# The Transistor

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- In the nineteenth century, scientists were rarely inventors: Samuel F.B. Morse, Alexander Graham Bell, Thomas Alva Edison
- In the twentieth century, scientists invaded the domain of invention: John Fleming invented the vacuum diode tube and Lee De Forest invented the triode tube
- The transistor can be viewed, as can the laser, as an invention of physicists.
  - Source: Bunch and Hellemans, *The Timetables of Technology*, Simon and Schuster, 1993

# William B. Shockley (1910-1989)

- Known as the "Father of the Transistor"
- joined Bell Labs in 1936 in the vacuum tube department (solid state physicist)
- Moved to the semiconductor laboratory:
  - "It has today occurred to me that an amplifier using semiconductors rather than vacuum tubes is in principle possible."

# William B. Shockley

# Walter Houser Brattain

- Experimental physicist who also worked on vacuum tubes
- Joined Shockley and Bardeen in semiconductor research.

# Walter Houser Brattain

# John Bardeen (1908-1991)

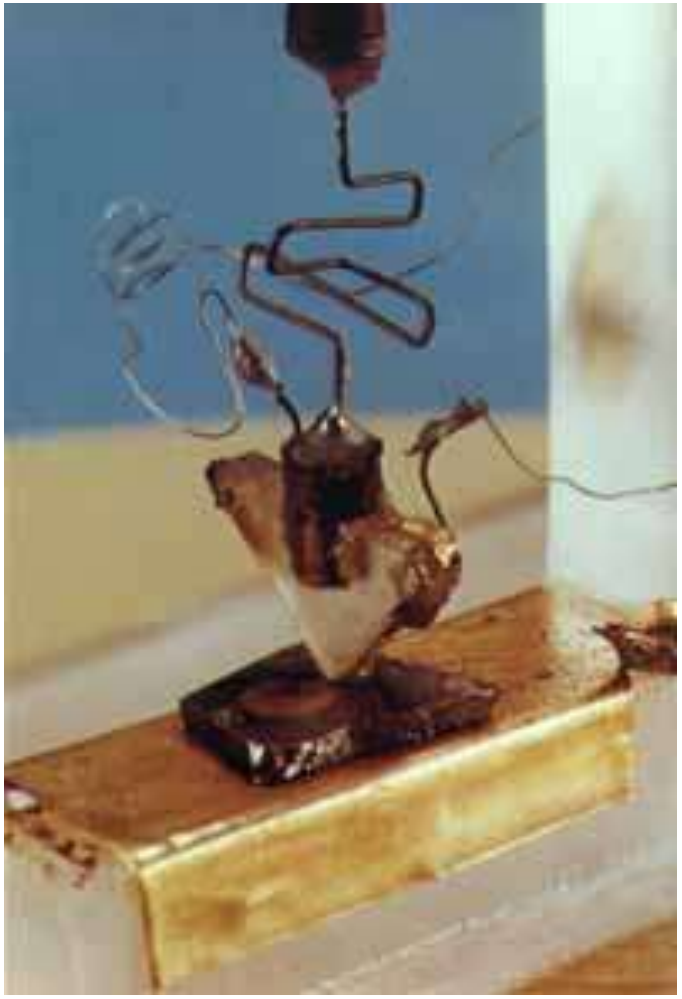
- Physicist, Naval Ordnance Laboratory 1941-1945
- Research Physicist, Bell Telephone Laboratories 1945-1951 (theorist)
- Professor of Electrical Engineering,
  - University of Illinois, 1951-1978
- Nobel Prize in Physics: 1956 and 1972
    - transistor (1956) and superconductivity (1972)
  - *"I knew the transistor was important, but I never foresaw the revolution in electronics it would bring."*

# John Bardeen

# Nobel Prize in 1956

- Shockley, Brattain and Bardeen start working with p- and n- type germanium and silicon semiconductors in 1946
- Bardeen and Brattain put together the first transistor in December 1947:
  - a point-contact transistor consisting of a single germanium crystal with a p- and an n- zone. Two wires made contact with the crystal near the junction between the two zones like the "whiskers" of a crystal-radio set.

# Point-contact-transistor



- Shockley immediately set out to define the effects that they had observed, i.e., to explain the physics of transistors
- A few months later, Shockley devised the junction transistor, a true solid-state device which did not need the “whiskers” of the point-contact transistor.
- AT&T licensed the transistor very cheaply to other manufacturers and waived patent rights for the use of transistors in hearing aids, in the spirit of its founder, Alexander Graham Bell

# Shockley's sandwitch transistor

# Manufacturing transistors on a chip

- Shockley Semiconductor Laboratories,

  Palo Alto, CA (1954)

  – the beginnings of "Silicon Valley"
- Fairchild Semiconductors founded in Mountain View, CA (1957) by eight Shockley employees including Gordon Moore and Robert Noyce
- Bell Labs had made several improvements in the manufacturing of crystals of silicon and germanium with the impurities needed to create semiconductors

# Meanwhile….

- Jack Kilby worked for Texas Instruments
- Conceived of a manufacturing method that allowed the miniaturization of electronic circuits on semiconductor chips, called integrated circuits or ICs.
- Kilby had reduced the transistor to the size of a match head
- Texas Instruments sold these for $450.

# And at Fairchild….

- Noyce adapted a system called "planar" manufacturing, in which all the transistors and resistors were formed together on a silicon chip with the metal wiring embedded in the silicon.
- Noyce filed for a patent five months after TI
- Lawsuit: TI claimed patent infringement; TI lost but companies needed licenses from both companies.
  - source: Shurkin, *Engines of the Mind*, 1984

# Field Effect Transistor (Lucent)

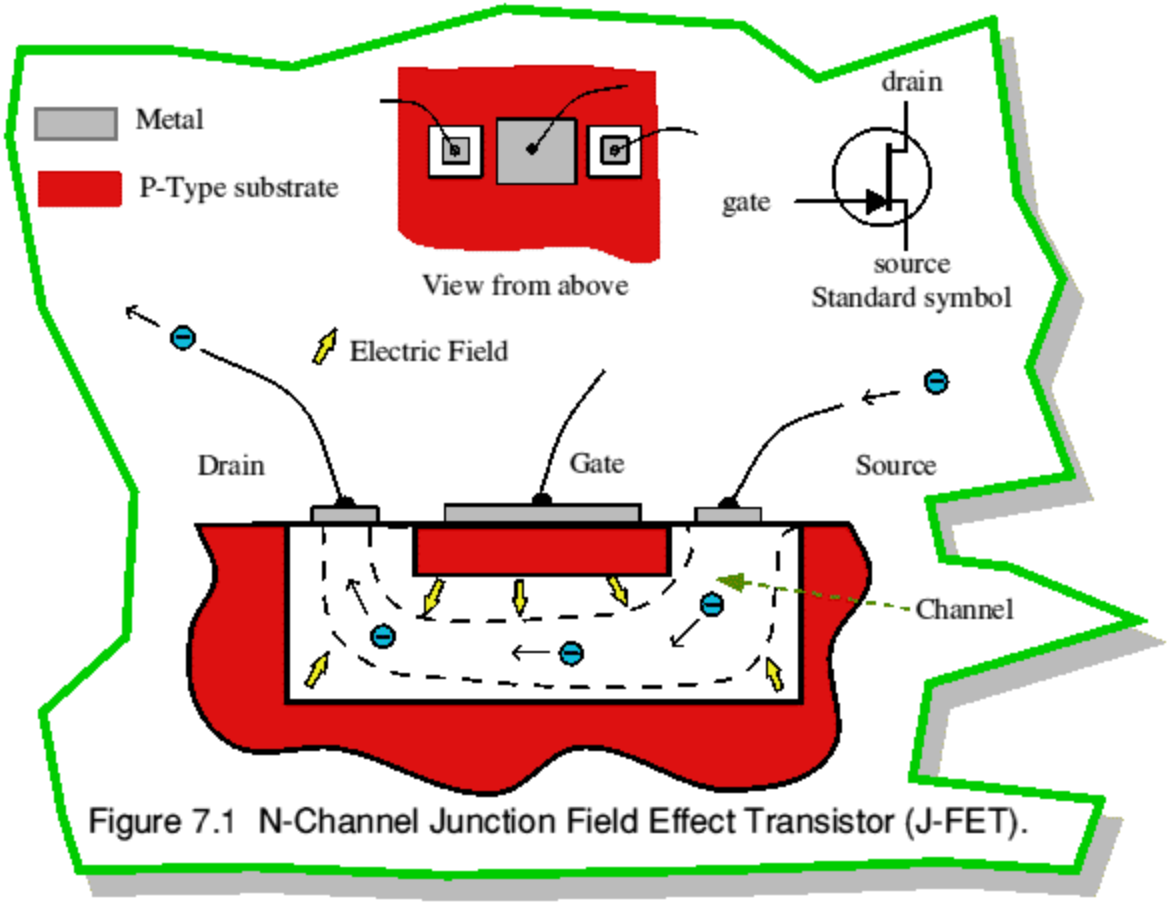



Figure 7.1 N-Channel Junction Field Effect Transistor (J-FET).

- Due to improvements in manufacturing, integrated circuits became smaller and smaller

- Gordon Moore observed that "the number of transistors on a chip seems to double every year…."
  - Moore's Law: the number of transistors on a chip seems to double every 18 months, while the price remains the same.
  - Grosch's law for mainframes: every year, the power of computers doubles while the price is cut in half

# A Little Economic Sociology

- No matter how rich you are working for someone else, think of how rich you could be if you worked for yourself!
- People figured out quickly that one could bolt from one company, and with enough science, engineering and venture capital start a new company down the street.
- Silicon Valley grew and grew and grew!
  - source: Shurkin, *Engines of the Mind*, 1984

# Bergin's musings….

- The greatest deterrent to success is success!
- Large companies tend to be conservative and bureaucratic with lengthy approval processes which stifle new ideas.
- Small companies have no history, they need to take risks and they have no stockholders to answer to: Apple, Osborne, etc.
- Starting technology companies became the new gold rush (and it was in California!)

# Intel

- Noyce, Moore, and Andrew Grove leave Fairchild and found Intel in 1968
  - focus on random access memory (RAM) chips
- Question: if you can put transistors, capacitors, etc. on a chip, why couldn't you put a central processor on a chip?
- Ted Hoff designs the Intel 4004, the first microprocessor in 1969
  - based on Digital's PDP-8

# Intel processors

| *CPU* | *Year* | *Data* | *Memory* | *MIPS* |
|---|---|---|---|---|
| 4004 | 1971 | 4 | 1K | |
| 8008 | 1972 | 8 | 16K | |
| 8080 | 1974 | 8 | 64K | |
| 8088 | 1980 | 8 | 1M | .33 |
| 80286 | 1982 | 16 | 1M | 3 |
| 80386 | 1985 | 32 | 4G | 11 |
| 80486 | 1989 | 32 | 4G | 41 |
| Pentium | 1993 | 64 | 4G | 111 |

# Altair 8800 Computer

# Microcomputers

- Ed Roberts founds Micro Instrumentation Telemetry Systems (MITS) in 1968
- *Popular Electronics* puts the MITS *Altair* on the cover in January 1975 [nee PE-8, Intel 8080]
- Les Solomon's 12 year old daughter, Lauren, was a lover of *Star Trek*. He asked her what the name of the computer on the *Enterprise* was. She said " 'computer' but why don't you call it *Altair* because that is where they are going tonight!"

# References


- Photos courtesy of Lucent Technologies and other web sources
- Bunch and Hellemans, *The Timetables of Technology*, Simon and Schuster, 1993
- Lee, *Computer Pioneers*, IEEE Press, 1995
- Freiberger and Swaine, *Fire in the Valley: The Making of the Personal Computer*, Osborne/McGraw-Hill, 1984