

15-292

History of Computing

Computer Memory and the
Invention of the Transistor



Evolution of Circuitry & Memory in the 1940s and 1950s



- Vacuum tube
- Williams-Kilburn tube
- Mercury delay line
- Magnetic tape
- Magnetic drum
- Core memory
- Transistor

Vacuum Tubes



- American inventor Lee de Forest introduced a third electrode called the grid into the vacuum tube, allowing it to act as an amplifier and a switch.
- A vacuum tube is a glass tube from which all gas has been removed, creating a vacuum.
 - Vacuum tubes contained electrodes for controlling electron flow and were commonly used in early computers as a switch or an amplifier.
 - Very poor reliability: burned out easily.
- Today vacuum tubes are no longer used and have been replaced by transistors

Williams-Kilburn Tubes

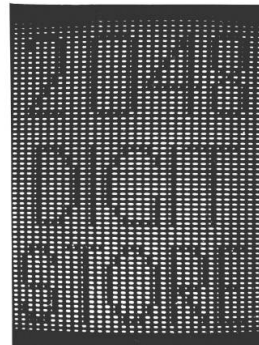


- Developed by Dr. Freddie Williams and Tom Kilburn in 1947.
- A charge is placed in one of two different ways at an array of spots on a CRT using standard techniques.
- The type of charge at any spot, representing a 0 or 1, could be sensed by a metal pick-up plate on the outside of the CRT screen, thus "reading" the "value" of the spot.
- The charge dissipated very quickly, so values were preserved indefinitely by continuously reading their value and resetting the charge as appropriate to the value.
- Used in the Manchester "Baby" Computer

Williams-Kilburn Tubes



display from a Display Cathode Ray Tube for a Williams-Kilburn CRT Store from a Ferranti Mark 1 (University of Manchester)



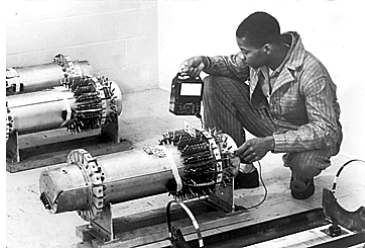
A C.R.T. DISPLAY - 2048 DIGITS
Photograph 2.
Photo from report by Kilburn
(University of Manchester)

Mercury Delay Lines

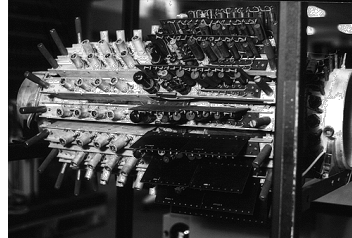


- Used by Eckert and Mauchly in EDVAC
- Operation:
 - Consisted of a column of mercury with piezo-crystal transducers (a combination of speaker and microphone) at either end.
 - Data from the computer was sent to the piezo at one end of the tube, and the piezo would pulse and generate a small wave in the mercury.
 - The wave would quickly travel to the far end of the tube, where it would be read back out by the other piezo and sent back to the computer.
 - To form a memory, additional circuitry was added at the receiving end to send the signal back to the input.

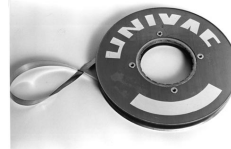
Mercury Delay Lines



3 of the 10 memory units
of the UNIVAC I
(from Thomas DeBoni
of the National Energy
Research Scientific
Computing Center)



Magnetic Tape



- First used in the UNIVAC I
 - The recording medium was a thin band of solid steel.
 - Recording density was 128 characters per inch at a linear speed of 100 ips, yielding a data rate of 12800 characters per second.
- IBM computers of the late 1950s used oxide-coated tape similar to that used in audio recording
 - IBM's technology soon became the de facto industry standard.
 - Magnetic tape was half an inch wide and wound on removable reels 10.5 inches in diameter. Different lengths were available with 2400 feet and 4800 feet being common.



Magnetic Drum

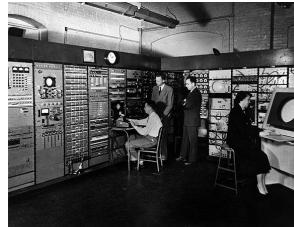


- Drum memory was an early form of computer memory that was widely used in the 1950s and into the 1960s.
 - A drum is a large metal cylinder that is coated on the outside surface with a ferromagnetic recording material.
 - A key difference between a drum and a hard disk of today is that with a drum the heads do not have to move, or seek, in order to find the track they are looking for



ERA Magnetic Drum (left), English Electric Magnetic Drum (right)

Whirlwind



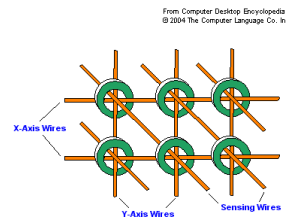
- Developed by Jay Forrester and Robert Everett the late 1940s at MIT
- Conceived as a U.S. Navy flight simulator
- Tested the use of computers in military combat information systems
 - MIT's first digital computer
 - The first digital computer built specifically for real-time control
 - Originally used electrostatic storage tubes for memory
 - Utilized magnetic core memory in grids
 - Originally projected to cost \$200K. Eventual cost \$8M.
- MITRE is formed in 1958 from MIT's Digital Computer Laboratory to work on SAGE

Whirlwind

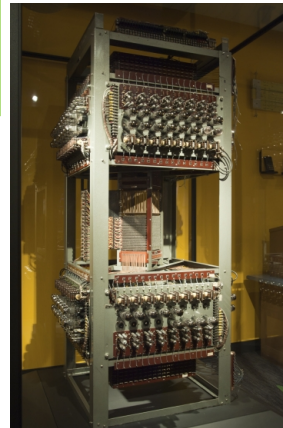


Core Memory

- Patented by An Wang at Harvard University in 1949
 - involved using the cores on single wires to form delay lines
- Jay Forrester at MIT uses cores in grids to create RAM
- Each magnetic disk, or core, had three wires passing through its center (X, Y, sense)
 - By transmitting a current (approximately 0.6 amps) through an (X,Y) pair of wires, the single core that has both wires passing through it will become magnetized through a process called *hysteresis*.
- The sense wire is used to read or write to the core cells.



Core Memory & Whirlwind



Whirlwind Core Memory – first use of a Core Memory (Computer History Museum)

Whirlwind Computer—Core Memory Bank from the Digital Equipment Corporation Museum Collection. (MIT Museum photo)

SAGE

Semi-Automatic Ground Environment



- Air defense system developed by MIT's Lincoln Laboratory in the 1950s
 - Coordinated the complex system of radar, aircraft, telephone lines, radio links and ships to detect and identify aircraft when they entered US airspace.
- Whirlwind was the “brain” for SAGE
- IBM awarded contract to build computer for SAGE, known as AN/FSQ-7
- Used 55,000 vacuum tubes, about 1/2 acre of floor space, weighted 275 tons and up to 3 mW of power.
- Fully deployed by 1963 – rendered obsolete due to USSR's deployment of ICBMs

SAGE

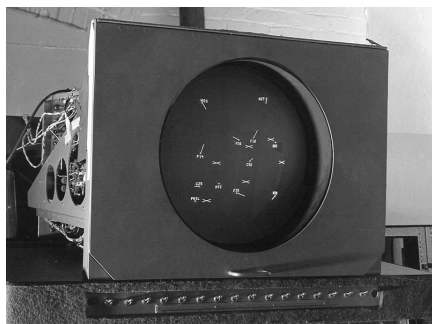
Semi-Automatic Ground Environment



SAGE Control Room

SAGE

Semi-Automatic Ground Environment



SAGE Digital Display (from MITRE)



SAGE Control Room (wikipedia.org)

SAGE

Semi-Automatic Ground Environment



SAGE Film Segments

"In Your Defense"



Transistors



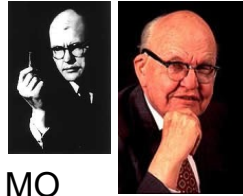
- First invented & tested in 1947 by William Shockley, Walter Brattain, and John Bardeen for AT&T Bell Labs in New Jersey
 - Awarded Nobel Prize in Physics in 1956
- One of the most important inventions of the 20th Century
 - Certainly for modern computers
- Started the trend towards miniaturization

Transistors



- A transistor is a semiconductor device used to amplify or switch electronic signals and electrical power.
- Philco pioneers a surface barrier transistor
 - Builds SOLO in 1955 for the National Security Agency based on the UNIVAC 1103
 - Commercial versions: S-1000, S-2000
 - Acquired by Ford Motor Company in 1962 and the computing line was dropped
- IBM Stretch
 - Transistor-based computer built for Los Alamos
 - Goal of 100X performance of IBM 704
 - Only had 60X speed increase
 - Leads to the IBM/360 in the 1960s

Jack St. Clair Kilby



- Born in 1923 in Jefferson City, MO
 - EE degree from University of Illinois in 1947
- He invented the integrated circuit in 1958 while working at Texas Instruments.
 - In 1970, in a White House ceremony, he received the National Medal of Science.
 - In 1982, he was inducted into the National Inventors Hall of Fame.
 - He was awarded the Nobel Prize in Physics in 2000 for his breakthrough discovery.

What's an Integrated Circuit?



- A microchip
- A small electronic device made out of semiconductor material with transistors, resistors, & capacitors on it
- Used to build CPUs (we'll see soon)
 - replaced simple transistors
- Used to build RAM
 - replaced core memory

TI's First IC



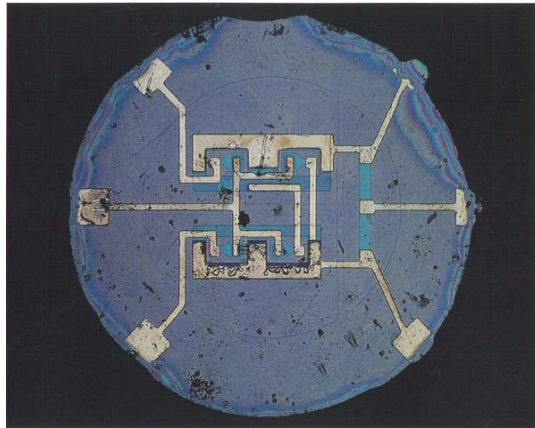
Robert Noyce



- Born in 1927 in Grinnell, IA
 - Ph.D. from Massachusetts Institute of Technology in 1953.
- Worked for Shockley Semiconductor Labs in CA
- Co-founded Fairchild Semiconductor in 1957 and Intel in 1968.
 - Intel's headquarters building, the Robert Noyce Building, in Santa Clara, California is named in his honor.
- Nicknamed the “Mayor of Silicon Valley”
- Improved upon Jack Kilby’s IC (microchip)
 - Fabricated chip with entire components out of a single piece of silicon – almost like a sculpture
 - - the planar IC, which got help from Swiss Fairchild employee Jean Hoerni

The first Planar IC – Fairchild

<http://smithsonianchips.si.edu/augarten/i10.htm>

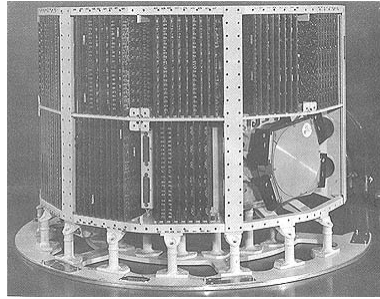


Integrated Circuits: SSI



- SSI = Small Scale Integration
- Early to mid 1960s
- Contained transistors numbering in the tens.
- Crucial to early aerospace projects that needed lightweight digital computers
 - U.S. Air Force Minuteman missile - forced IC technology into mass-production
 - NASA Apollo flight computer - led and motivated the IC technology
- Germanium & then Silicon used as semiconductor for ICs

Integrated Circuits: SSI



Minuteman I Guidance Computer D-17
(Ballistics Research Laboratory,
Aberdeen, MD)



Apollo Guidance and Navigation System
(Smithsonian National Air
and Space Museum)

Apollo Guidance Computer



"The Apollo guidance computer, a device with electronics simpler than those in a toaster that has "start" and "stop" buttons, is sufficient to provide the accuracy required to send a man to the Moon without help from any Earth-based navigation system."
- The New York Times



Integrated Circuits: MSI

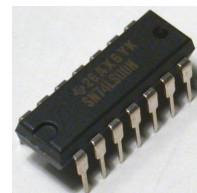


- MSI = Medium Scale Integration
- Late 1960s
- Contained transistors numbering in the hundreds.
- These ICs were attractive economically
 - They cost little more to produce than SSI devices
 - They allowed more complex systems to be produced using smaller circuit boards,
 - They required less assembly work (because of fewer separate components)

Transistor-transistor logic (TTL)



- Notable for being the base for the first widespread semiconductor integrated circuit (IC) technology.
- Gained almost universal acceptance after Texas Instruments had greatly facilitated the construction of digital systems with their 1962 introduction of the 74xx series of ICs.
 - TTL devices are also limited to a set voltage, typically 5V.
 - Contains many hundreds of devices that provide everything from basic logic gates to special purpose bus transceivers and Arithmetic Logic Units (ALU).



7400 NAND

Integrated Circuits: LSI



- LSI = Large Scale Integration
- mid 1970s
- Contained tens of thousands of transistors per chip.
- LSI circuits began to be produced in large quantities for computer main memories and pocket calculators.
 - In 1970, Intel created the 1103--the first generally available DRAM chip. By 1972, it was the best-selling semiconductor memory chip in the world.
 - You would need more than 65,000 of them to put 8 MB of memory into a PC.

Gordon Moore



- Born in San Francisco, CA, in 1929.
 - He received a B.S. degree in Chemistry from the University of California, Berkeley in 1950 and a Ph.D. in Chemistry and Physics from the California Institute of Technology in 1954.
- He co-founded Intel Corporation in 1968.
- Famous for his prediction on the growth of the semiconductor industry: Moore's Law
 - <ftp://download.intel.com/research/silicon/moorespaper.pdf>

Silicon Valley



- Silicon Valley is a nickname for the southern part of the San Francisco Bay Area centered roughly on Sunnyvale.
 - coined by journalist Don C. Hoefler in 1971
- It was named "Silicon" for the high concentration of semiconductor and computer related industry in the area, and "Valley" for the Santa Clara Valley.
- Fairchild Semiconductor really started and then fueled it all