DEC PDP-11 Family

MANAGEMENT SUMMARY

DEC's PDP-11 family barely predates the 1970's, but it has evolved into the minicomputer industry's broadest series of processors, supported by a family of common peripherals, operating systems, and applications software. The evolution of this extensive family has been steady and deliberate, with DEC improving the line by incorporating technological advances only after each member had gained a degree of stability. By adopting this more conservative approach, DEC has consistently produced reliable, cost-effective systems.

The original PDP-11, the 11/20, introduced in March 1970, defined the architecture that was eventually to become 15 models using 4 basic processors. Over a year later, in April 1971, an OEM version of the PDP-11/20, the PDP-11/15, was introduced. This new model employed the same CPU as the 11/20, and differed only in market orientation.

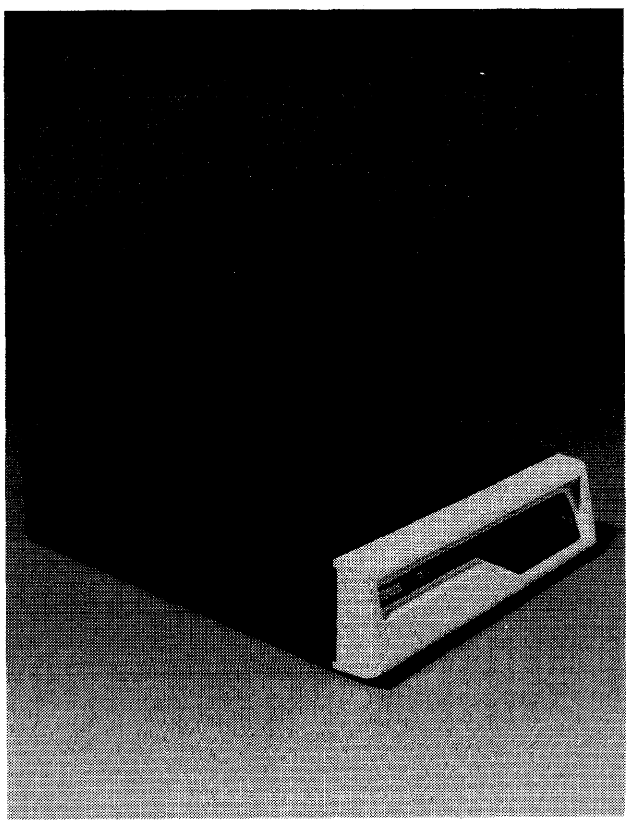
In October 1971, the first update to the infant PDP-11 line appeared in the form of the OEM-oriented

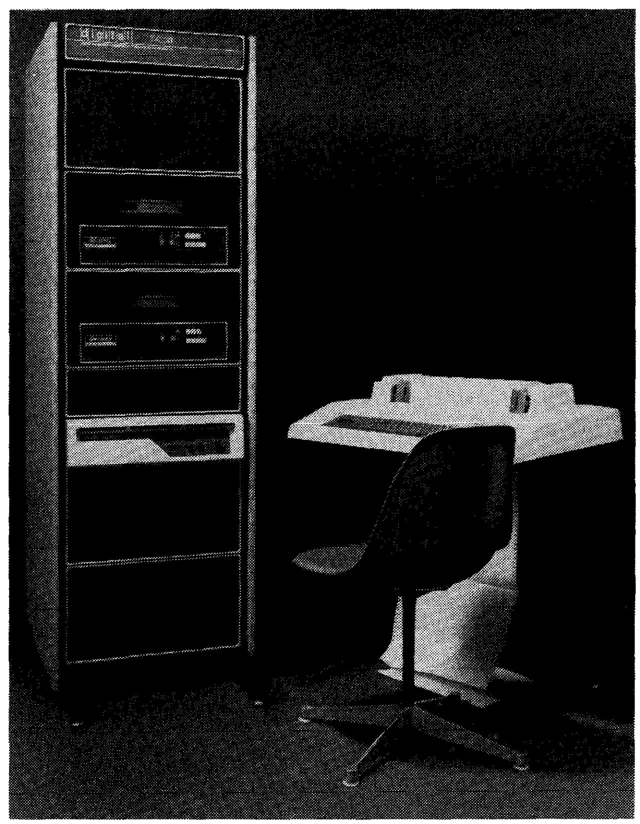
The PDP-11 family is the most prolific and most versatile line of minicomputers offered by a single manufacturer. This 16-bit family offers a broad range of configurations and processing capabilities, extending from the LSI-11 microcomputer to the powerful PDP-11/70. The newer PDP-11/04 and 11/34, with wider performance ranges, signal a reduction in the number of models in the line.

CHARACTERISTICS

MANUFACTURER: Digital Equipment Corporation (DEC), 146 Main Street, Maynard, Massachusetts 01754. Telephone (617) 897-5111.

DEC is a worldwide corporation and the world's largest manufacturer of minicomputer systems. The company employs about 23,000 persons and maintains sales and service offices in all major U.S. cities and in major cities throughout Canada and the Western world.





The heirs-apparent to the PDP-11 line are the PDP-11/04 (left) and the PDP-11/34, shown at right in a standard package configuration, the PDP-11T34 system. The two computers use the same backplane and memories. The only difference between them is in memory management hardware, present on the PDP-11/34 and not included in the PDP-11/04. The 11/04 can have up to 56K bytes of memory, while the 11/34 can address up to 248K bytes. These newest PDP-11's use more cost-effective packaging techniques and are the models after which future PDP-11's will be patterned. The PDP-11/04 basic system with 32K bytes of MOS memory is priced at $7,695. The 11T34 packaged system includes an 11/34 CPU with 64K bytes of core or MOS memory, dual RK05 2.4-megabyte disk drives (4.8 megabytes total), and an LA36 DECwriter II console and sells for $30,900. Monthly maintenance charge for the 11T34 system is $263.

DISTINGUISHING CHARACTERISTICS OF THE PDP-11 FAMILY MEMBERS

	LSI-11, 11/03	11/04	11/34, 11/35, 11/40	11/45, 11/55	11/70
Processor Characteristics	11/40 instruction set, 11/05 execution speed, unique internal architecture; floating-point optional	"Standard" PDP-11 architecture first appears; standard instruction repertoire	850-nanosecond CPU plus 32-bit floating-point on 11/35 and 11/40; extra and extended instructions first appear	300-nanosecond CPU using Schottky logic; 64-bit floating-point, Floating-Point Processor (FPP)	300-nanosecond CPU using Schottky logic; 64-bit fast floating-point, Floating-Point Processor (FPP)
Memory Usage (in 8-bit bytes)	8K to 15K (will support up to 64K in addressing capability, less in std. chassis); core, static & dynamic RAM, PROM, fusible-link PROM	8K to 56K (will support up to 64K, but architecture reserves high-end 8K); core or MOS memory	16K to 248K, the amount over 64K using memory management (map) feature; core or MOS memory on the 11/34	32K to 248K, the amount over 128K using memory management (map) feature; core, MOS, bipolar	128K to 2M, the amount over 128K using memory management (map) feature; interleaved core & cache memory management
Bussing Structure	"Sub-Unibus" that is low-cost & asynchronous	"Standard" Unibus which lends flexibility across this range of the PDP-11 family		Unibus plus an internal solid-state bus for I/O memory reference overlap	Unibus plus 32-bit internal data busses between core & cache and between high-speed controllers & cache
Operating Software (typical, and "intent" of usage)	RT-11 & RSX-115 support; "one program for life" intent	RSX-11 & RT-11; usually dedicated to an application	RSTS/E time-sharing runs in this range of the PDP-11 family; the intent is for many similar programs or dedicated real-time or time-sharing applications running concurrently		Multiple-purpose, using IAS, or maximum power using RSX-11M (real-time) or RSTS/E (time-sharing)
			RT-11, RSX-11M real-time	RSX-11M real-time	
Prices (representative)	$630-$2,000	$2,000-$15,000	$15,000-$80,000	$60,000-$100,000	$100,000 and up

PDP-11/05. This new unit, announced with the PDP-11/45 and 11/50, was a functional replacement for the 11/20 (and the OEM 11/15), repackaged into a more cost-effective unit that offered performance comparable to that of the older 11/20. Introduced at the same time, the 11/45 and 11/50 models each featured extensions to the PDP-11/20 capabilities, as well as the newer packaging techniques found in the 11/05. The PDP-11/45, like the other PDP-11's, was a core-only machine, but this new model included memory management circuitry that raised the maximum memory capacity from 56K bytes to 248K bytes.

The 11/45 actually represented a new processor that incorporated Schottky TTL logic and had a special high-speed internal memory bus in addition to the normal Unibus. This new bus was identical to the Unibus, and in some systems was connected to it as an extension. But the major purpose of the new bus was to interface DEC's new dual-ported 300-nanosecond bipolar and 450-nanosecond MOS memories, which represented significant enhancements to the system. The new memories, although more expensive at that time, enabled the 11/45 to perform at levels twice those of the PDP-11/20. In addition to the new memories, the 11/45 also featured an optional FP11-B floating-point processor, capable of handling

MODELS: LSI-11, PDP-11/03, PDP-11/04, PDP-11/05, PDP-11/10, PDP-11/35, PDP-11/40, PDP-11/45, PDP-11/50, PDP-11/55, and PDP-11/70. Models PDP-11/05, 11/15, 11/20, and 11/35 are no longer actively marketed.

DATA FORMATS

BASIC UNIT: 16-bit word plus two parity bits. The processor can also handle 8-bit bytes, and is capable of bit manipulation.

FIXED-POINT OPERANDS: 16-bit words or 8-bit bytes are used as operands in both single- and double-operand instructions. Bit manipulation is provided through Boolean AND/OR instructions.

FLOATING-POINT OPERANDS: Optional 32-bit single-precision operands with an 8-bit exponent and signed 24-bit fraction on the LSI-11 and the 11/35 and larger models; or 64-bit double-precision operands with an 8-bit exponent and signed 56-bit fraction on the 11/45, 11/55, and 11/70. Single-precision hardware is currently available on the 11/45 and larger systems; other PDP-11 family models use floating-point software subroutines (also usable on the 11/40 and larger). The LSI-11 can have optional plug-in, ROM-implemented, 11/40-style floating-point firmware. A new floating-point processor for the 11/34 has been announced, but no details have been received.

INTERNAL CODE: ASCII for text-oriented data; binary for calculations.

DEC PDP-11 Family

PERIPHERALS/TERMINALS

DEVICE	DESCRIPTION	MANUFACTURER
MAGNETIC TAPE		
TWU/45 & TJU/45	TW for 11/70 & TJ for other PDP-11's; 800/1600 bpi, 75 ips; up to 8 drives per controller; 250 ips rewind; vacuum column; 60/120 KBS	DEC
TU16	Industry-compatible, 45 ips, 9-track, 800/1600 bpi, tension arms; 36/72 KBS	DEC
TS03	Industry-compatible, 12.5 ips, 9-track, 800 bpi, 7-inch reels, tension arms; 10 KBS	DEC
TA11	Dual-Drive Cassette, 43K words each; 562 bytes/sec.	DEC
LINE PRINTERS		
LA180-PA	Serial Printer, 132-position, 128-character, 7 x 7 dot matrix; 180 cps	DEC
LA11-PA	Serial Printer with controller, 132-position, 128-character, 7 x 7 dot matrix; 180 cps	DEC
LP11-VA	132-position, 64-character, 1 small peripheral controller; 300 lpm	Dataproducts
LP11-RA	132-position, 64-character, 1 small peripheral controller; 1200 lpm	Dataproducts
LP11-SA	132-position, 96-character, 1 small peripheral controller; 900 lpm	Dataproducts
LP11-WA	132-position, 64-character, 1 small peripheral conroller; 230 lpm	—
LV11-BA	Electrostatic Printer/Plotter, 132-position, 96-character; 500 lpm	Versatec
CARD UNITS		
CR11	Reader, 80-column, tabletop, 1 small peripheral controller; 300 cpm	Documation
CD11-A	Reader, 80-column (DMA interface), 1 system unit; 100 cpm	Documation
CD11-EA	Reader, 80-column (DMA interface), 1 system unit; 1200 cpm	Documation
CM11	Optical Reader, 80-column, EIA-standard, 1 small peripheral controller; 285 cpm	Documation
PAPER TAPE UNITS		
PC11	Reader/Punch, 1 small peripheral conroller; 300/500 cps	Remex
TERMINALS		
LA36	DECwriter II, 132-position, 96-character, 7 x 7 dot matrix; 30 cps	DEC
VT50	DECscope, 12 lines x 80 characters, 64-character set; 75 to 9600 bps	DEC
VT52	DECscope, 24 lines x 80 characters, 128-character set; 75 to 9600 bps	DEC
VR14	Point Display, 7 x 9-inch	DEC
RT01	Numeric Display, 4 to 12 digits; 110/300 bps	DEC
VT11	17-inch CRT, light pen	DEC
VS60	High-performance graphics subsystem, 21-inch CRT, light pen graphics subsystem	DEC

64-bit double-precision operands. The PDP-11/50, announced along with the 11/05 and 11/45 models, was merely a PDP-11/45 with MOS memory instead of core.

The next PDP-11 model, the 11/40, announced in August 1972, could be considered a fill-in-the-gap model. It uses the memory management circuitry originally introduced in the 11/45 and 11/50 models, operates at about the same speed as the original 11/20, but can have up to 248K bytes of core memory.

The PDP-11/40, 11/45, and 11/50 were primarily end-user processors chiefly because of the size of the systems for which they were intended. As OEM's began offering progressively larger systems, it became apparent that an OEM unit with large memory capability was highly desirable. For this market, DEC announced the PDP-11/35, a CPU identical with the 11/40, but offering many 11/40 standard features as options.

MAIN STORAGE

General aspects, including type, cycle time, and capacity, are covered for the entire family in the Main Storage Characteristics table (page M11-384-305). The categorized entries in the text that follows emphasize exceptions and noteworthy features. It should be noted that all storage capacities allow for the 8192 bytes (4096 words) that are reserved for use by the I/O system. Non-DEC storage choices are listed in Report M13-100-101, Minicomputer Add-On Memories.

STORAGE TYPE: Magnetic core, MOS (both static and dynamic), and bipolar are the three types most commonly used within the PDP-11 family. Core is available in a variety of speeds and can be used in every PDP-11 except the newer 11/04 and 11/34. The PDP-11/45, 11/50, and 11/55 can also use the faster and more expensive bipolar memories. The cache memory found in the 11/70 is bipolar.

Read-only memories (ROM's) and programmable ROM's (PROM's) are available for dedicated-function processors

DEC PDP-11 Family

PDP-11 MODEL AVAILABILITY SUMMARY

	LSI-11	11/03	11/04	11/05*	11/10	11/15*	11/20*	11/34	11/35*	11/40	11/45	11/55	11/70
Date Announced	2/75	12/75	11/74	10/71	1/73	4/71	3/70	2/76	10/73	8/72	10/71	12/75	2/75
First Delivery	5/75	—	7/75	2/72	2/73	6/71	8/70	3/76	1/74	1/73	4/72	3/76	5/75
Typical Purchase**	$1.8K	$10.5K	$3.2K	$5.7K	$7K	$9.6K	$10.8K	$12K	$10K	$13K	$27K	$40K	$170K
Number Installed	—	—	2000	11,000		4250		—	8000		400	—	—

* System is no longer actively marketed.

**Includes most popular memory and I/O configurations; quantity prices are shown for the LSI-11 and 11/04.

For over a year after the 11/35 announcement, the PDP-11 family remained stable, at least in terms of CPU's. During this period, DEC turned its attention to packaged systems and support software.

In November 1974, the PDP-11/04 was introduced with a totally new low-end processor. Again, as in the case of the PDP-11/05, this new CPU had the same architecture as the existing family members and incorporated several technological innovations to achieve substantially improved price/performance characteristics. Designated the successor to the PDP-11/05 and PDP-11/10, this new processor, 11/04, used MSI components to reduce the CPU from two boards to a single hex board. While offering slightly better performance levels than the 11/05 and 11/10, the new 11/04 could accept either core or MOS memory. Priced about the same as the PDP-11/05 (a core-only machine), the 11/04 employed a newly developed power supply and less expensive memory modules to provide about 15 percent greater performance levels.

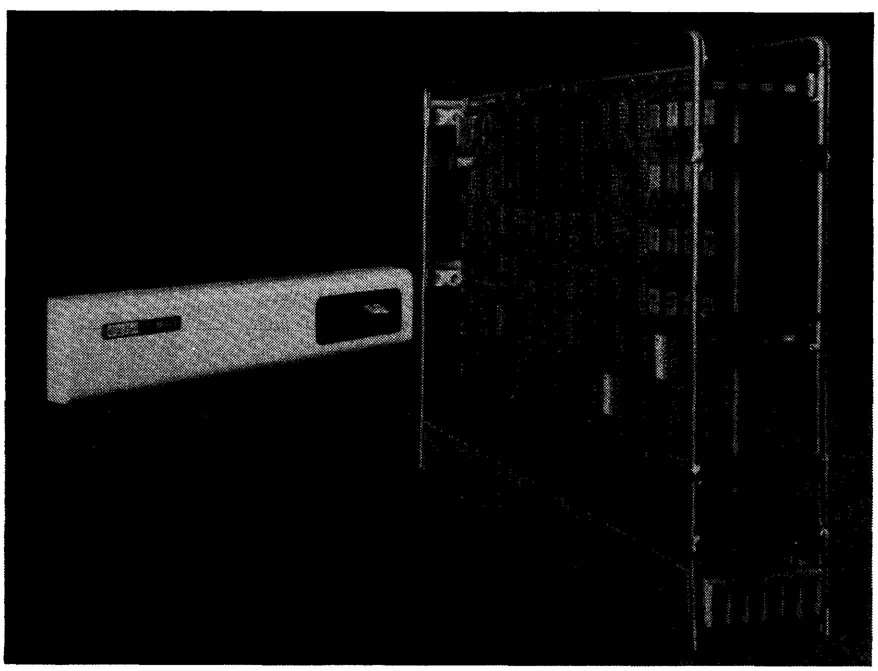
Early in 1975, two innovative PDP-11's were announced at opposite ends of the family line. The LSI-11 microcomputer, for OEM applications, and the PDP-11/70, for very large systems, were both introduced

(e.g., the LSI-11 used in some other machine) or for specific processor functions (e.g., bootstrap loader or ASCII device console simulation in the 11/04). These take the form of diode ROM, ultraviolet-programmable ROM, and fusible-link ROM. Much of the ROM usage cannot really be classified as storage (e.g., floating-point ROM in the LSI-11).

CYCLE TIME: 980 nanoseconds for all currently offered core; 495 or 725 nanoseconds for MOS; and 300 nanoseconds for bipolar. Cache on the 11/70 has a 240-nanosecond cycle time. In some models, the storage access cycle *rate* (as opposed to the access cycle-time capability of the storage) is a function of the processor, not of the storage; e.g., the constant 1.2-microsecond cycle time of the LSI-11 regardless of storage technology. On the 11/70, DEC states that the main storage bandwidth is easily raised from the basic 4 million bytes per second to 5.8 million bytes per second by interleaving. All 11/70's with more than the minimum memory use memory interleaving. The company also states that a 90 to 95 percent cache "hit" rate on the 11/70 will yield an effective 11/70 memory cycle time of less than 400 nanoseconds. The various memories for each model are summarized in the Main Storage Characteristics table.

CAPACITY: Please refer to the table. Capacity is a function of packaging and/or marketing (e.g., the 16K-byte limit on the 11/04), of bussing structure (the Unibus requires the uppermost 8K bytes to be dedicated as I/O registers, thus limiting direct address space to 56K bytes), and of whether memory mapping is available. Memory mapping is

Every line has a beginning, and these two systems, the OEM LSI-11 microcomputer (right) and its end-user (or OEM) packaged counterpart, the PDP-11/03, mark the low end of the PDP-11 family. Although these two microcomputer systems boast an instruction repertoire equal to that of the PDP-11/40, they use a different type of common bus. The LSI-11 microprocessor, including 8192 bytes of memory mounted on the CPU module, in its backplane, is priced at $1,536 in single-unit quantity. The more aesthetically pleasing PDP-11/03, in its 3.5-inch chassis with 8K bytes of memory, is priced at $1,995. The LSI-11 is marketed only by DEC's Components Group, a different organization than the one that markets all the other PDP-11's.



MAIN STORAGE CHARACTERISTICS

Model	Storage Type	Cycle Time (nanoseconds per word)	Storage Capacity (bytes)	Increment Sizes (bytes)
LSI-11 & PDP-11/03	Static MOS, dynamic MOS, core, PROM, fusible-link ROM	1200	8K to 56K	2K MOS (static) 8K MOS (dynamic) 8K core 512 or 1024 PROM
PDP-11/04	MOS (dynamic) or core	725 MOS 1000 core	8K to 56K	8K, 16K
PDP-11/34	MOS (dynamic) or core	725 MOS 1000 core	16K to 248K	16K, 32K, 64K
PDP-11/35	Core	1200	16K to 248K	16K, 32K, 64K
PDP-11/40	Core	1200	16K to 248K	16K, 32K, 64K
PDP-11/45	Core, MOS (dynamic), or bipolar	980 core 495 MOS 300 bipolar	16K to 248K	32K, 64K core 8K MOS 2K bipolar
PDP-11/50	Core, MOS (dynamic), or bipolar	980 core 495 MOS 300 bipolar	8K to 248K core 8K to 64K MOS & bipolar	32K, 64K core 8K MOS 2K bipolar
PDP-11/70	Core (with 240-nanosecond bipolar cache "front end")	980	64K to 2048K (excluding 2K of cache)	64K

in February 1975. The LSI-11 addressed the rapidly growing market for smaller, less powerful computers for inclusion in very small systems such as intelligent terminals and process controllers. Built from an LSI microprocessor chip, this entirely new low-end PDP-11 featured the same instruction set as the PDP-11/40, but offered only half the performance of the other PDP-11 members, due chiefly to the architecture of the CPU.

At the other end of the scale, the PDP-11/70 still represents the top of the PDP-11 line. Announced in February 1975, the 11/70 appeared amidst the flurry of 32-bit minicomputers that reached the market in late 1974 and early 1975. Intended for very large systems, and said to be capable of delivering 75 percent of the throughput of an IBM 370/158, the 11/70 is essentially a PDP-11/45 with a 32-bit bipolar cache memory placed between the CPU and main memory. In addition, the memory management feature used in the 11/70 permits addressing over 4 million bytes, although physical limitations reduce this capacity to 2 million (2048K) bytes. Specially designed mass storage controllers that access the 32-bit cache memory bus were already substantially increased system performance. DEC expects to add new denser memories in the near future that will permit full implementation of 4-million-byte main memories in the 11/70.

The PDP-11/55 was next to appear. Announced in December 1975, the 11/55 is the fastest PDP-11. It is a very specialized version of the 11/45 designed primarily for the scientific market, and specifically for use in

automatic effective address translation that enables a 16-bit computer to address memory in excess of 64K words. The LSI-11 central processor board comes with 8K bytes of static MOS memory on it.

The 11/45's core increment size is 32K bytes, the MOS increment is 8K (max. 64K), and its bipolar increment is 2K (max. 16K); those types can be intermixed.

The basic PDP-11/50 has semiconductor memory that is expandable to 56K bytes. This limit is extended to 248 bytes if core is substituted.

CHECKING: Parity, on a one-bit-per-byte basis, is optionally available on all models from the 11/34 through the 11/50. On the 11/70, parity core memory is standard.

STORAGE PROTECTION: Via the memory mapping function in the larger models. Mapping automatically provides hardware storage protection. Although mapping does not appear until the 11/34 level, neither does any multiple-user operating system.

RESERVED STORAGE: The uppermost 8192 bytes on all models with a Unibus are reserved for I/O registers. This apparent "waste" of storage is more than compensated for by the resulting I/O programming flexibility.

CENTRAL PROCESSORS

The "mainstream," or original, PDP-11 family architecture began with the 11/20 and its closely related, stripped-down 11/15 version, each of which contained about 19 boards and some 600 integrated circuits (IC's). The 11/05 and 11/10 are identical to one another, are about 20 percent slower internally than the 11/15 and 11/20, and have improved architectural implementation over their predecessors, using only 2 boards and about 200 IC's. The latest 11/04 and 11/34 processors use one and two boards, respectively.

DEC PDP-11 Family

INSTRUCTION REPERTOIRES

Instruction Type	Number of standard (and optional) instructions				
	LSI-11, 11/35, 11/40	11/04	11/34	11/45, 11/55	11/70
Single Operand	14	13	16	16	16
Double Operand	7 (4 more with opt. EIS)	7	12	12	12
Branch	17	17	17	17	17
Subroutine	5	3	5	5	5
Program Control	6	1	6	6	6
Trap	6	5	6	6	6
Miscellaneous	4	4	3	7	7
Condition Code Operator	10	10	10	10	10
Floating-Point	(4; opt. EIS)	None	None	(46; opt. FPP)	(46; opt. FPP)
TOTALS:					
Standard	69	60	75	79	79
Optional	8	0	0	46	46
Combined	77	60	75	125	125

FORTRAN systems. The 11/55 attains its faster operation through three specific improvements over the 11/45: the use of 300-nanosecond bipolar main memory; incorporation of the more efficient PDP-11/70 microcode (the 11/70 is also 11/45-based); and the use of the FP11-C, a new floating-point processor that is twice as fast as the FP11-B, the standard unit for the 11/45.

More recently, and in close succession, the PDP-11/03 and 11/34 were announced. The 11/03, announced in January 1976, responded to OEM buyers' desire for a packaged LSI-11. It is housed in a 3.5-inch chassis, contains a power supply and space for up to 16K bytes of memory, and is intended for use as a single-user terminal system or even as a small distributed processing system.

The 11/34, announced in February 1976, is an outgrowth of the PDP-11/04 and, in fact, uses the same backplane and memories. It bears the same relationship to the 11/04 that the 11/40 had with the 11/05; the PDP-11/34 is based on the same CPU as the 11/04, but has the memory management feature that permits main memory capacities of up to 248K bytes. Like the 11/04, the 11/34 can use either MOS or core memories. From a performance standpoint, the 11/34 is more than 50 percent faster than the 11/04; and, since both computers use the same backplane, the 11/04 can be upgraded to 11/34 status. Recently, floating-point capabilities, in the form of the FPU-AU floating-point processor, have been added to the 11/34, eliminating the only major difference between it and the older systems.

ARCHITECTURE

A distinguishing characteristic of the PDP-11 family is its common physical architecture, arising primarily from the patented DEC Unibus, a single high-speed, asynchronous, bidirectional communications path to which all system components (CPU, memories, and I/O controllers) are connected. This common bus structure enables all functional elements to communicate with one another

Subsequent PDP-11 family models offer design improvements that relate closely to the product's intended market objectives. For example, as the table entitled "Distinguishing Characteristics of the PDP-11 Family" (page M11-384-302) points out, the LSI-11 design drops the Unibus in order to lower cost, and the 11/45 and larger models augment the Unibus for performance gains.

The 11/04 uses TTL in a single-board processor. Multiplexer printed-circuit modules, which provide cost advantages from a packaging standpoint and speed advantages due to reduced signal path lengths, are now used throughout the PDP-11 family. The 11/34 uses the same technology, backplane, and chassis as the 11/04, differing only in the addition of memory management to extend addressing capabilities to 248K bytes. Schottky TTL logic appears in the 11/45 and larger models, as does an autonomous Floating-Point Processor; and 32-bit internal data paths and bipolar cache memory appear in the 11/70.

The 11/34, 11/40, 11/45, and 11/55 can access up to 248K bytes of main memory in 64K-byte segments through one or two sets of eight address translation registers and an 18-bit Unibus interface. Two or more sets of length registers are used to delineate the bounds of addressability for individual programs, and these together with associated status registers give memory protection for multiprogramming. The 11/70 uses this scheme to address up to 2 million bytes of main memory.

Mapped memory in any 16-bit machine will limit the address space of any one program to that which is directly addressable within the mapped-to-memory region. Also, the automatic mapping process may add processor overhead. In the 11/34, this amounts to 120 nanoseconds per address mapped, and in the 11/45 and 11/50, it totals 90 nanoseconds per address. In the 11/70, however, mapping is concurrent, with no overhead time.

With memory management, the 11/34, 11/35 or 11/40 operates in either a "kernel" or a "user" mode; the user mode prevents programs from modifying key machine states relating to memory mapping and protection. The 11/45, 11/50, or 11/70 with memory management has three modes: kernel, user, or supervisor. The supervisor mode is intended to facilitate multiprogramming by providing a control program state for more efficient and secure system management. All other PDP-11 family systems operate in basic kernel mode only, i.e., with all

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INSTRUCTION TIMES IN MICROSECONDS

Instruction	1104 (MOS)	11/34 MOS	11/34 Core	11/35, 11/40	11/45 & 11/55 Core	11/45 & 11/55 Bipolar	11/70
Fixed-Point (16 bits):							
Load/Store	2.9/3.5	2.5	2.3	2.32/2.58	2.01/2.13	0.75	0.95/1.4
Add/Subtract	3.2	NA	NA	1.07	0.97	0.30	0.40
Multiply/Divide	9.9/11.3	8.9/12.6	8.8/12.5	9.16/11.58	3.89/8.39	3.3/7.8	3.4/7.9
Branch/No Branch	2.6/1.9	2.3/1.76	2.2/1.76	1.07/2.36	0.97/1.18	0.3/0.6	0.4/0.7
Floating Point (32 bits)*:							
Load/Store	NA	NA	NA	NA	7.0/6.38 (10.8/10.0)	5.34/4.72 (7.52/6.7)	5.54/5.62 (7.93/8.5)
Add/Subtract	NA	NA	NA	26.8/27.1	5.67 (6.97)	5.67 (6.97)	5.67 (6.97)
Multiply/Divide	NA	NA	NA	33.4/51.1 (11.4/23.0)	7.62/8.62 (11.4/23.0)	7.62/8.62 (11.4/23.0)	7.62/8.62 (11.4/23.0)
Compare & Branch	NA	NA	NA	NA	4.62 (4.87)	4.62 (4.87)	4.62 (4.87)

*Times for 64-bit operands are shown in parentheses.

independently of the CPU. This ability reduces the time spent by the CPU in supervising I/O operations and allows it to devote more time to actual data processing.

Since memory and I/O controllers alike are residents of the same bus, they are addressed alike. The result is that the PDP-11's do not employ I/O instructions as a separate class; instead, certain addresses are reserved for I/O devices, and each controller can read and write to memory in the same manner as the CPU. Hence, transfers to and from I/O controllers are accomplished in the same way that data is transferred between general-purpose registers and memory. More specifically, the highest 4096 memory addresses (8192 bytes) in any PDP-11 system are reserved for use by I/O controllers and cannot be used for memory.

Two small disadvantages arise from this I/O scheme. First, since 4096 addresses are reserved for I/O usage, they cannot be used for memory. Hence, the maximum physical memory that can be incorporated in a particular system is always 4096 words (8192 bytes) less than the *theoretical* maximums. For example, the PDP-11/04 is *theoretically* capable of addressing 65,536 bytes, but only 57,344 bytes can actually be implemented. This limitation arises only in the case of the maximum memory configuration. If the system only required 16,384 words there would not be a problem.

Secondly, the instructions for the I/O controllers address various controller registers as memory locations. Generally, these must be loaded individually through load- and store-type commands. While presenting an easy and understandable I/O system, this technique also precludes the implementation of instructions that perform more complex I/O functions, resulting in higher I/O overhead times.

The second salient characteristic of the PDP-11's, software compatibility, is a result of all CPU's, from the LSI-11 up to the PDP-11/70, using the same basic instruction set. It should be noted, however, that the LSI-11 and PDP-11/03

available memory (always 64K bytes or less) accessible by all.

All PDP-11 family processors have an instruction stack capability to facilitate the implementation of sharable (re-entrant) routines. The size of the pushdown stacks is limited only by the size of available memory.

CONTROL STORAGE: The LSI-11 and 11/03 are controlled by microcoded read-only memories (MICROM's), among whose functions are provision of PDP-11/40 instruction set emulation and automatic refreshing of any dynamic MOS RAM used. Also, the LSI-11 extended arithmetic option (fixed-point multiply/divide and floating-point arithmetic) is achieved by the use of a plug-in ROM chip. Users can create special LSI-11 operations by purchasing fusible-link programmable ROM (PROM) chips. These PROM's are packaged 256 words per chip, two chips to a half-board; the LSI-11 accepts half-boards in its backplane sockets. Other ROM-supplied LSI-11 functions are standard. They include resident initialization, power fail/auto restart, bootstrap loading, and debugging routines. ROM and PROM speeds in the LSI-11 are largely irrelevant, since they are at least an order of magnitude faster than the 1.2-microsecond overall LSI-11 processor cycle.

The 11/04 and 11/34 have a standard ROM bootstrap loader, ROM diagnostics, and a ROM console simulation routine that permits use of any ASCII device as a console.

Control storage in the remainder of the PDP-11 family is of no concern here, since the line has no user-accessible control storage.

REGISTERS: All PDP-11 family members have eight user-accessible 16-bit registers (six general-purpose, one stack pointer, and one program counter), and a 16-bit processor status register. The general-purpose registers can be used as index registers, hardware stack pointers, or accumulators. In the 11/34 and 11/40, there are two stack pointers (kernel and user modes), whereas the 11/45, 11/50, and 11/70 have three stack pointers (kernel, user, and supervisor modes) and a full duplicate set of general-purpose registers, but only one program counter.

ADDRESSING: Eight address modes are provided, with each operand address consisting of three bits to specify address mode and three bits that specify the register used to calculate the address. The modes consist of Register (operand in register), Register Indirect (operand address in

have a "pseudo-Unibus" structure in place of the standard Unibus and cannot presently use DEC's standard Unibus-compatible I/O controllers. Instead, DEC offers two low-to-medium-speed "universal" controllers, one parallel and one serial, that can be adapted to handle most standard peripherals. At least one independent manufacturer is offering an LSI-11/Unibus adapter to alleviate this limitation.

CURRENT MODELS

Currently, DEC offers the LSI-11 and PDP-11/03 microcomputers, sold by the company's Component Group, and the PDP-11/04, 11/10, 11/34, 11/40, 11/45, 11/50, 11/55, and 11/70, sold by DEC's other seven market groups. The PDP-11/10, though still listed in the current price list, is generally sold only to existing users for replacement or for hardware conformance. The 11/10, like the 11/05, will be replaced by the more cost-effective PDP-11/04. In a similar fashion, the PDP-11/40, like the 11/35 (which is no longer listed in DEC's price list), will be replaced by the newer PDP-11/34, again because of lower cost for improved performance. It can be said that the 11/04 and 11/34 systems represent the models from which future DEC products will evolve.

DEC groups the current PDP-11 line into four application levels:

- *Microcomputers*—the LSI-11, for board-level integration into dedicated applications, and the PDP-11/03, for packaged microcomputer applications.
- *Minicomputers*—the PDP-11/04, for dedicated applications.
- *Systems computers*—the PDP-11/34, 11/45, and 11/55, for multi-task applications.
- *Multi-function computer*—the PDP-11/70, for simultaneous real-time, batch, and time-sharing applications.

The LSI-11 is a board-level microcomputer product specifically designed for sophisticated users who can incorporate the LSI-11 into a product, taking advantage of its PDP-11 family capabilities that were previously unavailable in such packaging. The LSI-11 has the capabilities of a real minicomputer, including a CPU with the 11/40 instruction repertoire, 8K 8-bit bytes of memory, and an I/O bus port on one board. Additional memory on other boards can be used to expand the capacity to up to 57,344 bytes.

The PDP-11/04 minicomputer provides solutions to dedicated applications in which the computer is used to solve one or two problems and run one or two programs. It is used, for example, in data acquisition, to convert analog signals to digital signals, to analyze pulse heights, and to store data on magnetic tape. As little as 8K bytes

register), Auto Increment/Decrement (self-incrementing/decrementing operand address in register), Auto Increment/Decrement Indirect (self-incrementing/decrementing register which points to an address in memory), Indexed, and Indexed Indirect. The eight modes can allow a specific operation code (e.g., MOV, for move) to accomplish register/register, register/memory, memory/memory, memory/stack, and register/stack manipulations.

INSTRUCTION REPERTOIRE: Please refer to the table entitled "Instruction Repertoires" (page M11-384-306) for the individual instruction class makeup of the various PDP-11 family members. The classes are:

- **Single Operand—General (e.g., clear, increment, decrement, complement, negate, test); Shifts; Multiple Precision (e.g., add and subtract with carry, extend sign); and Rotate. Many of these instructions have word and byte operand versions.**
- **Double Operand—General (e.g., storage-to-storage move, add, subtract, compare); Register Destination (e.g., multiply, divide. Exclusive OR); and Logical. Move and Compare can have word and byte versions; logical instructions can have bit and byte versions.**
- **Branches—Unconditional; Simple Conditional Branches; Signed Conditional Branches (for testing values of 2's complement arithmetic); and Unsigned Conditional Branches (for testing results of comparing unsigned operands).**
- **Subroutine—e.g., Jump to Subroutine, Mark, and Return from Subroutine.**
- **Program Control—e.g., Jump, Subtract One and Branch, and, in some models, Set Priority Level.**
- **Traps—these are calls to emulators, I/O monitors, debuggers, and user-defined interpreters.**
- **Miscellaneous—e.g., Halt, Wait, Reset, and, in various models, No Op, Move to/from Previous Instruction/Data Space.**
- **Condition Code Operators—Set/Clear conditionally or unconditionally all or each of the four PDP-11 condition code bits.**
- **Floating Point—the four arithmetic functions for floating-point arithmetic. In models with both single- and double-precision floating-point arithmetic, these instructions will have single- and double-precision versions. In the 11/45, 11/50, and 11/70, which have autonomous Floating-Point Processors, the floating-point instruction repertoire includes loads/stores for full operands and exponents only, similar compares, floating-point processor condition code operators and set/clear floating-point/integer mode, tests, load/store status, make absolute value, etc.**

INSTRUCTION TIMINGS: Please refer to the table entitled "Instruction Times" on page M11-384-307.

INTERRUPTS: All models except the LSI-11 and 11/03 have four automatic hardware priority level interrupts. The 11/45, 11/50, and 11/70 can also use any of seven programmable software-supported additional interrupt levels; these have an automatic vectoring instruction held in a reserved main storage location. Each of the interrupt levels can accommodate independently prioritized peripheral devices.

DEC PDP-11 Family

This compact microcomputer time-sharing system points up the power of the PDP-11/04. This configuration, the PDP-11V03, is a multi-user, disk-based, real-time system offered as a standard package. Included in the package is a PDP-11/03 CPU with 8K words of MOS memory and a dual RX11 512K-byte floppy disk subsystem. Users can choose either an LA36 DECwriter II hard-copy terminal or a VT52 CRT terminal as a console device. Also included in the package is the operating system software, as well as the user's choice of the BASIC or FORTRAN language. The system can be expanded to accommodate up to four simultaneous users. Purchase price for the basic system is $9,950.

of memory can suffice in straightforward applications, but the systems can be expanded to up to 56K bytes in order to handle more complex applications, perhaps coded in a high-level language such as FORTRAN IV or BASIC.

The PDP-11/34, 11/40, and 11/45 system computers are used in multiple-task applications where the computer must solve many problems or run multiple programs. They are being used to automate entire industrial processes, for example, monitoring and controlling multiple operations in real-time while preparing and printing production reports for management. Memory sizes can range from 16K to 248K bytes to accommodate several programs in memory simultaneously. The system speed is dependent on the user's choice of memory, and DEC offers core, MOS, and bipolar for instruction cycle times as fast as 300 nanoseconds.

The multi-function PDP-11/70 can handle simultaneous batch, real-time, and time-sharing applications in its larger configurations, or pairs of these in smaller configurations. It incorporates such advances as integral bipolar cache memory and interleaved core memory to reduce effective memory cycle times to below 400 nanoseconds, fast mass storage devices, and a special high-speed 32-bit data bus to accommodate them. Also, the 11/70 can make use of a powerful new operating system, IAS, in addition to the other PDP-11 family operating systems.

MARKETING GROUPS

One aspect of the PDP-11 family (as well as other DEC products) that often causes confusion to both prospective and current DEC customers is the many marketing groups within Digital Equipment Corporation. Spokesmen for the manufacturer pictured the company as eight different

PHYSICAL SPECIFICATIONS: Nominal operating environments for the PDP-11 processors are 50 to 104 degrees Fahrenheit (10 to 40 degrees Centigrade), at 10 to 90 percent relative humidity within specified wet-bulb and dew-point limits. These are processor specifications; electromechanical peripherals may be more sensitive to their environments.

DEC offers a vast array of PDP-11 family equipment, and it is beyond the scope of this report to present more than generalized information regarding the physical specifications of the processors. Please note that all cabinet-mounting components fit in RETMA-standard (19-inch) cabinet interiors, and that the cabinets generally measure 21 inches wide, 30 inches deep, and 72 or 50 inches high. DEC processor and peripherals handbooks are readily available for use by those who need details on individual units.

INPUT/OUTPUT CONTROL

UNIBUS: The patented Unibus, a single common data path that treats all components or modules of a PDP-11 family system as equal-level devices for data access and transfers, including the processor, memory modules, and peripheral controllers, is part of all PDP-11 family members with the exception of the LSI-11 and the 11/03. The 11/45 and 11/50 have a pair of Unibusses, plus augmentation by a special solid-state bus for I/O and memory reference overlapping. The 11/70 incorporates 32-bit internal busses between core memory and cache memory and between high-speed peripheral controllers (e.g., disk and 1600-bpi magnetic tape) and cache memory. The LSI-11 and 11/03 have a "pseudo-Unibus" structure that eliminates some lines by doubling-up address and data lines through time-sharing them.

The priority of any device connected to the Unibus is determined by its physical position; hence, the processor is normally attached so as to give it the highest priority. There is no logical limit to the number of devices that can be attached to the Unibus, with bus access and control handled by the interrupt system.

small companies, each specializing in different applicational markets that have been carefully delineated to have little or no jurisdictional overlap. Each group has been given the freedom to develop products and markets within its own sphere of responsibility, independently of other groups. All groups, however, draw equipment for their products from the common pool of DEC hardware and, to a lesser degree, develop software from the major DEC operating systems.

PPD-11's are sold by DEC's OEM Marketing Group, Industrial Products Group, Distributed Data Processing Group (responsible for data communications, finance, transportation, and government markets), Telco and Engineering Computation Group, Laboratory Data Products Group, and—in Datasystem 500 and Datasystem 350 packaging—by the Business Products Group, Education Products Group, and Graphic Arts (Typeset) Group.

The laboratory was one of DEC's first markets, and is still one of its best application areas, with demands for its products running well ahead of previous years. The Lab Data Products Group has the charter of developing and promoting laboratory and scientific systems based mainly on the PDP-11 family.

The Business Products Group is responsible for the development and marketing of special PDP-11-based systems for the business market. DEC's business products have become popular with major users in the insurance, manufacturing, finance, transportation, and wholesale distribution fields to perform such functions as order entry, inventory control, billing, payroll, accounts receivable, and other classic general accounting and information handling applications. The PDP-11-based DEC Datasystem 500 is fully described in Report M11-385-401, and the Datasystem 350 is the subject of Report M11-385-501.

The orientation of the Education Products and Graphic Arts Groups is implied in their names. Both are forces with constantly evolving products to offer their respective fields. However, this report does not dwell on their specialized offerings. (The CLASSIC system from the Education Group is covered in Report M11-385-301.)

The OEM Marketing Group is really composed of two groups, OEM Computer Marketing and Components. OEM (Original Equipment Manufacturers) Marketing sells computers in quantity to industrial and commercial firms who then add value to the computer (e.g., develop a package system for resale) and market it. The Components Group sells the DEC-built minicomputer peripheral line—presently the LA36 and LA180 DECwriter II, the VT50 and VT52 DECscope CRT terminals, and the LSI-11 and PDP-11/03 microcomputers. This group also operates a direct sales facility open to both OEM's and end users who wish to reduce maintenance and repair costs by performing some of this activity through their own qualified personnel. For this purpose, the

The theoretical maximum Unibus data transfer rate is 5 million bytes per second, and attached components communicate in a master/slave manner. The maximum date rate of the 11/45 and 11/50 solid-state bus is 6 million bytes per second, without affecting the Unibus's. capability. On the 11/70, the 32-bit bus is fast enough (i.e., 2 million 8-bit bytes per second) to permit overlapped use by the CPU, Unibus, and/or several mass storage units, the fastest of which presently operates at 1 million bytes per second. DEC also states that interleaved core memory raises this 32-bit bus bandwidth to 5.8 million bytes per second. Interleaving is done whenever more than minimum memory is purchased.

It should be noted that the 32-bit bus connects high-speed peripheral controllers to main memory, not cache memory, for data transfer purposes. Cache is used for priority resolution only, and is "flagged" whenever a write hit on an I/O transfer occurs, so as to indicate that the data in the cache is invalid, but that correct data is in core memory. The Unibus, meanwhile, handles the interrupt requests and transfer protocols for the high-speed units.

The LSI-11 and PDP-11/03 bus has a maximum data transfer rate of 1666K bytes per second.

SIMULTANEOUS OPERATION: While I/O using the programmed interrupt structure cannot be simultaneous with processing or other I/O, NPR (non-processor data transfers) can. These are DMA (direct memory access) data transfers via the Unibus (or other busses in the large processors). Examples of NPR data transfers are memory to/from main storage and directly between devices (e.g., disk refreshing a CRT display) in an 11/70. NPR is available to all PDP-11 family members.

CONFIGURATION RULES

In general, all PDP-11 devices that tie into the Unibus impose a single "bus load." (CPU's and the multi-device bulk storage bootstrap loader impose two bus loads each.) The Unibus can support 20 bus loads before a Bus Repeater must be added. In order to physically attach devices to a PDP-11, sufficient mounting hardware must be present. Free-standing and cabinet-mounted devices do not tie up space on the system's chassis.

Each PDP-11 has a basic chassis with a unique number of "system unit" positions in it. Each system unit (SU) can contain one complex (large) device interface or controller; or the SU may contain four small peripheral controller (SPC) slots. For memory/processor modules, a "dual SU" can be used that has room for up to nine slots (instead of eight as with two single SU's). In order to expand memory and/or peripherals beyond the space limits permitted by the basic chassis, certain kinds of expander boxes must be used, depending upon the PDP-11 family model.

The basic prewired backplane used in the LSI-11 and 11/03 has 16 slots that are grouped into eight pairs. Each pair can accommodate one LSI-11-type module. The CPU module, with or without the integral 8K-byte memory, requires two pairs, leaving six pairs for peripherals and options. Most peripherals require only one pair of slots. Semiconductor memory modules, like the CPU module, require two pairs of slots. Core memory modules are thicker than semiconductor memory modules and, while requiring only two pairs, preclude the use of the adjacent two pairs of slots. Customers must provide DC power for the LSI-11.

The PDP-11/04 basic chassis has a prewired four- or nine-slot backplane. The four-slot version has expansion space for three small peripheral controller (SPC) slots and one system unit (SU) slot. The nine-slot version has

DEC PDP-11 Family

Components Group has issued a Direct Sales Catalog that permits ordering supplies, modules, chassis, power supplies, terminals, and microcomputers in the same way consumers order merchandise from mail order houses. DEC is one of a few pioneers in this service that allows users to take advantage of the substantial savings that can be realized through this do-it-yourself approach.

The final group, the Industrial Products Group, sells hardware and software solutions for data acquisition and process control applications.

SOFTWARE

DEC's approach to software has been to avoid situations that require much "handholding" with customers. Instead, the company prefers to provide users with advanced data processing tools that facilitate development of specialized applications software. With the exception of certain packages offered as integral parts of its specialized product lines, such as Typeset, DEC offers only operating systems and language processors.

There are four basic operating systems offered for the PDP-11, one of which has three distinct versions, making a total of six. RT-11, one of the oldest and smallest, is a single-user system for interactive program development. It can support both single-job and foreground/background modes of operation. The single-job version requires a 16K-byte system, and the two-partition version requires 32K bytes. RT11 supports both the FORTRAN IV and BASIC languages for program development.

RSX-11 is a real-time operating system available in three versions that vary widely in functionality and in system requirements.

RSX-11D, the original and most powerful of the three, is an event-driven, disk-based multiprogramming system for the PDP-11/34 and larger systems. Using the memory management functions of these CPU's, RSX-11D permits user programs to be loaded and executed anywhere in memory, without modification. At least 96K bytes of main memory and two hard disks (no floppy disk) are required for single-user operations, and 112K bytes of main memory with 4 megabytes of disk storage are needed for multi-user operations.

RSX-11M, also a disk-based real-time operating system, extends the functions of RSX-11D to lesser PDP-11 systems, and can be run on any PDP-11, starting with the 11/03 and the LSI-11. RSX-11M requires a minimum of 32K bytes of main memory and one hard disk plus one other disk (which can be a floppy). To perform concurrent program development and real-time processing, at least 48K bytes of memory are required.

Both RSX-11D and -11M use the same file management modules, providing automatic space allocation and file structures for any block-structured file device.

expansion space for seven SPC slots. Additional system expansion is available via BA11 expansion chassis.

The PDP-11/34 uses the same prewired nine-slot backplane as the 11/04.

The OEM PDP-11/05 is available in either a 5.25- or 10.5-inch cabinet, while the end-user PDP-11/10 is offered only in a 10.5-inch cabinet. In the 5.25-inch cabinet, there is space for 8K or 16K bytes of core memory with four SPC slots remaining. In the 10.5-inch cabinets, there are two configurations: one with 16K bytes of core memory (expandable to 32K bytes) and space for three SU's, and another with 32K bytes core memory, three SU spaces, and three additional SPC slots. Additional peripherals can be added to the 11/05 or 11/10 through the BA11 Expander Box that provides six additional system units. (Therefore, the BA11 can accommodate 24 individual SPC slots.)

The 11/35 or 11/40 basic chassis has room for nine SU's (four of which are replaced by dual SU's for a capacity of 18 individual slots instead of 16). Two of these SU portions are reserved for the CPU, extended instruction set, floating-point instructions, real-time clock, memory management option, and console interface. Two more SU positions are used for the basic 32K MF-11U memory, with room for an additional 32K bytes of memory. The remaining five system unit positions are available for memory expansion or peripheral attachment. If additional memory is required beyond the capacity of the basic chassis (more than 160K bytes), an H960-D General Purchase Expander Box (nine system units) can be added. For additional peripherals, either the H960-D or a BA11 Expander Box can be added.

The 11/45 or 11/50 basic chassis is similar to the 11/40 box with nine SU positions. On the 11/45, eight of these are prewired to contain the processor, real-time clock, floating-point instructions, Memory Management option, space for up to 64K bytes or semiconductor memory, 32K bytes of core, and space for 32K additional bytes of core. One SU position is available on the 11/45 for additional memory or peripherals.

The 11/50 is identical to the 11/45 except that only six SU positions are prewired, and no provisions are made for core memory modules. This results in the availability of three SU positions for peripheral devices or optional core memory in the basic chassis. If more peripherals or main memory are required than can be handled by the basic chassis, either an H960D expander (nine SU positions) or an H960E Expander (18 SU positions) can be used.

Slot requirements for memory and special processor interface features include: two SU positions for each memory backplane, which comes with 32K bytes of memory and is prewired for a second 32K bytes of core; one SPC for each diode memory (ROM), except two SPC's for the 11/40 or 11/45 64-word ROM loader; one SU position for each asynchronous interface (DL11) or synchronous interface (DU11 or EQ11) or automatic dial (DN11)/General Purpose "B" (DR11B) interface; two SU positions for the DM11 asynchronous interface multiplexor; and one SPC for general-purpose interface "A" and "C" (DR11A, C). Other processor options generally require one SPC, except the KG11-A extended arithmetic feature which uses one SU position.

The 11/70 contains the CPU, memory management, bootstrap loader, real-time clock, DECwriter II console, terminal interface, 2K-byte cache memory, a CPU cabinet, and a memory cabinet with 128K bytes of parity memory. Each memory cabinet can accommodate 1 million bytes of core memory. In the CPU cabinet there is prewired expansion space for a floating-point processor, four

RSX-11S is a memory-based subset of RSX-11M and does not require any disk storage. It does not support program development or a file system, and merely provides a run-time environment for application programs developed on larger host systems. RSX-11S requires only a 16K-byte CPU and a loading device and supports only the smaller mass storage devices.

RSTS/E is DEC's resource-sharing, time-sharing system that supports up to 63 simultaneous users performing either interactive data processing using the BASIC-PLUS language or batch-mode operations using COBOL. RSTS/E also has a more sophisticated file system than RSX-11, supporting both random and sequential files. In addition, the newly announced RMS-11 adds multi-keyed indexed sequential (ISAM) files to the list. RMS-11 enhances the RSTS/E file capabilities with multi-level privacy control and allows both generic and approximate key searches. RSTS/E requires an 11/34 or larger with a minimum of 64K bytes of memory, hard disk, magnetic tape, and a console terminal.

IAS, originally developed to take advantage of the new PDP-11/70 functions, can also run on a PDP-11/45. IAS permits three concurrent operating modes—real-time, interactive, and batch—providing interactive multi-language services for up to 20 simultaneous users. IAS uses the same file management modules as RSX-11D and -11M as well as other control modules. In addition, IAS provides output spooling services to printers and non-interactive terminals, accounting information for both interactive and batch users showing CPU and memory utilization and connect time, automatic error logging on disk, and user-initiated diagnostic routines for confidence checks.

DEC recently announced the availability of DBMS-11, a data base management software system based on Cullinane Corporation's IDMS. This makes two powerful data base management systems available for PDP-11 systems, since Cincom Systems a few weeks earlier announced a version of its popular TOTAL system for PDP-11's. DEC chose to go with the Cullinane system because it conforms to CODASYL recommendations.

In programming languages, DEC offers PDP-11 users two versions of FORTRAN, three versions of BASIC, COBOL, DIBOL (DEC's own business-oriented language), and RPG II. However, it should be noted that not all these languages are available with all operating systems. In fact, DIBOL is available only for the Datasystem 350 and the Datasystem 500 line. Generally, the language restrictions are based on whether or not the operating system can support enough hardware to permit the incorporation of a particular language processor.

A substantial library of user-generated, but not DEC-supported, software is available from two groups within DEC. DECUS, the DEC Users Society, offers a catalog of nearly 370 software packages that includes languages, editors, numerical functions, utilities, display

high-speed peripheral controllers, and four standard peripheral slots; the memory cabinet contains prewiring for a second 128K bytes of core memory.

MASS STORAGE

TC11 DECtape Subsystem: A magnetic tape system in which the tape is preformatted into blocks in much the same way that a disk pack is formatted for use. The basic unit contains dual bidirectional drives, each holding a 260-foot reel of 10-track tape. Data is recorded on 3 redundant data tracks, requiring 6 line positions to store a 16- or 18-bit word. Since the tape is preformatted, searches and random access operations can occur much more efficiently than with standard magnetic tape subsystems. The controller can accommodate up to four dual TU56 transports, each capable of storing up to 288K bytes of data in blocks of 1156 bytes each. Data transfer rate is 10K bytes per second. Recording density is 350 bpi, and tape speed is 97 ips in either direction.

RX11 FLOPPY DISK: The RX11 is a flexible disk drive with a capacity of 256,256 bytes per drive. Up to two drives per controller can be configured. Average access time is 483 milliseconds; rotational speed is 360 rpm, yielding an average rotational delay of 83 milliseconds. A track-to-track move takes at least 10 milliseconds. The surface of the diskette is divided into 77 tracks, each with 26 sectors. The RX11 floppy disk drive is manufactured by DEC.

RS03 AND RS04 FIXED-HEAD DISKS: The RS03 and RS04, respectively, store 512K and 1024K formatted bytes with respective data transfer rates of 500K bytes per second (4 microseconds per 16-bit word) and 1 million bytes per second (2 microseconds per 16-bit word). To realize the higher data rate, an 11/70 with a high-speed controller is required. Both models are identical in all other specifications. Average rotational delay is 8.5 milliseconds, and minimum access time is 6.4 microseconds. (Using 50-Hertz power, these times become proportionally greater.) Up to eight drives of either type can be intermixed on a controller.

RK11 2.4-MEGABYTE CARTRIDGE DISK SUBSYSTEM: Includes an RK05J cartridge disk drive, with one removable IBM 5440-type cartridge, and a controller for up to eight drives. The RK05J drive records data at 512 bytes per sector, 12 sectors per track, and 203 tracks per surface. Formatted capacity is 2.4 megabytes. Average rotational delay is 20 milliseconds, and average head-positioning time is 50 milliseconds. Data transfer rate is 156K bytes per second (11.1 microseconds per 16-bit word). The RK05J cartridge disk drive can be intermixed with the RK05F double-density drive on the same controller. The RK05J disk drive is manufactured by DEC.

RK05F 4.8-MEGABYTE CARTRIDGE DISK DRIVE: A double-density version of the RK05J cartridge disk drive having 406 tracks per surface. It uses a nonremovable cartridge and has a capacity of 4.8 megabytes. The RK05F drive can be intermixed with the RK05J drives on the same controller, although there must be at least one RK05J drive in the subsystem. To the operating software, one RK05F appears as two logical RK05J's. Hence, a maximum subsystem using RK05F's has three RK05F drives and two RK05J drives. The RK05F disk drive is manufactured by DEC.

RPR11 20-MEGABYTE DISK PACK SUBSYSTEM: Includes one RPR02 disk pack drive (a *rebuilt* IBM 2315-type drive) and a controller for up to seven additional drives. The drive uses IBM 2316-type disk packs with 20 recording surfaces. The formatted data capacity of each drive is 20 megabytes. Data is recorded on 20 surfaces with 203 tracks per surface, 10 sectors per track, and 512 bytes

routines, and various other types of applications software. Also, the Educational Products Group publishes the Index and Description of Educational Applicational Software (IDEAS), which lists about 110 applicational software packages developed by users specifically for educational purposes. Some of the programs listed in the IDEAS catalog are from the DECUS catalog. Users can obtain copies of these programs on various media for a nominal charge by contacting either of these organizations.

USER REACTION

From early responses to Datapro's 1976 survey of computer users, we obtained the combined experiences of 33 PDP-11 users who collectively owned 131 systems of varying sizes. Of the 33 users, two accounted for 40 systems each, while the remaining 31 had the other 51 systems spread fairly evenly among them.

Most members of the PDP-11 family were represented among the 33 responses. Absent were the PDP-11/03 and LSI-11, the PDP-11/50, and the PDP-11/55. By far the most popular CPU's were the PDP-11/35 and 11/40, accounting for over 60 of the 131 systems. Eleven PDP-11/70's were also in the group, the oldest having been installed for about six months. The average installed life of the 131 systems was slightly over one year. Average memory for the systems was about 90K bytes, although 64K-byte memories were most common.

The results of the survey are tabulated and summarized below.

	Excellent	Good	Fair	Poor	WA*
Ease of operation	16	14	3	0	3.3
Reliability of mainframe	17	15	1	0	3.5
Reliability of peripherals	9	19	5	0	3.1
Responsiveness of maintenance service	7	17	7	2	2.9
Effectiveness of maintenance service	6	19	5	3	2.9
Technical support	2	14	7	10	2.2
Operating systems	8	17	6	0	3.1
Compilers and assemblers	7	18	6	0	3.0
Application programs	1	9	6	4	2.4
Ease of programming	10	15	5	0	3.2
Ease of conversion	6	12	4	1	3.0
Overall satisfaction	8	21	2	1	3.2

*Weighted Average on a scale of 4.0 for Excellent.

Generally, the PDP-11 users were satisfied with their systems, although, as the figures point out, there were some reservations. Nearly all agreed that the systems were easy to use and that the CPU was quite reliable. The peripherals were rated slightly lower, although no specific problems were noted. The DEC operating systems and language processors, both strong points with the company, were well rated. Application programs were not thought of as highly as the operating systems and language processors, but it must be remembered that DEC does not generally supply this type of software. These programs are available through DECUS, the DEC user group, and while

per sector. Average rotational delay is 12.5 milliseconds, and average head-positioning time is 35 milliseconds. Data transfer rate is 312K bytes per second (6.4 microseconds per 16-bit word). The RPR02 disk drive is supplied to DEC by several vendors.

RP11 40-MEGABYTE DISK SUBSYSTEM: Includes one RP03 disk pack drive, a double-density version of the RPR02 disk pack drive. Double density is achieved through the use of 406 tracks per surface. The drive uses an IBM 2316-type 20-surface disk pack and stores up to 40 megabytes of formatted data. Data organization is identical with that of the RPR02, except for the number of tracks per surface. Average rotational delay is 12.5 milliseconds, and average head-positioning time is 29 milliseconds. Data transfer rate is 312K bytes per second (6.4 microseconds per 16-bit word). The RP03 disk pack drive is supplied to DEC by several vendors.

IBM 3330-TYPE DISK PACK SUBSYSTEMS: DEC offers three disk pack drives: the RP04 and RP05 88-megabyte drives and the RP06 double-density, 176-megabyte drive. Each subsystem includes a controller for up to 8 drives. Two types of controllers are offered: the "W" controllers, which take advantage of the higher I/O rate of the PDP-11/70; and the "J" controllers, usable with all current PDP-11's. A dual-port kit is optional, permitting any two CPU's to access a single disk drive. Both the "J" and "W" controllers can connect to a dual-ported disk pack drive.

The RP04 and RP05 drives are nearly identical. Both use IBM 3336-type disk packs, recording data on 19 of 20 surfaces. Data is organized on 411 tracks per surface, 22 sectors per track, and 512 bytes per sector. The major difference between the two drives is that the RP05 can be field-upgraded to RP06 status.

The RP06 is a double-density version of the RP05 drive and uses the IBM 3336 Model 11-type disk pack. Double density is achieved by organizing the disks into 815 tracks.

All three models have identical characteristics. Average rotational delay is 8.3 milliseconds, and average head positioning time is 28 milliseconds. Data transfer rate is 860K bytes per second (2.5 microseconds per 16-bit word). The RP04, RP05, and RP06 disk pack drives are supplied by DEC by several vendors

INPUT/OUTPUT UNITS

Please refer to the Peripherals/Terminals Table on page M11-384-303 for information on the DEC peripheral equipment for the PDP-11 computers. Non-DEC peripheral devices that can be used with these and other popular minicomputers are summarized in Reports M13-100-301 through M13-100-601.

DATA COMMUNICATIONS

A discussion of data communications capabilities for the PDP-11 family involves more than a collection of hardware interfaces and a few software packages. Rather, it involves a marketing and engineering group—the Distributed Data Processing Group—which is chartered to develop, market, and generally further DEC's position in data communications. This group has taken its assigned tasks quite seriously and has developed hardware components, systems, and software packages in great numbers—so great, in fact, that the offerings of this *group* to the market are greater than those of many *companies* dedicated entirely to data communications.

Of the numerous DEC processor lines, the PDP-11 family was chosen for data communications emphasis. That doesn't mean that only 11's are found in these systems.

DEC PDP-11 Family

The largest member of the PDP-11 line, the PDP-11/70, features two powerful extensions: memory management hardware, capable of addressing up to 2048K bytes of memory, and a 240-nanosecond bipolar cache memory. According to DEC, the cache memory between the CPU and main memory reduces the effective memory cycle time to about 400 nanoseconds. The 11/70 finds usage in distributed processing systems, as a host system, and in the Datasystem 570, the high-end model of DEC's business product line.

distributed *through* DEC, they are not supported by the company. Again, no specific problem areas were noted.

Numerically, the categories of Responsiveness of Maintenance Service, Effectiveness of Maintenance Service, and Technical Support were rated substantially lower than most of the other categories. These low averages, especially the one for Technical Support, were the result of a large percentage of the returns coming from one particular area where DEC is not as well established as it is in most other regions. Because these ratings were substantially reduced by returns from a single geographic area, indicating a possible regional problem, Datapro recalculated the average user ratings for these categories *without* the user inputs from that one region. The ratings *would have been* 3.3, 3.3, and 2.8, respectively, for the three categories—much more consistent with the user ratings on all other aspects of the PDP-11 family.

Finally, one brief note on the PDP-11's competitive position in the minicomputer marketplace: there is not one system represented in *DATAPRO REPORTS ON MINICOMPUTERS* that does not compete directly with one or more members of the PDP-11 family or their Datasystem counterparts. The product line ranges from the LSI-11 microcomputer to the powerful PDP-11/70, and this, coupled with the fact that DEC is the largest minicomputer manufacturer in the world, makes the family the foremost market target for nearly every other minicomputer vendor.□

Quite the contrary. The PDP-8's (see Report M11-384-101) were there initially also, and this family has its representatives in every DEC application line, due mostly to longevity.

Members of the PDP-11 line were selected for data communications use because of the wide spectrum of models with varying capabilities, ranging from the PDP-11/10 to the PDP-11/70. DEC states that it has placed much emphasis on giving all the PDP-11's considerable data communications capabilities, pointing to their byte-handling capabilities and the Unibus architecture, which does not require additional multiplexing hardware for multiple communications channels or for DMA transfers. Also, all PDP-11 communications interfaces follow standard PDP-11 configuration rules. Special chassis and/or backplanes for communications options are not required, as is the case with some other vendors' equipment.

This section covers both the hardware and software aspects of the PDP-11's data communication equipment, including systems offerings. The software packages, which are the breath of life to the various hardware configurations, are often used to name a specific product line, such as an RSTS/2780 system. RSTS is the name of a software package. This name is also given to product systems which use RSTS to control the associated hardware that makes up the *physical* system. This point has been brought out because the ensuing section will mention product names that may otherwise be considered additional hardware offerings, but which are merely standard components configuations with particular software packages controlling them.

Data communications control for all PDP-11's is supplied by nine interface controllers. However, each of these nine has a number of variants and options so that PDP-11's can be connected to almost any type of communication channel (private phone, dial-up phone, 20-mA line, telegraph line), almost any type of terminal, or almost any type of modem. Supplementing these interfaces is additional data communications hardware to provide flexibility in unique situations.

The following basic interfaces are available—

	Single-line	Multiple-line
For asynchronous lines and terminals—		
Character interrupt	**DL11**	**DZ11 & DJ11**
DMA (output only)	**–**	**DH11**
For synchronous lines—		
Character interrupt	**DUP11 & DU11**	**–**
DMA	**DQ11 & DMC11**	**DV11**

DEC PDP-11 Family

DEC's approach has been to provide a variety of price and performance choices and to provide as much capability within the interface hardware as possible. For instance, the DV11, which connects PDP-11's to synchronous lines, is actually a complete communications preprocessor that is capable of relieving the PDP-11 CPU of the major portion of the load involved in interrupt handling, special character handling, and error checking. The characteristics of these communications interfaces are presented in more detail below.

The *DL11 Asynchronous Serial Line Interface* provides control for one full- or half-duplex line–changeable under program control. Mode changing, however, is the only programmed change that can be made to this unit. All other characteristics are set when the device is ordered, usually by straps on the board. Those features include a choice of 13 standard data rates between 50 and 9600 bits per second, choice of character size (5, 6, 7, or 8 bits) and stop element size (1, 1.5, or 2 bits), and selection of parity (odd, even, or none). Appropriate parity is appended to outgoing characters, and parity is checked on incoming characters. The unit contains independent two-character buffers (one to transmit data and one to receive data), permitting longer delays between interrupt servicing without annoying rate errors. The DL11 can operate with different input and output line speeds *except* when the 110 or 134.5 bps speeds have been selected. The DL11 provides all necessary signals to control Bell 103A, E, and F, 113A, or 202C and D modems or their equivalents, or to connect to 20mA or EIA terminals. The DL11 is contained on one board and requires one SPC slot.

The *DJ11 Asynchronous Multiplexer* provides control for up to 16 full- or half-duplex lines. This unit bears some resemblance to the DL11, in that similar functions on both are hardware-selectable. The major difference is that the DL11 interfaces one line and this unit controls 16; but, as in the DL11, data rate, character size and stop element length, and parity check/generation are all set up through hardware (switches or straps). In the case of the DJ11, it's all switches, whereas in the DL11 some of the above functions are selected through straps. Unlike the DL11, this multiplexer has no provisions for data set handshaking.

Another minor difference to note: the DJ11 offers 11 different speeds compared to the 13 offered by the DL11. Character buffering in the DJ11 is also slightly different. A common 64-character buffer serves all 16 lines and can be used to reduce per-character overhead as well as to prevent rate errors if the incoming characters temporarily exceed the CPU's processing rate. The 16 lines are not totally independent of each other. Character formats and speeds are selectable only for four-line groups rather than on an individual-line basis.

Since the DJ11 has no capabilities for modem control signals (handshaking), it can be used only on dedicated lines. It can still be used with a modem to send and receive data between itself and remote terminals, but these have to be connected to dedicated lines. No dial-up interfacing is possible. Up to 16 DJ11's can be used in one system, providing a total of 256 controlled lines. The EJ11 will be replaced by the single-card 8-line DZ11 Asynchronous Multiplexer (below).

The *DZ11 Asynchronous Multiplexer* has characteristics similar to those of the DJ11 but provides control for up to eight asynchronous terminal devices or eight full- or half-duplex lines. Each line can be individually programmed through software control for one of 15 line speeds between 50 and 9600 bps. The DZ11 is a lower-cost, reduced-performance multiplexer and does not have DMA facilities. However, the DZ11 includes enough modem controls to operate a Bell 103 or equivalent 300-bps data set. An EIA RS-232C interface is standard, and a 20-milliampere current loop is available as an option. Interrupts can be programmed to occur for each character or after 16 characters. The DZ11 is generally transparent to data, but can report parity errors and framing errors. Input characters are buffered with identification hardware in a first-in/first-out (FIFO) buffer or "silo" (in DEC terms). Up to 16 DZ11's can be used in a system. The card requires one hex slot.

The *DH11 Programmable 16-Line Asynchronous Multiplexer* has many similarities to the DJ11. Both provide full- or half-duplex control for up to 16 lines. The DH11 provides programmed selection of nearly all parameters that are switch-selectable on the DJ11–data rate, character and stop element size, and parity check/generation on receive and transmit lines. A few other differences can also be noted. First, the DH11 offers a choice of 14 data rates plus 2 special rates of the user's choice. Second, each of the 16 lines can operate independently at any speed. As in the DJ11, receive characters for each line are buffered in a 64-word buffer to reduce CPU loads. Transmit characters can be sent directly in blocks from memory (DMA). The DH11 has 16 separate DMA transmitters, each with its own hardware byte count and address registers. Also, special hardware to detect data breaks and to generate program-controlled breaks is provided. Various models of the DH11 exist for 20-mA or EIA connections or both on the same DH11.

The PDP-11 can accommodate up to 16 DH11's, providing a total of 256 lines each with an individual DMA transmitter interface. The DH11 consists of a double system unit and distribution panel.

The *DU11 Synchronous Line Interface* is a single-line, double-buffered controller for full- or half-duplex operation. This unit is fully programmable for sync character, character length (5 to 8 bits), and parity check/generation on receive and transmit (odd, even, or none). Data rates are normally controlled by an attached modem, but an optional clock (DFC11-A) can be used for local connection not requiring a modem. Auto answering can also be selected. This unit cannot be used for DMA transfers. The DU11 occupies one SPC slot in a DD11 Peripheral Mounting Panel.

The *DUP-11 Synchronous Line Interface* is a single-line, program-controlled, double-buffered controller capable of handling both byte-oriented protocols, such as binary synchronous and DEC's DDCMP, and bit-oriented protocols, such as SDLC, HDLC, and ADDCP. The DUP-11 features full- or half-duplex operation and is restricted to 8-bit characters. Bit- or byte-oriented operations are software-selectable. Modem controls are provided, permitting operation with Bell 200 Series or equivalent synchronous data sets at speeds up to 9600 bps.

Additional features of the DUP-11 include calculating and checking of CRC-16 block check characters and bit stuffing. The latter is used in several of the new data communication protocols to preclude data characters from being confused with control characters. Specifically, the DUP-11 inserts "0" bits in bit streams containing five or more consecutive "1" bits so that the receiving device will not interpret this stream as a FLAG control character. The DUP-11 is mounted on one hex card. Up to two can be mounted in a DD11-B peripheral mounting panel.

The *DQ11 Synchronous Line Interface* offers many of the features of the DU11 plus a number of unique qualities. The similar characteristics are modem-controlled data rates (up to 1 megabit per second in this case), optional clock (DQ11-KA) for local connection, and programmable selection of sync character and character size (to 16 bits this time). Unlike the DU11, the DQ11 makes use of DMA, through on-board word count and address registers, for data transfers, which explains the high rate that is possible. Although sync characters are program-selectable, the choice as to whether there will be one or two sync characters per frame is made through a switch on the board. Three different operating modes–auto idle, strip sync, and half-duplex–are also program-selectable. In auto idle mode, sync characters are transmitted continuously until either the CPU or terminal signals its intention to send data. In strip sync mode, only the text portions of received messages are sent to the CPU and main memory. Sync characters are discarded after detection. Straps are provided for the user to designate any three characters as control characters. When any of these characters is received, a vectored interrupt will be generated to the CPU.

Another useful feature of the DQ11 is programmable selection of parity on received data (odd, even, or none) and programmable LRC/CRC generation and checking in hardware. If desired, LRC and/or CRC characters are appended to the transmitted data stream and checked when arriving with the input data stream.

Input and output sides of the DQ11 have two sets of word count and address registers. The DQ11 can be set to automatically switch from one set to another when a buffer is exhausted. This permits longer delays between interrupt servicing without incurring annoying rate errors. This unit furnishes RS-232C/CCITT V.24-compatible control Bell 201 or 303 modems or equivalents. It occupies one slot in a DD11 peripheral mounting panel.

The *DMC11 Network Link* is a complement to the DQ11 and is designed for high-performance interconnection of PDP-11 computers in network applications. Data rates of up to 1 million bps can be obtained over coaxial cable at distances of up to 6000 feet. Lesser data rates can be realized over greater distances.

The DMC11 is a microprocessor-based unit consisting of two modules, the DMC11-AD microprocessor module and one of the DMC11-MA, DMC11-MD, or the DMC11-DA line unit modules. Even though the line units are also mounted on hex-sized modules, they only require an SPC (quad) slot having been cut away to permit mounting over the normal Unibus connector in a DD11 peripheral mounting panel.

The three line modules adapt the DMC11 to various applications. The DMC11-MA contains a built-in modem and is used for local operation at 1 million bps over coaxial cable up to 6000 feet long. The DMC11-MD also contains a built-in modem but is used to send data over distances up to 18,000 feet at rates up to 56,000 bps. The DMC11-DA does not have a built-in modem, and only includes an EIA RS-232C interface. It is intended for use with Bell 208, 209, or equivalent modems at data rates up to 19,200 bps.

The DMC11 is intended specifically for the DDCMP protocol. The microprocessor communicates with the host computer through DMA operations and is assigned a 256-byte memory block by the operating software, for use as a control and status block. Up to seven input and seven output messages can be queued in main memory by the DMC11.

The DMC11 also features a built-in bootstrap, permitting remote program loading and control transfer on CPU's that do not have bootstrap facilities.

The *DV11 Synchronous Preprocessor* is a high-performance 8- or 16-line microprocessor-based multiplexer that features DMA data transfers and data rates of up to 9600 bits per second for each of 16 full-duplex lines. (Total throughput capacity is 38,400 characters per second). It can relieve up to 95 percent of the central processor's load in terms of interrupt handling, generating block characters, and special character handling.

A control table scheme tells the DV11 how to act on each incoming data or control character. Table entries specify a number of choices for each possible character: to store or not to store the character in the data buffer, to include or to exclude the character from the block check calculation, to cause or not to cause a vectored interrupt to the CPU. In addition, receipt of a character can designate that a different table is to be used for subsequent characters, thereby enabling the DV11 to detect sequences of control characters without CPU intervention. The DV11 consists of a double system unit and a distribution panel.

The *DX11B IBM 360/370 Channel Interface* can connect to either a multiplexer or selector channel of an IBM System/360 or 370 computer and perform data transfers via the PDP-11's DMA facilities. The unit can recognize up to 128 of the 256 possible IBM device addresses and handle all channel-generated control signals. Data transfer rates can be as high as 250K bytes per second, depending on the particular model of IBM 360/370 processor interfaced. The DX11B can work with a PDP-11 to emulate an IBM 2848 controller or 2703 or 3705 transmission control unit.

The following units provide support functions to the line interfaces previously described:

The *DN11 Automatic Call Unit Interface* provides a buffered interface for up to four Bell 801A, 801C, or equivalent automatic all units. The DN11 uses programmed I/O for data transfers and occupies one system unit.

The *KG11-A Communications Arithmetic Option* is a programmable hardware block check character generator. It computes three different cyclic redundancy check (CRC) polynomials and two different longitudinal redundancy check (LRC) characters. This single-board unit replaces software routines for generating and checking the standard check characters listed above. The choice of checking polynomial is made through program control. The unit can be used with any PDP-11 synchronous interface.

The KG11-A can be shared between multiple lines by storing interim check characters in main memory and passing the interim character to the KG11-A along with each new character. The KG11-A then computes the desired polynomial, which is read back to the CPU and stored again in main memory as the updated interim check character. In this way, several lines can make use of one unit.

COMMUNICATIONS CONTROL

A variety of communications-oriented software packages are available from DEC. These can be divided into two classes: software for communications between PDP-11's and non-DEC mainframes, and software for communications between PDP-11's and other DEC computers.

For communications with non-DEC systems, emulators provide the necessary software interfaces. DEC offers several IBM 2780 batch terminal emulators, including Core 2780, a stand-alone package for small PDP-11's with at least 16K bytes of main memory, a line printer, and a card reader; RSTS/E 2780; RT-11/2780; and RSX-11D/2780–all packages that augment the appropriate operating system and permit communications with IBM System/360 or 370 computers.

DEC PDP-11 Family

For all-DEC computer networks, there is *DECNET*, which is actually a number of specific products aimed at several broad markets. Announced in April 1975 as a series of hardware and software extensions to standard systems, DECNET permits users to create communications networks merely by adding appropriate software and hardware to existing computer systems.

DECNET is not a turnkey solution. At the very least, customers must purchase communications links such as a telephone line or private wire, one or more of DEC's communications interfaces for each computer in the network, and often a modem for each end of every link. Some of the more complicated applications will require considerable programming, as well.

DECNET allows customers to:

- Transmit data files across a room or around the world, with less expense and greater speed than is generally possible through other media.
- Share expensive peripherals among several CPU's, some of which may be remote.
- Use another tool in the creation of high-availability (super-reliable) systems, adding to the Unibus links and multi-port options that Digital already supplies.
- Make more extensive use of memory-only systems.

DECNET is also the collective name for the set of software products which extend various DEC operating systems so they can be interconnected with each other to form computer networks. The DECNET user can configure a variety of networks by choosing the appropriate CPU's, line interfaces (and speeds), and operating systems software. Such networks typically fall into one of three classes: 1) these that move data from one physical location to another; 2) file-oriented networks, often the case for remote job entry systems; or 3) line-oriented networks, as occurs with the concentration of interactive terminal data.

DECNET includes a set of network protocols, each designed to fulfill specific functions within the network. Collectively, these protocols are known as the Digital Network Architecture, or DNA. The major protocols, and their functions, are as follows. Digital Data Communications Message Protocol (DDCMP) handles the link traffic control and error recovery within DECNET. DDCMP has been designed to operate over full- and half-duplex facilities, using synchronous, asynchronous, and parallel facilities. Network Services Protocol (NSP) handles network management functions within DECNET, including the routing of messages between systems and within any given system. Data Access Protocol (DAP) enables programs on one node of the network to utilize the I/O Services available on other network nodes. Each operating system in DECNET provides facilities for translating its own unique I/O calls into the DAP standard, and vice versa. DAP thus allows remote file access, including OPEN, READ, WRITE, CLOSE and DELETE for sequential and random files, and remote device access for unit record devices.

The versions of DECNET announced to date are primarily oriented toward computer networking applications involving inter-program communication. As DEC continues to expand both its terminal marketing and commercial data processing marketing efforts, it seems reasonable to expect that the DECNET concept will be extended to include more terminal capability on a turnkey basis. The existence of terminal concentrators and front ends, based on DEC minis and used with large DEC computers (the DECsystem-10 and DECsystem-20), seems to point the way for this future DECNET capability.

A goal for the set of DEC products has been to provide as general an interconnection mechanism between specific products as possible, limited only by the technology and cost considerations which constrain each individual member of DECNET. Those latter constraints make totally general interconnectability impractical. The individual DEC Software Product Descriptions for each product should be consulted in order to ascertain whether any particular configuraion violates the guidelines for the individual product. The following table lists the DECNET products and delivery dates:

Product	Prerequisite Software	Date Available
DECNET-11D	RSX-11D Version 6	5/76
DECNET-11M	RSX-11M Version 2	12/75
DECNET-11S	RSX-11S Version 1	12/75
DECNET-E	RSTS/E Version 7	10/76
DECNET-IAS	IAS Version 2	8/76
DECNET-RT	RT11 Version 2	4/76

While DECNET represents a generalized approach to computer networks within the DEC family, the company is continuing development of a series of remote terminal emulators for other manufacturers' host mainframes. DEC came out with its first such product, an IBM 2848 emulator based on the PDP-11, over four years ago. Today, Digital provides IBM 2780 emulators for PDP-8's, PDP-11's, and the DECsystem-10. In the PDP-11 family, the emulator has been integrated into RSX-11D, RSX-11M, RSTS/E, and RT-11. Multi-leaving HASP emulation is now available under RSX-11D and RSX-11M, as well as in a stand-alone version. Direct channel interfaces to IBM computers via the DX11 have also been sold in custom situations under RSX-11M.

DEC has a history of supporting IBM communications protocols, and it seems likely it will continue to do so. Although the company would neither confirm nor deny this, we believe it will inevitably provide the capability for interfacing a stand-alone system or a DECNET network to an IBM host, probably via both the DX11 channel interface and SNA terminal emulation.

Remote job entry to Control Data and Univac mainframes is also available under RSX-11D and RSX-11M. Sold under the names MUS-200 and MUS-1004, DEC's RJE emulators offer sophisticated replacements for the Control Data 200 User Terminal and the Univac 1004. The power of DEC's real-time operating systems, coupled with the RJE emulation, provides an attractive price/performance mix.

SOFTWARE

OPERATING SYSTEMS: The major operating systems for the PDP-11 include: 1) the single-user PTS-11 paper tape system, CAPS-11 cassette programming system, and RT-11 disk-based system; 2) the RSTS/E resource-sharing time-sharing system; 3) the RSX-11 real-time multiprogramming systems: RSX-11D, RSX-11M, and RSX-11S; and 4) the multifunction, multilingual IAS operating system. Two operating systems for the packaged DEC Datasystem 500's, the Commercial Data Management System (CDMS) and Commercial Timesharing System (CTS-500/E), are covered in greater detail in the DEC Datasystem 500 report, M11-385-401.

PTS-11 Paper Tape System: PTS-11 is the minimal PDP-11 operating system, usually utilized only on the smaller PDP-11 processors. It requires a paper tape reader and console terminal with 8K bytes of memory. Included are the PAL-11 assembler, Editor, and debugging aids. In 16K bytes of memory, a relocating assembler, linker, and

DEC PDP-11 Family

optional FOCAL and BASIC language processors are available. A multi-user BASIC (up to eight users) is also optional.

CAPS-11 Cassette Programming System: CAPS-11 is an entry-level operating system that requires a TA11 cassette unit, 8K bytes of memory, and a console terminal. File support is provided for Digital standard cassette files. Program development support includes the PAL-11 relocating assembler, linker, editor, ODT debugger, and PIP file transfer utility. An optional BASIC language processor is also available.

RT-11 Disk-Based Operating System: RT-11 is an easy-to-use yet powerful operating system that includes two monitors: a single-job and a foreground/background (F/B) monitor. The single-job monitor can support program development or a real-time application for one user, while the F/B monitor can support concurrent real-time execution in the foreground and program development in the background, typically for one user. RT-11 is generally disk-based, with a cassette, magnetic tape, or additional cartridge disk drive needed for backup. The single-job monitor can also be DECtape-based. The single-job monitor can be run in as little as 16K bytes of memory, while the F/B monitor requires at least 32K bytes. RT-11 supports a wide range of peripherals, including graphics (GT44, VT11) and signal processing (AR11, LPS11) subsystems.

Programs supported by RT-11 include a MACRO assembler, Editor, linker, librarian, PIP file transfer program and utilities for file converting, dumping, comparing, and verifying. A contiguous file structure is implemented to provide fast response. Program development may be done interactively through the console terminal, or in batch mode. Batch streams can be entered through a card reader or stored and initiated from a mass storage device such as the system disk.

RT-11 supports three optional high-level language processors: FOCAL, BASIC and FORTRAN IV. FOCAL is a computational language suitable for use by scientists or students as a first computer language. FOCAL/RT-11 is a compatible superset of FOCAL/PTS. BASIC/RT-11 is the popular language implemented as an incremental compiler to achieve higher execution speeds than conventional interpreters. A multi-user version, MU BASIC/RT-11, is available that can support up to eight simultaneous users. BASIC/RT-11 is a compatible superset of BASIC/CAPS and BASIC/PTS, while MU BASIC/RT-11 is a compatible subset of MU BASIC/PTS. FORTRAN/RT-11 is an optimizing compiler that is compatible with the ANSI standard and includes many additional features. FORTRAN/RT-11 is also compatible with the FORTRAN IV language processors available with the RSX-11 family products and IAS. All RT-11 language processors utilize the RT-11 file structure, and can be used independently or in combination with MACRO assembly-language modules.

Optional applications packages available with RT-11 include a Scientific Subroutine Package, a Lab Applications Package, and a Plotting Package for the LV11 electrostatic printer/plotter. The GAMMA-11 nuclear medicine system is based upon the RT-11 operating system, as is the PHA-11 pulse-height analysis system application.

RSTS/E (Resource-Sharing Timesharing System/Extended): RSTS/E is a time-sharing system designed to accommodate large numbers of interactive users. The interactive language is BASIC-PLUS, an enriched version of the popular BASIC language. RSTS/E requires a PDP-11/34, 11/35, 11/40, 11/45, or 11/70 with hardware memory management for memory expansion and protection. A wide range of communications interfaces is supported to allow mixes of local and remote terminals with varying characteristics. For a normal job mix, up to 24 concurrent users can be supported on a PDP-11/34, 11/35-, or 11/40-based system, while up to 32 and 63 users can be supported on an 11/45 and 11/70, respectively.

RSTS/E supplies a comprehensive file system. User files may be random or sequential, numeric or alphanumeric. Files can be created, updated, extended, and deleted interactively from a user terminal or under program control. Files can be protected from access on an individual, group, or universal basis; can be accessed by many terminal users simultaneously; and can be updated on-line. RSTS/E supports a wide range of storage peripherals, and files can be stored on disk packs, disk cartridges. DECtape, and industry-standard magnetic tape in a format readable by other computer systems.

The BASIC-PLUS language implemented under RSTS/E is an enhanced version of Dartmouth BASIC, featuring more than 40 basic commands, 35 built-in functions, and 3 different data types: integer, string, and floating-point (single and double precision). A commercial extension package is available to provide output formatting features such as comma insertion, floating dollar sign, trailing minus, asterisk protect and sort, line printer spooling, and indexed access file method routines. Although BASIC-PLUS is a compiler, the immediate mode of operation permits it to be used as an interpreter. To supplement the BASIC-PLUS language in commercial applications, a batch COBOL option is available. RSTS/E also supports BASIC-PLUS II, intended for use in data processing production environments. An RPG II compiler for PDP-11's is also available from DEC's Business Products Group.

RMS-11 is a file management system designed to run under RSTS/E on a PDP-11/34, 11/45, or 11/70. RMS-11 is a multi-key indexed sequential (ISAM) file management system that supports the ANSI-74 COBOL Level 2 Indexed I/O Module specification. The system permits both fixed- and variable-length records and provides RSTS/E users with sequential, relative, and indexed file organization. This allows sequential, random, dynamic, or direct physical access to data records. Combinations of the above modes can also be invoked. Other significant features of RMS-11 are multi-level privacy control and both generic and approximate key searches in multi-keyed indexed processing.

Other applications packages available under RSTS/E include DECAL, a computer-aided instruction package for education; WISE, a data base management tool primarily intended for college administration; Picture Book, a utility for managing graphics files; and RSTS/2780, an emulation package for IBM 2780-protocol communications.

RSX-11 Real-Time Operating Systems: The RSX-11 family consists of three compatible operating systems: RSX-11D, RSX-11M, and RSX-11S. Each features event-driven multiprogrammed responses to real-time stimuli. The RSX-11 systems handle many tasks (programs) concurrently, with requests for system resources handled on a priority basis. The compatibility among systems is achieved by a hierarchical structure of Monitor Console Requests (MCR's), File Control System (FCS), and common language processors. RSX-11S is a subset of RSX-11M, which is in turn a subset of RSX-11D. As a result, programs developed for RSX-11S run directly under RSX-11M, and, by relinking, under RSX-11D. The file systems allow easy transportability of data and programs between systems.

RSX-11D Advanced Real-Time Operating System: RSX-11D is the largest and most flexible RSX-11 system. It requires an 11/34 or larger processor with hardware memory management, 96K bytes of main memory, and adequate disk and backup storage for full operation. RSX-11D has the capability to keep many tasks going at once, each with a set priority at one of 250 levels which may be amended as necessary, and all in a totally hardware-protected environment. Tasks are scheduled and executed in response to external stimuli, operator commands, or a function of time, in a multiprogrammed environment. Flexibility is obtained by the use of checkpointing (suspending an executing task, sorting it on disk, substituting a higher priority task in its place, and swapping the original task back when the higher priority task is finished) and dynamic allocation of memory (which can change the partitioning of memory and the tasks assigned to partitions in real-time).

Tasks under RSX-11D are developed in MACRO assembler, FORTRAN IV, or, optionally, FORTRAN IV-PLUS. Program development can take place concurrently with real-time execution, in either BATCH mode or interactively from one of four possible time-shared terminals. The text Editor is sharable, as can be application programs developed under FORTRAN IV-PLUS. The PDP-11 COBOL language processor is also available under RSX-11D, to supplement the business data processing requirements of the real-time operations. A full set of utility programs is included.

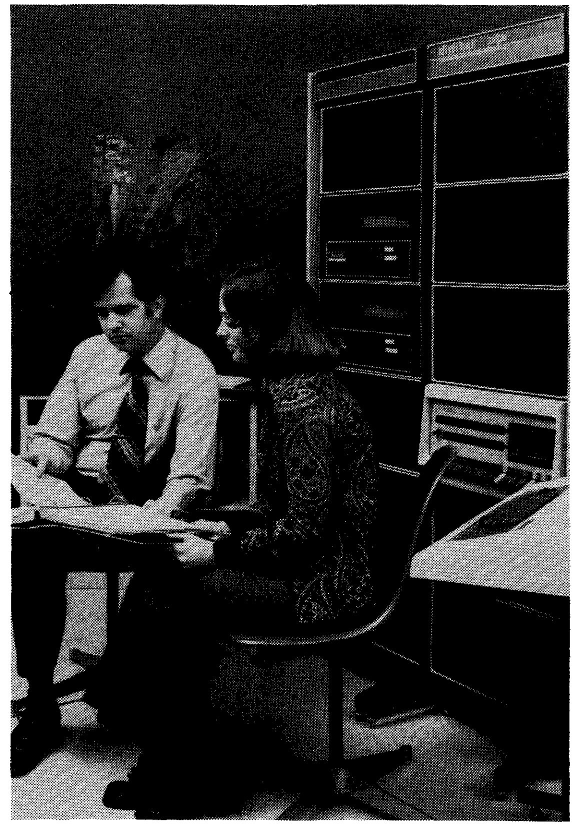
Applications available under RSX-11D include a commercial subroutine package (CSP-11) for FORTRAN IV-PLUS and engineering applications such as COGO, STRESS, and PCS. Communications applications include TC/D, a terminal concentrator package which can be used with RSX-11D systems to form a basis for transaction processing systems, and the RSX-11D/2780 emulation package for IBM 2780 protocol communications.

RSX-11M is a subset of RSX-11D that provides less flexibility at a lower overhead. Real-time execution is event-driven by priority in a multiprogrammed environment, as in RSX-11D. RSX-11M supports checkpointing, but memory allocation is not dynamic. Memory partitions are fixed and named at system generation time, making RSX-11M suitable for applications where the operating environment is not highly volatile, as it can be for RSX-11D applications. The resulting lower overhead allows RSX-11M to operate on PDP-11/04, 11/05, and 11/10 systems as well as on 11/34's, 11/35's, 11/40's and 11/45's. On the latter four systems, hardware memory management is not required, but it can be utilized for protection and expansion to 124K bytes.

Program development is accomplished from an interactive console terminal, in MACRO assembler, FORTRAN IV, or, optionally, FORTAN IV-PLUS. It is accomplished in a background partition, concurrently with real-time execution on systems with at least 48K bytes of memory. A foreground-only (i.e., real-time execution only) system can operate in as little as 32K bytes, with program development taking place when no tasks are executing. RSX-11M is disk-based and requires a backup/distribution device in addition to the system disk drive.

The RSX-11M file management system provides automatic allocation and file structures for all block-structured devices, including the RX11 floppy disk. Files can be organized as either random or sequential and can be accessed by file name. A selective protection feature permits file access to specified users.

RSX-11M has a program logical space extension feature that allows execution of very large application programs without requiring disk overlays. A single program can occupy all user space (less the resident system). This feature



This is DEC's fast-flying FORTRAN machine, the PDP-11/55. It looks like many other PDP-11's, but appearances can be deceiving. The PDP-11/55 is really a PDP-11/45 with 300-nanosecond bipolar main memory and the new faster FP11-C floating-point processor that adds two 64-bit double-precision operands in 1.63 microseconds or multiplies two similar operands in 5.43 microseconds. The configuration shown is an 11T55 system, a standard packaged system that includes the PDP-11/55 CPU with 64K bytes of memory, the FP11-C floating-point processor, a dual RK05 4.8-megabyte cartridge disk subsystem, and an LA36 DECwriter II console terminal. The 11T55 system is purchase-priced at $67,000, and monthly maintenance charges are $510.

permits faster execution of larger programs, but at some expense to smaller lower-priority programs that must be stored on disk while the larger program occupies main memory.

RSX-11S is a memory-based subset of RSX-11M that requires no disk storage for operation. It is an execute-only system, with program development accomplished on an RSX-11M system. Since there is no disk storage, checkpoint is not supported. The application programs are transported from the RSX-11M development system to the RSX-11S target system through a mutual exchange medium such as cassette. The priority structure and execution of tasks is compatible with RSX-11M.

RSX-11S is suitable for use where harsh environments prohibit disk-based operation, or where dedicated applications do not require the expense and flexibility of a disk. However, RSX-11S supports all the disks (and other peripherals) supported by RSX-11M. Devices with full file directory support (such as disks) under RSX-11M are utilized without directory support under RSX-11S. The system can operate on a PDP-11 with as little as 16K bytes of memory, a terminal, and a program loading device.

DEC PDP-11 Family

IAS (Interactive Application System): IAS is a multifunction, multilingual operating system that can support a mix of concurrent time-sharing, batch, and real-time processing activities. It is geared for operation on a PDP-11/70, but can also be utilized with larger PDP-11/45 configurations. IAS is disk-based and supports a wide range of standard peripherals.

The heart of the IAS system is a real-time executive compatible with RSX-11D. When not servicing real-time requests, the executive yields control to the time-sharing and batch supervisor to allow priroty processing by interactive terminals and any job that may be active in the batch stream. The key to the IAS system's flexibility is its ability to support multiple user interfaces. The system-supplied interface provides program development and execution facilities to an interactive terminal. A number of user-supplied, application-specific interfaces can also be active, and certain terminals can be attached to them. Thus, some terminals can be attached and dedicated to, say, editing, while others are dedicated to data base updating or retrieval, and the rest to general program development.

IAS can support up to 16 interactive terminals. The interactive user (when connected to the system interface) can develop programs in BASIC, FORTRAN, COBOL, or MACRO assembler, call any system utility (such as the editor, linker, or a file utility), execute a program, submit a program into the batch stream, or combine these functions, all from his terminal. The system supports a variety of data file storage methods, protection codes, passwords, integrity checks, and system management controls, as required for a large and diversified environment. The system manager can tune the IAS system to meet his present or changing requirements.

DBMS-11 is DEC's adaptation of Cullinane Corporation's IDMS data base management system. IDMS was originally developed by a *Fortune 500* company in 1970 and 1971, and was put into production in early 1972. In 1973 Cullinane was awarded complete responsibility for the system, including all technical developments, enhancements, field support, and marketing. Enhancements have generally followed the CODASYL guidelines, with emphasis on performance and usability, making DEC the first minicomputer vendor to offer a data base management system consistent with the CODASYL recommendations.

DBMS-11 encompasses a data base design methodology; a language to describe the physical and logical data base (DDL); a data manipulation language (DML); compilers for COBOL, PL/1, and FORTRAN; and a data base manager that provides record storage, control, space management, security, and backup and recovery functions. Also included is a data base dictionary subsystem.

The basic unit of physical space under DBMS-11 is the page, a fixed-length block between 1024 and 2048 bytes long. Data bases can be divided into physical areas made up of any number of pages and also into logical files. The entire data base can be assigned to one file, and many logical files can be assigned to a physical area.

DBMS-11 uses the concept of data sets. Within a data set, one record type functions as the "owner" and one or more record types function as "members." Using the set concept, hierarchical, network, partially inverted, indexed, and bill of material data bases can easily be defined. Set characteristics are defined by the system designer and consist of independent choices of set order, set membership, and set linkage.

The designer can select one of five logical orders for each set:

- SORTED–members are stored under control of a logical sort field.
- FIRST–members are stored LIFO (last-in, first-out).
- LAST–members are stored FIFO (first-in, first-out).
- NEXT–members are stored in a descending sequence under control of the application program.
- PRIOR–members are stored in ascending sequence under control of the application program.

The same member record may be in a different sequence in each set in which it participates.

The designer can select one of four membership specifications for each set. The choices are:

- Mandatory Automatic–members are automatically inserted into a set at the time they are stored and remain in the set until erased from the data base.
- Mandatory Manual–members are inserted into a set under program control but remain in the set until erased from the data base.
- Optional Automatic–members are automatically inserted into a set when stored but may be disconnected from one set and connected to another under program control.
- Optional Manual–members are inserted into sets under program control but must remain in that set until erased from the data base.

A member record may have different linkage specifications in each set in which it participates. Four linkage options are available for each set:

- NEXT–the system maintains unidirectional pointers for processing in the forward direction only.
- NEXT and PRIOR–the system maintains bidirectional pointers for processing in forward as well as reverse order.
- NEXT and OWNER–the system maintains pointers back to the respective owner in each member record as well as pointers in the forward direction.
- NEXT, PRIOR, and OWNER–a combination of the second and third options noted above.

Records are stored into the DBMS-11 data base by one of the following three techniques:

- CALC–provides for record storage based on a symbolic key within the data record which the data base management system uses to calculate a relative storage address. CALC is used to define entry points into the data base and is often used for "master" type data. Duplicate keys may be accepted or rejected based on design criteria.
- VIA–provides for storage of member records physically near the owner record to which they are related within the set. VIA is often used for "transaction" type data and provides for more efficient processing because all the associated data are brought into main memory with a single access.
- DIRECT–the application program directs the data base management system to store a record at a given relative

location. This technique is useful when the application program desires to establish a custom addressing scheme.

In all cases, actual record storage, space management, buffering, and control are the responsibility of the data base management system.

The subschema provides for a logical subset of the data base and defines the rules by which the individual application system may access the data base. Data independence and data security features are implemented in the subschema, and the user can define additional privacy control through the use of passwords, special keys, or data range analysis. DBMS-11 also provides special routines for data compression and decompression, variable-length records, editing and validation, record subsitution, auditing, statistical analysis, and encoding/decoding through the use of special DBA procedures.

Application programs access the data base through use of the DML, which provides the interface to the data base system. DML commands such as STORE, ERASE, CONNECT, DISCONNECT, MODIFY, and OBTAIN minimize the need for coding CALL statements. The DML commands and the host-language statements, which may be COBOL, PL/1, or FORTRAN, are read into a DML compiler which checks the syntax of the DML command, checks its logical consistency with the data base, and inspects the security and privacy locks associated with the application subschema. In addition, the DML compiler builds the user data work areas, data base communication areas, and data base declarative statements.

Assembler-language programmers access the data base through the use of a set of DML macros. In addition, the programmer may communicate directly with the data base in any language at the CALL level if desired.

Currently, DBMS-11 requires a minimum system consisting of a PDP-11/70 with 256K bytes of main memory, a large disk pack drive, and the IAS multi-user operating system.

CDMS-500 is a data management system for the Datasystem 500 that is based on MUMPS-11 (Massachusetts General Hospital Utility Multi-Programming System) and is designed to support up to 32 active users with a data base of up to 320 million bytes. CDMS-500 supports variable-length data strings stored without preformatting in a hierarchical storage structure where frequently used data is strategically placed. Program development support for the MUMPS high-level interpretive language is also provided. The minimum Datasystem 500 required for CDMS-500 includes a 32K-byte processor with one disk drive. An 8-user configuration requires a 64K-byte main memory, 2 or more disk drives, an industry-compatible magnetic tape drive, and a line printer. CDMS-500 systems were first delivered in August 1973.

CTS-500/E is an outgrowth of the Resource Time-Sharing System (RSTS) and its extended (RSTS-E) version. CTS-500/E can support up to 32 concurrent users (depending upon processing demands) on a Model 540, 550, or 560 Datasystem, or up to 63 on a Datasystem 570. Program development support for BASIC-PLUS is provided. The minimum configuration consists of a 64K-byte Datasystem 500 (96K bytes for 32 users), two disks, and a line printer.

COS-500 runs on the Datasystem 500 and offers program development support for RPG II (compatible with the IBM System/3 and Burroughs B 700 and B 1700), a macro assembler, and FORTRAN IV (compatible with IBM 1130), as well as program development aids for on-line debugging (ODT), RPG trace, general-purpose editing (EDIT-II), and non-DEC RPG conversion aids. A powerful System/3-compatible sort program is also provided. COS-500 runs on a 56K-byte system with two disk drives, a card reader, operator console, and lineprinter.

LANGUAGES: The major programming languages for the PDP-11 include FOCAL, which operates under PTS and RT-11; BASIC, which operates under PTS, CAPS-11, RT-11, and IAS in single-user mode and under PTS and RT-11 in multi-user mode; BASIC-PLUS, which operates under RSTS/E; FORTRAN IV, which operates under RT-11, RSX-11, and IAS; and FORTRAN IV-PLUS, which operates under RSX-11, IAS, and RSTS/E.

FOCAL is a computation language best suited for first-time computer users such as students, scientists, and researchers. FOCAL/PTS operates from paper tape and can be utilized in just 8K bytes of memory. FOCAL/RT-11 can be used to interface to real-time devices for experiment control and monitoring under the RT-11 operating system. The FOCAL language is conversational in nature and quite efficient.

BASIC for the PDP-11 is implemented as an incremental compiler, which retains the interactive nature of the language while providing increased execution speeds over conventional interpreters. It is an enhancement of Dartmouth standard BASIC that includes support for string and arithmetic functions. Peripheral support includes routines that can directly interface to the laboratory peripheral systems (AR11, LPS11) and graphics display systems (VT11, GT40, GT42, GT44) through BASIC.

BASIC-11, an extension of BASIC, is supported by the IAS and RSX-11 operating systems. This further enhanced version of BASIC features a CALL interface for COMMON subroutines, support for block terminals as well as character terminals, the ability to handle virtual arrays, and integer support. This the first BASIC compiler offered for RSX-11 systems.

BASIC/PTS is a paper tape BASIC language processor that is loaded into and executed from main memory. A multi-user version that can handle from one to eight simultaneous users (MU BASIC/PTS) is also available. BASIC/CAPS operates from TA11 cassettes. It is a single-user system and supplies all the features of BASIC/PTS with the addition of sequential cassette files, chaining, and overlay support to facilitate larger programs. BASIC/RT-11 is disk- or DECtape-based under the RT-11 operating system. A multi-user version (MU BASIC/RT-11) is available to handle from one to eight simultaneous users. BASIC under RT-11 supplies all the features of BASIC/CAPS with the addition of sequential, random-access, and virtual memory file support. A similar BASIC is implemented under the IAS operating system.

BASIC-PLUS is a compiler that is an integral part of the RSTS/E time-sharing operating system. The BASIC/PLUS language is a superset of PDP-11 BASIC, including many extensions and built-in functions.

BASIC-PLUS II is a further enhancement of BASIC designed to be used in EDP production environments. Specifically, BASIC-PLUS II supports indexed sequential (ISAM) files, and thus supports DEC's RMS-11 record management system. It also features the CALL statement found in BASIC-11 and is compatible with other DEC BASIC language processors. BASIC-PLUS II also includes debugging aids such as breakpoints, step mode, and change of variables. Other important features of BASIC-PLUS II include support for block-mode terminals, long variable names, and a decimal arithmetic package.

BASIC-PLUS II is currently supported by RSTS/E, but versions for use with RSX-11M and IAS will be released next year.

PDP-11 FORTRAN SYSTEMS: DEC offers a series of packaged systems designed specifically for FORTRAN users. These range from single-user PDP-11V03 systems to 63-user 11/70-based systems with memory expansions to 1024K bytes and high-speed I/O. The PDP-11T34, the next larger system above the 11V03, provides memory expansion to 248K bytes (compared to 56K bytes with the 11V03), disk storage to over 700 megabytes, and a choice of either a real-time or a time-sharing system. The PDP-11/34 CPU, with the newly announced FP11-AU floating-point processor, offers the performance of a PDP-11/40, but is priced very close to the PDP-11/10.

The highly specialized 11T55 package is designed as a very fast FORTRAN machine with larger system capabilities, such as 248K-byte main memory. The 11/55 CPU is a 300-nanosecond processor and uses 450-nanosecond bipolar memory and a fast parallel floating-point processor.

The following table summarizes the important characteristics of these four FORTRAN systems.

	11V03	11F34	11T55	11/70
CPU	11/03	11/34	11/55	11/70
Basic memory (bytes)	32K	32K	64K	96K
Expansion limit	56K	124K	64K (bipolar) 124K (core)	1024K
Mass storage medium	Floppy disk	Floppy disk	Cartridge disk	Disk pack
Mass storage capacity (bytes)	512K	512K	4.8M	88M (per pack)
Operating system	RT-11	RT-11	RSX-11M	IAS or RSTS/E
Number of users (typical)	1	1	2 to 3	10 to 63
Price of basic system (approximate)	$10,450	$20,620	$67,000	$200,000

PDP-11 FORTRAN IV is an optimizing compiler that implements a superset of ANSI standard FORTRAN. The same basic language processor is implemented under RT-11, RSX-11M, RSX-11D, and IAS. Some of the extensions added to make the FORTRAN IV language more efficient are the permitting of general expressions wherever a variable or a constant is called for; the addition of the .XOR. and .EQV. logical operators; the elimination of redundant subexpressions within blocks of code; and automatic array vectoring to speed of multiply operations required in array subscripting.

Additional features, such as convenient commenting capability for each line and easier error messages and debugging aids, are implemented to reduce program development times. As a final polish to each program, FORTRAN IV does extensive "peephole" optimization, examining each sequence of operations and substituting a shorter, faster group if possible. Under RSX-11M and RSX-11D, the ISA real-time extensions are implemented to facilitate real-time interfacing to standard devices.

FORTRAN IV-PLUS is an optimizing compiler oriented toward minimizing execution times. It requires a PDP-11/45 or PDP-11/70 with a hardware floating-point processor (FPP). FORTRAN IV-PLUS is a further superset of FORTRAN IV and operates under the RSX-11M, RSX-11D, and IAS operating systems. Features include specialized flow analysis of DO loops, the ENTRY (multiple entry points to a subroutine), PARAMETER (custom-tailoring of program parameters), and OPEN and CLOSE (for direct file manipulation) language enhancements; and implementation of the ISA real-time extensions.

The key to the speed of FORTRAN IV-PLUS is the way it uses the general registers, asynchronous FPP registers, and instruction set to generate hard in-line code for increased execution speed. The compiler can generate sharable code as well, and since it is implemented with software virtual memory, large programs can be compiled efficiently in a 32K-byte user partition.

PDP-11 COBOL is implemented as a low-level compiler conforming in language elements, representation, symbology, and coding format to the ANSI-1974 COBOL specification. It is designed to meet the business data processing requirements of an RSX-11D, RSTS/E, or IAS system application. PDP-11 COBOL meets the ANSI full-level specifications in the COBOL Nucleus, Table-Handling, Sequential I/O, and Random I/O modules. In addition, the Segmentation and Library modules have been implemented, but not at full level. DEC expects to release the Communications module, the CALL facility, and the Indexed I/O module in near-future releases.

PDP-11 COBOL comes with three utility programs: RFRMT, a source program maintenance facility; COBRG, a report program generator; and a SORT utility. In a manner similar to FORTRAN IV-PLUS, COBOL is implemented as a software virtual memory system. This allows large source programs to be compiled in relatively small user partitions.

UTILITIES: The paragraphs following are generalized descriptions of PDP-11 family utility programs.

The *Disk Compression Utility (DCU)* consolidates the area used by files on a disk. If the disk is not full, DCU provides the user with larger contiguous free areas on the disk.

DSKINT (Disk Initializer) is a stand-alone program used to format RK11 or RP02 disks and to build RSTS-11 file structures on RK11, RP02, RP03, RP04, RP05, RP06, or RF11 disks. The structures that DSKINT builds include two file directories, two monitor files, and a dummy bootstrap routine. Format and building operations permit the initialization of RSTS-11 private disk and public non-system disks, and enable bad-block checking of all RSTS-11 disks.

The *Dump Utility (DMP)* allows users to obtain a printout of any file in ASCII or octal format.

Editor is a symbolic editor program that allows users to create and modify source-code programs from the console keyboard (or via a paper tape or card reader). Modifications are entered into memory as they are typed, thus facilitating checking, correction, and further modification. When the editing process is complete, Editor produces a source program that is suitable for creating a binary object program.

FILCOM (File Compare) traces changes to a file by comparing the two files and providing a list of differences. The files must be ASCII. This utility can be a valuable debugging tool when used following editing changes to a file.

FILDMP (File Dump) examines the contents of a file by reading the entire file or specified blocks of that file and creating a dump copy in octal bytes, words, or ASCII characters. The file may be formatted or unformatted binary data or formatted ASCII data. FILDMP can also treat each word as a group of three packed Radix-50 characters and print the characters represented. More than one representation of the file can be specified. Output can be sent direct to the keyboard device or line printer or stored in a file.

File Control Services (FCS), available under RSX-11D, provide the user with record-oriented and block-oriented file I/O and additional functions required for file control

DEC PDP-11 Family

such as open, close, wait for event flag, and delete operations. The user issues macro calls to specify desired file control operations. FCS supports both sequential and direct-access files. Sequential access is device-independent and can be used for both record-oriented and file-structured devices. Direct access is used for file-structured devices only.

The *File Transfer Program (FLX)* is a utility that converts files between DOS/BATCH and RSX-11D formats and can also convert files using different data types within the DOS/BATCH and RSX-11D formats. Files converted can be of any data type; i.e., task image, binary, or ASCII.

LINK is a DOS/Batch utility that links program segments to one another when they have been successfully compiled or assembled. It also corporates programs that are held in a library and 1) relocates each object module and assigns absolute addresses; 2) links the modules by correlating the global symbols that are defined in one module and referenced in others; 3) when applicable, implements the overlay structure the user has defined; 4) creates an executable load module, writing it as a data set rather than into memory, allowing it to be used more than once; and 5) provides a cross-reference listing of globals.

The *RT-11 Linker* is very similar. It converts object modules produced by the RT-11 Assembler into a format suitable for loading and execution. It allows users to separately assemble a main program and needed subroutines without assigning absolute load addresses at this time. In addition to the functions performed by the DOS/Batch Link program referenced above, the Linker creates an initial core control block for the linked program and produces a load map showing the load module layout.

The Linker requires at lease 16K bytes of main memory; any additional memory available is used to extend the symbol table. Input is accepted from any binary device on the system. There must be at least one random-access device (disk or DECtape) for "save image" output.

MONEY is an RSTS-11 system accounting that allows a user to obtain printed data concerning his own account status. The program can be called by any user who is logged into the system.

The *On-Line Debugging Technique (ODT)* aids users in debugging programs that have been assembled/compiled and built into tasks. From the keyboard, the user can 1) print the contents of any location in the task for his examination or alteration; 2) run the entire program or any portion of it, using the breakpoint feature to halt its execution at specified points; 3) search the object program for specific bit patterns, words, or references to a particular address; 4) calculate offsets for relative addresses; and 5) fill a block of words or bytes with a designated value.

A *TRACE* program is also provided for FORTRAN debugging.

ROLLIN is a stand-alone utility program used to transfer data quickly between a disk and either DECtape or magnetic tape or between RK11 disk cartridges. Disks handled by ROLLIN are the RF11, RC11, RP02, and RK11. ROLLIN assumes no file structure, and all data transfers are performed in image mode. Magnetic tapes are treated as file-structured devices in that each ROLLIN file is preceded by a DOS-compatible file label.

When transferring data onto either type of tape device, ROLLIN automatically writes an initial record containing a tape sequence number called a reel label. For DECtape transfers, the reel label also contains the number of blocks of data transferred. The reel label guards against mounting tapes out of sequence when returning data to a disk device. Preceding all data records on a DECtape or the first file on a magnetic tape, ROLLIN copies a core image of itself. This image permits ROLLIN to be bootstrapped from the tape to load the remainder of the tape.

The *SYSTAT* program provides current system information in the areas of job, device, disk, and buffer status. SYSTAT can be called by a user logged into the system or from a terminal which is on-line but not logged into the system.

The *RSX-11D Task Builder* creates actual core images from assembled or compiled tasks. It links relocatable object files together and resolves any references to global symbols, the common area, and the shared libraries. The Task Builder also uses an overlay descriptor language to construct task overlays.

The *TTYSET* system program is used to establish the terminal characteristic of the user terminals. TTYSET can be run by any user before or after logging into the system.

VERIFY checks the consistency and accuracy of system files on a file-structured device. It also prints the number of available blocks in a volume, locates files that could not otherwise be accessed, and lists the files that have entries in the system-maintained index file for the volume.

QUOLST allows the PDP-11 user to determine what portion of his disk quota is currently in use or occupied and the number of free blocks that remain on the system disk. Output from QUOLST includes the user account number and information printed under the following headings:

STR—the file structure of the device being reported
USED—the number of 512-byte blocks used under the user account
FREE—the number of free blocks remaining in the user account disk quota
SYSTEM—the number of free blocks remaining to the system on the device indicated.

The *Peripheral Interchange Program (PIP)* is used to transfer files between devices, merge and delete files, and list, zero, and compress directories. PIP accepts up to nine input files and outputs to one file. Since PIP performs file transfers for all types of files, ASCII, IMAGE or SAVE format, or binary, there are no assumed extensions. All extensions for either input or output must be explicitly specified in the commands to PIP. For the PDP-11 family, PIP is available in two forms. One contains Record I/O copy options and is available only to systems with the Record I/O feature. The other version can perform only formatted ASCII file transfers.

LOGIN and *LOGOUT* are a pair of PDP-11 family user terminal utilities that operate under RSTS-11.

LOGIN connects a user terminal to RSTS-11, attaches a user to another job already running in the system, or permits the user to run designated system programs from a logged-out terminal. LOGIN can be called either when the user first logs into the system or at a later time.

LOGOUT is called when the user has completed all processing and is ready to leave the terminal. The LOGOUT program is started by a command typed at a user terminal logged into the RSTS-11 system. LOGOUT checks the current user's disk quota to ensure that the user does not log out of the system with more than the acceptable disk quota size, LOGOUT disconnects the terminal from the system, removes the current job number from the list of active jobs, and prints information on the duration of the current job.

DEC PDP-11 Family

APPLICATIONS SOFTWARE: DEC PDP-11 applications software packages tend to take the form of advanced tools that can be applied with configured systems that are marketed by groups within the company. DEC issues press releases on new application tools in various applications fields with great regularity, and space limitations preclude complete coverage in this report. Examples of the sophisticated tools DEC can provide are the Industrial Data Acquisition and Control Systems and the LA-11 Laboratory Data Processing packages.

The Industrial systems are used either as on-the-floor satellite computers or as stand-alone development/process control systems. They provide hierarchical configurations with computer-process or computer-communications capability. The Industrial systems operate under RSX and its compatible supersets. An example is the Industrial 1100 System with Power Demand Control software.

LA-11 is a package of application software modules designed to solve most laboratory automation problems such as data acquisition and instrument control, data display and manipulation, and file storage and retrieval. The library comprises assembly-language routines which are callable at the macro level.

Included in the library is SPARTA, the Signal Processing and Real-Time Analysis program. SPARTA consists of five major components: console interface, data acquisition, interactive graphics, data reduction, and data storage/retrieval. The console interface passes command input from the research user and controls the execution of the other SPARTA components.

SPARTA facilitates interaction through the use of operator-controlled cursors which may either ride along a waveform (fixed) or move freely in two dimensions (free). SPARTA will further display decimal readouts of cursor coordinates and provide display scaling, normalizing, general graphic compressions, and a special zoom-in feature for amplifying regions of interest within a spectrum.

The data reduction functions include both spectrum-to-spectrum and scalar operators for addition, subtraction, multiplication, and division. SPARTA will extract derivatives, both running and absolute integrals, and strip peaks with or without baseline corrections. In addition, the data analysis routines can calculate both forward and inverse complex FFT's (Fast Fourier Transforms) on up to 8192 data points and generate a power spectrum or magnitude and phase angle. With the aid of RT-11's file I/O processor, the program can generate under a scientist's direction a permanent library of laboratory data profiles for future access by SPARTA or any other RT-11 software, e.g. BASIC or FORTRAN.

Other modules included in LA-11 are:

- Interactive Dialog Module—provides a standard interface to facilitate console question-and-answer dialogue for such activity as initiating or controlling an experiment and providing parameters for manipulation routines.
- Output Formatter Module—converts internal data types and prints them in a user-specified format on the console terminal.
- Analog Data Acquisition Modules—sample data from up to 64 analog channels simultaneously.
- Point Plot Display Module—displays single-precision integer data on an XY point plot scope and displays one or two spectra simultaneously with a moving window display and cursors.
- Graphics Display Module—plots byte, single-precision, double-precision, or floating-point data on a CRT under control of an independent asynchronous hardware graphics processor. This processor can also display alphanumeric characters and vectors for axis labeling and decimal readout of XY coordinate pairs.
- FFT Module (Fast Fourier Transform)—completes both forward and inverse complex transformations on any number of data points from 8 to 8,192 in powers of two.

Minimum system requirements for running LA-11 include a PDP-11 processor with an ASCII terminal, 16K bytes of main memory, AR11 or LPS-11 analog front-end, and a dual-drive cassette unit.

PRICING

POLICY: DEC generally provides the PDP-11 minicomputers on a purchase basis, with separately priced maintenance agreements. Leasing arrangements are available through DEC's joint venture with U.S. Leasing Corp. at a monthly charge of 2.4% of the purchase price. DEC software is not sold, but rather, it is licensed. Users purchase licenses and distribution rights separately.

On-site installation and basic education are included in most system prices. One-time installation charges are generally made to install add-on equipment. Separately priced training is available.

EQUIPMENT: The following typical systems purchase prices include all required control units, adapters, and software.

PDP-11/04 SINGLE-USER BASIC/RT11 SYSTEM: Includes a PDP-11/04 CPU with 32K bytes of MOS memory, real-time clock, serial line interface, bootstrap loader, console terminal emulator, CPU self-diagnostic module mounted in a 10.5-inch cabinet, RX11 dual floppy disk system, LA36 DECwriter II, 50-inch short cabinet, and RT-11 basic software. Purchase price is $16,965.

PDP-11/34 FORTRAN CONFIGURATION (11F34): Includes a PDP-11/34 processor with 64K bytes of core or MOS memory, bootstrap ROM loader, real-time clock, memory management, FP11-AU floating-point processor, extended instruction set, virtual console, dual-drive floppy disk, LA36 DECwriter II, cabinet, and RT-11 software. Purchase price is $22,420.

TYPICAL PDP-11/34 RESOURCE TIME-SHARING SYSTEM: This system can be expanded to 16 simultaneous users programming in BASIC-PLUS. The configuration includes an 11/34 processor with 96K bytes of MOS memory, clock, bootstrap ROM loader, TM11, RK11 DECpack removable (dual-drive) cartridge disk subsystem (2.4 million bytes per drive), 16-line multiplexer, and LA36 DECwriter II. Purchase price is $45,700.

TYPICAL LARGE-SCALE PDP-11/45 CONFIGURATION: Includes a PDP-11/45 processor with 184K bytes of 900-nanosecond core memory plus 8K bytes of 300-nanosecond bipolar memory, hardware memory management, bootstrap loader, floating-point processor, two 40-megabyte RP03 disk drives, two TU56 DECtape transports, one TM11 9-track tape drive, CR11 card reader (300 cpm), LP11 line printer (300 lpm), and LA36 DECwriter II. Purchase price is $184,100.

TYPICAL BUSINESS DATA PROCESSING CONFIGURATION: Includes a PDP-11/34 processor, 128K bytes of parity MOS memory, dual 20-megabyte disk pack drives,