Celebration of the 75th Anniversary of the Transistor

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Celebrate December 23, 1947
And/Or June 1948

CB PNP Amplifier

Bardeen Shockley Brattain 1948

https://eds.ieee.org/about-eds/75th-anniversary-of-the-transistor
Celebrating 75 years of the transistor

eds.ieee.org/about-eds/75th-anniversary-of-the-transistor
Evolution of the transistor and integrated circuit

- Point contact transistor
- Bipolar junction
- Lithography
- Planar process
- Ion implantation
- MOSFET
- Self-alignment
- FinFET
- and more

→ MOORE’s Law
Point contact is replaced by junction transistor

- Grown-junction transistor 1949
  William Shockley
  Gold wire welded to base

- Alloy-junction transistor 1951
  General Electric and RCA
  Switch to Silicon
Photolithography is invented to replace wax

• Lathrop and Nall 1959
From mesa etched to planar process

• Comparison of the mesa (left) and planar (Hoerni, right) technologies. Dimensions are shown schematically.

• Common schematic view of the npn transistor

Die of a 2N2222 NPN transistor. Bond wires connect to the base and emitter
Hybrid and Monolithic Integrated circuits

• Jack Kilby 1958 and Robert Noyce 1959
Ion implantation improves precision

- John D Macdougall, Kenneth E Manchester 1969
The other transistor was invented earlier

- Julius Edgar Lilienfeld
Demonstration of the MOSFET 1959

• Mohamed Atalla and Dawon Kahng
Self-alignment opened up for scaling

- Dennard
- Moore’s law
Self-alignment of contacts

• SALICIDE = Self-Aligned Silicide
Intel 4004 the first microprocessor

Nov 15, 1971
4 bit, 740KHz
2,300 transistors
10 um pMOS

Other improvements to the MOSFET

- Strained channel
- High K gate and replacement/metal gate
- Copper + low K interconnects
- FinFET
- Nanosheet
- BSPDN
Other changes

PIDS/FEP - Simplified Transistor Roadmap

[Examples of “Equivalent Scaling” from ITRS PIDS/FEP TWGs]

- poly
- metal, high k
- gate stack
- planar
- 3D
- PDSOI
- FDSOI
- MuGFET
- MuCFET
- stressors
- + substrate engineering
- + high μ materials

Electrostatic control

65nm: 2007/7.5, 2010
45nm: 2010, 2013
32nm: 2013
22nm: 2016

Source: ITRS, European Nanoelectronics Initiative Advisory Council (ENIAC)
Channel design

- The FinFET replaced the planar FET, and will be replaced by the nanosheet or gate-all-around transistor
MOSFET memory

- EPROM
- EEPROM
- Flash
- Stacked NAND
- eDRAM
- HBM
- FeFET
Moore’s Law

Moore’s Law: The number of transistors on microchips doubles every two years. Moore’s law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important for other aspects of technological progress in computing — such as processing speed or the price of computers.

- Moore’s Law: number of transistors double every two years
  - 32x for 10 years
  - 1000x for 20 years
  - 32 000 000x for 50 years
Literature

- Crystal Fire 1997 Riordan and Hoddeson
- Chip War 2022 Chris Miller
- The Microprocessor Michael Malone
- Wikipedia