors)

Growth in DRAM Capacity

•Example of increased integration

•Quadruple capacity every 3 years (DRAM growth rule)



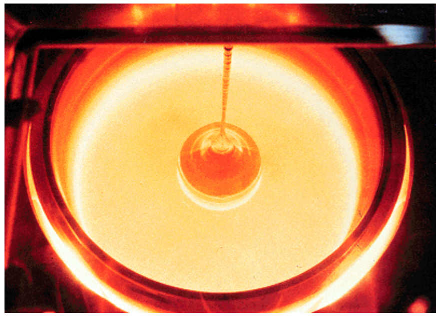
1999 256 Mbit

2002 1 Gbit

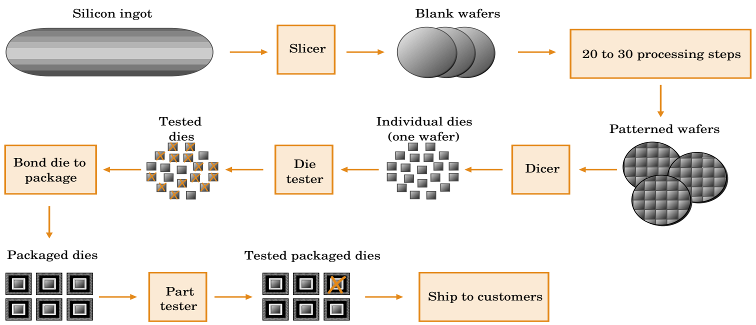
At The Beginning: Silicon

- Substance found in sand
- Does not conduct electricity well
- Apply special chemical process to obtain
  - ✓Conductors of electricity
  - ✓Insulators from electricity
  - ✓Conduct or insulate under special conditions (transistors)

At The Beginning: Silicon



Chip Manufacturing Process



Yield = % of good dies from the total number of dies on the wafer

In Fig. Yield = 6/20 = 30% (X means a bad die)

Cost of Integrated Circuits

Refer to exercises 1.48-1.53 on pages 48-49

Cost per die = Cost per wafer / (Dies per wafer * yield)

Dies per wafer = Wafer area / Die area

Approximation (why?)

Yield = $1/(1+(\text{Defect per area} * \text{Die area}/2))^2$

Empirical based on observation of yields

Cost of Integrated Circuits

Example

Manufacturing a wafer costs \$1500

#of defects/cm^2 = 2.5 Wafer radius = 10 cm

Case A: dies are 1 cm * 1 cm

die area = 1 cm^2

Dies per wafer = Pi * R^2 / Die area = 3.14 * 10^2 / 1 = 314 (an integer)

Yield = $1/(1 + ½ (2.5) (1.0))^2$ = 0.198

Cost per die = Cost per wafer / (Dies per wafer * yield) = 1500 / (314 * 0.198) = \$24.13

Case B: dies are 2 cm * 2 cm

Die area = 4 cm^2

Dies per wafer = 3.14 * 10^2/4 = 78.5 → 78 (integer)

Yield = 0.0278

Cost per die = 1500/ (78 * 0.0278) = \$691.75

What do you observe here?

How does die area affect cost per die?

Manufacturing Pentium chips

Manufacturing Pentium chips

Fig. 1.16 & 1.17

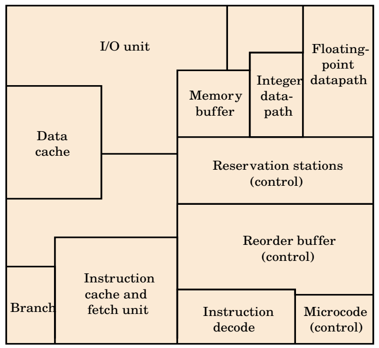
Pentium Pro die

5.5 million transistors

Cache is only 1 million transistors

Die area is 306 mm^2

Pentium Pro packaged with an external cache with 31 million transistors (Fig. 1.19)



Manufacturing Pentium chips

Fig. 1.16 & 1.17

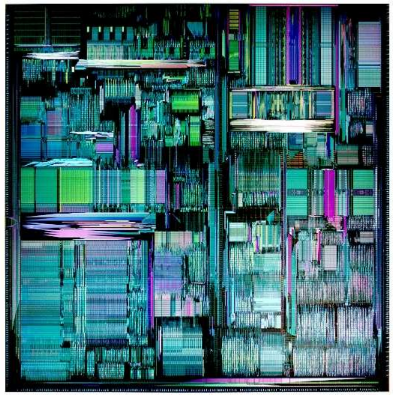
Pentium Pro die

5.5 million transistors

Cache is only 1 million transistors

Die area is 306 mm^2

Pentium Pro packaged with an external cache with 31 million transistors (Fig. 1.19)



Manufacturing Pentium chips