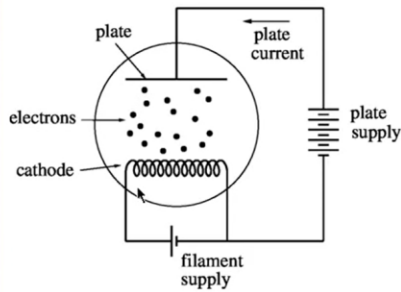


History

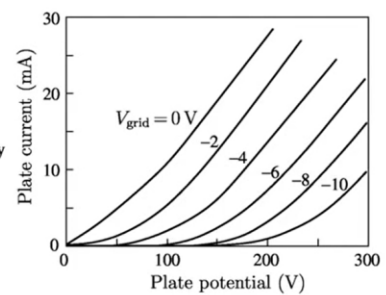
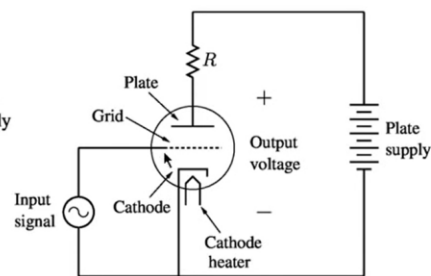
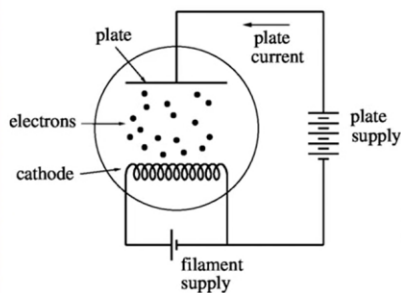
Vacuum tubes

- ❖ 1904: the simplest vacuum tube – the diode – was invented by John Fleming.

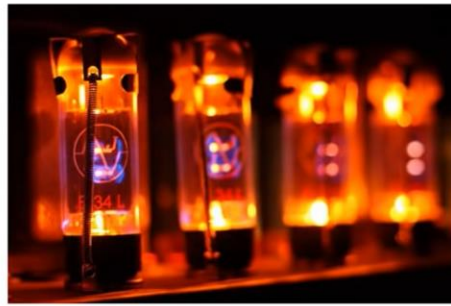
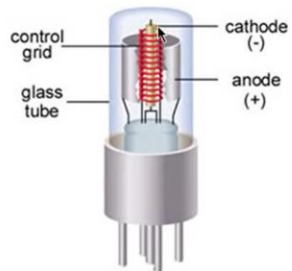


Vacuum tubes

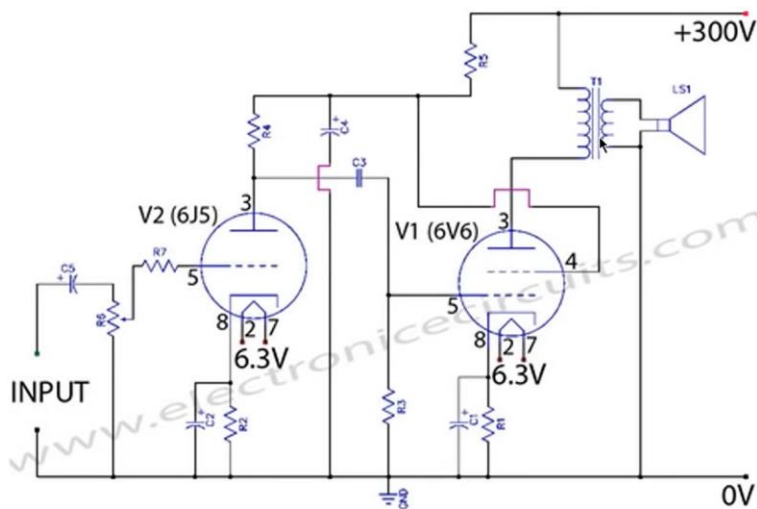
- ❖ 1904: the simplest vacuum tube – the diode – was invented by John Fleming.
- ❖ 1907: De Forest invented the triode by inserting a third electrode between cathode and anode.



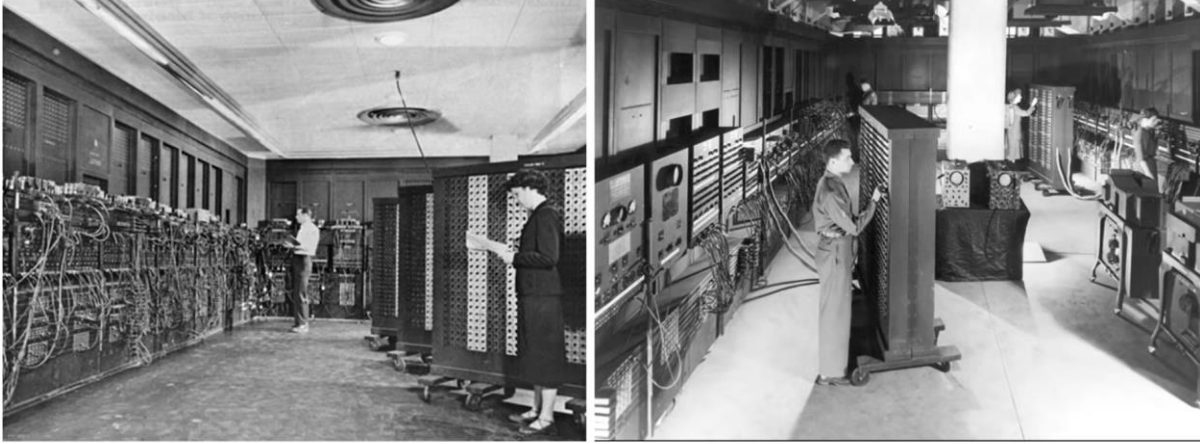
Vacuum Tubes



Vacuum tubes: audio amplifier



ENIAC computer (1946, Univ of Pennsylvania)



ENIAC computer

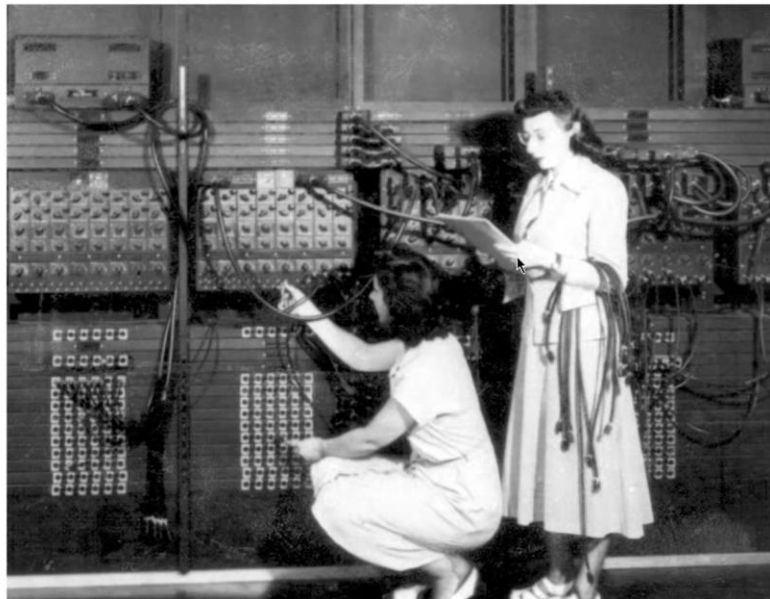
- ❖ heralded as a "Giant Brain" by the press
- ❖ thousand times faster than electro-mechanical computer
- ❖ 17,468 vacuum tubes, 7200 crystal diodes, 1,500 relays, 70,000 resistors, 10,000 capacitors, 6,000 manual switches, and approximately 5,000,000 hand-soldered joints.
- ❖ consumed 150 kW
- ❖ Input 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.

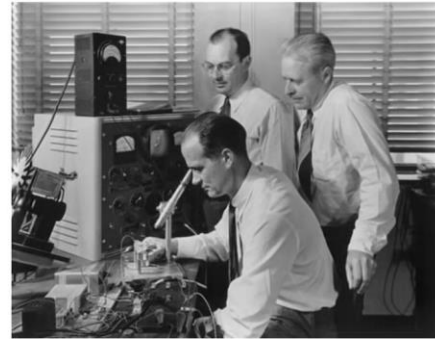
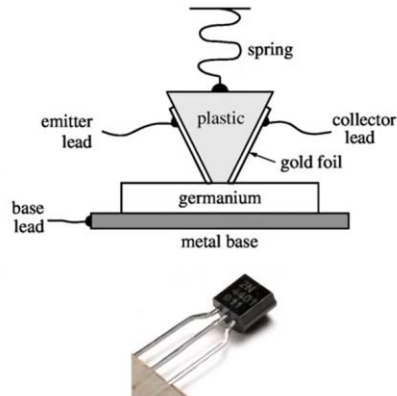
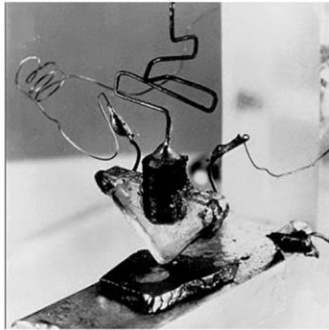
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ENIAC computer (1946, Univ of Pennsylvania)



The first transistor

- ❖ The vacuum tube was a bulky and fragile device which consumed a 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).

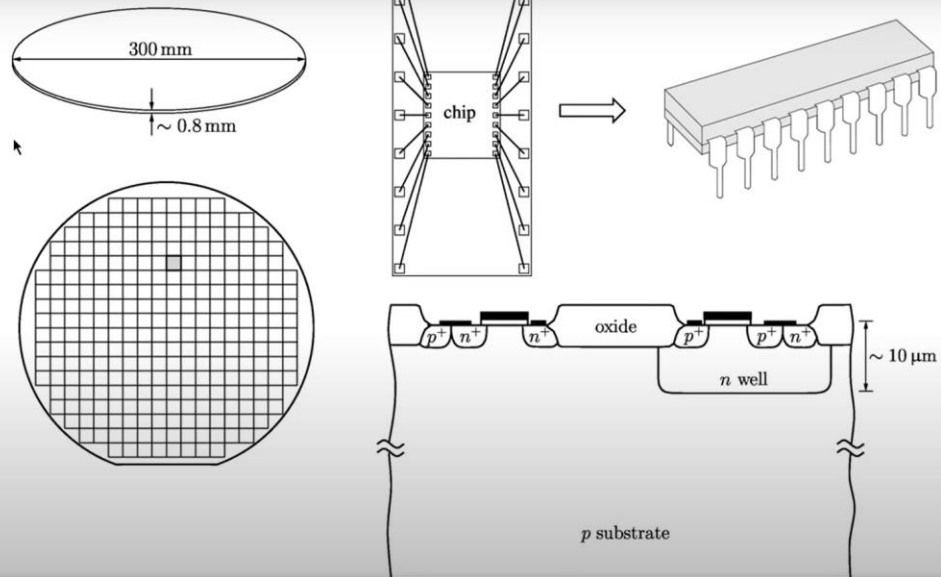


Semiconductor technology

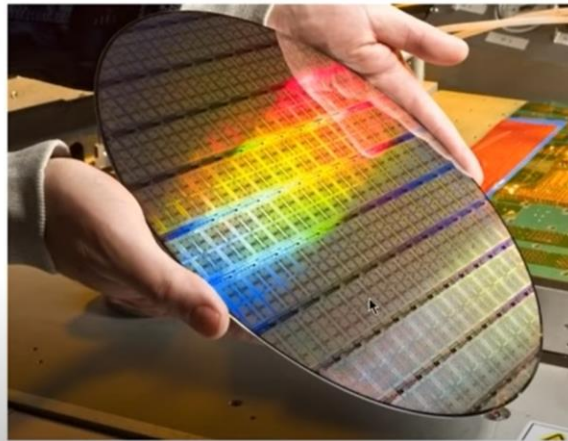
- ❖ The bipolar transistor continues to be an important device both as a discrete device and as part of Integrated Circuits (IC).
- ❖ However, in digital circuits such as processors and memory, the MOS (Metal Oxide Semiconductor) field-effect transistor has surpassed the bipolar transistor because of 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.

A BRIEF HISTORY OF ELECTRONICS

Semiconductor technology

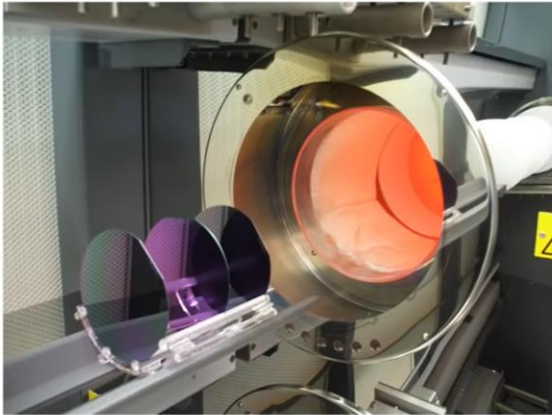


Modern semiconductor technology



silicon wafer

Modern semiconductor technology



Diffusion furnace



Modern semiconductor technology



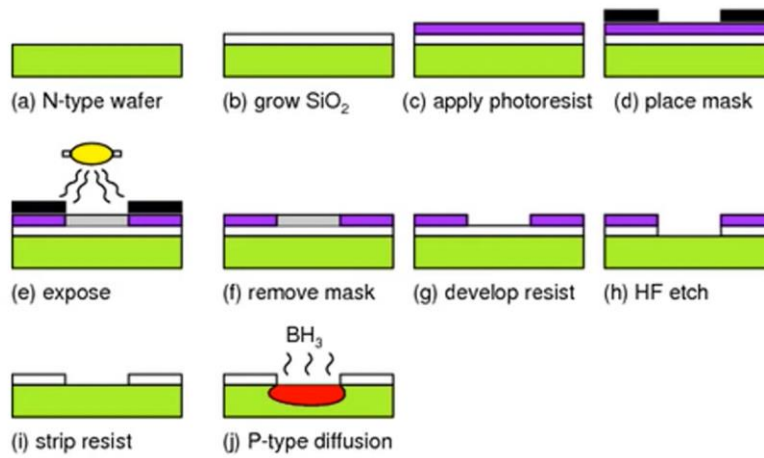
Modern semiconductor technology



Modern semiconductor technology

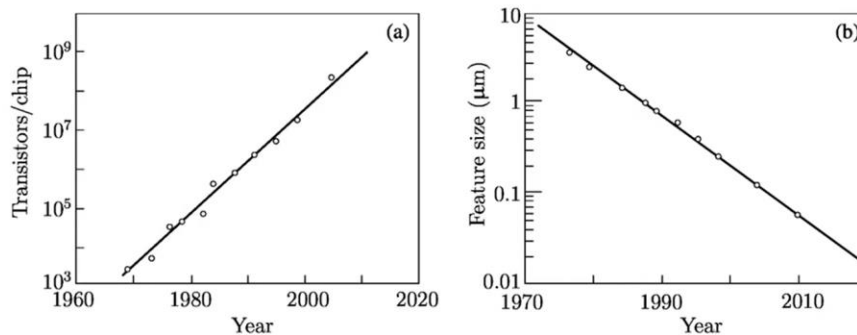


Fabrication of a p-n junction diode



MOS technology: scaling

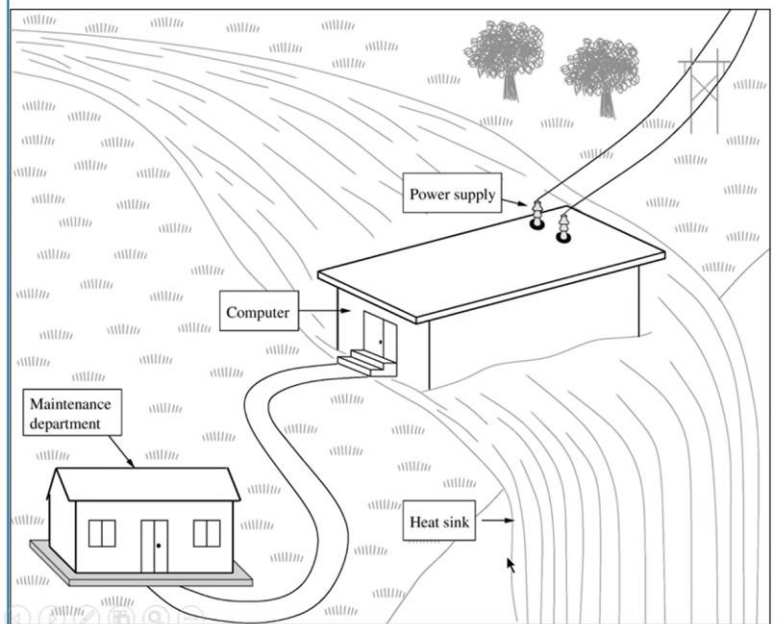
- ❖ Shrinking of the smallest definable dimension ("feature size") on the chip has enabled a huge number of transistors to be integrated on one chip.
- ❖ 1970: feature size of $10\ \mu\text{m}$, 2010: $0.032\ \mu\text{m}$
- ❖ Moore's law: a prediction by Gordon Moore (Intel founder) in 1965: number of 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

Vacuum tube computer with 1 million tubes (not built)



CATHODE RAY TUBES - 1920'S





TELEFUNKEN

