The Life of SPICE

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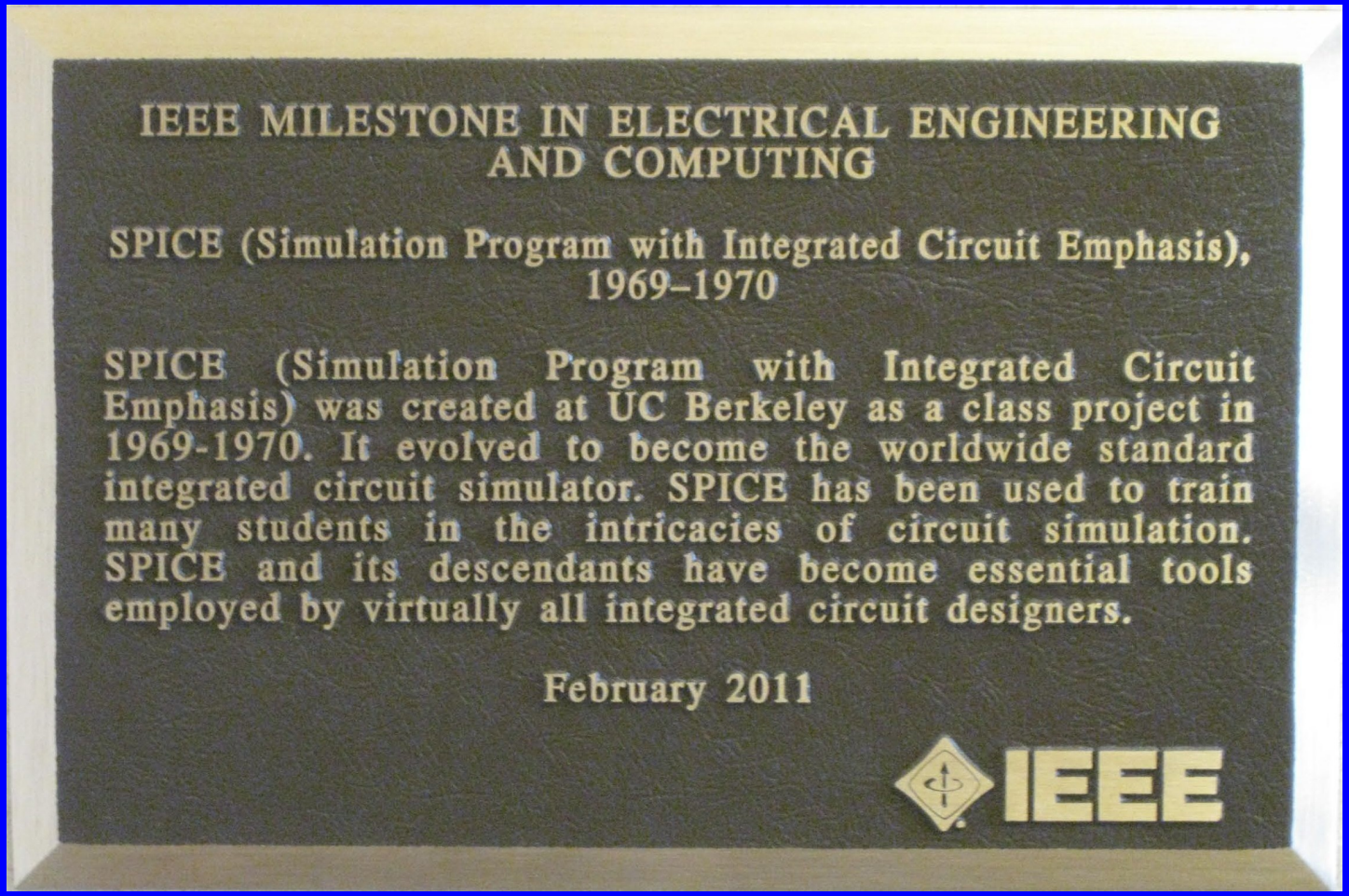
Simulation Program with Integrated Circuit Emphasis (SPICE)



Simulation Program with Integrated Circuit Emphasis (SPICE)

- SPICE is a computer tool that allows an engineer to simulate a circuit
  - Predict how a circuit will work without building and testing the circuit
- The input is a circuit schematic, or a netlist describing the schematic in textual form
- The output is whatever circuit voltages and currents the engineer wants to know
- SPICE works for dc, ac and transient time-domain analysis

Advantages of Using SPICE

- Allows the student to learn how circuits work without having to build them
- Allows the engineer to verify that a circuit works properly without having to build it
- Allows the engineer to determine the effects of variation of component values
- Allows the engineer to evaluate design alternatives prior to building anything
- Allows the engineer to evaluate the sensitivity of the circuit to component variations

Disadvantages of Using SPICE

- SPICE doesn't always “work”
- Student/engineer spends too much time playing with computers and not enough time thinking about circuits
- Student/engineer puts too much trust in SPICE and not enough trust in his or her thought process

“but the circuit must work --- SPICE said it would!”

(disillusioned undergraduate student)

SPICE (Simulation Program with Integrated Circuit Emphasis)

- First Released in 1971 and announced in 1973 at the Sixteenth Midwest Symposium on Circuit Theory
- Rapidly adopted by universities and industry in the early 1970's
- SPICE 2G6 became the de facto industry standard in the early 1980's
- How did this happen?

The Early Origins of SPICE

- SPICE began as an innovative class project under the direction of Ron Rohrer in the academic year 1969-1970
- The class topic was circuit synthesis but became a class on circuit simulation
- We learned by doing --- we wrote a simulator!
- The final judge of success was Don Pederson: if Don approved, we passed. Otherwise …
- I was appointed liaison to Don Pederson

A Perspective on Computing in 1970

- The computer at UC Berkeley at that time was a CDC 6400
- The input to the computer was punched cards
- The output of the computer was from the line printer
- The MIPS rate was comparable to on Intel 286
- The maximum available memory was 100,000 octal 60 bit words daytime and 140,000 octal at night

CANCER (Computer Analysis of Nonlinear Circuits, Excluding Radiation)

- The simulation program developed in Ron Rohrer's classes was named CANCER and became my Master's project with Ron Rohrer
- DC operating point analysis, small-signal AC analysis and transient analysis in one package
- Built-in models for diodes and bipolar transistors
- CANCER was the first simulator to utilize sparse matrix techniques

CANCER (Computer Analysis of Nonlinear Circuits, Excluding Radiation)

- Modified Newton-Raphson iteration with heuristics that worked well with bipolar circuits
- Implicit integration techniques to reduce problems with the widely spread time constants of an IC
- Use of Adjoint Circuit techniques to implement Sensitivity Analysis, Noise Analysis, and Distortion Analysis using Volterra Series
- About 6,000 lines of FORTRAN code

SPICE (Simulation Program with Integrated Circuit Emphasis)

- CANCER was never released, but was renamed SPICE and released into the public domain in 1971
- The Shichman-Hodges MOSFET model was added to assist Dave Hodges in teaching a MOSFET design course
- SPICE was used in undergraduate EE courses at UC Berkeley as a teaching tool
- SPICE also was used by graduate students in their IC design research projects

Why Was SPICE Successful?

- Public Domain
- DC, AC, Transient, Noise, and Sensitivity Analyses in the same program
- Built-in models for diodes, bipolar transistors, MOSFETs, and JFETs
- Heavy use of SPICE by students led to many improvements in robustness
- At the time, could handle fairly large circuits
- Written in fairly portable FORTRAN

SPICE Limitations

- According to student feedback, not very user friendly!
- Limited error checking
- DC Nonconvergence
- No Transient Timestep Control
- No dynamic memory allocation
- After all, this was a class project!

SPICE2

- Once SPICE was released, I began the development of SPICE2 as a part of my doctoral research with Don Pederson
- This work allowed me to study the algorithms and techniques of circuit simulation in depth
- This work involved a total rewrite of SPICE

SPICE2

- First released into the public domain in 1975
- Contained all features of SPICE
- Data structures totally revamped to incorporate dynamic memory allocation
- Thorough upgrade of DC convergence and transient numerical integration algorithms
- About 8,000 lines of FORTRAN

More About SPICE2

- After I left UC Berkeley to work at Bell Labs, Ellis Cohen took command
- Ellis spent endless hours improving and debugging SPICE2
- Ellis then passed the reigns on to Andrei Vladimirescu, who also worked hard and long
- SPICE 2G6 was released in 1981 and became the industry standard version of SPICE

University Use of SPICE2

- SPICE2 replaced SPICE at many universities and was adopted by many more universities
- At this point, SPICE simulations were an integral part of circuit design courses and even included in Gray & Meyer
- SPICE2 was used as a platform for research that spawned hundreds of research projects

Industrial Use of SPICE2

- Many industrial research centers adopted SPICE2 and developed proprietary versions of the program, including Bell Labs (ADVICE), Texas Instruments (TISPICE), Motorola (MCSPICE)
- Shawn and Kim Hailey formed Meta Software and modified a copy of SPICE 2E into the most successful version of a commercial SPICE known as HSPICE
- Numerous other “alphabet SPICEs” followed

Why SPICE2 was Successful

- Public domain
- Totally compatible with SPICE
- Dynamic memory allocation
- Vastly improved DC convergence and transient timestep control
- The addition of many useful features such as subcircuits, transmission lines, etc.

SPICE3

- Inl 1983 Tom Quarles did a Master's project at UC Berkeley where he converted SPICE2G6 into a RATFOR version that he named SPICE3
- In 1989, SPICE3 was released into the public domain
- This later version of SPICE3 then was coded into the C language to utilize the more sophisticated data structures of C
- SPICE3 contains about 135,000 lines of C code
- The latest version 3F5 was released in 1993

University Use of SPICE3

- Adopted by many universities who welcomed SPICE3 both as a more robust circuit simulator and as a computer program utilizing a modern language and its more sophisticated data structures
- Prompted many new research projects in circuit simulation, particularly more computer-science oriented projects

Commercial Use of SPICE3

- Microsim adapted a version of SPICE3 for the most popular of all SPICE programs --- PSPICE
- Many other companies utilized SPICE3 as a platform for additional “alphabet SPICE” programs

Why SPICE3 Was Successful

- Public Domain
- Easy to add device models, which has become the defining point of circuit simulators
- Modern data structures and the C language made new enhancements easier for researchers who didn't understand FORTRAN

Why is SPICE Still Around?

- SPICE provides the capability to accurately simulate the DC, AC, and transient characteristics of a fairly large circuit at the device level
- SPICE is in the public domain
- It is taught at almost all universities
- It clearly is the industry standard

The Real Reasons SPICE is Still Around

- Two Visionaries in the IC Industry
  - Ronald A. Rohrer
  - Donald O. Pederson
- A tremendous amount of effort on the part of a huge team of graduate students