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DONALD OSCAR PEDERSON
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A Biographical Memoir by

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DONALD O. PEDERSON IS BEST known in the field of electronic design automation for leading the development of a groundbreaking program for integrated-circuit computer simulation called SPICE (Simulation Program with Integrated Circuit Emphasis). Beginning in the 1960s, he carried on this work with colleagues and students at the University of California, Berkeley. SPICE allows engineers to analyze and design complex electronic circuitry with speed and accuracy. Pederson's colleagues point out that virtually every electronic microchip developed anywhere in the world today uses SPICE or one of its derivatives at critical stages during its design.

Donald O. Pederson was born in Hallock, Minnesota (just south of the Canadian border), son of Oscar Jorgan and Beda Emilia Pederson, in 1925. He had one sister, Beatrice, two years older. Don never talked much about his youth, but when he won the Medal of Honor of the Institute of Electrical and Electronics Engineers in 1998, he gave a long interview that was the basis for an article published in IEEE's *Spectrum* magazine (Perry, 1998). Most of the following account of his youth and early career is adapted from that article, with thanks to and by permission of Tekla S. Perry and IEEE.

While still in elementary school in Fergus Falls, Minnesota, Don built his first crystal radio, using parts given to him by an uncle and a cousin as well as junkyard finds. Soon after, he got a paper route and saved his money to buy his first soldering iron and his first vacuum tube. His enthusiasm for electronics was apparent in his high school physics class, in Fargo, North Dakota, where his family had moved. From that class he was recruited for a weekend job repairing electric motors at the Fargo Electric Motor Co.

When Don graduated from high school at age 17 in 1943, in the thick of World War II, he had three months before the U.S. Army would pounce on him for service. Having spent his life so far in Minnesota and North Dakota, he decided to see the West Coast, and went to Seattle. His first stop was a shipyard, where he asked for a job working with electricity. He was sent to the union hall, and officials there offered him a post as an apprentice electrician.

"No," the teenager told the union representative, "I want to be a journeyman. I've been working for two years in electric motor repair, I must have learned something." The union officials gave him an oral test. After he answered the last question, which he recalled had concerned safety precautions in working with hot electrical lines, a listening electrician laughed, muttering, "Well, the kid is wrong on that one." The shop steward corrected him. "No, the kid is right, you're wrong," he said, and gave Pederson his journeyman assignment. He was put in charge of providing temporary electric power, when needed, for lights and tools on a destroyer that was being built.

His knowledge of electrical safety was to be tested further. Often he had to work with live wires, so as not to cast workers in various sections of the destroyer into the dark. "I would get a couple of very dry pieces of wood," he said, "put them on the metal deck, make the break, hold the two ends, then remake the connection. But the guys from a welding crew would sneak up on me and, just when I had broken the line, pour salt water on my feet. The shock would knock me down, and they'd laugh." Pederson said he retaliated by cutting off power to the coworkers when they were in the farthest reaches of the ship; eventually a truce was called.

Just before turning 18, Pederson joined an army training program in engineering. He completed one term at Iowa State University, in Ames, but then the program was terminated and the would-be engineers ended up in the infantry. After combat in Germany, France, and Austria, Pederson was sent to the Philippines. The war ended shortly after he arrived, but he remained there for about a year, taking charge of the regimental power station. "I had two primary missions," he remembered. "The colonel had to have power for his shaver and the troops had to have power for the movie at night."

Pederson returned to the United States and to college in 1946, when he enrolled at North Dakota State University in Fargo. After a day of aptitude tests, a counselor told him that if he wanted to make money, he should forget about college and go to work for a local electric shop, buy into the business, and have a nice life as an electrician. But Pederson hung on to his childhood ambition to be a radio engineer.

After half a semester of college, though, the freshman found himself a C student. That, he concluded, was not going to get him anywhere; clearly, he couldn't have fun and be an engineering student at the same time. Therefore, he worked with a study partner for six days each week, and took an overload of courses to speed through college ahead of other returning veterans. In 1948 he finished his bachelor's degree after two years and one term and, at the urging of a professor, applied to several graduate schools, eventually choosing Stanford University in California.

The late 1940s were an exciting time at Stanford. William Hewlett of soon-to-be Hewlett-Packard fame had just discovered the distributed amplifier, a broadband amplifier used in high-frequency systems. An analysis and redesign of that device was to become Don's thesis project, under the guidance of Professor Joseph Pettit. After earning his Ph.D. in 1952, he stayed on for two years as a postdoctoral researcher at Stanford, designing high-performance electronic amplifiers. The work led to his first professional publications.

Don joined Bell Laboratories, in Murray Hill, New Jersey, in 1953. "Bell Labs had a superb recruiting effort," he recalled. "They would spot the young students who were coming along, then nurture that relationship. It seemed that every time I turned around, there was somebody from Bell Labs in the hallway, so when it was time for me to leave Stanford, it was natural that I would consider Bell." At Bell, he continued working on electronic circuits, switching from tubes to transistors. He doubts he made any major technical breakthroughs during this period, but achieved solid day-to-day development. "I earned my keep," he said.

Soon after he started at Bell Labs, he was contacted by a former North Dakota State professor, Harry Dixon, who had become head of the electrical engineering department at the Newark College of Engineering (now the New Jersey Institute of Technology). Dixon asked Pederson to teach a course on electrical network theory, saying he had committed the school to offering this course in the fall and did not have the knowledge to teach it himself. Despite having decided years earlier that he would never pursue an academic career, and despite the objections of his supervisors at Bell

Labs, Pederson agreed. His former mentor was asking for help, and he felt that he owed it to him.

Preparing for the course and teaching it filled up most of Pederson's nights and weekends, but when the year was over, he concluded that he had enjoyed teaching better even than his work at Bell Labs. He taught another class the next fall, and the following year, 1955, contacted acquaintances back in California and obtained a position as an assistant professor at the University of California, Berkeley.

This was the turning point in Pederson's career, and out of all his accomplishments, he is most proud of his efforts working, he says, with so many "bright, eager students." "He certainly didn't do it for money," commented John Whinnery, one of those who helped to recruit Pederson and now a Berkeley emeritus professor. "He took a big [salary] cut to come to the university. The idea of teaching was what motivated him." "He always could excite students," recalled Ernie Kuh, a Berkeley professor emeritus, who followed Pederson from Bell Labs to California.

In 1959 the integrated circuit (IC) was developed, and the world of electronics changed. According to Don, some engineers thought the IC was merely another way to make amplifiers and switching circuits, but others, including himself, realized that ICs opened up a new world, one in which dramatic reductions in size and cost of electronics would become possible.

Don decided that to undertake research in ICs and to teach students to design them, the university needed its own semiconductor fabrication facility. When he voiced this idea, he met a host of objections: Building a fab was too complicated; his group was made up of engineers, not chemists; the university had no money for expensive fabrication equipment; and the project simply couldn't be done. Ignoring the objections, Pederson, with professors Tom Everhart, Paul Morton, Bob Pepper, and a group of graduate students, started designing the facility. One of us (D.A.H.) was among those students. "Never wait for approval, don't tell anyone you are doing something, just do it," Pederson said later. "That's my motto."

Funds were very limited, but industry was willing to donate used processing equipment as the technology sped ahead to new IC generations. Some key equipment was built locally, with appropriate compromises, recognizing that no mass production was planned. A sympathetic department chair reassigned offices to free up space. A few university grants to young faculty and graduate students, along with some money from the Army Research Office and the U.S. Air Force, provided about $300,000 in cash. In 1962 Pederson announced at a conference of the Institute of Radio Engineers (IRE), the predecessor of the IEEE, that his group had produced its first working circuit. "We stole [the fab] fair and square," he said.

Before the university could consider whether to give the project formal approval, notable engineers from industry were visiting and praising the facility, the first IC fab at a university. "His vision, which gave Berkeley an IC fab way ahead of any other universities, proved to be a key move for the university, for we educated a large number of outstanding students," Berkeley's Kuh said.

"Other universities were arguing at the time that a university can't possibly keep up in the microfabrication field, because you can't afford the most modern facilities," Whinnery, the Berkeley professor who helped to recruit Pederson, said later. "This is true, but Don saw that if you didn't have reasonable facilities, you wouldn't be able to contribute to the field at all. That was one of the farsighted things he did that really paid off. Students that came out of that program became leaders in the semiconductor industry."

Microfabrication capabilities at Berkeley have advanced and grown steadily ever since. Currently, in 2006, several hundred students and faculty members from a wide range of academic fields make use of an extremely flexible research facility.

In the middle 1960s Don became interested in the application of computer programs to the analysis of integrated circuits. He and his students had used a Bendix G15 machine (the very one now displayed in the National Museum of American History at the Smithsonian Institution in Washington, D.C.) with only typewriter and paper tape input and output, to try to gain a deeper understanding of the behavior of certain linear circuit designs. In his circuit design work he found that many of the first-order approaches to the analysis of circuits did not predict the correct behavior of real circuits. In fact, depending on the assumptions made, first-order theory could be used to predict a variety of outcomes for the same circuit.

One of Don's graduates, William Howard, had been working at the U.S. Army's Harry Diamond Laboratory to better understand a particularly tricky problem involving the thermal behavior of the input characteristics of a linear IC design. It was 1967 when Bill Howard first implemented a computer program at Berkeley for the analysis of the nonlinear dc operating point of an IC—he called the program BIAS—on a 16-bit IBM 1130 machine. Don was now convinced that the computer was to play a central role in the design and analysis of integrated electronics. Around 1968 Bill Howard left Berkeley for Motorola, where he eventually retired as a senior vice-president. He was a senior fellow at the National Academy of Engineering from 1987 to 1990.

Many other computer-aided design projects followed at Berkeley, based on techniques developed in Don's laboratory as well as elsewhere (most notably at IBM's San Jose laboratories and North American Rockwell), and included the work of William McCalla and Frank Jenkins—Don identified Frank's potential and brought him into the group as a freshman—leading to programs like SLIC, Frank, and SINC. Bill McCalla, now deceased, made many significant contributions to the CAD industry over the years, including the reworking of the original BIAS program and the integration of nonlinear dc and ac analyses into a single code; Frank Jenkins went on to develop the commercial circuit simulator ASPEC in the late 1970s and some early commercial logic and switch-level simulators, including LOGIS and ILOGS.

In the fall of 1969 the young professor Ron Rohrer returned from a leave at Fairchild and began teaching a course designed to apply modern system and circuit-theoretic concepts and advanced numerical methods to circuit analysis and design. He set about to build the best and most comprehensive circuit simulator he could, assigning various aspects of the task to different students in the class. At the end of the class he told them their grade would be based on how well they had convinced Don Pederson that their contribution was the best that could be done. The outcome of that course was a program called CANCER (Computer Analysis of Circuits, Excluding Radiation), a program that later became the starting point for SPICE 1 (Simulation Program, Integrated Circuit Emphasis) development. A postdoctoral student from Belgium, Hugo De Man, was visiting Berkeley at the time and made his own contributions to the CANCER effort. Professor De Man, of Katholieke Universiteit Leuven and IMEC, both in Belgium, is well known for the many significant contributions he and his group have made to electronic design automation.

In the fall of 1970 Don selected CANCER for his classroom instructional programs, rejecting the other Berkeley competitors of that time, SLIC and SINC. Unfortunately, Don's ability to distribute the CANCER code to his friends and colleagues in industry was hampered by the fact that the program had been declared proprietary. Because much of the IC design and development work was going on in industry, Don felt that this was an unacceptable barrier. A young graduate student named Larry Nagel had been closely involved in the CANCER project and when his adviser Ron Rohrer left Berkeley, Don took him on as a graduate student on the condition that he could use the CANCER source as a starting point for a truly public-domain, general-purpose circuit simulator. In May 1972 the first version of that new program, SPICE 1, was released from Berkeley. Larry Nagel continued his work with SPICE, releasing SPICE 2A.0 before joining AT&T Bell Laboratories, where he led the AT&T in-house circuit simulation development efforts for many years.

A freshman that Don identified and recruited from one of his classes, Ellis Cohen, picked up the SPICE baton from Larry and carried SPICE 2 forward, making significant contributions even as an undergraduate. Ellis was quickly recognized as a superbly talented computer scientist. Much of what became the version of SPICE 2 that formed the basis of the many commercial versions should be attributed to Ellis.

A.R.Newton (one of the authors) joined Don's group at Berkeley in early 1975. Don recruited him from the University of Melbourne after he had already been effectively working for Pederson there for two years, in both undergraduate and M.S. programs. Newton contributed to SPICE as well. Newton remembers one day when Ellis Cohen had just added dynamic memory management to SPICE 2. (Note that SPICE 2 was a Fortran program in punched-card form and ran on a CDC 6400 computer, whose only output device was a 132-column line printer). Adding dynamic memory management was no small feat. But it slowed the program down by almost a factor of two. This was not acceptable to Don and, in his own way, he challenged Ellis to fix the problem. Within 24 hours Ellis had designed and repunched the cards needed to add automatic machine-code generation to the program—where SPICE itself generated the native object code needed to solve the sparse-matrix circuit equations for that particular circuit, rather than using the more general code produced by the Fortran compiler. He had debugged and installed the program and, since he managed to get back the factor of two as a result, he was able to keep his dynamic memory management. Ellis Cohen now is with Mentor Graphics Corp. in Oregon.

The Army Research Office (ARO) also played a critical role in the development of SPICE. In these days of tight budgets and congressional pressures, many agencies that fund university research are being asked to show increasingly shorter-term payoffs, force technology transfer to industry, and reduce their long-term commitments to research programs. It is clear that the long-term research funding commitment ARO made to Don's effort was instrumental in giving him the flexibility to continue his work to completion over many years. There were a number of occasions when the ultimate pay-off of the work was questioned, when the path was not perhaps as clear to those outside the SPICE group, but the ARO support continued. The SPICE 2 work continued until the early 1980s, when the program was converted to the C language, new models added, and some analysis techniques generalized, resulting in SPICE 3.

Don and his students have made contributions to electronic design automation (EDA) in many other areas including device modeling, mixed-mode simulation, rule-based circuit diagnosis, and macromodels. In fact, his analog macromodel for the operational amplifier, developed in conjunction with Jim Solomon and Graeme Boyle in the 1970s, is still a standard today. Jim Solomon, formerly of National Semiconductor Corp. and founder of SDA Systems (now Cadence Design Systems) received his M.S. degree under Don's supervision at Berkeley; Graeme Boyle received his Ph.D. with Don before joining Tektronix.

Many other leaders in our field worked as graduate students with Don Pederson. They include Gary Baldwin, the former laboratory director at Hewlett-Packard Labs; Professor Mohammed Ghausi, former dean of engineering at the University of California, Davis; Professor Gary Hachtel, University of Colorado; Robert Pepper, founder and CEO of Level 1 Communications (acquired by Intel); and Professor Bruce Wooley, Stanford. Almost every major design technology company of today has been influenced significantly by at least one of Don Pederson's former graduate students.

The industrial impact of Pederson's early work in electronic design automation is best measured by the use of the technology he and his colleagues developed over a quarter century ago. As mentioned in the introduction, virtually every semiconductor company and the vast majority of electronic system design companies throughout the world use a version of SPICE, or a program derived directly from it. In addition to companies who have obtained SPICE from Berkeley and who have adapted it for their own in-house use, over the past 20 years more than a dozen companies have been formed based around SPICE versions. In almost every case the basic architecture of the program, as originally designed by Don Pederson and his students, is still used and in most cases, much of the original code is still present. Not only has Don's pioneering work been of vital importance to the semiconductor industry, it also has contributed significantly to the formation of a significant, new industrial base—integrated circuit CAD companies.

Beyond the clear commercial impact of the SPICE effort, one cannot overlook the impact this contribution has had on engineering education. In fact, the first versions of SPICE, in use at Berkeley in May 1972, were intended to augment instructional laboratories. Brian Preas noted that he had counted 12 textbooks and monographs at the Stanford University student bookstore that contained the word "SPICE" in the title, such as "Integrated Circuit Design Using SPICE." We concur when he says that he cannot think of a significant undergraduate electrical engineering instructional program anywhere in the world today that does not use the SPICE program as an integral part of its curriculum. No other electronic design automation tool or technology has had such a broad educational impact.

While there were numerous important scientific contributions in the original SPICE 1 and SPICE 2 programs, the success of this technology cannot be attributed to science alone. In fact, even the original developers of SPICE admit that there exist "better" algorithms than those used in SPICE, when considered separately. It is the *engineering* contribution—the way the algorithms and ideas were combined—and the unique, open relationship Don Pederson and his students established with industry that have resulted in a family of programs that have lasted almost intact and without significant competition for over a third of a century. Many programs have been developed for specific technologies, or which produce approximate results (using simpler models and algorithms) and so can run faster than SPICE on larger circuits, but for general purpose, robust circuit simulation, the user community seems always to fall back to the trusted and well-tested SPICE-based solution.

At the time the SPICE program was being developed, there were similar programs under development in major electronics companies worldwide. These programs used precursors to many of the techniques present in SPICE. A number of the early innovations in circuit simulation were developed as company proprietary. However, the original vision of Pederson's SPICE program development team was to put together the best combination of algorithms, to code them in as flexible and portable a style as possible, and to make them freely available. The only restriction placed on users was that they should never charge any third party for the SPICE program itself; Pederson considered it a public-domain resource. As a result, new ideas and contributions to SPICE flowed from many sources, both in universities and in industry.

Don always saw the circuit simulator as a means to an end, not as an end in itself. His attention was always directed to the solution of circuit design problems, both through heavy classroom use and in research; the simulator was developed as the best way to achieve that goal. It was the process used to develop the technology, as much as the technology itself, that represented the great insight Don Pederson contributed to the steps needed to develop and transfer the knowledge embodied in engineering research. In fact, Berkeley has continued to use this model, pioneered by Pederson, for its ongoing research in other electronic design automation areas. Other universities (for example, MIT and Carnegie Mellon University) follow similar models for their interaction with industry, based in part on the early Berkeley success.

Don Pederson died on December 25, 2004, aged 79, of complications from Parkinson's disease. He is survived by

Karen, his wife of 27 years; four children from his first marriage (to Claire Nunan): son John, daughters Katharine Rookard, Margaret Stanfield, and Emily Sanders; and four grandsons, all in California.

He was elected to membership in the National Academy of Engineering in 1974 and the National Academy of Sciences in 1982. He garnered numerous other honors and awards, including a Guggenheim Fellowship in 1968, an American Association for the Advancement of Science Fellowship in 1988, the Berkeley Citation in 1991, the Phil Kaufman Award from the Electronic Design Automation Consortium in 1995, and the Medal of Honor from the Institute of Electrical and Electronics Engineers in 1998. He also received an honorary doctorate from Katholieke Universiteit Leuven in Belgium.

The narrative above fails to do full justice to the Don Pederson so greatly loved by generations of students and close colleagues. Bill Howard, a former student already mentioned above, eloquently articulated an image of the man we knew so well in comments prepared for Don's memorial service (Howard, 2005), presented below in mildly edited form.

Don Pederson (or DOP, as he is affectionately known by students) was the guiding influence in my professional career and in many other dimensions of my life. Knowing many of his other students, I know the feeling to be universal. On the most elementary level, Don embodied the ideal of an engineer as one who uses science to achieve useful results. He practiced our profession with a spirit and enthusiasm that coupled all his and his students' efforts with his dedication. His face was a mirror reflecting all his zest, surmounted by a pair of expressive, brushy eyebrows that punctuated every thought.

He was an inspired teacher. All who studied circuits with Don knew that he held the Guinness World's Record for drawing a single transistor amplifier stage on the blackboard. His diagrammatic artistry was faster than the circuit itself could switch. After taking electronics from Professor Pederson you knew you had triumphed over the most challenging intellectual marathon in the field. His students were infected with his exuberance for whatever he was teaching. That, alone, makes Don an inspired educator, but he was much, much more.

Don was one of the most innovative people it has been my joy to know. When he and Bob Pepper established the Berkeley Integrated Circuits Lab, they led the world. Many said ICs couldn't be done in university environments. Many said it was too expensive. And many said it was too advanced for university work. Many were proven wrong. Berkeley has been the leader in this area for nearly forty years, based on Don and his team's foundation.

Don's imagination did not prevent him from having strongly held views. This applied to his technical work as well as to wine. When confronted with a circuit thermal drift problem I could not solve, I was compelled to consult Don for help. I informed him it was necessary to use computer simulation to find out what was going on, and was told, in his own inimitable way and in no uncertain terms, that "any problem worth solving can be solved on the back on an envelope." Don was the master at practical circuit engineering. We each agreed to take our own approach to see who could get to the solution first. When, after spending many nights writing a program that revealed the source of the drift, I went back to Don. I found him in his office, with his board covered with calculations and diagrams (and a lot of filled envelope backs) and no answer. Many at that point would have become defensive. Don looked at the computer results, went "humpf," and returned the next morning full of ideas on how to use circuit simulation in his electronics teaching and research. As we all know, he soon became the godfather of IC CAD and changed the way we all work. Don's and his students' creation, SPICE, is now the gold standard in IC design.

Don's innovativeness applied to every aspect of his work and life. Once he decided he was tired of trudging through the same subject material every semester and devised the idea of having his sophomore students read up on class material beforehand. He would come to class prepared to answer questions; if there were none, he would tell jokes. The first few weeks of the term were hilarious! After the first exam, things rapidly became very serious; his students really learned to be prepared and many developed the skills of independent research early.

Don's vitality was ubiquitous. Anyone who accompanied him on his lunchtime "safaris" (many of which entailed walking three or four miles), could not help but be affected by his enthusiasm, spirit and curiosity. When the two of us went to a Japanese woodworking shop, he became so intrigued with the novel tools that we almost did not get back home for the dinner party he and Karen were having (thereby earning a stern rebuke).

Although he professed to hate it, Don's talent for management was immense. His stints as Electronics Research Laboratory Director and Department Chair left Berkeley in superb shape. His skill at assembling a team of outstanding colleagues is evidence by their subsequent roles in the University.

It was Don's personal touch, however, that is my most treasured memory. He was always there to listen to his students' problems. His advice was always sound, well grounded, and definitive. As a young faculty member, he provided support when times seemed tough and when the road ahead seemed lost in a fog of uncertainty—the ideal mentor. He (together with Karen) was the best man at Kathy's and my wedding. He provided the most memorable moment of the ceremony: as Kathy started down the aisle, Don leaned over and whispered in my ear, "Look at her in all her beauty—and remember this moment all your married years.

Thank you, Don Pederson, for everything you mean to all of us. We will treasure having known you, been guided and taught by you, being shaped by you and inspired by you. And I can't suppress a grin at the image of Don at the Pearly Gates, correcting Saint Peter's great book by labeling each dangling participle with a red "dp," as he used to do for all of us.

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