

“The Legacy of Fairchild” in the Computer History Museum’s Visible Storage Exhibit



Fairchild Semiconductor personnel invented the planar manufacturing process, the monolithic integrated circuit, and CMOS technology – the foundations of every significant computer chip made today. They also pioneered semiconductor memory, analog devices, ASIC products, E-CAD, and numerous other technology and business innovations that established Silicon Valley at the center of the computer and communications revolution. This guide describes eight exhibits in the Visible Storage gallery at the Computer History Museum that depend on processes, products, or people associated with Fairchild Semiconductor. They are described in the order of location in the gallery.

1. Philco Model 212 Computer

Robert Noyce contributed to Philco’s surface-barrier transistor technology

2. Minuteman I Missile Guidance Computer

Potential reliability problem stimulates Jean Hoerni’s invention of the planar process

3. Apollo Guidance Computer (AGC)

The first production computer to commit to use monolithic integrated circuits

4. The CDC 6600 Supercomputer (Serial number 1)

The first high-performance computer to use silicon transistors

5. Cray Research Cray-1A Supercomputer

The iconic machine was powered by Fairchild ECL logic and memory devices

6. Illiac IV Supercomputer

The first machine to employ all-semiconductor memories – complete systems designed and built by Fairchild

7. The Illiac IV Processor Element Memory board

The Dual-Inline Package (DIP) format significantly eased printed circuit board layout and reduced computer assembly cost.

8. Semiconductor technology display

Every chip in this exhibit is based on the combination of Jean Hoerni’s planar process, and Robert Noyce’s monolithic IC concept



1. Philco Model 212 Computer

Robert Noyce contributed to Philco's surface-barrier transistor technology

In the late 1950s, Philco Corporation was one of the largest manufacturers of transistors in the U.S. Using a proprietary surface-barrier process, in 1953 Philco introduced a line of germanium high-speed switching transistors that were used in MIT's 1956 TX-0 (Transistor Experimental), the first transistorized computer to operate at a 5MHz-plus clock rate. (1) The company took advantage of these components to enter the computer business with the Philco Transac S-2000 in 1956. Introduced in 1960 for scientific, real-time, and data processing applications, the Model 212 shown here derived substantially from the design of the S-2000. Both machines benefited from improvements in semiconductor manufacturing techniques made by a young Robert N. Noyce who co-founded Fairchild in 1957.

On graduating with a Ph.D. in Physics from M.I.T. in 1953, Robert Noyce joined the transistor research group at Philco in Philadelphia. His first assignment was to develop a repeatable production method of etching the base width of germanium transistors to ensure predictable performance. In 1955 he co-authored the basic paper on surface-barrier transistor theory. (2) Noyce worked at Philco for nearly 3 years until he was recruited by William Shockley as the only new hire into his Mountain View, CA start-up Shockley Semiconductor Laboratories who was familiar with semiconductor devices.

2. Minuteman I Missile Guidance Computer

Potential reliability problem stimulates Jean Hoerni's invention of the planar process

In early 1958 the new Fairchild Semiconductor Corporation booked its first order for 500 core-memory driver transistors for the B-70 aircraft computer at \$150 each from IBM Federal Systems Division. Delivery was urgent as other manufacturers had been unable to meet IBM's specifications. Within five months the company designed the first diffused-base silicon mesa transistor, developed a process, built a manufacturing line in it's facility at 844 E. Charleston Road, Palo Alto, and shipped the devices to IBM. (3)

Announced to great acclaim at the Wescon Show, the 2N697 transistor was selected by the Autonetics Division of North American Aviation for the Minuteman I missile guidance computer. The section of the missile shown here houses a 24-bit serial minicomputer that controlled an on-board inertial guidance system. Late in 1958 Autonetics reported a potential reliability problem. Tiny particles from the metal can package could short across the mesa transistor's exposed junctions. The future of the high-flying start-up was in jeopardy.

Management personnel augmented line operators who applied a "pencil tap test" to each device to detect the presence of errant metal flakes before shipment. Swiss physicist co-founder Jean Hoerni sought a more permanent solution. He recalled an idea he had recorded in December 1957 - a new transistor design in which the oxide layer is left in place on the silicon wafer to protect the sensitive $p-n$ junctions underneath. (4) Due to concerns about possible contaminants, conventional wisdom required removing this layer after completion of oxide masking, thus exposing the junctions. Hoerni viewed the oxide instead as a possible solution - his "planar" approach, named after the flat topography of the finished device, would protect these junctions.

After writing a patent disclosure in January 1959, Hoerni demonstrated a working planar transistor that March. As he predicted, the oxide was found to be largely free of contaminants. Planar devices also proved to have better electrical characteristics - particularly far lower leakage currents, which is critical in computer logic design. And

they permitted fabrication of all the components of semiconductor devices from one side of a wafer. The billion-transistor integrated circuits (ICs) of today rely on Hoerni's breakthrough idea. One historian calls it "the most important innovation in the history of the semiconductor industry." (5)

3. Apollo Guidance Computer (AGC)

The first production computer to commit to use monolithic integrated circuits

Developed by the MIT Instrumentation Laboratory under the direction of Eldon Hall and manufactured by Raytheon, this is an engineering prototype of the Apollo Guidance Computer (AGC) that guided the Apollo Spacecraft Command Module from Earth orbit to the Moon and back. It also controlled the Lunar Module descent to and from the moon's surface. In 1962, MIT selected a Fairchild Micrologic "Type-G" (3-input NOR gate) circuit for the AGC logic. Each system used about 4,000 ICs. This decision, which was challenged by conservative advisers who warned that they may not be reliable, was the first production commitment to ICs. The Apollo program was the largest consumer of ICs through 1965 during which time it used 200,000 units at \$20 - 30 each. (6)

Micrologic, the first monolithic IC family, was developed using Jean Hoerni's planar process and the concepts described in Robert Noyce's "Semiconductor device-and-lead structure" patent filed in July 1959. (7, 8, 9, 10) Noyce realized that it did not make sense to separate transistors fabricated next to each other on a wafer, only to reconnect them again later on a PC board. He therefore conceived the idea of using the silicon dioxide as an insulator and placing metal interconnects above the oxide to make electrical connections.

In September 1959 co-founder Jay Last assembled a team including Sam Fok, Isy Haas, Lionel Kattner, and James Nall to develop a Direct Coupled Transistor Logic (DCTL) circuit designed by applications engineer Robert Norman. Working with multiple devices on the same chip and with smaller physical tolerances than required for making single transistors posed many new challenges but by May 1960 engineers tested a fully functional circuit comprising four-transistors and five resistors in a flip-flop configuration. The first commercial Micrologic devices shipped to customers following a highly publicized introduction at the March 1961 IRE Show in New York. (11)

4. The CDC 6600 Supercomputer (Serial number 1)

The first high-performance computer to use silicon transistors

When Seymour Cray, chief architect of scientific computer manufacturer Control Data Corporation of Minneapolis, set-out to design the world's most powerful machine he realized that the high ambient temperature generated by its densely-packed logic circuits would exceed the reliable operating range of germanium transistors. Early silicon transistors offered superior operation to germanium at elevated temperature but could not achieve the under 3-nanosecond switching performance required by CDC.

Cray awarded Fairchild Semiconductor a \$500,000 development contract to develop a high-speed silicon transistor. Jean Hoerni met Cray's specification by combining "gold-doping," his discovery by that the addition of gold impurities enhanced the speed of silicon devices, with the recently developed epitaxial deposition process. (12, 13) Fairchild introduced the 2N709 (FT-1310) *n-p-n* device as the first silicon transistor to exceed germanium speed in July 1961.

Each CDC machine used 600,000 transistors packaged in a unique cordwood-style module configuration to minimize connecting wire lengths. It executed about three million

instructions per second and remained the fastest machine in the world for the next five years. Selling for \$6 to \$10 million each, CDC manufactured about 100 machines. In 1964 the company placed one of the largest single orders in the history of the semiconductor industry with Fairchild for over 10 million devices. (14)

5. Cray Research Cray-1A Supercomputer

The iconic machine of the 1970s was powered by Fairchild ECL logic and memory devices

In 1972 Seymour Cray left Control Data Corporation to create Cray Research, Inc. to continue his tradition of building the world's most advanced supercomputers. Four years later he released the Cray-1A that reigned as a supercomputing icon for decades. Selling for about \$6 million, the machine featured hand-tailored wiring and a Freon cooling system. Its world beating performance of 160 MFLOPS was enabled by Fairchild Isoplanar technology.

Doug Peltzer developed the Isoplanar oxide-isolated process to build high-speed bipolar memories. The first Isoplanar device, the 93410 256-bit TTL RAM designed by Bill Herndon in 1971, delivered about 50% faster performance in half the die size of the previous generation junction-isolated chips. The 95415, a 1024-bit ECL memory based on this design, formed the main storage of the Cray 1. (15) Applying Isoplanar technology to logic devices delivered the F100K family of sub-nanosecond ECL devices, the industry's fastest gates and flip-flops. Each Cray I consumed 250,000 dual ECL gates and 65,000 ECL RAMs manufactured by Fairchild.

6. Illiac IV Supercomputer

The first machine to employ all-semiconductor memories – complete systems designed and built by Fairchild

Fairchild involvement in the development of semiconductor memory devices dates back to the early 1960s. Gordon Moore noted in a 1995 interview "In the early days of the integrated circuit Bob Norman suggested the idea of semiconductor memory ... the whole idea of how semiconductor flip-flops could be used as a memory structure. I decided it was so economically ridiculous, it didn't make any sense to file a patent on it." (16) Despite Gordon's skepticism work did proceed at Fairchild R&D. Don Farina built one of the first dedicated semiconductor RAMs, a 9-bit bipolar device on the pilot line (17) and in 1964 John Schmidt designed a 64-bit MOS *p*-channel static RAM (18). Fairchild Memory Products division designed a Semiconductor Advanced Memory (SAM) 1024-bit hybrid module using 16 of Schmidt's chips for Burroughs in 1967. Lee Boysel built an early 256-bit dynamic RAM (DRAM) in 1968 and one year later after founding Four Phase Systems he quadrupled his design to 1024-bits.

Illiac IV was an advanced computer sponsored in the mid-1960s by the Defense Advanced Research Projects Agency. It was designed and developed at the University of Illinois by Professor Daniel Slotnick and built by Burroughs Corporation, Paoli, PA. The Illiac IV exhibit at the Museum includes the central control unit, a processing element cabinet, and a disk drive.

The original 1966 design for Illiac IV specified a high-speed thin-film memory. Failure of that approach set the stage for the first application of a semiconductor main memory system. Burroughs contracted with Rex Rice at Fairchild R&D to use a new 256-bit bipolar TTL chip (93400) designed by H.T. Chua to build a 2048 word by 64 bit (131,072 bits) memory system for each of the 64 Illiac processing elements. A team led by Frank

Greene and Wendell Sander delivered the first system on April 15, 1970. The final system shipped one year later. Slotnick recalls "Illiic IV was the first machine to have all-semiconductor memories. Fairchild did a magnificent job of pulling our chestnuts out of the fire ... the memories were superb and their reliability to this day is just incredibly good." (19)

7. The Illiac IV Processor Element Memory board

The Dual-Inline Package (DIP) format significantly eased printed circuit board layout and reduced computer assembly cost.

The printed circuit board from the Illiac IV Processor Element Memory system in this exhibit uses integrated circuits mounted in the Dual-in-Line Package (DIP) developed by Fairchild personnel in 1965. The DIP revolutionized computer manufacturing by simplifying layout and allowing automated insertion of ICs with large numbers of leads into printed circuit boards. (20)

Rex Rice, manager of the Digital Systems Department at Fairchild R&D came up with a single-in-line concept where all the leads emerged from one side of the IC package to avoid board layout restrictions imposed by the circular pin-outs of round metal can packages. Bryant ("Buck") Rogers working for Mel Phelps in Special Projects realized that as IC chip size grew a single in-line configuration standing on its edge would impose board-to-board spacing restrictions. He suggested tilting the in-line package over and adding another row of leads without losing the layout benefits. The resulting dual-in-line format constructed as a sandwich of a rectangular ceramic base and lid with two rows of pins 100 mils apart designed by Don Forbes established a package outline that was quickly adopted by the industry. Low-cost, plastic-molded versions of the DIP continue to be manufactured in volume today. (21)

[This board is on loan specifically for this exhibit courtesy of Frank Greene]

8. Semiconductor technology display

Every chip in this exhibit is derived from the combination of Jean Hoerni's planar process, and Robert Noyce's monolithic IC concept

See descriptions for exhibits # 2 and 4 for more information.

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More Information and References

"The Silicon Engine" references are posted on the Computer History Museum's History of Semiconductors in Computers website at:

<http://www.computerhistory.org/semiconductor/welcome.html>

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(15) "The Silicon Engine" - Timeline entry "1966 - Semiconductor RAMs Developed"

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(16) Silicon Genesis website interview with Gordon Moore (March 3, 1995)

<http://www-sul.stanford.edu/depts/hasrg/histsci/silicongenesis/moore-ntb.html>

(17) Bob Norman's Fairchild memories (September 3, 2007)

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(21) "The Silicon Engine" - Timeline entry "1965 - Package is the First"

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