A brief history of electronics

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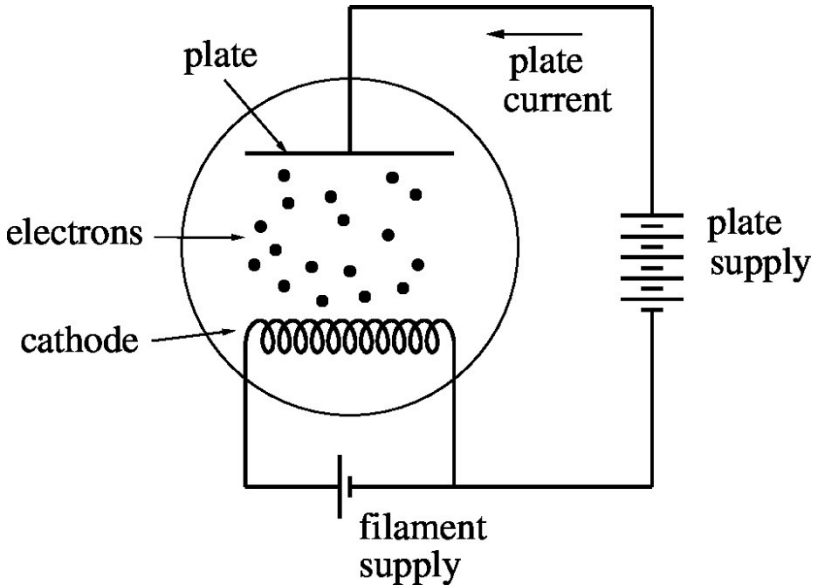
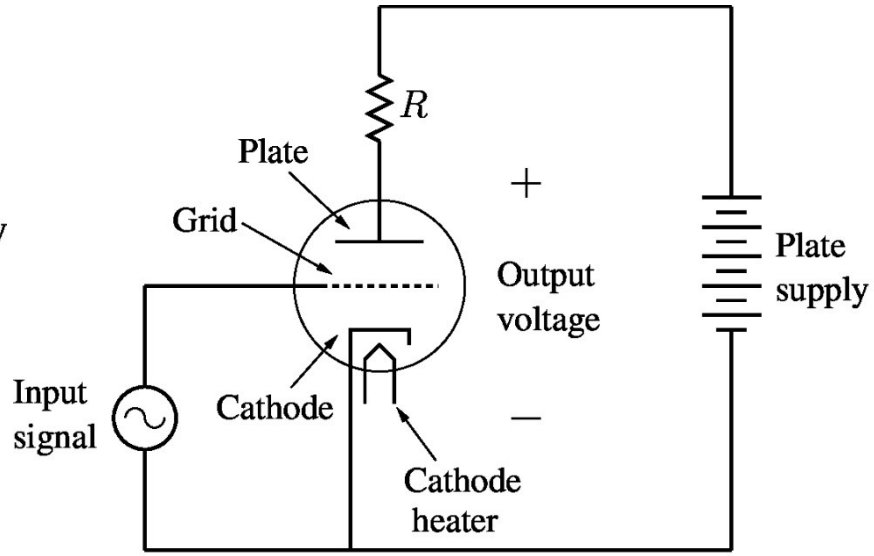
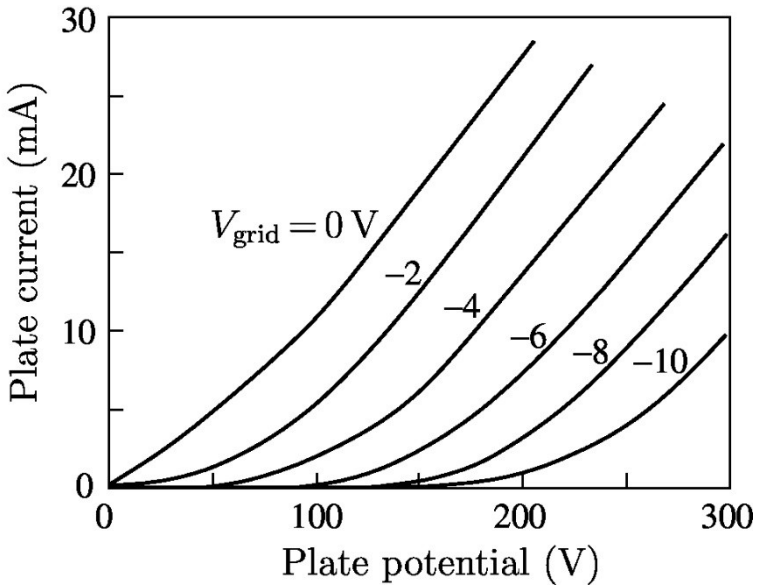
(images taken from internet)

Vacuum tubes

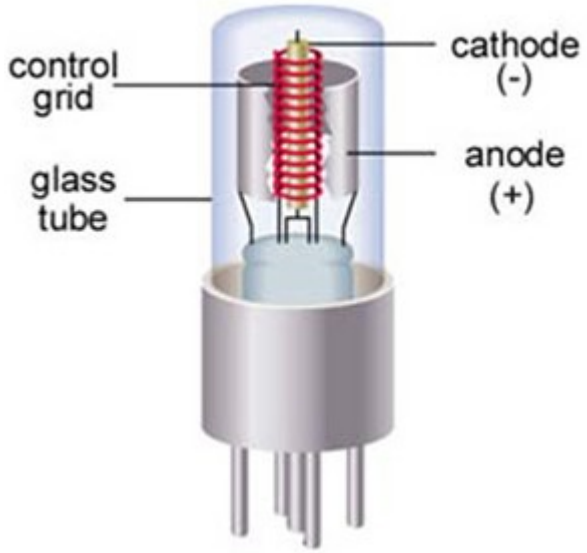
- 1904: the simplest vacuum tube – the diode – was invented by John Fleming.
- 1907: De Forest invented the triode by inserting a third electrode between cathode and anode.

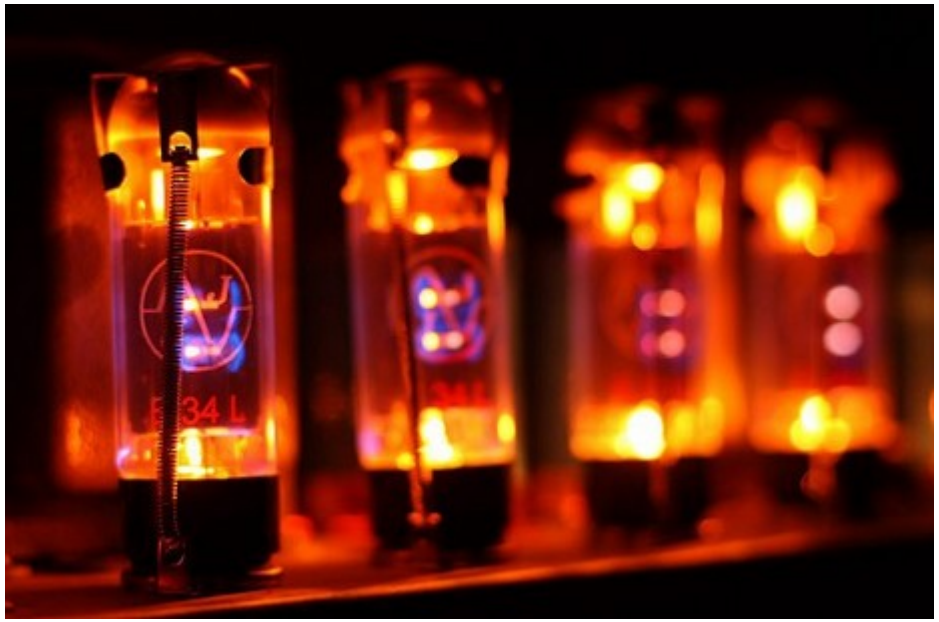




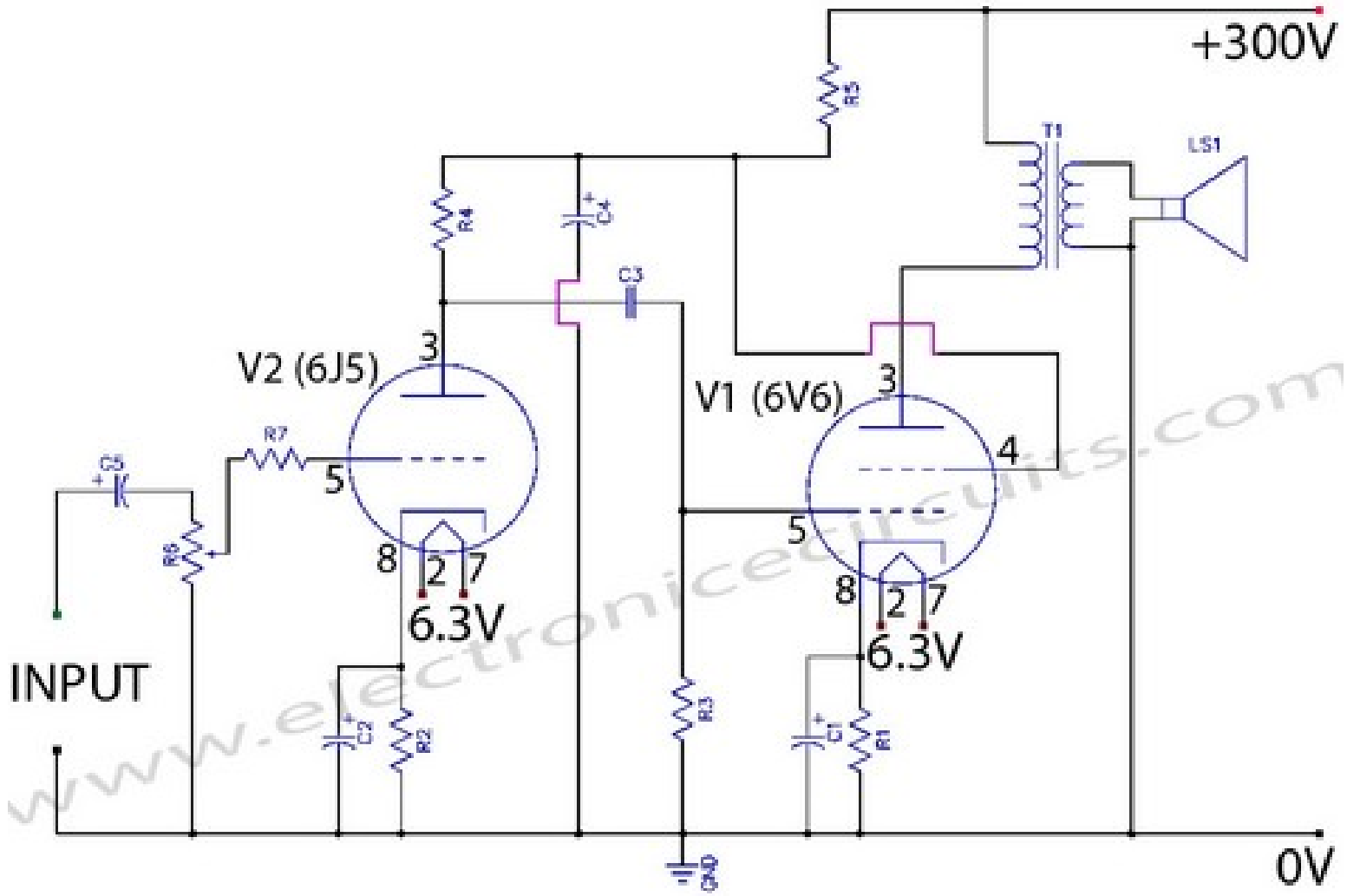


Vacuum Tubes

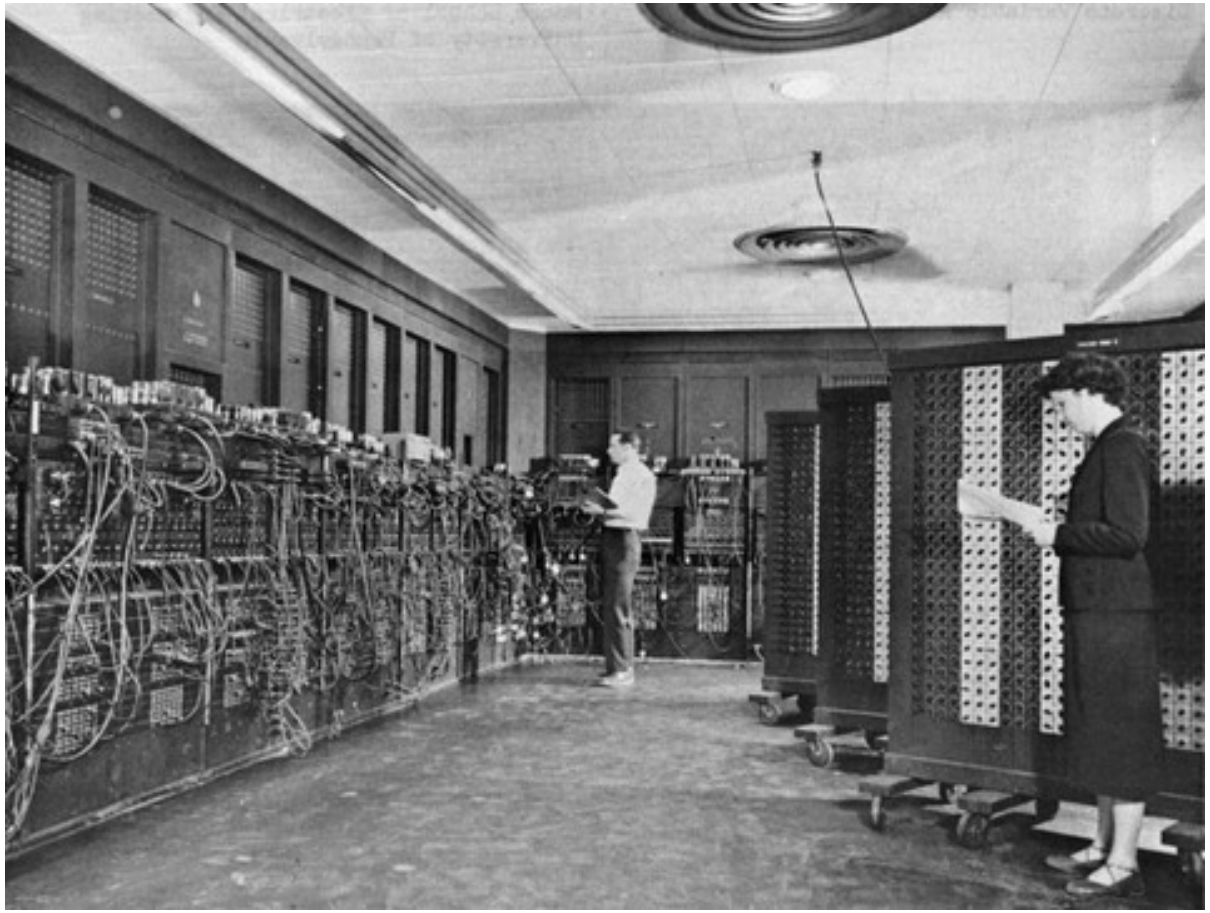


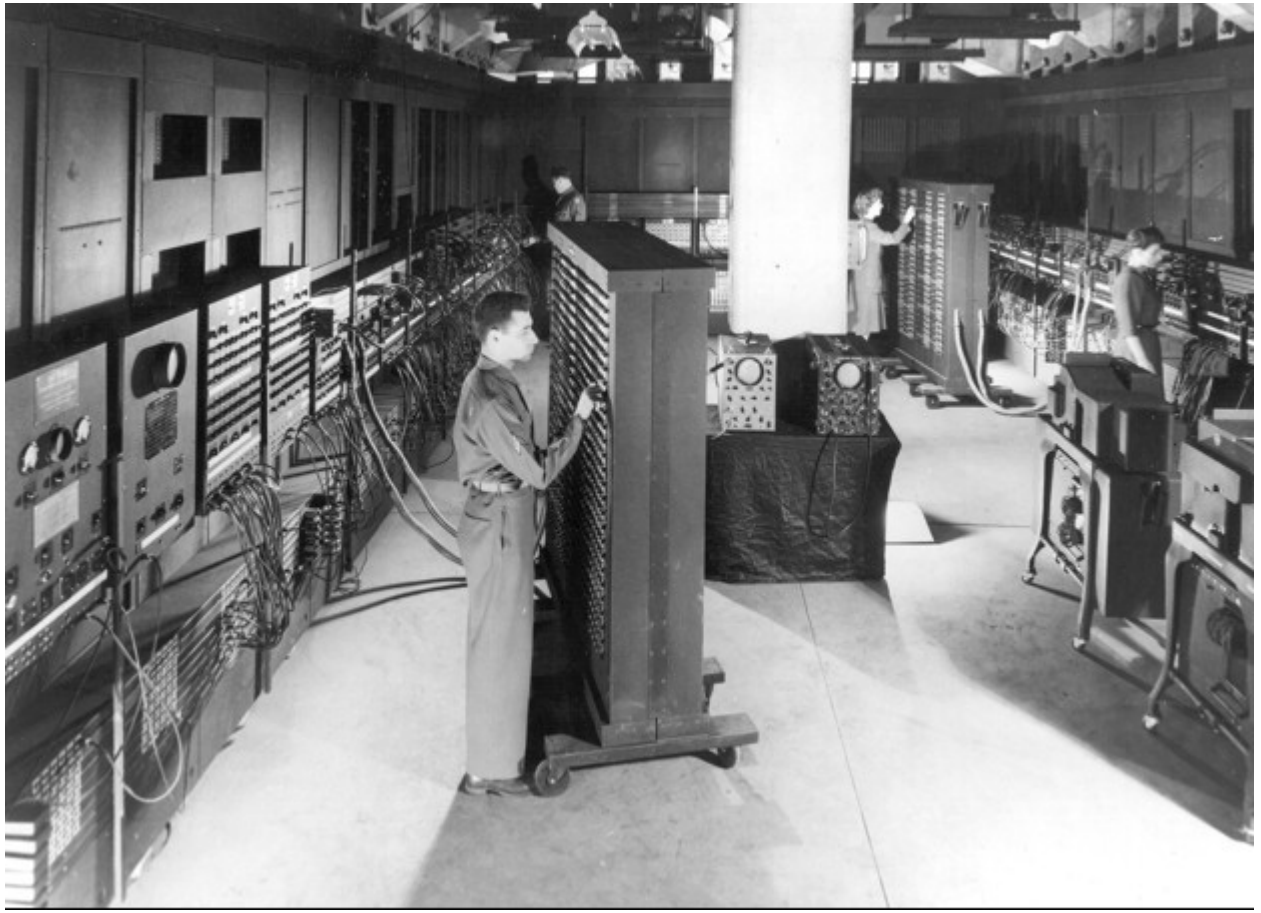


Vacuum tubes: audio amplifier



ENIAC computer (1946, Univ of Pennsylvania)





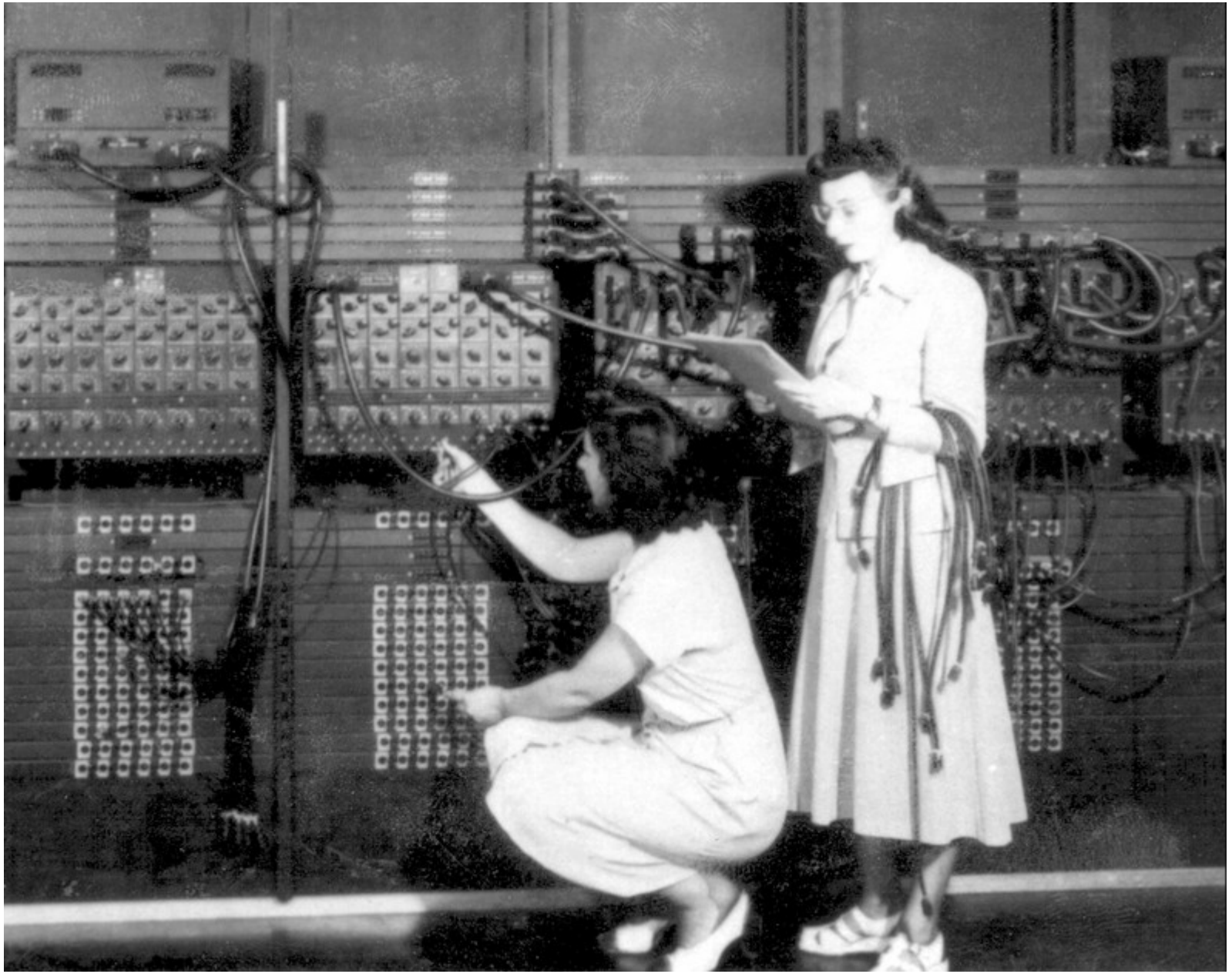
ENIAC computer

- heralded as a "Giant Brain" by the press
- thousand times faster than electro-mechanical computer
- 17,468 vacuum tubes, 7200 crystal diodes, 1,500 relays, 70,000 resistors, 10,000 capacitors, 6,000 manual switches, and approximately 5,000,000 hand-soldered joints.
- consumed 150 kW
- Input was possible from an IBM card reader
- 100 kHz clock
- Several tubes burned out almost every day, leaving it non-functional about half the time.

ENIAC computer

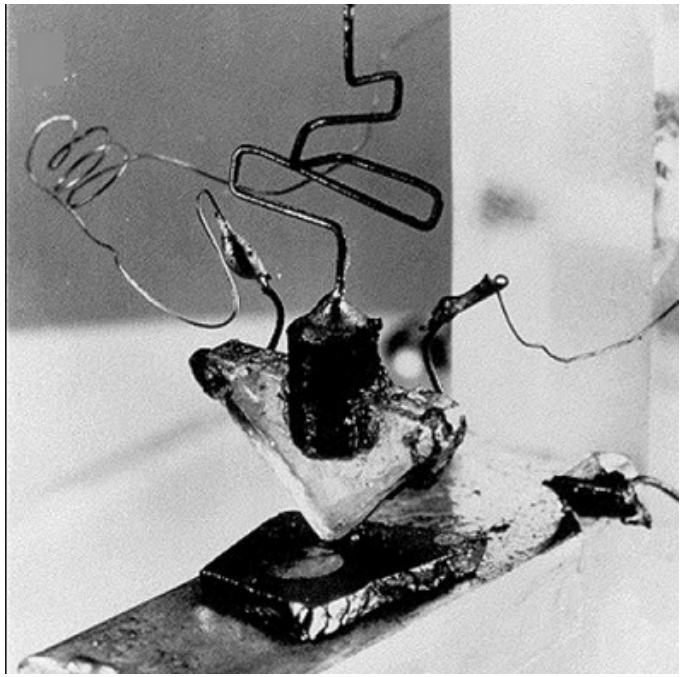
- could be programmed to perform complex sequences of operations, including loops, branches, and subroutines.
- After the program was figured out on paper, the process of getting the program into ENIAC by manipulating its switches and cables could take days.
- The task of taking a problem and mapping it onto the machine was complex, and usually took weeks.
- The programmers debugged problems by crawling inside the massive structure to find bad joints and bad tubes.
- The first test problem consisted of computations for the hydrogen bomb.

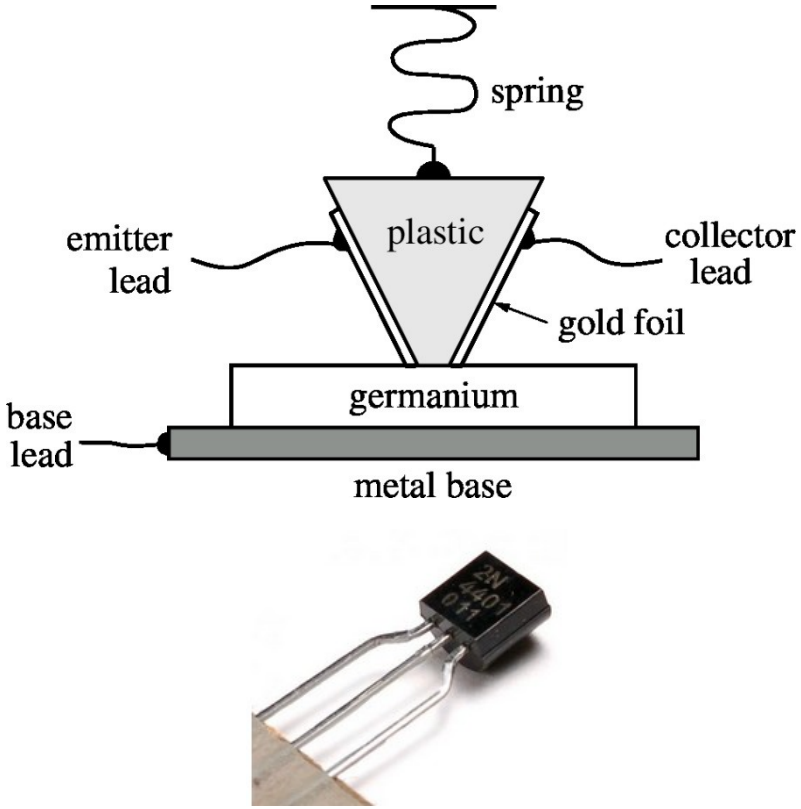
ENIAC computer (1946, Univ of Pennsylvania)

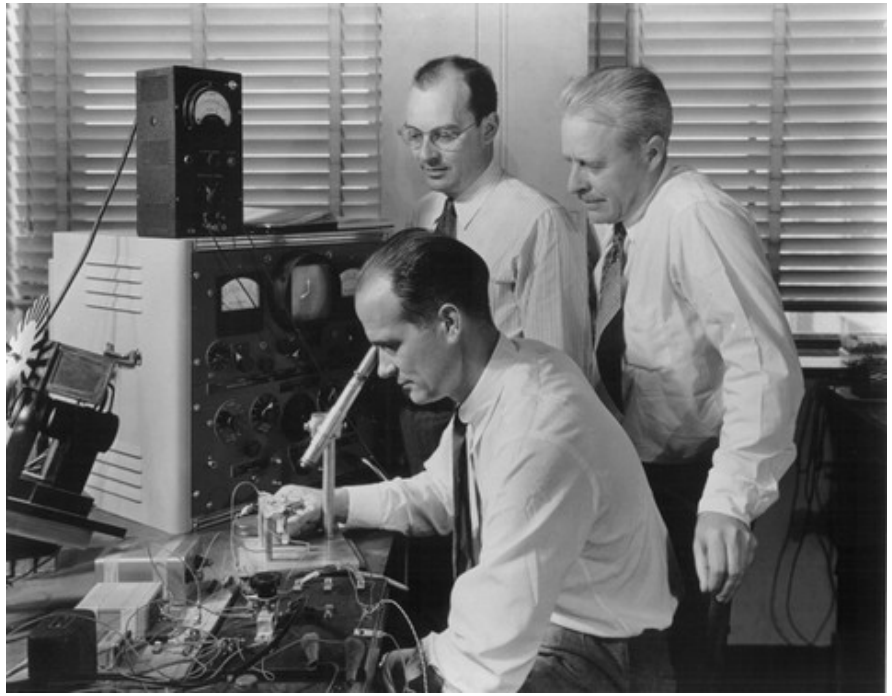


The first transistor

- The vacuum tube was a bulky and fragile device which consumed significant power.
- 1947: Shockley, Bardeen, and Brattain at Bell Labs invented the first transistor.
- The first transistor was a “point contact transistor.” The modern transistor is a junction transistor, and it is monolithic (in the same semiconductor piece).



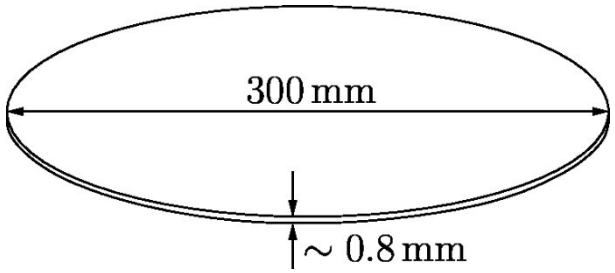


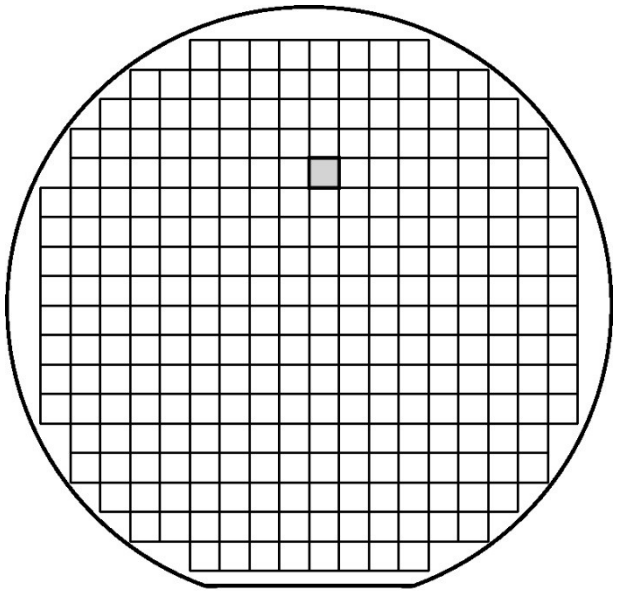


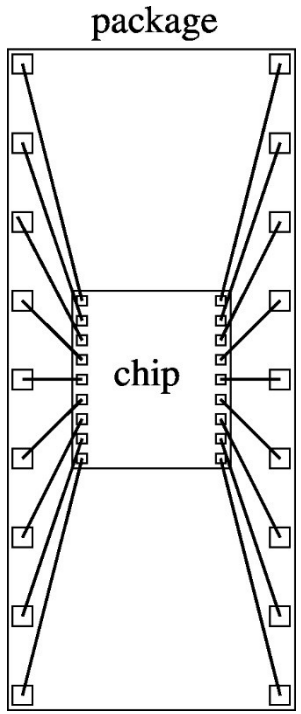
Semiconductor technology

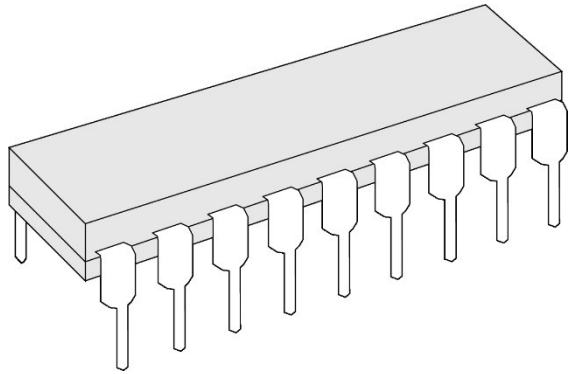
- The bipolar transistor continues to be an important device both as a discrete device and as part of Integrated Circuits (IC).
- However, in digital circuits such as processors and memory, the MOS (Metal Oxide Semiconductor) field-effect transistor has surpassed the bipolar transistor because of the high integration density and low power consumption it offers.
- 1930: patent filed by Lilienfeld for field-effect transistor (FET).
- 1958: Jack Kilby (Texas Instruments) demonstrated the first integrated circuit (bipolar transistor, resistor, capacitor) fabricated on a single piece of germanium.
- The rest is history!

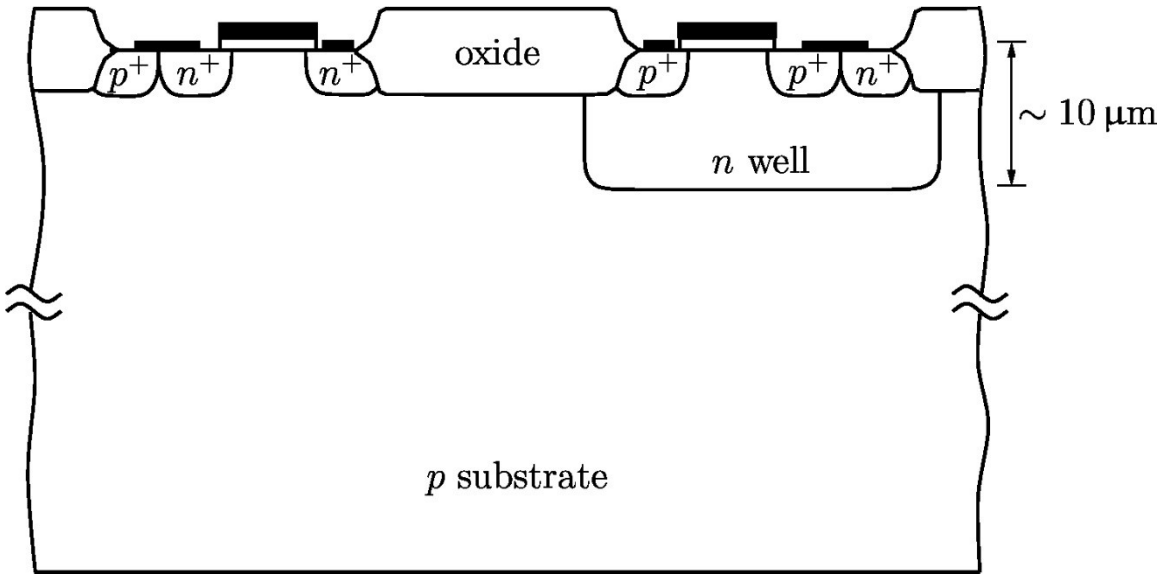
Semiconductor technology



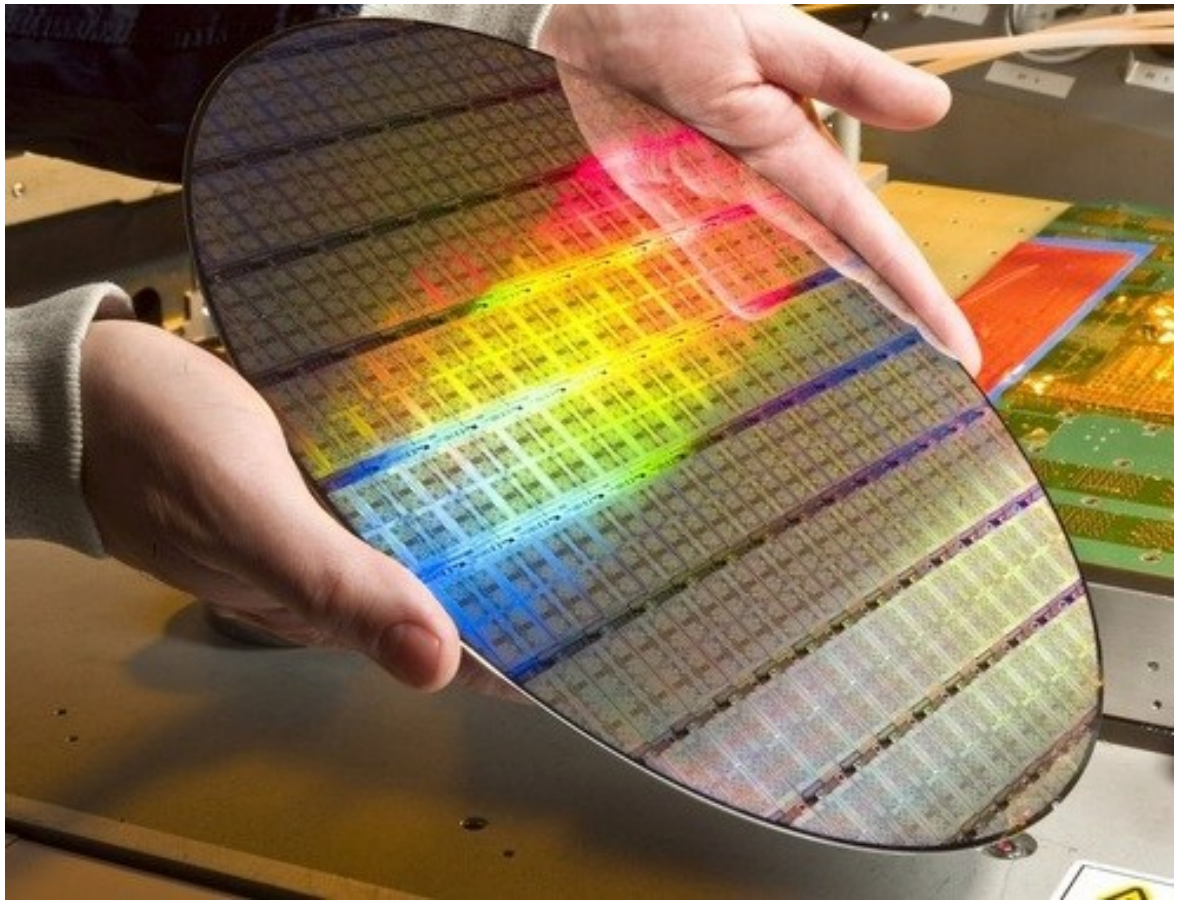






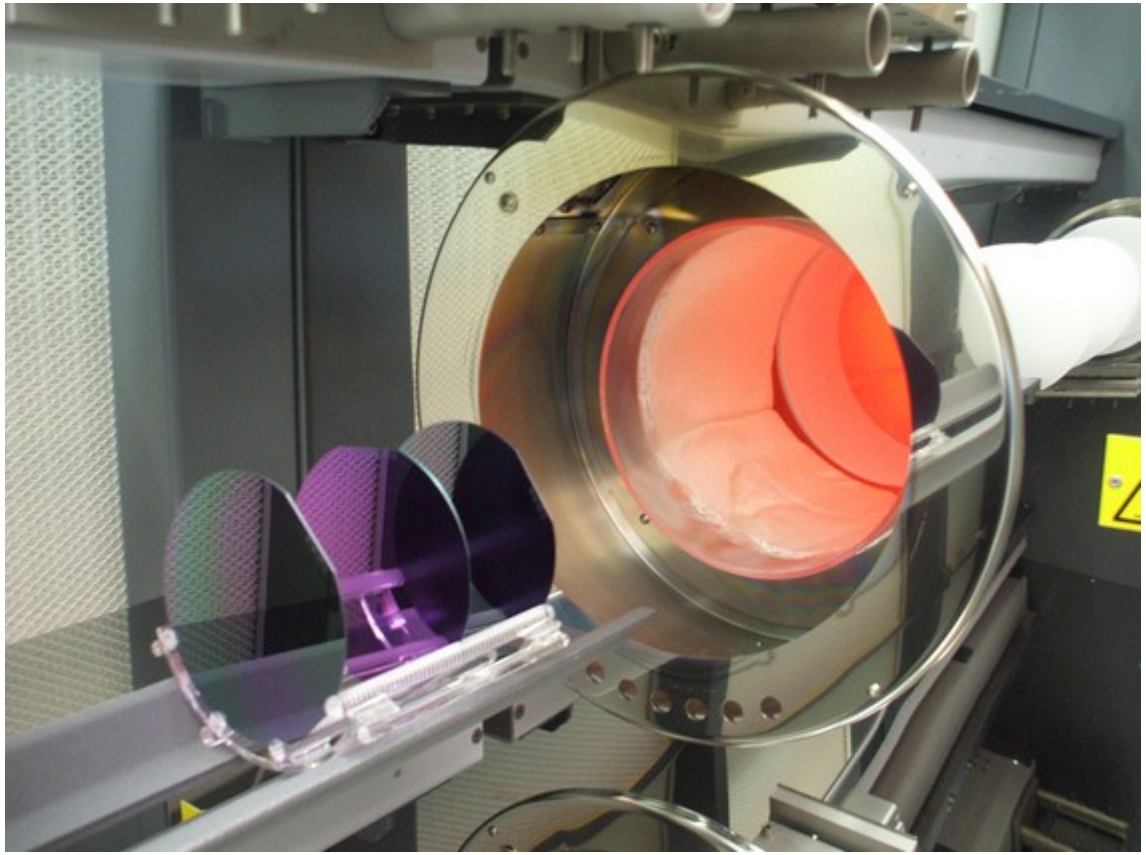


Modern semiconductor technology



silicon wafer

Modern semiconductor technology



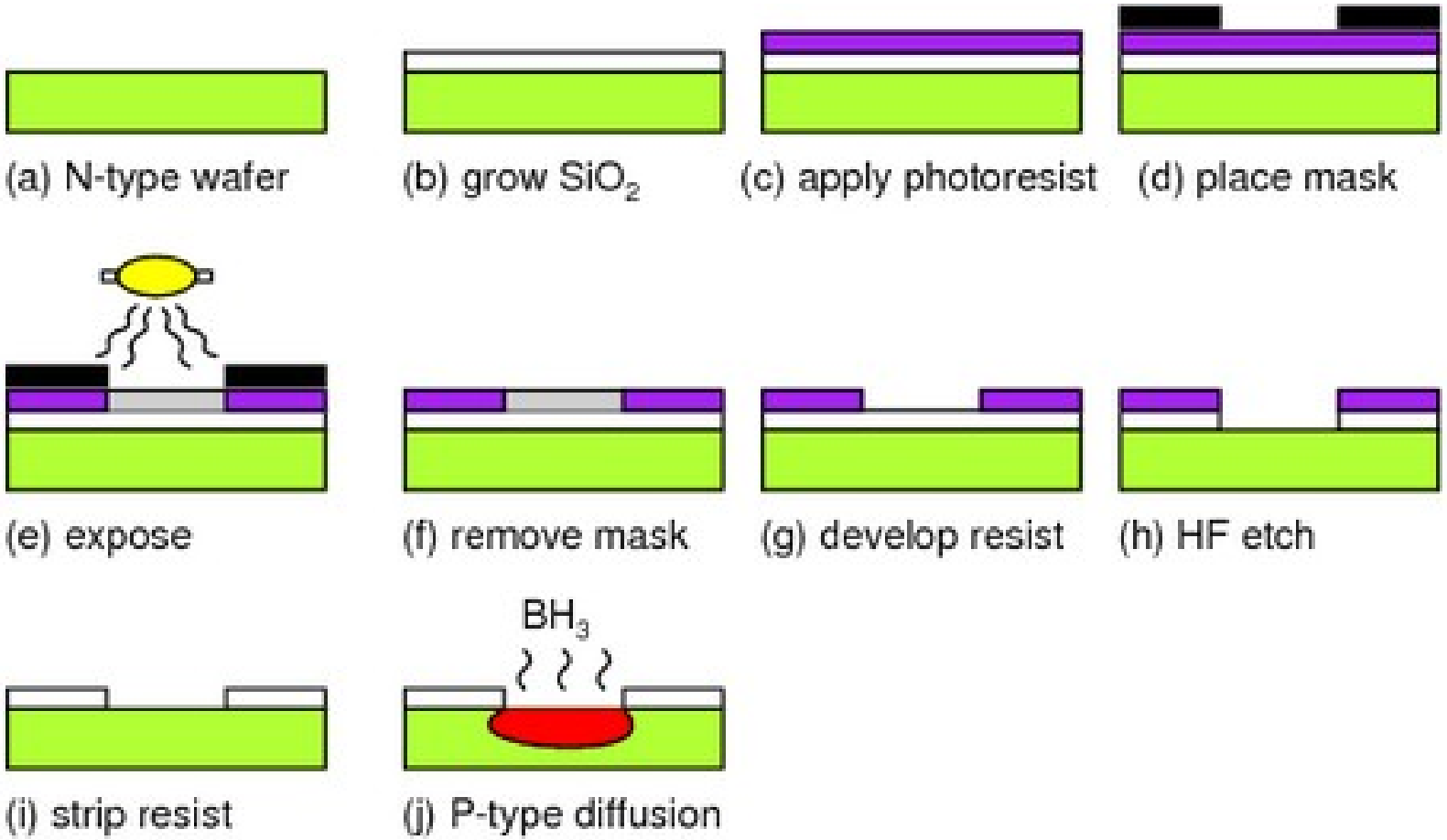
Diffusion furnace

Modern semiconductor technology

Modern semiconductor technology

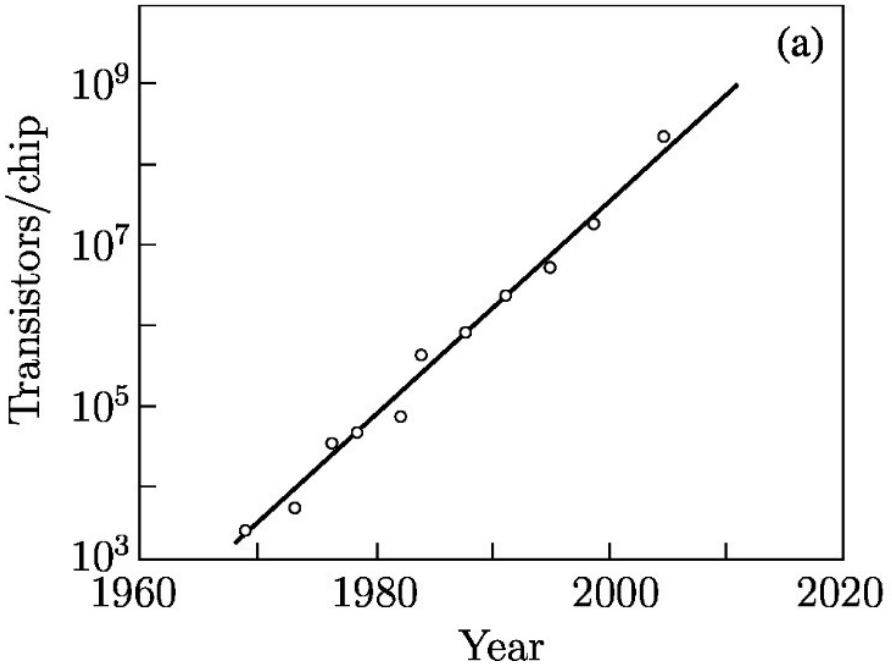
Modern semiconductor technology

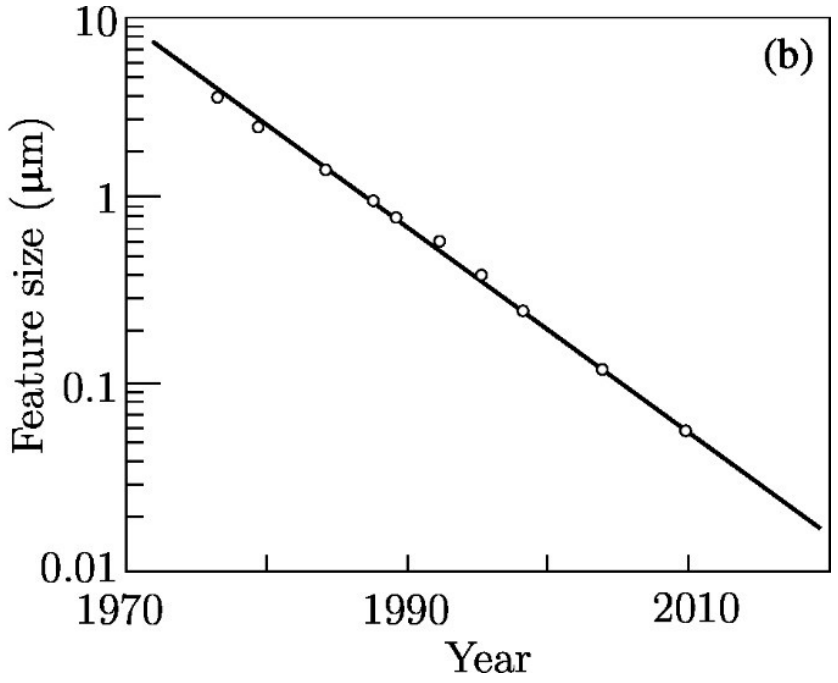
Fabrication of a p-n junction diode



MOS technology: scaling

- Shrinking of the smallest definable dimension ("feature size") on the chip has enabled a huge number of transistors to be integrated on one chip.
- 1970: feature size of 10 μm, 2010: 0.032 μm
- Moore's law: a prediction by Gordon Moore (Intel founder) in 1965: number of transistors will double every two years
- Increased functionality: "system on a chip" is now possible.





Vacuum tube computer with 1 million tubes (not built)

- Each vacuum tube is 5 cm x 5 cm: large area
- Each vacuum tube consumes, say, 1 W to 10 W power: total power in the MW range
- Need to remove the heat dissipated by the tubes
- Poor reliability because of a large number vacuum tubes/soldering joints
- Even if it was actually built, the speed would be much lower than a modern CPU due to parasitic capacitances and inductances of the cables

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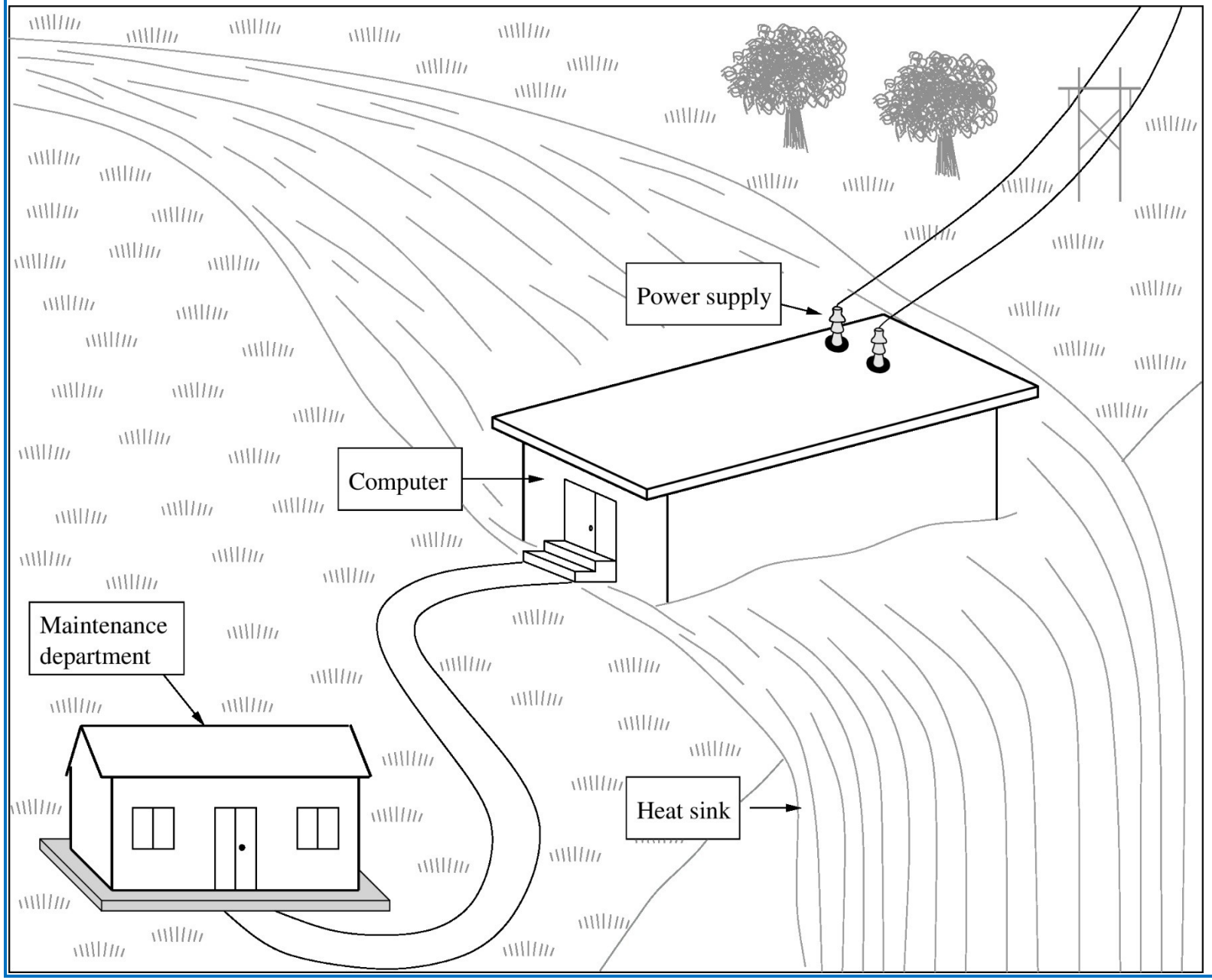

Compare that with your mobile phone!