Recent Extension to the Collection - HP 9100 - First Desktop Calculator

The HP 9100 Calculator:
A fundamental item in the HP Computer History,
A fundamental item in the Personal Computing History.

The calculator, computer and peripheral part of the Memory Project is not yet on line. To help the computer enthusiasts waiting patiently, we will take advantage of the recent acquisition of a 9100B desktop calculator to develop a little chapter dedicated to this major item in the Hewlett-Packard Computer history.

Many sources of information are available for an accurate understanding of the importance of the Model 9100 calculator. A collection of links to other web sites and references to other writings are available in the last paragraph at the bottom of this page.

It is very difficult to make it short while talking of the importance of the 9100 in the history of HP. Before the 9100, born in 1968, every HP computer was almost dedicated to internal production test and automation. Even if these first products, like the 2116, frequently found customers in the stand-alone minicomputer market, early HP computers were very industry oriented. The 9100 marks the first step of HP in the large public market, and above all, the technologies developed for the hardware and software of this first, desktop sized computer, will be the basis of the next to come leap forward: The HP35, the world's first pocket scientific calculator, which will cause the death of the slide rule in 1972.

In his book: "Inventions of Opportunity" Bill Hewlett summarizes the Model 9100 Project:

"...a new project took its place in HP Labs to develop a powerful desktop electronic calculator. We were approached by a young inventor who had perfected a simple four-function calculator of practical design using reverse Polish notation. At about the same time, a technique for achieving single-key transcendental functions also was brought to our attention. The question: Can the two technologies be made to work together? The answer: Yes, and a formal development project was initiated. This was a formidable program, for not only were the technical problems pioneering and difficult, but as this calculator was to be used for general scientific work, often by customers unskilled in computer operation, it had to be well-styled, "friendly," and easy to use. This obviously was a major problem, and ultimate manufacturing responsibility was assigned to our division in Loveland, Colorado. Engineers from Loveland came to Palo Alto and worked hand in hand with engineers in HP Labs to complete a prototype unit, thus insuring that the transfer to Loveland would be achieved without difficulty. Within two years, the project was completed and the unit in production. There are four articles which discuss various aspects of this program. I particularly call your attention to Barney Oliver's article, "How the Model 9100A Was Developed," one of several articles about the calculator in the September 1968 HP Journal..."


The HP 9100B Calculator

The HP 9100 Computing Calculator

The model 9100A is introduced in the September, 1968, Hewlett-Packard Journal and appears for the first time in the 1969 catalog, page 130 with the following description:

The 9100A is a programmable, electronic calculator which performs operations commonly encountered in scientific and engineering problems. Its log and trig functions are each performed with a single key stroke, providing fast, convenient solutions to intricate equations. Computer-like memory enables the calculator to store instructions and constants for iterative solutions. The easily-readable cathode ray tube instantly displays entries, answers and, when desired, intermediate results.

Direct keyboard operations include: Arithmetic, Logarithmic, Trigonometric, Hyperbolic and Coordinate transformation. Decimal point is selectable, fixed or floating-point notation for display of entries or answers. A decimal wheel selects 0-9 decimal places, with automatic rounding to the number of places selected.

Magnetic core memory contains 19 registers: 3 displays registers (keyboard, accumulator, temporary) and 16 storage registers, with store/retrieve controls. These registers may be used to store 16 constants, or 196 program steps plus 2 constants, or a combination of constants and program steps. The read-only memory contains over 32,000 bits of fixed information for keyboard routines.

Programming: The program mode allows entry of program instructions, via the keyboard, into program memory. Programming consists of pressing keys in the proper sequence, and any key on the keyboard is available as a program step. Program capacity is 196 steps. No language or code-conversions are required. A self-contained magnetic card reader/recorder records programs for program memory onto wallet-size magnetic cards for storage. It also reads programs from cards into program memory for repetitive use. Two programs of 196 steps each may be recorded on every reusable card. Cards may cascaded for longer programs.

Speed: Maximum times for total performance of typical operations, including decimal-point placement:

Add, substract: 2 milliseconds. **Multiply:** 22 milliseconds. **Divide:** 27 milliseconds. **Square-root:** 30 milliseconds.
Sin, cos, tan: 330 milliseconds. **In x:** 130 milliseconds. **Coordinate transformation:** 280 milliseconds.

It is interesting to note that computer performance of this size was state-of-the-art just one year before the first moon landing.

Price: $4900. (Average cost of a new car in the USA in 1968 was $2800)

Inside the HP 9100

The model 9100A is made of discrete components only. It does not contain integrated circuits, except for a couple of operational amplifiers in the card reader board . The storage capacity (Read Only Memory) required by the HP 9100 design is about 1000 times beyond the abilities of the primitive integrated circuits available at the time. The ROM used must have 64 outputs and must store 32,768 bits. It is made of a large, complex, 16-layer, Teflon printed circuit board and 2400 discrete diodes.
Program and variable storage-space requirements are also beyond the then state-of-the-art integrated circuits so the HP 9100A uses magnetic core memory popular in mainframe and minicomputers of the 1960s.

The display consists of a CRT with oscilloscope-like internal adjustment of brightness, focus and astigmatism. The numbers are formed from an 8 segment format just like the LED displays that will come later. The entire three level stack is displayed on three lines.

An in-depth description of the 9100 hardware design is made in the September, 1968, Hewlett-Packard Journal.

Inside View of the 9100B Calculator

The 9100, Versions & Accessories

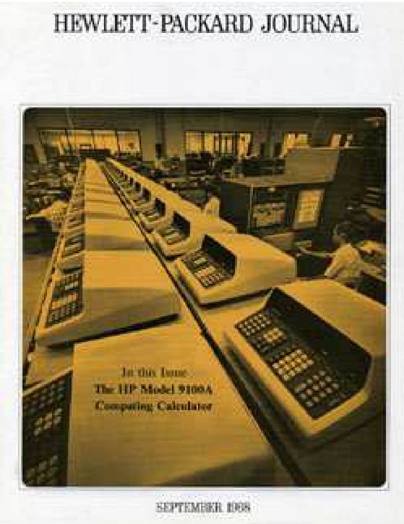
The HP 9100A was introduced first in 1968 with maximums of 16 storage registers and 196 program steps.


The HP 9100B Calculator with 9120A Printer

The HP 9100B, in 1970 doubles this capacity with maximums of 32 storage registers and 392 program steps. On both machines, core was shared between registers and program steps. (The 9100B had two pages of core.) The HP 9100B also added subroutines, a dual program display, and a key to recall numbered registers into X.

The HP 9101A Extended Memory, is introduced in the 1971 catalog supplement. It is a rack mountable box of core memory providing an additional 3472 program steps or 248 data registers. This option could be added to either model.

The Model 9120A Printer, shown on the above photo, attaches to the top of the calculator. It is introduced in late 1969 for use with the 9100A and remains compatible with the 9100B version. The 9120A, electrostatic printer, prints the contents of display registers X, Y, Z, singly or in any combination, upon manual or programmed command.



Cover of Sep. 1968, Hewlett-Packard Journal
Courtesy of the Hewlett-Packard Company

The HP 9100 in the Hewlett-Packard Journal

The September, 1968 edition of the Hewlett-Packard Journal is entirely dedicated to the 9100 calculator. The following four articles are reproduced here:

1- A New Electronic Calculator with Computerlike Capabilities

2- Hardware Design of the Model 9100A Calculator

3- Internal Programming of the 9100A Calculator

4- Computer-Testing the HP Model 9100A Calculator

Full content of this Hewlett-Packard Journal, and many others, can be downloaded in PDF format from the Glenn Robb "hparchive" Web Site.

Barney Oliver Analysis of the 9100 Project

On the back cover of the September,1968 Hewlett-Packard Journal R&D Vice President Barney Oliver discusses the HP Model 9100 project. The reading of this page gives a measure of the motivation generated inside the various divisions who contributed to the Model 9100 project.

How the Model 9100A Was Developed

By Bernard M. Oliver
Vice President for
Research & Development

Some lab projects are endothermic: the desired reaction proceeds only with the application of considerable heat and pressure and stops the moment these are relaxed. Others are exothermic: when the proper ingredients are brought together the reaction starts automatically and it is only necessary to harness and control the power that is generated. The 9100A project was one of the most exothermic I have known.

The ingredients started coming together in the late summer of 1965 when we were shown a prototype of a calculator invented by Malcolm McMillan that had one interesting feature: it could calculate all the common transcendental functions. The machine operated in fixed point and took a few seconds to calculate a function, but it did demonstrate the feasibility of providing these functions in a small calculator, and the power of the algorithm used to compute them.

The second ingredient was Tom Osborne who came to see us carrying a little green balsa wood calculator, which he had built on his own to demonstrate the virtue of some of his design concepts.

The task of compressing the floating point arithmetic operations and functional computations into the limited read only memory of the 9100A was accomplished by Dave Cochran. To make sure that all the calculations were accurate over the enormous range of arguments allowed by the floating point operation, to assure exact values at certain cardinal points, and above all to get so much in so little memory space was an enormous achievement.

I sometimes wonder if Dave realizes what a remarkable job he did. It took several passes. On the first pass it appeared hopeless to include all the functions. But by nesting routines and by inventing a number of space saving tricks he was able to save enough states to crowd them all in. Then various bugs were discovered and more states had to be freed to correct these. The 'battle of the states' continued for several months and the end result was one of the most efficient encoding jobs ever done.

The necessity for magnetic card program storage and entry became apparent as soon as we had an operating prototype. Don Miller,

What impressed us was its millisecond speed and its ten digit floating point operation and display.
A third ingredient was the imagination of Paul Stoft and other engineers in his group. It took no genius to see the appeal of a calculator that combined the speed and dynamic range of Tom's machine with the transcendental computing ability of the other machine. But to combine them into a small machine faster than either prototype, to adapt the transcendental algorithm to floating point, to add programmability and magnetic card storage and entry of programs, to provide the flexible display with automatic roundup, and to design the whole assembly for automated production required not only imagination but engineering skill of the highest order.
Another ingredient, the read only memory, which stores all the calculating and display routines, was already under development by Arndt Bergh and Chuck Near before we began the 9100A project. By carrying printed circuit techniques beyond the existing state of the art, Chuck was able to compress the required 32,000 bits into an amazingly small space. While the 9100A uses only discrete diodes and transistors, it it fair to describe the read only memory as one large integrated circuit with extremely long life expectancy.
As soon as the development began, everyone, it seemed, had ideas for new features. Hardly a day went by without someone proposing a new keyboard with a new key arrangement or new functions. It was Dick Monnier's responsibility as section leader to steer the project through these conflicting currents of ideas. Although we went down a couple of blind alleys, for the most part the course was held true. That we arrived at such an elegant solution in a short time is a tribute to Dick's navigation.
Tom Osborne joined the development team as a consultant on the general architecture of the machine. His contributions include the basic logical design, and the details of the control logic, flip-flops, mother board gates, and the memory drive and sense circuitry. He also contributed a large measure of sound judgment that resulted in an economy of design, low power consumption, high performance, and the ability of the 9100A to interface with peripherals and systems.
Tony Lukes developed the display routines, which include the features of automatic roundup in fixed point display, choice of decimal places, suppression of insignificant zeros, and the display of program step addresses and key codes, as well as numerical data. Tony also developed the program storage, editing, and execution routines which, together with the display, make the 9100A easy to use and program.
I should at this point emphasize that the 9100A, while small, is, in a sense, much more complicated than many general purpose computers. Most general purpose computers have relatively large memories but can execute directly only certain elementary machine instructions. To compute complicated functions and indeed, in some cases, even to perform simple arithmetic, the computer must be externally programmed.By contrast the 9100A has a very sophisticated external instruction set: the entire keyboard. The 9100A is a small computer with a large amount of 'software' built in as hardware.
Dick Osgood and Bob Schweizer deserve praise for the speedy development of this unit, which adds so much to the convenience of the 9100A.
Clarence Studley supervised the overall mechanical design and assembly, reducing to manufacturing drawings and to the final metal the handsome cabinet styling of Roy Ozaki, Don Aupperle and others in the Industrial Design group, while Harold Rocklitz and Doug Wright handled much of the tooling.
Many other people contributed to the 9100A — too many to give proper credit to all; but I must mention the fine art work of Frank Lee on the read only memory and other printed circuit boards, Chung Tung's work on the core memory electronics and Bill Kruger's development of the short high brightness cathode ray tube. Chris Clare made many contributions to the project especially in the area of interfacing the calculator with printers and other peripherals. A special measure of recognition is due Ken Petersen whose expert technicianship and whose genius at trouble shooting saved us weeks of time and bailed us out of many tight spots. Ken also laid out the multilayer mother board with its thousand diode gates and interconnections.
The transfer of the 9100A from Hewlett-Packard Laboratories to the Loveland Division took place gradually rather than abruptly. As various portions reached the final prototype stages, responsibility for these was assumed by the Loveland group headed by Bob Watson in engineering and by Jack Anderson in production. Many visits both ways and some transfer of people to Loveland accomplished the transmission of much unwritten information. The Loveland team introduced several engineering improvements. Especially significant were the improved read only memory margins obtained by Rex James and the many contributions by Ed Olander, whose comprehensive understanding of the entire machine helped greatly. That we were able to go from an incomplete lab prototype stage in Palo Alto to a pilot run of final instruments in Loveland in only 10 months attests to the skill and dedication of the Loveland group and to the fine cooperation on both sides.
Finally, I must confess that very few projects receive as much direct attention from corporate management as this one did. Early in the spring of 1967 a skiing injury landed Bill Hewlett in the hospital. We learned about this right away when he called up to have some 9100A programming pads sent over. I found myself hypnotized by the project and unable to share my time equitably. Here was management in the unusual role of consumer, for if Bill and I did anything constructive it was mainly to assess and modify the developing product from the user's standpoint. I owe the 9100A group an apology for being constantly in their hair, and everyone else in HP Labs an apology for slighting their projects. Now that it's all over I find the 9100A as fascinating to use as it was to develop. Caveat emptor!

HEWLETT-PACKARD JOURNAL SEPTEMBER 1968 Volume 20 · Number 1
TECHNICAL INFORMATION FROM THE LABORATORIES OF THE HEWLETT-PACKARD COMPANY PUBLISHED AT 1501 PAGE MILL ROAD, PALO ALTO, CALIFORNIA 94304
Editorial Staff: F. J. BURKHARD, R. P. DOLAN, L. D. SHERGALIS, R. H. SNYDER Art Director: R. A. ERICKSON

Model 9100 Position in the HP Computer Timeline

The panoramic picture below is made of various computers available in the collection. The selected items are the most representative of the computer product line evolution at HP.
A chronological developement of their characteristics and their respective historical importance in the HP history is under construction and will be inserted, step by step, in the "Quick Tour". Planned dead lines for this work are: First half 2007 for the 1960-1980 period, and second half 2007 for the 1980-2000.

The objective of this animation is just to give an overall view of the very large variety of computers made by HP from 1966 to 2000. The position of the products relative to the dates are approximate. For the purists, we are working on an accurate classification, like the one made for the instruments. It will be inserted later in the Collection chapters. Waiting for that, the best information related to the Hewlett-Packard Computers production story can be found on Jon Johnston's Web Site.

In-depth Understanding of the Model 9100

Many sources of information are available for an accurate understanding of the importance of the 9100 calculator in the Hewlett Packard entry in the computer age.

The Steve Leibson web site is certainly the most accurate about the early computing evolution at HP. Steve Leibson who worked at the Loveland factory made an in-depth description of the major steps of the HP early computer production. Starting with the 2116 instrumentation computer up to the birth of the 9825 "The little Computer that could!", Steve relates a complete historical timeline of the various orientation taken by HP to produce a co product line as successful as was its previous production in the instrumentation business. In a chapter specifically dedicated to the 9100 Project, Steve Leibson unveils all the details of the human side of the story with a wonderful style rarely found in technical writing.

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" Sometimes it feels like the planets have aligned, the fates are all pointing at you, and "somethin's just gonna happen." HP's VP of Research Barney Oliver must have felt like this in June of 1965 when he was visited by not just one but two inventors who had different but equally radical ideas for building a scientific calculator."

What follows this Steve's introduction is the most pleasant reading you could find regarding computer birth at HP.

The David G.Hicks web site gives many details on the 9100 functionalities. A very detailled description of the ROM program memory used in the Model 9100 calculator is available on the "Technology and Packaging" chapter. It is a wonderful description of the theory of Magnetic Core Memory... For young people who don't know that early computer memory was made of magnetic cores, and for older folks who don't remember :-)

The Jacques Laporte web site offers a very clear and accurate description of the "CORDIC" algorithm employed first in the 9100A, then in the HP35 handheld scientific calculator.

John Minck himself had many important influences all long the 9100 developement project. From its R&D to its Production, John's "Inside HP Narrative" includes many chapters dedicated to the 9100. A mine of information never published elsewhere.

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