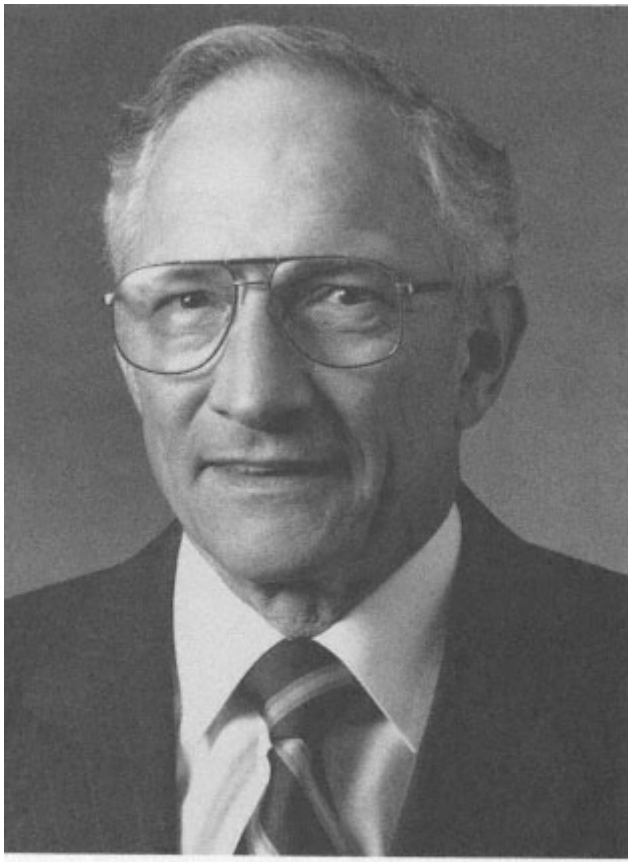

Robert N. Noyce

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1927-1990

By Gordon E. Moore

ROBERT NOYCE died suddenly on June 3, 1990, at his home in Austin, Texas, where he had been living since becoming president of SEMATECH two years earlier. His career as a physicist, inventor, and entrepreneur was closely tied to the development of the semiconductor industry.

Born in Burlington, Iowa, he received his undergraduate education at Grinnell College before going on to Massachusetts Institute of Technology for his Ph.D. in physical electronics under Professor Wayne Nottingham. Upon graduation he worked on germanium transistors at the Philco Corporation. One of his early contributions was a technique for controlled etching of very thin regions in a germanium crystal that facilitated making the first commercially available high frequency transistors.

In 1956 he joined the fledgling Shockley Semiconductor Laboratory, a subsidiary of Beckman Instruments. There he tackled the physics of silicon devices and the development of technology for their production. His paper (with William Shockley and Chih-Tang Sah) on space-charge generated currents in silicon *p-n* junctions explained the observed voltage current characteristics. This discovery was an important foundation for subsequent development of silicon transistors and other semiconductor devices.

Bob left Shockley Laboratory in 1957 to become one of eight founders of Fairchild Semiconductor Corporation. This com

pany later became the Semiconductor Division of Fairchild Camera and Instrument Corporation. In 1959, while director of research and development at Fairchild, he saw how a complete circuit containing interconnected transistors, diodes, and resistors could be built in a small chip of silicon—the integrated circuit. By adding extra junctions in the silicon wafers the individual circuit elements could be isolated electrically from each other, and a metal film insulated from the silicon by a silicon dioxide layer then could be used to form interconnections. Shortly after Noyce's invention, Texas Instruments Inc. announced that Jack Kilby had built a circuit consisting of several elements in a germanium crystal. Noyce and Kilby are generally credited as coinventors of the integrated circuit. In fact, the first Charles Stark Draper Prize awarded by the National Academy of Engineering was shared by Noyce and Kilby, recognizing the unique importance that their inventions have had on society. It is worth noting, however, that their contributions were developed independently and were very different in their execution.

In 1959 Bob became general manager of Fairchild Semiconductor giving him the opportunity to guide the commercialization of his invention. Fairchild was the first to market with integrated circuits and was the world's leading producer for much of the 1960s. Under Bob's management Fairchild continued to make key contributions, both technical and in the development and evolution of the semiconductor business. Fairchild scientists developed an understanding of the silicon-oxide interface, enabling the corporation to make stable metal-oxide semiconductor (MOS) transistors. This continues to be the dominant element in today's integrated circuits. They invented complementary MOS (CMOS) circuitry, the basic circuit form still commonly used today. They also came up with the idea of using gate arrays and standard cells as low-cost design approaches, making possible the economical production of small quantities of logic functions. Based on these discoveries, the company designed and sold a host of digital and analog circuits.

The early market for integrated circuits was slow to develop. So Noyce, who appreciated the potential price elasticity of integrated circuits, announced that Fairchild would sell the

chips at a price lower than the sum of the costs of the individual components necessary to make the equivalent circuit. This decision helped trigger the explosion of the integrated circuit market.

In 1968 Noyce left Fairchild and cofounded Intel Corporation to pursue opportunities in large-scale integration. He was Intel's president and chief executive officer until 1975. Over this time frame, Intel introduced the first principal semiconductor memory types—DRAM, SRAM, and EPROM—as well as the microprocessor.

Once Noyce turned over the day-to-day management of Intel, his broader interests in the electronics industry and its relation to government and society consumed the majority of his time. By offering his technical and business advice, he nurtured a number of technology-based companies in Silicon Valley. He was among the first to appreciate the increasing importance of foreign competition in electronics and the weaknesses of American companies. He dedicated much of the last dozen years of his career trying to improve the competitiveness of U.S.-based industry. Noyce was a familiar and effective figure in Washington, D.C.; a founder of the Semiconductor Industry Association; and a tireless advocate of change—in education, capital formation, the tort system, and other areas—aimed at removing impediments to U.S. competitiveness.

He was on the board of trustees of Grinnell College from 1962 until his death and served as its chairman from 1966 to 1970. He was also a regent of the University of California.

Noyce played a prominent role in the formation of SEMATECH, which represented a unique attempt to foster cooperation among semiconductor companies and the U.S. government in an effort to increase U.S. competitiveness in manufacturing. When the search committee (of which Noyce was chairman) could not identify someone to be SEMATECH's first chief executive officer, Noyce responded to the urging of his colleagues in the industry and agreed to take on the responsibility himself. As he put it, "It was just too important a job to leave to others."

He was elected to the National Academy of Engineering in

1969 and to the National Academy of Sciences in 1980. He received both the National Medal of Technology and the National Medal of Science, the Stuart Ballantine Medal of the Franklin Institute, the IEEE Medal of Honor from the Institute of Electrical and Electronics Engineers (IEEE), the Faraday Medal from the Institute of Electrical Engineers (United Kingdom), the Cledo Brunetti Award from the IEEE, and the Harry Goode Memorial Award from the American Federation of Information Processing Societies.

Although Noyce's technical contributions in the development of the integrated circuit are what earned him his long list of prizes and fellowships, his many friends best remember him as someone who was always approachable, always interested in their problems and ideas, and always ready with suggestions —often involving innovative and unusual approaches at odds with conventional wisdom. In my thirty-four years of association with Bob, many of his suggestions proved invaluable in the progress of my work.

Noyce was totally involved in living. He was a good athlete—a champion diver in college and an excellent skier—and he loved scuba diving, hang gliding, and piloting his airplanes, which ranged from an ancient Seabee to a private jet. In fact, he was scheduled to leave Austin to pick up his new jet the very day he died. It was a plane in which he could fly nonstop from Austin to either Washington, D.C., or Silicon Valley.