THE DEC PDP-8 STORY

THE FIRST LINE OF TRULY SMALL COMPUTERS

Part I - the beginning

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On August 11, 1963, Digital Equipment Corporation unveiled a new machine at Wescon (the Western Computer Conference); this machine, the PDP-5 was the first of the family of machines that continued with the PDP-8 and ended with the demise of the DECmate III+ in 1990. This article is the first of a series of articles on these computers, covering the early history of the "Family of 8" computers and the dawn of the minicomputer revolution.

Today, the word minicomputer sounds a bit quaint, referring as it does to a breed of computer that has all but disappeared from the scene. Today, the world is dominated by microcomputers, personal workstations, file servers and supercomputers, and it is easy to forget the revolutionary impact of the minicomputer.

In late 1964, DEC began taking orders for the PDP-8, a new machine that was to replace the PDP-5. At $18,500, this machine cost one third less than the PDP-5 because of the new technology it used.

The Historical Setting

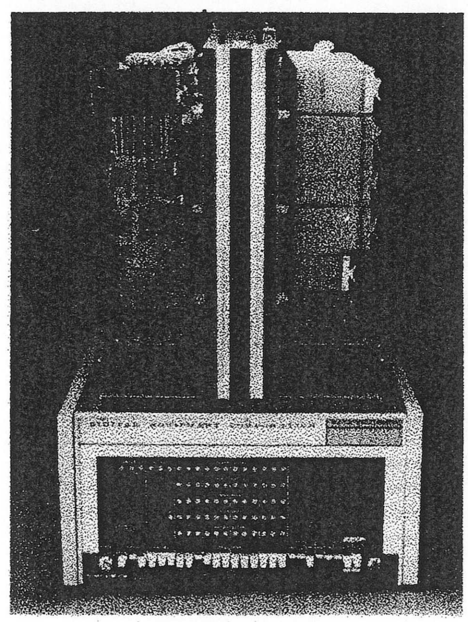
In 1960, the world of computing was dominated by giants, hulking great monsters of machines, costing millions of dollars, hidden away in air conditioned solitude, tended by white-coated technicians and isolated from their users behind security doors and layers of bureaucracy. Vacuum tubes were the dominant technology, and various companies were racing to bring the new generation of transistorized computers to market. IBM's experimental 704T, a transistorized version of their 704, was the machine to beat, but young aggressive companies like Digital Equipment Corporation and Control Data Corporation had their own transistorized machines on the market.

Digital Equipment Corporation, or DEC, was founded in 1957 with $100,000 in capital, mostly provided by the venture capitalists at American Research and Development Corporation. Ken Olson and Harlan Anderson founded the company with the aim of producing transistorized computers, and they wanted to call it the Digital Computer Corporation. The people at ARDC, though, didn't like this name; they felt that the market for computers was too small, and urged the new company to concentrate on the market for transistorized digital logic modules.

Despite this pressure from their major stockholder, DEC developed a digital computer, but to avoid offending their stockholders, they didn't call it a computer, they called it a "Programmable Data Processor," the PDP-1. The first of these was delivered to BBN in early 1961, and DEC quoted a price of $85,000 for a bare bones system. The PDP-1 was a moderate sized machine, with 18 bits per word, but even so, it undersold most of the other machines on the market by a wide margin. The PDP-4 was a modestly successful follow up, but while it was being developed, two other groups came out with even smaller machines.

At CDC, one of Seymour Cray's first ventures was the design of the CDC 160, a transistorized computer with only 12 bits per word. The CDC 160 was packaged in a desk, a revolutionary idea at the time, with a front-panel display that looked like an expensive digital clock. The CDC 160 hit the market at about the same time as the DEC PDP-1, and within a few years, hundreds were sold, helping to pave the way for CDC's explosive growth into the world's leading producer of supercomputers, a position they held until Cray left CDC to form his own company.

While this was going on, Wesley Clark at Lincoln Labs and Mary Brazier, a neurophysiologist at MIT developed the idea that a small computer, equipped with analog to digital and digital to analog converters, would be the ideal laboratory tool for biomedical research. Like Cray, they chose a 12 bit word for their machine, which they named the LINC, or Laboratory Instrumentation Computer; they built this machine using logic modules purchased from Digital Equipment Corporation. The LINC was an immediate success, and as is common in the research community, the plans were made available to others. Over 24 LINC systems were built from these plans by various laboratories around the country before DEC recognized the market and began to sell machine in ready-made form.



An early pdp-8

The DEC PDP-5

The early market success of the CDC 160 and the demonstrated market for LINC systems led DEC to develop a new machine, the PDP-5, unveiled in August 1963. The marketing campaign for the PDP-5 was aggressive - "Now, you can own the PDP-5 computer for what a core memory alone used to cost: $27,000." Other computer companies didn't usually sell computers at the time, they leased them. DEC not only sold their machine, but they advertised a list price that was far less than the annual payments on most of the computers then on the market!

What made the PDP-5 so inexpensive? Nothing was included that wasn't absolutely essential. The word size was 12 bits, the minimum memory offered was 1024 words, and there wasn't even a subtract instruction! With most computers, a complete listing of the instruction set would be out of place in a historical overview such as this, but with the PDP-5, such a list is easy to provide:

OPCODE I Z ADDRESS

000 - AND - and operand with the accumulator
001 - TAD - add operand to the accumulator
010 - ISZ - increment and skip if result is zero
011 - DCA - deposit (store) and clear accumulator
100 - JMS - jump to subroutine
101 - JMP - jump

Each of the above instructions had, in addition to the 3 bit opcode, 7 bits of address, I, an indirect bit, and Z, a bit to indicate whether addressing was to page zero or to the current page as indicated by the program counter. Instruction 110, IOT, was reserved for input output operations, with 6 bits of device address and 3 bits to tell the device what to do.

1 1 0 DEVICE OPERATION

Instruction 111 was used for two groups of microcoded operations; the first of these had one bit assigned to each of the following operations:

1 1 1 0 A B C D E F G H

a) CLA - clear the accumulator
b) CLL - clear the link (carry) bit
c) CMA - ones complement the accumulator
d) CML - complement the link bit
e) RAR - rotate accumulator and link one bit right
f) RAL - rotate accumulator and link one bit left
g) *** - double the shift count for RAR or RAL
h) IAC - increment the accumulator

These could be microcoded, so, for example, the instruction CMA IAC (7041 octal) did a two's complement, and the constant - 2 could be loaded with the microcoded combination of CLA CLL CMA and RAL (7344). There was no mnemonic for the bit that doubled the shift-count; instead, the assembly language mnemonics RTR and RTL set both the appropriate rotate bit and the double bit.

The second group of microcoded instructions allowed a full assortment of conditional skip instructions, as well as some miscellaneous operations:

1 1 1 1 A B C D E F G 0

a) CLA - clear the accumulator
b) SMA - skip on minus accumulator
c) SZA - skip on zero accumulator
d) SNL - skip on nonzero link (carry bit)
e) *** - invert the sense of the skip instruction
f) OSR - or switch register with accumulator
g) HLT - halt

These could also be microcoded, so, for example, SMA SZA CLA (7700 octal) would skip the next instruction if the accumulator was negative or zero and then clear the accumulator. There was no specific mnemonic for the skip-invert bit; instead, the assembly language mnemonics SPA, SNA and SZL would set both the appropriate skip bit as well as the invert bit.

Within a year of its introduction, 34 PDP-5 systems had been delivered, and another 28 more were on order; at the time, this was a respectable start for a new machine, and it was sufficient to justify expending the effort to design a follow up machine. DEC sales literature lists the following PDP-5 applications, at a time when about 75 machines had been delivered:

Research Experiments and Measurement
Pulse-height analysis
Time-of-flight and bubble-chamber measurements
General physics investigation

Quality Control Testing and Statistical Analysis
Tensile-strength testing
Electronic component testing
Analog to and digital circuit module testing
Computer peripheral equipment testing

Data Acquisition, Reduction and Analysis
Oceanographic research
Biomedical research
Telemetry
Real-time analog signal monitoring

Process Control
Steel mill control
Typesetting
Chemical and Petroleum industry process control
Nuclear Reactor monitor and control

Data Processing
Open shop computing
Hybrid processing
Media conversion

Communications
Multi-user time-shared computing
Message switching systems
Data collection and processing

Education
Engineering
Programming fundamentals
Colleges, high schools, industrial training

Despite DEC's announcement of the PDP-8, new orders for PDP-5 systems continued to come in until 1967; this is probably because customers with one machine wanted more machines that were fully compatible with what they already had. By the end of the production run, a total of 116 PDP-5 systems had been installed.

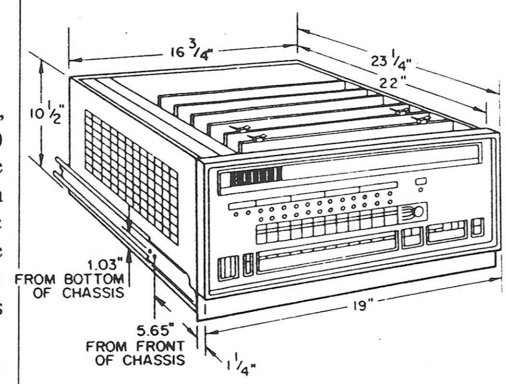


Figure 11-2 Rack-Mounted PDP-8/E Dimensions

The DEC PDP-8

In late 1964, DEC began taking orders for the PDP-8, a new machine that was to replace the PDP-5. At $18,500, this machine cost one third less than the PDP-5 because of the new technology it used. Among these innovations were the use of a new line of circuit boards designed for mass production, and semi-automatically wire-wrapped backplanes. Another technology DEC introduced with the PDP-8 was the Flip Chip (tm) very small scale hybrid integrated circuit. Flip-chips were networks of 5 or so diodes and resistors, mounted on a ceramic substrate. This was essentially a dead-end technology, but it allowed DEC to sell the PDP-8 as an integrated circuit computer. From the start, DEC also used the term Flip Chip to refer to their line of logic modules, and this usage persisted into the 1970's.

In addition to a price advantage, the PDP-8's use of new technology reduced the power consumption of the machine to 780 watts - less than many hair dryers! The new technology also allowed the size of the machine to be reduced to the point where a table-top model could be offered, but at 250 pounds, the table needed to be fairly strong.

In the case of the PDP-5, a number of shortcuts were taken to reduce the price at the expense of performance. The worst of these was the use of memory location zero as the program counter. Such measures were not needed in the PDP-8, and in fact, the PDP-8 was fairly fast, for its time, with most instructions limited by the core memory cycle time of 1.5 microseconds. The PDP-8 had a minimum of 4K words of core memory, and, with an optional memory management unit, it could be expanded to 32K words. Memory expansion required a considerable amount of rack mounting space; the 7 upgrade modules needed for the full 32K filled all of one 6 foot high mounting rack and part of another.

The PDP-8 was a wildly successful machine. The first 9 PDP-8 systems were delivered in July, 1965, and by December, 75 systems had been delivered and over 300 more were on order. Within another year, the 400th PDP-8 had been delivered, and almost 300 more machines were on order. The chief rival in the marketplace, the CDC 160, was left in the dust, and other competitors were scrambling to introduce their own small computers.

The PDP-8 was eventually displaced from the market by a newer model, the PDP-8/I, based on TTL integrated circuit technology. This machine was introduced in 1968, but the original model remained in limited production until 1970, by which time 1440 machines had been sold. Many of these survive to this day in operating condition.

Peripherals

Even in 1965, Small computers demanded small peripherals. While large computer centers were content to use massive and noisy line printers for text output, PDP-8 systems were usually sold with just an ASR 33 Teletype. The paper-tape reader and punch on the side of the ASR 33 was sufficient for small scale off-line storage, and in fact, many PDP-8 systems lived long productive careers with no other input-output devices. If a user needed higher capacity input-output than a Teletype could provide, DEC offered a high speed paper tape reader and punch, a conventional big line-printer, and interfaces to standard IBM punched card equipment. When equipped with such peripherals and expanded to the full 32,768 word capacity of the memory management unit, a PDP-8 looked suspiciously like a large mainframe computer system.

Wesley Clark, in developing the LINC, had realized that users needed a compact and reliable way to store data and programs. To meet this need, he had devised a new magnetic tape recording format, the LINCtape. This used 4 inch reels of 3/4 inch wide tape, with a highly redundant recording format that eliminated the need for most of the conventional warnings about careful tape handling. Linctapes could be carelessly stuffed in a jacket pocket or dropped on the floor with little fear that such treatment would damage them.

The data format used on LINCtape was block addressable, so that any block on the tape could be read or written without disturbing adjacent blocks. It is fair to say that the LINCtape was designed to meet most of the same specifications as were later met by floppy disks.

DEC took the idea of LINCtape and improved slightly on the data format, calling the result DECtape; this came close to being the perfect small magnetic tape format for a small computer, and as a result, the stereotypical modest sized PDP-8 system was one with two DECtape drives and a teletype. DECtape continued in use on most DEC computers well into the 1970's, both for off-line storage and data interchange.

Noting the success of the LINC and the CDC 160 in laboratory applications, DEC offered a full line of laboratory peripherals for the PDP-8, including analog to digital converters, computer controlled analog multiplexors, digital to analog converters and oscilloscope displays.

The PDP-8 was an open-architecture machine from the start; the maintenance manuals that came with one contained many of the engineering drawings for the machine, and they gave all the details necessary for users wishing to build their own peripheral interfaces. This was ideal for a machine that was used for laboratory instrumentation and industrial automation, and when you find a PDP-8 system today, chances are, you'll find a few homebrew peripherals.

Spinoffs

DEC sold many PDP-8 systems directly to end-users, but they quickly discovered the OEM, or Original Equipment Maker market, and began selling machines customized to the needs of specific OEMs. Frequently, this customization was minimal, for example, the Foxboro corporation, which used PDP-8 systems in the industrial automation products they sold, had them relabeled PCP-8. Another early OEM customer was Hewlett Packard, until they came out with their own line of minicomputers. DEC also began to package PDP-8 systems for specific applications; for example, the Typeset-8 system was a bundled hardware-software system that was widely sold to large newspapers and publishing houses. In effect, these were text editing and formatting systems, with rough-draft output on the computer's line printer, and final-draft output in the form of a paper-tape to control a typesetting machine.

Another standard package was the Display-8, or Type 338 buffered display. This consisted of a PDP-8 with attached CRT display and light pen; although this could be used as a stand-alone system, it was typically sold as a "smart terminal" for use with a large mainframe such as a PDP-6 or PDP-10. Much of the early interactive computer graphics work done at MIT in the 1960's used these display systems.

Finally, there was the LINC-8, a complete PDP-8 combined with most of a LINC in one package. This machine had two operating modes, LINC mode and PDP-8 mode, and it was a very successful laboratory machine, with convenient I/O support for lab peripherals provided by the LINC combined with the general purpose programming environment of the PDP-8. 142 of these systems were built, some of which survive to this day.

In the Next Issue

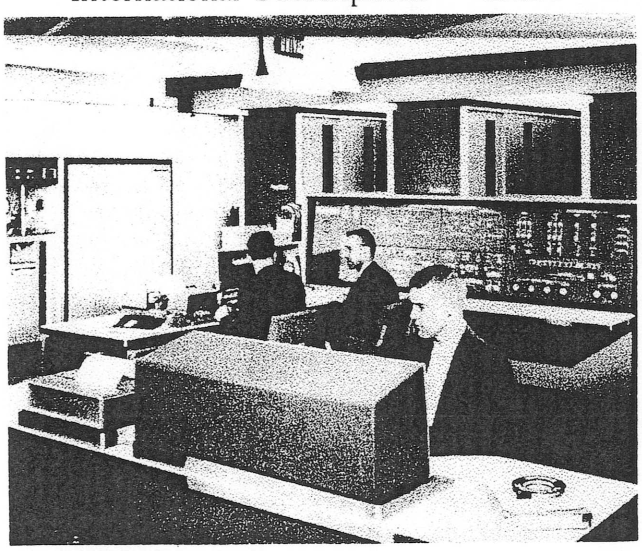
The classic PDP-8 was such a success that many other companies began to produce their own minicomputers. The next installment in this series will focus on the competition and on how DEC reacted to maintain its lead in the minicomputer marketplace.

Next month's story will cover the development of the PDP-8 family from the PDP-8/S, the first computer sold on a retail, cash and carry basis, to the PDP-8/E, introduced in 1970 and considered by many to be the definitive model of the PDP-8.

Sources

I have based my sales figures on a series of monthly "Computer Census" reports published by the journal *Computers and Automation* through the 1960's. The same journal also published many DEC press releases, as did *Communications of the ACM.* Another major source I have used is my collection of DEC handbooks, maintenance manuals, and sales literature.

Finally, I have relied on personal recollections of many long-time DEC users, including Bernard Weiss, who built one of the first 12 LINC systems, Charles Lasner, the owner of many PDP-8 systems and the keeper of a huge amount of DEC lore, and many others, many of whom populate USENET's alt.sys.pdp8 newsgroup.



A LARC Computer, 1965

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