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 central processors are ordered in incremental steps of speed and size, so that customers can match their needs with the required levels of processor power.

We're often asked how one categorizes processors into the classifications of "microcomputer," "minicomputer," and "computer" in this day and age, when manufacturers such as DEC offer such a broad range of systems and capabilities. Here's how DEC itself groups the PDP-11 family into four levels:

- *Microcomputer*—the LSI-11, for board-level integration into dedicated applications.
- *Minicomputers*—the PDP-11/04, 11/05, and 11/10, for dedicated applications.
- *System computers*—the PDP-11/35, 11/40, and 11/45, 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 ⊳

The powerful, versatile PDP-11 family of 16-bit minicomputers offers a wide range of processing capabilities to end users and OEM's, as well as in packaged DEC systems. Models are available at prices ranging from $630 (for a dedicated microcomputer) to $250,000 (for a multi-user concurrent time-sharing, real-time, and batch processing system).

CHARACTERISTICS

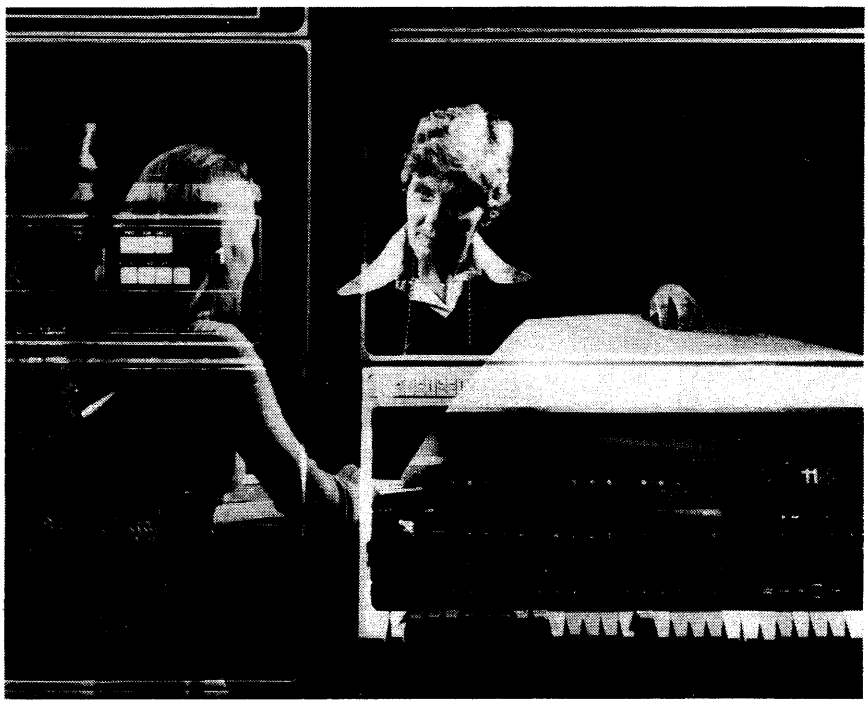
MANUFACTURER: Digital Equipment Corporation (DEC), 146 Main Street, Maynard, Massachusetts 01754. Telephone (617) 897-5111. Digital is a worldwide corporation with sales and service offices in all major U.S. cities and in major cities throughout Canada and the Western world.

MODELS: LSI-11, PDP-11/04, PDP-11/05, PDP-11/10, PDP-11/35, PDP-11/40, PDP-11/45, PDP-11/50, and PDP-11/70. (The original models in the PDP-11 Family, Models 11/15 and 11/20, 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.



DEC released this fanciful and artistic double-exposure photo with the release of WISE (Wheaton Information System for Education, developed at Wheaton College and "refined" by DEC). WISE is a data base management system that can be run on a PDP-11/40 or 11/45 under the RSTS/E operating system. The complete system has a typical cost of $115,000 and was first delivered in March 1975. WISE also can be purchased as a software package by users presently having the required equipment configuration for a $10,000 one-time license fee. The minimum WISE system costs $85,000 and includes an 11/40 or 11/45 with 48K words of memory, three disk cartridge drives, a line printer, and four video terminals.

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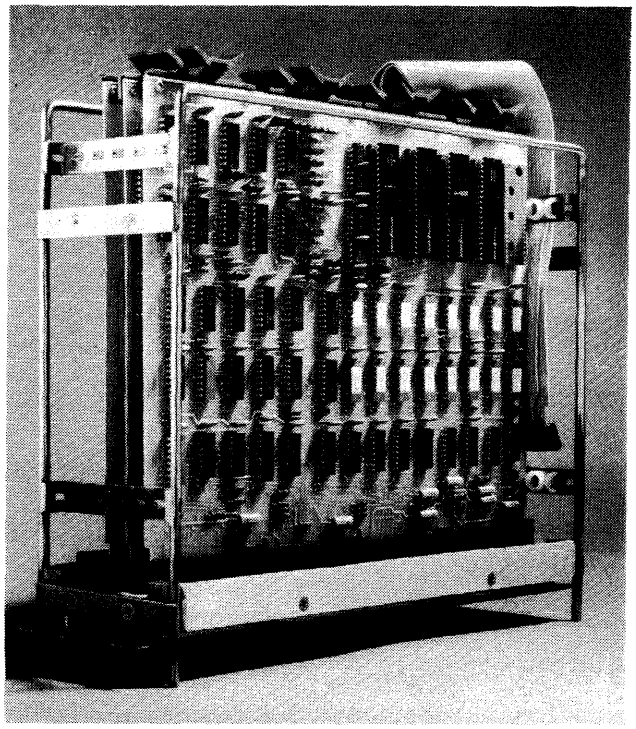
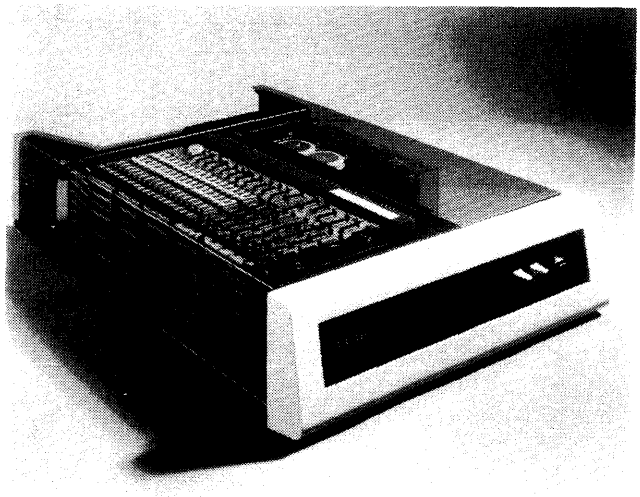
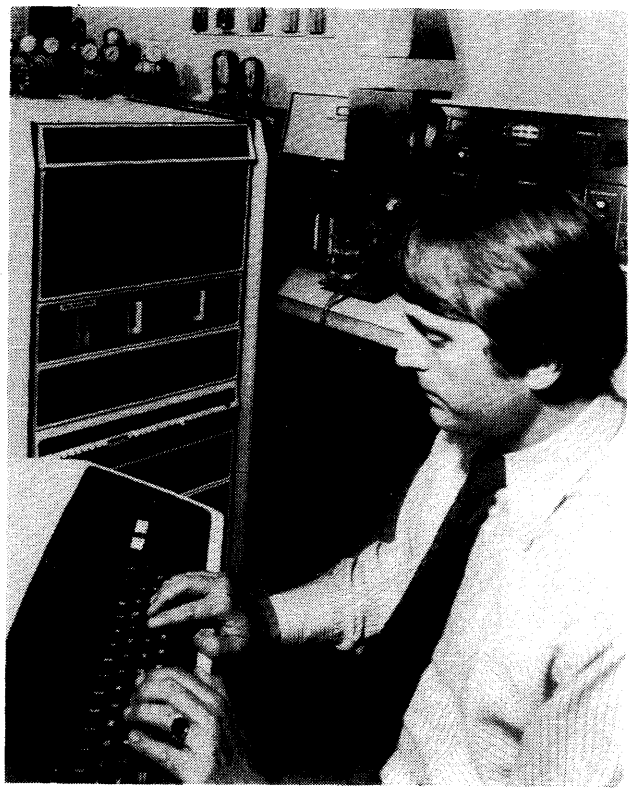


Some of the seven modules in the new DEC LSI-11 microcomputer series are shown in place in the backplane, which has nylon card guides and can be mounted in any position inside other equipment. The card in front is the KD11-F Microcomputer Module. At the card's upper right can be seen the four LSI microprocessor chips and a 40-pin socket for an Extended Instruction Set/Floating-Point Instruction Set MICROM. DEC feels that "popular" LSI-11 system prices will average about $1,797 in quantities of 100.

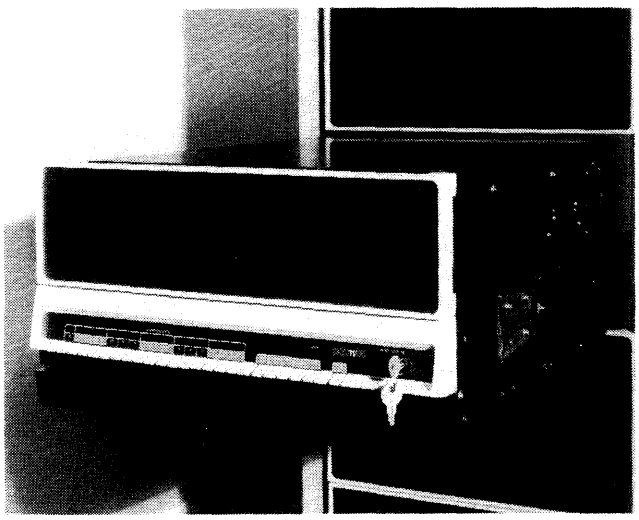


Priced at $2,495 in single units or $1,647 in quantities of 50 for a processor with 4K words of MOS memory, DEC's PDP-11/04 is especially OEM-oriented and offers internal speed 20 percent greater than that of the 11/05 at a price about 30 percent lower.

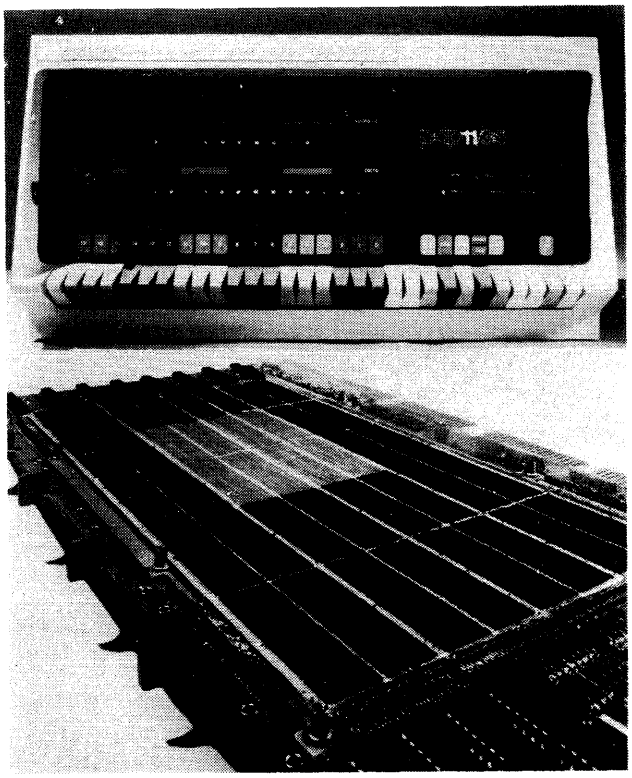
Here's a PDP-11/10 as part of a DEClab-11/10 Laboratory Computer System. The DEClab-11/10 family, at its introduction, included five models and featured prices some 37 percent below DEC's then-current laboratory systems at nearly equivalent performance levels, thanks to the introduction of the 11/10. A DECcassette unit can be seen at left rear.



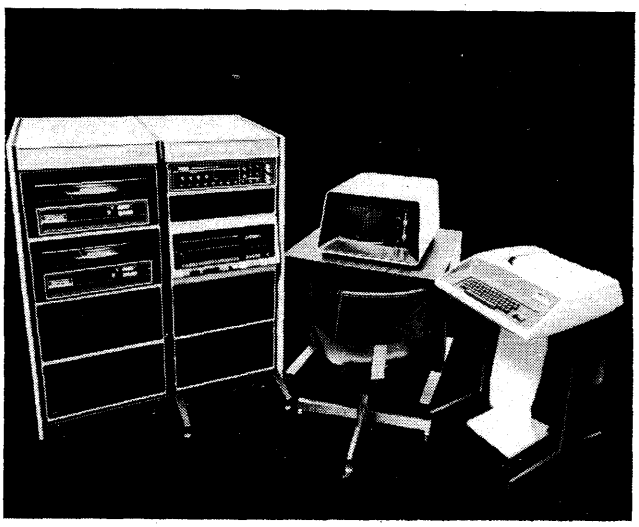
OEM users with greater expansion requirements may favor the expanded PDP-11/05, with a 10½-inch-high rack-mountable chassis and 8K words of memory with the capability to expand to 28K. Its base price is $5,995, with quantity OEM discounts available.



DEC PDP-11 Family



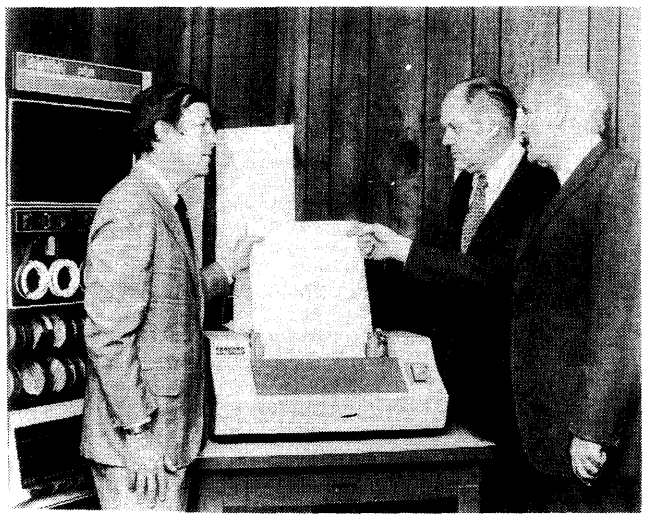
In the foreground is DEC's high-density core memory, which can be used to expand the PDP-11/35 in the background to 124K words of main storage.

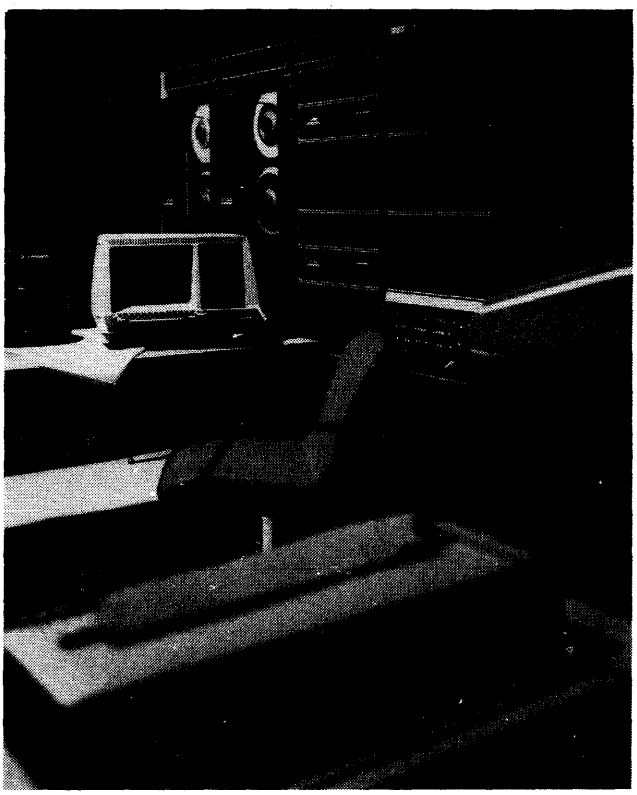


The DECgraphic-11 Laboratory System is a low-priced computer graphics system based upon the PDP-11/40. DEC offers many PDP-11-based systems oriented toward a wide range of specialized applications, including laboratory data processing.

The high-performance PDP-11/70, introduced in February 1975, features an integral cache memory and high-speed 32-bit data paths with parity checking. The system also has memory management, look-ahead, and internal memory expansion capabilities up to 2 million bytes. It features IAS, a new and advanced operating system. The 11/70 is upward-compatible with other members of the PDP-11 computer family and can run existing programs at two to three times the speed of the previous top of the PDP-11 line. Purchase prices for 11/70 systems will range from $54,600 to $240,000. Initial delivery was in May 1975.

A milestone: DEC's 30,000th minicomputer, a PDP-11/35, was presented to the Bureau of Air Quality Control of the Commonwealth of Massachusetts by the company in March 1974. (The 35,000 mark has since been surpassed.) Viewing output from the system, which monitors and analyzes air pollution levels on a continuous basis for statewide air quality forecasting and planning, are the state's former Lieutenant Governor, Donald R. Dwight (left); Kenneth H. Olsen, president of Digital Equipment Corporation (center); and John C. Collins, Director of the Division of Environmental Health.





DEC PDP-11 Family

DISTINGUISHING CHARACTERISTICS OF THE PDP-11 FAMILY MEMBERS

	LSI-11	11/04, 11/05, 11/10	11/35, 11/40	11/45, 11/50	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; 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 16-bit words)	4K to 8K (will support up to 32K in addressing capability, less in std. chassis); core, static & dynamic RAM, PROM, fusible-link PROM	4K to 28K (will support up to 32K, but architecture reserves high-end 4K); core (11/05 & 10), MOS (11/04)	8K to 124K, the amount over 64K using memory management (map) feature; core	16K to 124K, the amount over 64K using memory management (map) feature; core, MOS, bipolar	32K to 1M, the amount over 64K 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-11 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 RSX-11M real-time	RSX-11D real-time	Multiple-purpose, using IAS, or maximum power using RSX-11D (real-time) or RSTS/E (time-sharing)
Prices (representative)	$630-$2,000	$2,000-$20,000	$20,000-$60,000	$60,000 to $100,000	$100,000 and up

unavailable in such packaging. The LSI-11 has the capabilities of a real minicomputer, not just a stripped microprocessor; it includes a CPU with the 11/40 instruction repertoire, 4K 16-bit words 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 28,672 (28K) words.

The PDP-11/04, 11/05, and 11/10 minicomputers provide solutions to dedicated applications in which the computer is used to solve one or two problems and run one or two programs. They are 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 4K words of memory can suffice in straightforward applications, but the systems can be expanded to up to 28K in order to handle more complex applications, perhaps coded in a high-level language such as FORTRAN IV or BASIC.

The PDP-11/35, 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

FLOATING-POINT OPERANDS: Optional 32-bit single-precision operands with an 8-bit exponent and signed 24-bit fraction on the LSI-11, 11/35, and above; or 64-bit double-precision operands with an 8-bit exponent and signed 56-bit fraction on the 11/45, 11/50, and 11/70. Single-precision hardware is available on the 11/35 or 11/40; single- and double-precision hardware is available on 11/45 and larger systems; other PDP-11 family models use floating-point software subroutines (also usable on the 11/40 or larger). The LSI-11 can have optional plug-in, ROM-implemented, 11/40-style floating-point firmware.

INSTRUCTIONS: One-, two-, or three-word instructions. No decimal instructions are available for any PDP-11 Series member. Addressing in the PDP-11 family is done by byte through 16-bit internal registers, allowing addressing of up to 64KB. For the 11/35 and larger models, a Memory Management option is required to address larger main storage.

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 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.

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PERIPHERALS/TERMINALS

DEVICE TYPE	DESCRIPTION	MAXIMUM SPEED
MAGNETIC TAPE		
TU 56	Dual DECtape, block-addressable, 147K words	5K words/sec
TWU/45 & TJU/45	For 11/70 & other PDP-11's, respectively; 800 or 1600 bpi, 75 ips; up to 8 drives per controller; 250 ips rewind; first delivery 7/75	120KB/sec (at 1600 bpi)
TU 10-E/F	Industry-compatible, 45 ips, 9-track (800 bpi), 7-track (200/556/800 bpi)	36KB/sec (at 800 bpi)
TU 16	Industry-compatible, 45 ips, 9-track, 1600/800 bpi	72KB/sec
TS 03	Industry-compatible, 12.5 ips, 9-track, 800 bpi (uses 7-inch reels & tension arms)	10KB/sec
TA 11	Dual-Drive Cassette, 43K words each	562 bytes/sec
LINE PRINTERS		
LP 11-F, H, J, K	80- or 132-position, 64- or 95-character, (1 small peripheral controller)	300 lpm
LP 11-R	132-position, 64-character (1 small peripheral controller)	1000 lpm
LP 11-S	132-position, 96-character (1 small peripheral controller)	800 lpm
LP 11	132-position, 64-character (1 small peripheral controller)	60 lpm
LV 11	Electrostatic Printer/Plotter, 132-position, 96-character	500 lpm
CARD UNITS		
CR 11	Reader, 80-column, tabletop (1 small peripheral controller)	300 cpm
CD 11-A	Reader, 80-column (DMA interface) (1 system unit)	1000 cps
CD 11-EA	Reader, 80-column (DMA interface) (1 system unit)	1200 cps
CM 11	Optical Reader, 80-column, EIA-standard (1 small peripheral controller)	285 cps
PAPER TAPE UNITS		
PC 11	Reader/Punch (1 small peripheral controller)	300/500 cps
PR	Reader (1 small peripheral controller)	300 cps
TERMINALS		
LA 36	DECwriter II, 132-position, 96-character, 7 x 7 matrix	30 cps
VT 50	DECscope, 12 lines x 80 char., 64-char. set	75-9600 bps
VT01	Tektronix 611 CRT	—
VR01	Tektronix RM503 Oscilloscope Display	—
VR14	Point Display, 7 x 9 inch	—
RT01	Numeric Display, 4-12 digits	110/300 bps
VT11	Graphics Processor, 17-inch CRT, light-pen	—

Note: Chassis mounting requirements are in parentheses; refer to configuration rules. Lab peripherals, badge readers, etc. are also available. All of the above peripherals can be used with any PDP-11 family CPU.

sizes can range from 8K to 124K words 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 well 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.

The PDP-11 family includes processors specifically designed for end users and equivalent models intended for original equipment manufacturers (OEM's), who incorporate the minicomputers into larger systems for resale.

The 11/04 is an OEM processor. The 11/05 and 11/10 are, respectively, OEM and end-user versions of the same basic

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

MAIN STORAGE

General aspects, including type, cycle time, and capacity, are covered for the entire family in the Main Storage Characteristics table (page M11-384-307). The categorized entries in the text that follows emphasize exceptions and noteworthy features. Non-DEC storage choices are listed in Report M13-100-101, *Minicomputer Add-On Memories.*

STORAGE TYPE: Magnetic core, MOS (static and dynamic types), and bipolar are the three most commonly used main storage types. Core is available for all models in the family but the 11/04. MOS (dynamic) is featured in the LSI-11, the 11/04, the 11/45, and the 11/50. The latter two models can also use the faster and more expensive bipolar technology. Bipolar memory also forms the cache in the 11/70. (The basic 11/50 has semiconductor memory; this can be expanded to 32K, or to 128K if core is used also or instead.)

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

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SUMMARY AVAILABILITY DATA

	LSI-11	11/04	11/05	11/10	11/15	11/20	11/35	11/40	11/45 & 11/50	11/70
Announced	2/75	11/74	10/71	1/73	4/71	3/70	10/73	8/72	10/71	2/75
First Delivery	5/75	7/75	2/72	2/73	6/71	8/70	1/74	1/73	4/72	5/75
Typical Purchase*	$1.8K	$3.2K	$5.7K	$7K	$9.6K	$10.8K	$10K	$13K	$27K	$80K
Number Installed**	–	–	8,550 total		4,250 total		3,650 total		1,650 total	–

* "Popular" CPU, memory, console, and I/O interfaces; quantity prices are shown for LSI-11 and 11/04.

**As of May 1, 1975; the first LSI-11's and 11/70's were installed in mid-May 1975.

processor. The 11/35 and 11/40 are likewise OEM and end-user versions of the same basic processor, but the 11/35 is available in different-sized enclosures. This duality of model designations is not used at the high end of the PDP-11 family. The 11/45 and 11/70 are complete systems adaptable to either large end-user or OEM multi-task applications. The 11/50 is an 11/45 with a specific amount of fast memory.

End-user and OEM versions of the PDP-11 family differ in two ways: bundled services and terms of sale.

- End-user systems include training, documentation, warranty, and installation.
- OEM purchasers obtain just hardware in volume, and do not receive services unless they are contracted for.

Hallmarks of the PDP-11 family are its common physical architecture and software compatibility. The former arises from the design of the patented DEC PDP-11 Unibus, a single, high-speed, asynchronous, bi-directional communications path. The Unibus allows all system components and peripherals to communicate without processor intervention. Thus, the PDP-11's do not use I/O instructions; an instruction that transfers data between processor registers can do the same between processor and device or device and device register, or between a register and memory. A peripheral can be in communication with memory while the processor is computing. And all PDP-11 system elements plug into the Unibus, without regard for speed. Only the LSI-11 does not use a Unibus. Finally, all PDP-11 processors use the same basic instruction set. The LSI-11 contains two unique instructions, but use of PDP-11 programs on the LSI-11 has proven to be no problem.

MARKETING

We'd have to bore you with excessive repetition if we attempted to state the purpose and complete technical and marketing data on each PDP-11 family model in the text portion of this report. For that reason, this particular report, which deals with what must objectively be regarded as the premier minicomputer product family, is extensively tabular in its presentation. But we won't weigh you down with unwieldy tables, either. Rather, we present a number of compact and, hopefully, useful

classified as storage (e.g., floating-point ROM in the LSI-11).

CYCLE TIME: 1.2 or 0.95 microseconds for core; 495 nanoseconds for MOS; and 300 nanoseconds for 11/50 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.

CAPACITY: Please refer to the table. Capacity is a function of packaging and/or marketing (e.g., the 8K-word limit on the 11/04), of bussing structure (the Unibus requires the uppermost 4K to be dedicated as I/O registers, thus limiting direct address space to 28K), and of whether memory mapping is available. Memory mapping is automatic effective address translation that enables a 16-bit computer to address memory in excess of 32K words. The LSI-11 central processor board comes with 4K words of static MOS memory on it.

The 11/45's core increment size is 16K, the MOS increment is 4K (max. 32K), and its bipolar increment is 1K (max. 8K); those types can be intermixed.

CHECKING: Parity, on a one-bit-per-byte basis, is optionally available on all models from the 11/35 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 11/35 level, neither does any multiple-user operating system.

RESERVED STORAGE: The uppermost 4K words 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 original 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

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MAIN STORAGE CHARACTERISTICS*

Model	Storage Type	Cycle Time (microseconds per word)	Storage Capacity (words)	Increment Sizes (words)
LSI-11	Static MOS, dynamic MOS, core PROM, fusible-link ROM	1.2	4K to 28K	1K MOS (static) 4K MOS (dynamic) 4K core 256- or 512-word PROM
PDP-11/04	MOS (dynamic)	0.45	4K to 28K	4K, 8K
PDP-11/05	Core	1.2	4K to 28K	8K, 16K
PDP-11/10	Core	1.2	8K to 28K	8K, 16K
PDP-11/35	Core	1.2	8K to 124K	8K, 16K, 32K
PDP-11/40	Core	1.2	8K to 124K	8K, 16K, 32K
PDP-11/45	Core, MOS, or bipolar	0.95, 0.45, or 0.3	8K to 124K	16K, 32K (core); 4K (MOS); 1K (bipolar)
PDP-11/50	MOS (dynamic), bipolar, or core	0.45 or 0.3	4K to 32K (up to 124K core)	16K, 32K (core); 4K (MOS); 1K (bipolar)
PDP-11/70	Core (with 240-nanosecond bipolar cache "front end")	0.95	32K to 1,024K	32K (cache is 1K, not counted in this amount)

*Exceptions to the summary data in this table appear in the associated text.

tables, which we reference in both this Management Summary and in the Characteristics section of this report.

But before dwelling on the PDP-11 family products any further, let's briefly examine how the family is marketed: PDP-11's are sold by DEC's OEM Marketing Group, by DEC's Industrial Products Group, by DECcomm (DEC's Data Communications Group), by DEC's Laboratory Data Products Group, and, in Datasystem 500 packaging, by DEC's Business Products Group, Education Products Group, and 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.

DECcomm has a dual role. The first is to serve as a focus for PDP-11 data communications capabilities, and the second is to market products and packaged systems for use in data communications applications (i.e., networks, front-ends, concentrators, etc.).

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 over their predecessors, using only 2 boards and about 200 IC's.

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 M11-384-304) 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 use of higher-performance transistor-transistor logic (TTL, or T^2L) in data paths appears at the 11/35 and 11/40 level; 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 11/04 also uses TTL, as a single-board logic processor. Multilayer PC (printed circuit) boards, which can provide cost advantages from a packaging standpoint and speed advantages due to shortened signal travel lengths, are used variously throughout the PDP-11 family at this time.

The 11/35, 11/40, 11/45, and 11/50 can access up to 128K words of main memory in 32K-word 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 1 million words of main memory.

Memory Management, a concept used in many of the high-powered 16-bit-word minicomputers today, is often misunderstood. It is also often known by different names, such as memory mapping, dynamic mapping, or even dynamic memory management. It is not virtual memory. Rather, it is a scheme which allows a 16-bit-word machine to address locations in a memory that exceeds 65,536 addressable locations by automatically mapping a part of the address into a region of the total real memory. The

DEC PDP-11 Family

INSTRUCTION REPERTOIRES

Instruction Type	LSI-11, 11/35, 11/40	Number of standard (and optional) instructions		
		11/04, 11/05, 11/10	11/45, 11/50	11/70
Single Operand	14	13	16	16
Double Operand	7 (5 more with opt. EIS)	7	10	10
Branch	17	17	17	17
Subroutine	5	3	5	5
Program Control	6	1	6	6
Trap	6	5 (11/04); 4 (11/05, 11/10)	6	6
Miscellaneous	4	4	7	7
Condition Code Operator	10	10	10	10
Floating-Point	(4; opt. FIS)	None	(28; opt. FPP)	(28; opt. FPP)
TOTALS:				
Standard	69	60	77	77
Optional	9	0	28	28
Combined	78	60	105	105

Note: EIS = Extended Instruction Set; FIS = Floating-Point Instruction Set; FPP = Floating-Point Processor.

information handling applications. The PDP-11-based DEC Datasystem 500 series is fully described in Report M11-385-401.

The orientation of the Education and Typeset groups are pretty much as their names imply. But they are not to be underestimated, because both are powerful marketing 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.)

That leaves us, if you've been counting, with two DEC Groups, OEM Marketing and Industrial Products. The former 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 LA-36 DECwriter II and the VT-50 DECscope (and a DEC diskette announced as this goes to press)—and the LSI-11. The Industrial Products Group sells hardware and software solutions for data acquisition and process control applications, frequently based on the PDP-11.

ARCHITECTURE

Now we can look at what these groups are selling. The LSI-11 is a processor and 4K MOS RAM (metal oxide semiconductor random-access memory) on a board. Its technology is LSI (large-scale integration), and it is

number 65,536 arises because it is equal to 2^{16}. Thus, the PDP-11 can directly address 65,536 bytes. Words are addressed by using even-numbered addresses. Virtual memory, on the other hand, maps an address space that the machine's word size will accommodate into a smaller managed real memory resource.

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 11/35 and 11/40 this amounts to 150 nanoseconds per address mapped, and in the 11/45 and 11/50 it totals 90 nanoseconds per address mapped. In the 11/70, however, mapping is concurrent, with no overhead.

With Memory Management, the 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 available memory (always 32K words 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 is 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 an $83 (quantity of 50 to 99) plug-in ROM chip. Users can create special LSI-11

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INSTRUCTION TIMES IN MICROSECONDS*

Instruction	11/05, 11/10	11/35, 11/40	11/45, 11/50			11/70
			Core	MOS	Bipolar	
Fixed-Point (16 bits):						
Load/Store	3.2/4.0	2.32/2.58	2.01/2.13	1.17	0.75	0.95/1.4
Add/Subtract	3.5	1.07	0.97	0.51	0.30	0.40
Multiply/Divide	6.6/7.4	9.16/11.58	3.89/8.39	3.51/8.01	3.3/7.8	3.4/7.9
Branch/No Branch	2.5/1.9	1.07/2.36	0.97/1.18	0.51/0.98	0.3/0.6	0.4/0.7
Floating Point:						
Load/Store	NA	NA	7.0/6.38 (10.8/10.0)	5.66/5.04 (8.16/7.34)	5.34/4.72 (7.52/6.7)	5.54/5.62 (7.93/8.5)
Add/Subtract	NA	26.8/27.1	5.67 (6.97)	5.67 (6.97)	5.67 (6.97)	5.67 (6.97)
Multiply/Divide	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)	7.62/8.62 (11.4/23.0)
Compare & Branch	NA	NA	4.62 (4.87)	4.62 (4.87)	4.62 (4.87)	4.62 (4.87)

*The following notes apply to this instruction timing table: 1) DEC states that LSI-11 and 11/04 instruction timings are presently unavailable; 2) floating-point arithmetic is not available for the 11/05 and 11/01; 3) 11/35 and 11/40 floating-point timings are for memory-to-memory operations; 4) 11/70 fixed-point timings assume a 90 percent cache buffer hit rate; and 5) basic floating-point timings shown are for 32-bit operands, with 64-bit operand timings given in parentheses; 64-bit operands are available only on units with optional FPP, the 11/45 and up.

available with backplane wiring and additional memory boards for use inside other vendors' equipment. Its distinction is the PDP-11/40 instruction repertoire at the PDP-11/05's speed—and a very low price tag. (For a comparison of these and the other PDP-11 family model hallmarks, please see the table "Distinguishing Characteristics of the PDP-11 Family." The LSI-11 is normally sold in quantity, by the Components Group.

Seen as a group, the PDP-11/04, 11/05, and 11/10 comprise the first computers in the family that sport the "standard" PDP-11 architecture, that is, the Unibus. The 11/04 is even more OEM-oriented than the 1/05 due to price, packaging, and the fact that any ASCII terminal can simulate the console function. It uses MOS memory, as opposed to the 11/05's core, and storage is limited, as a marketing consideration (by the size of the standard mounting box) to 8K words, as compared to 16K on the standard 11/05 and 28K on an expanded 11/05. But the 11/04 is said to be as much as 20 percent faster internally than the 11/05 (and thus, by logical extension, the LSI-11) and is 30 percent cheaper.

Moving up to the PDP-11/35 and 11/40, we find increased speed, memory capacities well beyond 32K words, and floating-point instructions plus an extended instruction repertoire. Retained is the Unibus. The PDP-11/40 has met with considerable success in commercial time-sharing.

At the PDP-11/45 and 11/50 level, Schottky TTL (transistor-transistor logic) appears in the CPU. The Schottky diodes in the integrated circuits make this TTL

operations by purchasing fusible-link programmable ROM (PROM) chips at $25 each (50-99 quantity price). 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 speed 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 has a standard ROM bootstrap loader (optional in the 11/05), ROM diagnostics (software in the 11/05), 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 11/35 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.

INDIRECT ADDRESSING: Standard for all models; can be combined with indexing.

INDEXING: Six general-purpose registers (per processor mode) are commonly used as index registers, but the stack pointer and program counter can also be so used. Indexing takes such forms as addition of the register contents to the contents of the memory word following the instruction, use

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about three times faster than the "standard" TTL used in the 11/04 through 11/40. The net result is a 300-nanosecond processor. Also, a Floating Point Processor (FPP) that provides double-precision (64-bit) floating-point arithmetic appears for the first time. The trade-off (flexibility versus speed) of the Unibus rears its head at the 11/45 level, and these machines use internal solid-state busses (in addition to the Unibus) to achieve I/O channel and memory reference overlap.

In the PDP-11/70, presently the family's top-end model, we find the advances of the 11/45 plus main storage addressing to 1 million words, cache memory front-ending interleaved core storage, a memory manager that is overlapped with the processor to eliminate memory management overhead (90 nanoseconds per use in the 11/45 and others with the feature), and internal 32-bit-wide data paths, in addition to the Unibus, between cache and main memory and between memory and the special high-speed controllers used for some disks and fast tapes.

PDP-11 family prices range from $630 (in quantities of 100) for the basic LSI-11 to $250,000 for a very large single-processor PDP-11/70 system, and to $400,000 or more for an expanded dual-processor PDP-11/70 system. The bottom price for a single PDP-11 complete with power supply and cabinetry is $2,500 for a single PDP-11/04; any ASCII device can serve as the console for this system. System prices (e.g., processor, memory, peripherals, and software) within the family will range from about $2,000 at the LSI-11 end in quantity to nearly $500,000.

The distinguishing architectural feature of the "classical" PDP-11 family member is the Unibus, a feature whose design DEC has patented. (And, in fact, DEC may someday collect royalties on other companies' attachments to the Unibus.) The design concept of the Unibus is that of a bidirectional asynchronous path for data and instructions that any system component, including memory modules, can use. With the Unibus, any peripheral device can transfer data to main storage or another buffered peripheral device without processor intervention. Supporting the Unibus capability, DEC's PDP-11/04 through 11/50 reserve main memory portions as device register areas, thus permitting direct peripheral access by applications programs. This greatly simplifies I/O programming, because the entire instruction set is available for I/O routines. In the LSI-11, a "sub-Unibus" machine, fewer signal lines (34 versus the Unibus 56) are used, with addresses and data time-shared; this results in a lower board cost and a cost saving in backplane wiring. In the 11/45 and 11/50 the Unibus is augmented by a solid-state bus, and in the 11/70 a 32-bit wide bus appears in addition to the Unibus, as we have noted. Mention of 32 bits causes many ears to perk up in today's minicomputer market, and we'll watch DEC closely for further developments in this area.

of a general-purpose register as an accumulator and for indexing, and special autoincrement/autodecrement modes that are of particular value in stack and table handling (unless the program register is employed, which would be unwise). Registers R0 through R5 are the general-purpose registers, R6 is a stack pointer, and R7 is the single program counter.

INSTRUCTION REPERTOIRE: Please refer to the table entitled "Instruction Repertoires" (page M11-384-308) 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 M11-384-309.

INTERRUPTS: All models except the LSI-11 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.

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

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COMPETITION

DEC has competition all across the PDP-11 family range. In the range of "standard" minicomputers, the competitors are too numerous to mention. It's at the high and low ends of the PDP-11 family that some interesting competitive situations crop up, because it's here that debate can go on about such fundamentals as design appropriateness.

Consider the LSI-11. Two important competitors in its market are Computer Automation's Naked Milli and National Semiconductor's IMP-16 microprocessor. The former is called a "millicomputer" by CA, which touts it as more powerful than a microcomputer, but useful where a "traditional" mini would be an overkill. The latter is clearly a microcomputer, but National has given it a diskette-based disk operating system. DEC, in turn, can and will continue to strengthen the competitive position of its LSI-11. (Let us never forget that the ability to ship a lot of "iron" helps to maintain the company's financial base.) Digital neither confirms nor denies, but Datapro believes the following LSI-11 developments are likely: 1) an LSI-11 in a box with a power supply, 2) a version of the RT-11 real-time operating system for the LSI-11, 3) a 9-row LSI-11 backplane, and 4) a PROM programming module. Micro, milli, or LSI-mini? You'll have a choice.

At the top, there's also a debate over fundamental architecture, especially for business data processing usage. DEC packages the PDP-11/70 in its Datasystem 570 and endows it with powerful business-oriented operating system software. Data General has built special business-oriented instruction microcodes into its 16-bit Eclipse C/300, while Interdata, Modcomp, and Systems Engineering Laboratories now offer 32-bit-word computers to the same market.

SPEEDS

With regard to raw speed comparisons, the LSI-11, 11/05, and 11/10 are about equal in speed and are about 80 percent as fast as were the original PDP-11/20 and the 11/15, its OEM counterpart. The 11/04 is said to be about 20 percent faster than the 11/05, or about the same speed as the 11/20. The 11/35 and 11/40 are approximately twice as fast internally as the 11/20, and the 11/45 and 11/50 are five to six times as fast as the 11/20, or about six times as fast as the LSI-11, 11/05, and 11/10 trio. The 11/70, in turn, is said by DEC to be two to three times as fast as the 11/45 and 11/50. Chain-multiplying these ratios—which, it must be recalled, multiplies any inaccuracies—shows the PDP-11 family to span a speed ratio range of about 15 or 18 to 1 when the PDP-11/70 is compared to the 11/05 range.

In the previous edition of this report, mention was also made of the PDP-11/03, a stripped-down 11/05 with limited capabilities, and a model for which DEC acknowledged receiving no orders. Neither DEC nor Datapro is going to make the 11/03 disappear; the fact is

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 inches high. DEC processor and peripherals handbooks are readily available for use by those who need details on individual units.

System	Packaging	Power Supply	Max. Weight
LSI-11	Cards; DEC backplane is available	+5, +12 VDC	Slight, variable
11/04	Rack-mount, 5¼ in.	115 or 230 VAC	50 lbs.
11/05, 11/10	Rack-mount, 5¼ in. (std.) or 10½ in. (extended)	115 or 230 VAC	65 to 110 lbs.
11/35	Rack-mount, 10½ in.	115 or 230 VAC	To 400 lbs.
11/40	Single cabinet (min.)	115 or 230 VAC	To 400 lbs.
11/45	Single cabinet (min.)	115 or 230 VAC	To 600 lbs.
11/50	Single cabinet (min.)	115 or 230 VAC	To 600 lbs.
11/70	2 cabinets plus DECwriter II	3-phase, 115 or 230 VAC	1200 lbs.

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. 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 has 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.

The theoretical maximum Unibus data transfer rate is 2.5 million words per second, and attached components communicate in a master/slave manner. The maximum data rate of the 11/45 and 11/50 solid-state bus is 3 million words per second, without affecting the Unibus's capability. On the 11/70, the 32-bit bus is fast enough (i.e., 1 million 16-bit words 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 the bare minimum of 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 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.

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that the machine never really appeared. DEC now states that the 11/03 was announced for a market that failed to materialize.

APPLICATIONS

From an applications point of view, practically no business or industry area has been neglected for automation by some member of the PDP-11 family: commercial batch processing and multiprogramming; commercial, scientific, and educational time-sharing networks; communications front-end processing; intelligent terminals; process controllers; laboratory instrumentation; etc. In these varied applications environments DEC offers a multitude of applications-oriented packaged systems for both end-user and OEM use. These include the Typeset-11, DECcomm communications systems, industrial controllers, the DEClab-11 for laboratory monitoring, the EduSystem 85 educational time-sharing system, and others.

In August 1973 DEC took the important step of packaging its end-user PDP-11's in "mini systems," which are tightly defined configurations of equipment at substantial discounts. For example, the PDP-11E10 combines an 11/10 processor in a 10½-inch expansion chassis, 16K words of core memory, disk controller with moving-head disk, dual tape cassettes, and a DECwriter II for $22,000; the suggested single-user operating system, RT-11, costs an additional $750.

SERVICE AND SUPPORT

Service is never a problem for DEC users. The worldwide firm has over 2,500 service personnel with more than 150 service locations in the United States and Canada. Nor is software much of a problem. DEC, despite its size and strength, is not foolhardy enough to believe it can "hold hands" with every customer. The company provides advanced data processing tools, and the users are expected to develop their own applications software. Users can turn to DECUS, the DEC Users' Society, for valuable and nearly free help and/or programs; DEC itself will often provide some help, too; and a host of OEM "turnkey" or "systems" houses are ready to step in with complete DEC-based solutions for those users who are unprepared to program their own applications.

USER REACTION

Datapro interviewed five OEM companies who purchase a total of more than 1,000 PDP-11 minicomputers yearly. The companies are using PDP-11/05's, 11/35's, and 11/45's at this time. Some have previously used 11/15's and 11/20's. Others are now examining 11/04's or are planning to examine the LSI-11. One user feels that the 11/70, while a logical step up from the 11/45, is not as powerful as he'd ultimately like it to be, and is anxiously awaiting a 32-bit minicomputer from the industry leader.

Here's how these OEM users rated the PDP-11 products and DEC's support in nine important areas:

The LSI-11's bus has a maximum data rate of 833K words per second.

SIMULTANEOUS OPERATIONS: 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 in to 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 LSI-11 basic prewired backplane has eight 72-pin connector slots. The CPU module, with its 4K 16-bit words of memory, requires two slots. Most peripherals require one slot. Most memory modules require two slots (MOS, PROM, ROM). Core memory, however, requires four slots, and its double thickness eliminates usage of the adjacent four slots. DC power is supplied by the customer.

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 expansion space for seven SPC slots. Additional system expansion is available via BA-11 expansion chassis.

The PDP-11/05 basic chassis has prewired nine-slot backplane logic with expansion for four SPC slots. The 11/05 or 11/10 10½-inch chassis (8K memory chassis) has prewired nine-slot backplane logic with expansion space for 8K words of memory and three SU's. The 16K memory chassis has prewired nine-slot backplane logic with expansion for three SPC slots and three SU's. Additional system expansion is available via BA-11's.

The 11/05 or 11/10 basic chassis has a prewired nine-slot dual system unit. Four of these individual slots are prewired for SPC's (DD11); three for 8K words of memory; and two for the CPU, console interface, and real-time clock. Memory expansion is handled by the addition of an ME-11 Memory Expander Box with 8K words of memory (plus room for two more 8K memory stacks). 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,

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	Excellent	Good	Fair	Poor	WA*
Reliability of CPU	3	2	0	0	3.6
Reliability of DEC peripherals	0	4	0	0	3.0
Maintenance service:					
Responsiveness	1	0	3	0	2.5
Effectiveness	1	2	2	0	2.8
Technical support	2	2	0	0	3.5
DEC assembler programs	2	2	0	0	3.5
DEC operating systems	2	0	0	0	4.0
Overall satisfaction	2	3	0	0	3.4
Credibility of vendor	5	0	0	0	4.0

*Weighted Average on a scale of 4.0 for Excellent.

One fact is self-evident from this strong showing of user satisfaction: DEC's OEM customers feel secure with DEC as their supplier. Also, the two companies who make use of DEC operating systems (one uses RSX-11D in the end product, while the other lets his customers develop programs using DOS/BATCH) both rate them as "excellent." The ratings of CPU reliability are an admirable mixture of "excellents" and "goods," and user satisfaction, DEC's assembler, and DEC's peripherals also garnered high ratings. (By "DEC peripherals" we mean any peripheral unit supplied by DEC, regardless of whether the company manufactured the device.)

The ratings regarding DEC maintenance were the lowest, but were by no means a cause for concern. A factor in these depressed ratings was our combining of users with different service arrangements. The ratings also tend to reflect a variety of special maintenance arrangements (e.g., "depot" maintenance), wherein a complaint over lack of timeliness can result from poor carrier shipping. Also, both the "effectiveness of maintenance service" rating and the "reliability of DEC peripherals" rating would have been higher if one persistent tape control problem and several "noncatalog" peripheral devices hadn't been considered.

In addition to interviewing the five OEM users of DEC PDP-11's in March 1975, Datapro conducted a general survey of minicomputer users in September 1974. In that survey, 38 users of 115 DEC PDP-11's assigned these ratings:

	Excellent	Good	Fair	Poor	WA*
Overall performance	15	20	2	0	3.4
Ease of programming	11	21	4	0	3.2
Ease of operation	17	19	2	0	3.4
Hardware reliability	12	19	6	1	3.1
Maintenance service	5	23	7	2	2.8
Technical support	5	10	14	6	2.4
Operating systems	9	13	9	2	2.9
Compilers & assemblers	7	18	6	0	3.0
Applications programs	5	8	4	4	2.7
Totals	86	151	54	15	3.0
Percentages	28%	49%	18%	5%	–

*Weighted Average on a scale of 4.0 for Excellent.

With 77 percent of all the user responses in either the "excellent" or "good" classification, there seems little

floating-point instructions, real-time clock, memory management option, and console interface. Two more SU positions are used for the basic 16K MF-11U memory, with room for an additional 16K words 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 80K words), 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 (see above).

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 32K words of semiconductor memory, 16K words of core, and space for 16K additional words 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 16K of memory and is prewired for a second 16K 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 (DC11, DL11) or synchronous interface (DP11) 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 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 high-speed peripheral controllers, and four standard peripheral slots; the memory cabinet contains prewiring for a second 128K bytes of core memory.

MASS STORAGE

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 unit was announced early in May 1975.

RS03 & RS04 FIXED-HEAD DISKS: The RS03 and RS04, respectively, store 262,144 (256K) and 512,288 (512K) words, with respective data transfer rates of 250K words per second (4 microseconds per word) and 500K words per second (2 microseconds per word). The latter rate (1M bytes/second) requires an 11/70 with a high-speed control. The two models are identical in these respects: 8.5-millisecond average access time (latency), 6.4-micro-

DEC PDP-11 Family

need to be wary of selecting the PDP-11. Once again, the relatively low maintenance service and technical support ratings may stem from our failure to distinguish among users receiving different levels and types of service.□

second minimum access time, and 3600 rpm at 60 Hertz (3000 rpm at 50 Hertz). Up to eight drives of either or both types can be connected to a single controller. These disks are valuable as on-line real-time storage, especially in real-time data acquisition and control applications.

RP04 DISK PACK: Each of up to 8 units per controller can store 43,980,288 words, with an access time equal to the seek time for the moving heads (7 to 50 milliseconds, 28 average) plus a latency period averaging 8.3 milliseconds (based on 3600 rpm). The maximum data transfer rate is 2.5 microseconds per word or 800K bytes per second.

The 11/70 provides high-speed controllers for these units that contain 8-word (16-byte) data buffers, and the I/O transfers are on a 4-byte (2-word) basis using the 32-bit lines. The Unibus interface controllers for the 11/35 through 11/50 contain 64-word data buffers, and transfers are made on a two-byte (single-word) basis on the Unibus.

RK05 DECPACK SYSTEM: This removable disk cartridge system stores up to 1.2 million words per drive with an average access time (including head movement) of 70 milliseconds, and a data transfer rate of 90.25K words/second. Up to eight RK05's can be attached to an RK11 controller.

RS11 FIXED-HEAD DISK: Stores up to 256K words per drive with an average access time of 16.9 milliseconds and a data transfer rate of 62.5K words/second. Up to eight RS11's can be attached to an RF11 controller.

RS64 DECDISK FIXED-HEAD DISK: Provides storage for 64K words per drive with an average access time of 16.1 milliseconds and a data transfer rate of 62.5K words/second. Up to four RS64's can be attached to an RC11 Controller. The RC11 mounts in a 10½-inch panel.

RP03 MOVING-HEAD DISK: Stores up to 20 million words per drive with an average access time (including head movement) of 29 milliseconds and a data transfer rate of 133.3K words/second. Up to eight RP03's can be attached to an RP11 Controller. Each drive has its own free-standing cabinet.

The chart below outlines DEC mass storage device usage in the various models of the PDP-11 family. Non-DEC units that can be used with the PDP-11 computers are summarized in Report M13-100-201, *Minicomputer Disk and Drum Storage.*

System	RX11	RS11	RS64	RK05	RP03	RS03	RS04	RP04
LSI-11	X	–	–	–	–	–	–	–
11/04	X	X	X	X	–	–	–	–
11/05	X	X	X	X	–	–	–	–
11/10	X	X	X	X	–	–	–	–
11/35	X	X	X	X	X	X	X	X
11/40	X	X	X	X	X	X	X	X
11/45	X	X	X	X	X	X	X	X
11/50	X	X	X	X	X	X	X	X
11/70	X	X	X	X	X	X	X	X

INPUT/OUTPUT UNITS

Please refer to the Peripherals/Terminals Table on page M11-384-305 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 (GENERAL)

A discussion of data communications capabilities for the PDP-11 family involves more than a collection of hardware interfaces and a few software packages. In fact, it involves an entire applications group—the DECcomm 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 to carry the DECcomm banner. That doesn't mean that only 11's are found in these systems. Quite the contrary. The PDP-8's (see Report M11-334-101) were there initially also, and this family has its representatives in every DEC application line, due mostly to longevity. But these older 12-bit machines are not going to be pushed as the PDP-11's will be. Still, if someone really wants a PDP-8 system for data communications, far be it from DEC to dissuade him.

Members of the PDP-11 line were selected as the DECcomm standard-bearers 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 (SPC's & SU's); special chassis and/or backplanes for communications options are not required.

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 configurations with particular software packages controlling them.

Data communications control for all PDP-11's is supplied by seven basic interface controllers. However, each of these seven 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.

DEC PDP-11 Family

The following basic interfaces are available–

For asynchronous lines and terminals–

	Single-line	Multiple-line
Programmable:	DC11	DH11
Fixed:	DL11	DJ11

For synchronous lines–

	Single-line	Multiple-line
Character Interrupt:	DU11	–
DMA:	DQ11	DV11

DECcomm'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 for transmit data and one for receive data), permitting longer delays between interrupt servicing without annoying rate errors. The DL11 can operate with differing 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 20-mA or EIA terminals. The DL11 is contained on one board and requires one SPC slot.

The *DC11 Asynchronous Line Interface* is programmable–that is, some of its operating parameters can be changed by the program without the need of changing hardware. The programmable aspects of the DC11 are data rates, character size, and stop element length. The interface also has auto-answering capabilities. Another extra feature found on the DC11 is a reverse channel for Bell 202 modems. Only four of eight different data rates can be program-selected. The DC11 can supply all necessary signals to control Bell 103 and 202 or equivalent modems, conforming to RS-232C or CCITT V.24 specifications. The DC11 is a small system unit, requiring one SU space.

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 *DH11 Programmable 16-Line Asynchrnous 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 *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

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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 to Bell 201 or 303 modems or equivalents. It occupies one slot in a DD11 Peripheral Mounting Panel.

The *DV11 Synchronous Preprocessor* is a newcomer to the DECcomm line, having been introduced early in 1975. The unit 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 subseqeunt 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 call 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.

DATA COMMUNICATIONS PRODUCTS

Combining the hardware previously mentioned and the software systems detailed in the following Software section of this report, DEC has assembled a variety of packaged systems for all levels of communications needs. To illustrate this versatility, systems for three categories of usage are outlined below.

FRONT-END SYSTEM BASE (FSB): This package is intended to be the major element in an IBM 360/370 teleprocessing system, and will permit that system to interface many more terminals than are supported by standard IBM equipment. FSB products connect to the multiplexer or selector channels of S/360 Models 30, 40, 50, 65, 67, and 75 processors and to the multiplexer, selector, or block multiplexer channels of S/370 Models 135, 145, 155, 165, and 195 processors. Operating under DEC's COMTEX communications executive and using a 2848 Emulator terminal application program, these systems are completely compatible with OS/GAM, OS/TCAM (TSO), DOS/QTAM, and DOS/BTAM 2840 local support. Typically, hardware for these products includes a low-end PDP-11 processor, 8K to 16K words of core memory, the DX11 360/370 Interface, and other communications interfaces as required.

COMMUNICATIONS SYSTEMS BASE (CSB): These hardware/software packages are intended for use in building message switching systems, remote terminal data concentrators and controllers, front-ends, and remote computer systems. Software utilized in these systems is COMTEX or DOS/COMTEX. COMTEX is a core-only communications executive for terminal-oriented applications; it includes handlers for almost all of the PDP-11 communications interfaces. It is modular and can serve as a base for applications requiring multiple terminals (such as a data concentrator), or for communications to a non-Digital computer.

DOS/COMTEX combines the communications support of COMTEX with a complete disk-based operating system. It provides program development facilities such as PDP-11 assembler, FORTRAN, and utilities, and also has file handling capabilities.

Hardware generally used in CSB systems includes a PDP-11/10, 40, or 50; 8 to 16K words of core memory; real-time clock; RK11 or RK05 disks; magnetic tape system (DECtape or conventional); and a DECwriter as a console I/O device.

REMOTE COMPUTER SYSTEMS (RCS): These are a broad range of system sizes and capabilities which center around several different software packages (DOS/Batch, RSX-11D, and RSTS/E). All provide DOS/Batch, RSTS/E, and RSX-11D features, plus 2780 communications capabilities.

RSTS/E-based Remote Computer Systems can support up to 31 interactive time-shared terminals and manage data bases of 300 million characters or more. With the RSTS/2780 Emulator package, remote batch entry capabilities are added.

RSX-11D-based systems offer real-time, multitasking operations to scientific computing, laboratory process control, and transaction processing applications. These systems also have an associated IBM 2780 emulator package

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(RSX-11D/2780) to provide remote batch entry to IBM systems.

Various configurations of the RCS systems are available to handle both large and small volumes. Typically these systems will include a high-end PDP-11 processor, 48K words of core memory, at least one disk and/or magnetic tape subsystem, and interfaces as required.

DECCOMM 600 SYSTEMS: These are multiterminal RSX-11D systems with data communications extensions. They are intended for communications-intense transaction processing applications. DECcomm 600 systems allow substantial numbers of terminals to be used locally or to be clustered at remote sites. Communications control between the host RSX-11D system and the remote cluster controllers is turnkey, and transparent to the user.

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 4K words of memory. Included are the PAL-11 assembler, Editor, and debugging aids. In 8K words of memory, a relocating assembler, linker, and 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 words 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 8K words of memory, while the F/B monitor requires at least 16K words. 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 langauge 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-langauge 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 for large numbers of interactive users. The Interactive language is BASIC-PLUS, an enriched version of the popular BASIC language. RSTS/E requires a PDP-11/35, 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-11/35 or 11/40-based system, up to 32 users on an 11/45, and up to 63 users on an 11/70.

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 a powerful enhancement over 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. To supplement the BASIC-PLUS language in commercial applications, a batch COBOL option is available.

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.

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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 a PDP-11/35, 11/40, 11/45, or 11/70 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, optionallly, 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 11/35, 11/40, and 11/45 systems. On the latter three systems hardware memory management is not required, but it can be utilized for protection and expansion to 128K bytes if available.

Program development is accomplished from an interactive console terminal, in MACRO assembler, FORTRAN IV, or, optionally, FORTRAN 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.

Application packages supported by RSX-11M include a Power Demand Control System that can be utilized to save money on electrical power. The system can be used by larger facilities (office buildings, factories, universities, and hospitals, for example) to monitor and control equipment that consumes large amounts of electrical power.

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 8K words of memory, a terminal, and a program loading device.

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 priority 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.

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

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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 32KB processor with one disk drive. An 8-user configuration requires a 64KB 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 64KB Datasystem 500 (96 KB for 32 users), two disks, and a line printer. CTS-500/E systems were first delivered in February 1972.

COS-500, which runs on the Datasystem 500, offers program development support for RPG-II (compatible with IBM System/3, 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 sort program (System/3-compatible) is also provided. COS-500 runs on a 56KB system with 2 disk drives, a card reader, operator console, and line printer. COS-500 systems were first delivered in July 1972.

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 an easy-to-learn and easy-to-use computer language for computation. It is 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 4K words 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/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.

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 a highly optimizing compiler that is geared 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 therefore of ANSI FORTRAN) 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 16K-word 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 supplement the business data processing requirements of an RSX-11D, RSTS/E, or IAS system application. PDP-11 COBOL meets the ANSI low-level specification except for the RERUN (check-pointing) option, and features the high-level specification implementation of the ACCEPT, DISPLAY, STRING, and UNSTRING verbs; sequential and relative I/O modules; and full low-level library function with partial high-level REPLACING facility.

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.

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The *Disk Compression Utility (DCU)* consolidates the area used by files on a disk. If the disk is not full, DCU thus 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, 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 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 incorporates 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 least 8K words of core; any additional core 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 seqeunce 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 langauge 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.

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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 256-word 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.

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 8K 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)–computes 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, 8K words 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.

DEC PDP-11 Family

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 CONFIGURATION: Includes a PDP-11/04 processor with 8K words of MOS memory, RX11 dual flexible disk system, LA36 DECwriter II, and RT-11 basic software. Purchase price for this system is $10,395.

TYPICAL PDP-11/05 OR 11/10 CONFIGURATION: Includes a PDP-11/05 or 11/10 processor with 16K words of core memory, TA11 dual magnetic tape cassette unit, bootstrap loader, LA36 DECwriter II, and RT-11 basic software. Purchase price is $23,250.

TYPICAL PDP-11/40 BATCH CONFIGURATION: Includes 11/40 processor with 16K words of core memory, bootstrap ROM loader, real-time clock, TC11 dual DECtape drive, CR11 card reader (300 cpm), one RK11 DECdisk system, (1.2 million words), and an LA36 DECwriter II terminal. Purchase price is $43,400.

TYPICAL PDP-11/40 RESOURCE TIME-SHARING SYSTEM: This system can be expanded to 16 simultaneous users programming in BASIC-PLUS. The configuration includes an 11/40 processor with 24K words of core memory, real-time clock, bootstrap ROM loader, TM11 magnetic tape subsystem, RK11 DECpack removable cartridge disk subsystem (1.2 million words per drive), and an LA36 DECwriter II. Purchase price is $44,000.

TYPICAL LARGE-SCALE PDP-11/45 CONFIGURATION: Includes PDP-11/45 processor with 92K words of 900-nanosecond core memory plus 4K words of 300-nanosecond bipolar memory, hardware memory management, bootstrap loader, floating-point processor, two 20M-word RP03 disk drives, two TU56 DECtape transports, one TM11 9-track tape drive, a CR11 card reader (300 cpm), an LP11 line printer (300 lpm), and an LA36 DECwriter II. Purchase price is $184,100.

PDP-11/70 SYSTEMS: As this report went to press, DEC announced shipment of the first 11/70 (May 12) and expected delivery of a second system (late May) to Bell Telephone Laboratories. The system delivered consisted of an 11/70 CPU with 128K words of core memory, two disk drives, two tape drives, a communications multiplexer, a synchronous line interface, and a high-speed paper tape reader. It would sell for $168,000. The second system includes an 11/70 CPU with 192K words of core memory, a flexible disk unit, two disk drives, two tape drives, a card reader, and a line printer, and would sell for $230,000.■

LSI-11 COMPONENT PRICES*

COMPONENT		Purchase Prices (1-49)	(50-99)	(100-199)
KD11-F	Microcomputer Module (includes 4K dynamic MOS RAM)	$990	$653	$634
DLV11	Serial Line I/O Module (DC11-C compatible)	235	155	150
DRV11	Parallel Line Interface Module (DR11-C compatible)	195	129	125
MSV11-A	1K Static RAM Module (half-board)	475	314	304
MSV11-B	4K Dynamic RAM Module (half-board)	625	413	400
MMV11-A	4K core memory module (takes two board spaces)	895	591	573
MRV11-AA	Board to hold PROM chips (half-board)	175	116	112
MRV11-AC	Unprogrammed PROM chip (fit 8 to a board)	35	25	23
H9270	LSI-11 Backplane (four full board slots)	175	116	112
KEV11	Extended Arithmetic Chip (fixed/floating-point)	125	83	80
KD11-J	Microcomputer Module (with 4K core instead of MOS RAM, fits on 2 boards)	1,536	1,014	983
QJV10-AB	Paper Tape Software Package (Editor, Assembler, Loader, ODT, and I/O Exerciser)	100	100	100
QPV10-AE	Emulator Software Package (runs under RT11 on PDP-11/35 or 11/40; contains Editor, Assembler, Linker, debugging program, load, save, & execute packages)	500	500	500

*LSI-11's are sold by Digital's Components Group.

DEC PDP-11 Family

EQUIPMENT PRICES

		Purchase Price	Monthly Maintenance
PROCESSORS			
PDP-11/04-AA	Basic System 1: includes 4K words of MOS memory, operator console, ASCII console emulator, bootstrap loader, ROM diagnostics, power-fail/restart, and power supply. Provides 1 SU slot and 2 SPC slots	$2,495	—
PDP-11/04-AC	Same as above except provides no SU slots and 7 SPC slots	2,745	—
PDP-11/04-BA	Basic System 2: Same as PDP-11/04-AA above except with 8K words of memory. Provides 1 SU slot and 2 SPC slots	3,295	—
PDP-11/04-BC	Same as above except provides no SU slots and 7 SPC slots	3,545	—
PDP-11/05-KA	Basic System 1: includes 4K words of 900 nanosecond memory, console, power-fail/restart, line frequency clock, and power supply. Provides no SU slots and 4 SPC slots	4,395	$53
PDP-11/05-LA	Basic System 2: same as PDP-11/05-KA above with 8K words of memory	4,995	69
PDP-11/05-NC	Same as above except provides 3 SU slots and no SPC slots	5,995	—
PDP-11/05-SC	Basic System 3: same as above with 16K words of memory	7,495	74
PDP-11E05-SE	Packaged System: 16K words of 980-nanosecond memory plus above features, DECpack disk, dual cassette tape, and LA36 DECwriter II	22,000	246
PDP11/10-NC	Basic System: includes 8K words of 900-nanosecond memory, console, power-fail/restart, real-time clock, and power supply	5,995	69
PDP-11E10-SE	Packaged System: 16K words of 980-nanosecond memory, plus above features, DECpack disk, dual cassette tape system, and LA36 DECwriter II	22,000	246
PDP-11/35-JA	PDP-11/35 processor with 8K words of memory, extended instruction set, floating point option, memory management, stack limit option, line frequency clock, power-fail/restart, power supply, KM11-A maintenance card, programmer console, and cabinet. Expandable to 32K words	9,495	100
PDP-11/35-SC	Same as PDP-11/35-JA above except with 16K words of memory, expandable to 40K words	11,495	111
PDP-11/35-FC	Same as PDP-11/35-JA above except with 28K words of parity memory, expandable to 64K words	17,150	117
PDP-11/35-FL	Same as PDP-11/35-JA above except with 32K words of memory, expandable to 64K words	20,495	147
PDP-11/40-BK	11/40 processor with 16K words of parity memory, LA36 DECwriter II, and cabinet	16,800	127
PDP-11/40-BM	11/40 processor with 16K words of parity memory, VT05 display terminal, and cabinet	17,650	119
PDP-11/40-BS	11/40 processor with 28K words of parity memory (32K if KT11-D included), and LA36 DECwriter II	19,500	147
PDP-11/45-BW	11/45 processor with 32K words of parity memory, memory management, LA36 DECwriter II, multi-device bootstrap loader, line frequency clock, and cabinet	36,000	243
PDP-11/45-FK	PDP-11/45 processor with 16K words of memory, extended instruction set, memory management, floating point processor, line frequency clock, power-fail/restart, LA36 DECwriter II, power supply, and cabinet. Expandable to 32K words	23,900	184
PDP-11/45-FH	Same as PDP-11/45-FK above except with 16K words of parity memory	25,300	179
PDP-11/45-FU	Same as PDP-11/45-FK above except with 32K words of memory	32,000	247
PDP-11/45-FS	Same as PDP-11/45-FK above except with 32K words of parity memory	32,500	237
PDP-11/50-FK	Same as PDP-11/45-FK above except with 16K words of MOS memory, expandable to 64K words	32,000	334
PDP-11/50-FH	Same as PDP-11/45-FK above except with 16K words of MOS parity memory, expandable to 64K words	33,000	334
PDP-11/50-BW	11/45 processor with 16K words of parity MOS memory plus 16K words of parity core memory, memory management, LA36 DECwriter II, multi-device bootstrap loader, line frequency clock, and cabinet	36,000	397
PDP-11/50-BS	Same as PDP-11/50-BW above except with 32K words of MOS parity memory	40,000	551
PDP-11/70	Basic System includes 11/70 processor with 128K bytes of parity core memory, 2K bytes of cache memory, memory management, bootstrap/diagnostic loader, line frequency clock, LA36 DECwriter II, and 2 cabinets with pre-wired space for mounting a floating point processor, 4 high-speed mass storage units, and 4 small peripherals		
PDP-11/70-EA	PDP-11/70 basic system plus two RK05 2.4M-byte cartridge disk units and cabinet	72,650	453
PDP-11/70-FA	PDP-11/70 basic system plus one RP04 88M byte disk and one TW16 1600/800 bpi tape drive	105,100	607
PDP-11/70-FE	PDP-11/70 basic system plus one dual-access RP04 88M-byte disk with two controllers, and one TW16 1600/800 bpi tape drive	117,100	657
PDP-11/70-FK	Same as PDP-11/70-FE above except one disk controller for 11/70 and other controller for other PDP-11's (for resource sharing networks)	117,100	657
PDP-11/70-GA	PDP-11/70 basic system plus two RK05 2.4M-byte cartridge disks, one RS04 fixed-head disk, and one TW16 1600/800 bpi tape drive	109,350	658
PDP-11/70-HA	PDP-11/70 basic system plus one RP04 88M-byte disk, one RS04 fixed-head disk, and one TW16 1600/800 bpi tape drive	126,300	692

DEC PDP-11 Family

EQUIPMENT PRICES

		Purchase Price	Monthly Maintenance
PROCESSORS (Continued)			
PDP-11/70-HE	PDP-11/70 basic system plus one dual-access RP04 88M-byte disk with two controllers, one RS04 fixed-head disk, and one TW16 1600/800 bpi tape drive	$138,300	$742
PDP-11/70-HK	Same as PDP-11/70-HE above except one disk controller for 11/70 and one for other PDP-11's (for resource sharing networks)	138,300	742
PDP-11/70-FE	Dual 11/70 system with one dual-access RP04 88M-byte disk and two TW16 1600/800 bpi tape drives	187,200	1,044
900-NANOSECOND CORE MEMORY (for all PDP-11's except 11/04 and 11/70)			
MF11-L	8K words and control with expansion capability	4,700	37
MM11-L	8K-word expander for MF11-L (max. 2 per MF11-L)	4,400	37
MM11-LK	12K-word expander for MF11-L (max. 1 per MF11-L)	7,100	58
MM11-S	8K words and control	4,700	38
MF11-LP	8K words parity and control with expansion capability	5,700	32
MM11-LP	8K-word parity expander for MF11-LP (max. 2 per MF11-LP)	5,400	32
980-NANOSECOND CORE MEMORY (for all PDP-11's except 11/04 and 11/70)			
MF11-UR	32K words parity and control	8,000	54
MF11-US	64K words parity and control	15,000	108
MF11-U	16K words and control with expansion capability	4,900	32
MM11-U	16K-word expander for MF11-U (max. 1 per MF11-U)	4,500	32
MF11-UP	16K words parity and control with expansion	6,300	27
MM11-UP	16K-word parity and expander for MF11-UP (max. 1 per MF11-UP)	5,600	27
11/70 CORE MEMORY			
MJ11-AC	256K bytes parity; includes cabinet, power supply, and expansion space for up to 1,024K bytes	33,000	138
MJ11-AG	256K-byte parity expander for MJ11-AC (max. 3 per MJ11-AC); includes power supply	31,000	138
MJ11-AA	64K-byte parity expander for MJ11-AC (max. 3 per MJ11-AC)	13,500	50
MJ11-AE	64K-byte parity expander for MJ11-AA (max. 3 per MJ11-AA)	7,100	40
SEMICONDUCTOR MEMORY (for PDP-11/04 or 11/45)			
MS11-CC	Bipolar memory control for up to 4 MS-11-CM or MS11-CP	2,100	13
MS11-CM	1K words bipolar, 300-nanosecond	2,100	16
MS11-CP	1K words bipolar with byte parity, 300-nanosecond	2,700	16
MS11-BC	First MOS memory control for up to 4 MS11-BR or MS11-BT	2,100	13
MS11-BD	Second MOS memory control for up to 4 MS11-BR or MS11-BT	1,600	13
MS11-BR	4K words, MOS, 495-nanosecond	3,150	42
MS11-BT	4K words MOS with byte parity, 495-nanosecond	3,750	42

Note: Maximum of 2 semiconductor memory controls per system; 11/04 uses MOS memory, not bipolar.

PROCESSOR OPTIONS			
BM873-YB	ROM bootstrap for paper tape, all disks, magnetic tape, DECtape, and cassette	600	3
BM792-YC	ROM bootstrap for card reader	500	3
BM873-YA	ROM restart loader for paper tape, RK and RP disks, magnetic tape, DECtape, and cassette	600	2
MR11-DB	ROM bootstrap for mass storage devices	700	5
KE11-A	Extended arithmetic element for all PDP-11's except 11/40	2,100	11
KE11-E	Extended instruction set for PDP-11/35 or 11/40	1,470	11
KE11-F	Floating point option for PDP-11/35 or 11/40; requires KE11-E	1,600	11
FP11-B	Floating point processor for PDP-11/45 or 11/70	5,600	45
KJ11-A	Stack limit option for PDP-11/35 or 11/40	600	5
KT11-D	Memory management option for PDP-11/35 or 11/40; includes KJ11-A	2,600	21
KW11-L	Line frequency real-time clock for any PDP-11 CPU	350	3
KW11-P	Programmable real-time clock for any PDP-11 CPU	700	6
MASS STORAGE			
RJS03-BA	Fixed-Head Disk System: controller plus one RS03 disk drive, 256K words	14,900	75
RJS04-BA	Fixed-Head Disk System: controller plus one RS04 disk drive; 512K words	19,200	85
RWS03-BA	Fixed-Head Disk System: controller for 11/70 32-bit bus plus one RS03 disk drive; 256K words	14,900	75
RWS04-BA	Fixed-Head Disk System: controller for 11/70 32-bit bus plus one RS04 disk drive; 512K words	21,200	85
RS03-AA	Fixed-Head Disk Drive, 256K words; for RJS03-BA or RWS03-BA	9,500	45
RS04-AA	Fixed-Head Disk Drive, 512K words; for RJS04-BA or RWS04-BA	13,800	55

DEC PDP-11 Family

EQUIPMENT PRICES

		Purchase Price	Monthly Maintenance
MASS STORAGE (Cont.)			
RK11-DE	Cartridge Disk System: controller plus one RK05 disk drive; 1.2M words	$11,000	$106
RK05-AA	Cartridge Disk Drive for RK11-DE; 1.2M words	5,100	64
RK05K-11	Cartridge for RK05-AA	99	—
RP11-CE	Disk System: controller plus one RP03 disk drive; 20M words	33,500	233
RP03-AS	Disk Pack Drive for RP11-CE above; 20M words	20,000	159
RP02-P	Disk Pack for RP03-AS	295	—
RJP04-AA	Disk System: controller plus one RP04 disk drive; 44M words	35,000	220
RWP04-AA	Disk System: controller for 11/70 32-bit bus plus one RP04 disk drive; 44M words	35,000	220
RWP04-BA	Dual Access Disk System: two 11/70 controllers plus one RP04 disk drive; 44M words	47,000	270
RWP04-CA	Dual Access Disk System: two controllers, one 11/70-type and one PDP-11-type, and one RP04 disk drive; 44M words (for resource sharing network)	47,000	270
RP04-AA	Disk Drive for RJP04-AA or RWP04-AA above; 44M words	25,900	190
RP04-BA	Disk Drive with dual access capability for RWP04-BA or RWP04-CA above; 44M words	30,800	210
RP04-P	Disk Pack for RP04-AA or RP04-BA above	795	—
TA11-AA	Dual DECtape transport plus controller; 90K characters per reel	3,300	38
TC11-GA	Dual DECtape transport plus controller; expandable to 4 dual transports, 288K characters per reel; includes cabinet	10,500	45
TU56	Dual DECtape transport for TA11-AA and TC11-GA	5,500	32
MAGNETIC TAPE EQUIPMENT			
TM11-EA	9-track, 800 bpi, 45 ips, TU10 transport and controller; expandable to 8 TU10's	11,500	101
TU10-EE	9-track, 800 bpi, 45 ips tape transport for TM11-EA	8,000	74
TJU16-EA	9-track, 800/1600 bpi, 45 ips TU16 transport and controller; expandable to 8 TU16's	15,500	120
TWU16-EA	9-track, 800/1600 bpi, 45 ips TU16 transport and controller for 11/70 32-bit bus; expandable to 8 TU16's	15,500	120
TWU16-EK	9-track, 800 bpi, 45 ips TU16 transport and controller for 11/70 32-bit bus; expandable to 8 TU16's	14,450	110
TU16-EE	9-track, 800/1600 bpi, 45 ips tape transport for TJU16-EA, TWO16-EA, or TWU16-EK	8,950	60
TM11-FA	7-track 200/556/800 bpi, 45 ips TU10 transport and controller; expandable to 8 TU10's	13,225	101
TU10-FE	7-track, 200/556/800 bpi, 45 ips transport for TM11-FA	9,725	74
TWU/45	9-track, 800/1600 bpi, 45 ips controller/drive subsystem; for 32-bit bus on 11/70, TJU/45 is for other PDP-11's; add'l drives $14,000 each	26,500	NA
PUNCHED CARD EQUIPMENT (80-column)			
CR11	300 cpm reader and controller	5,100	53
CM11-FA	285 cpm mark-sense and punched card reader	5,700	53
CD11-A	1000 cpm reader and controller	11,500	74
CD11-EA	1200 cpm reader and controller	15,900	95
PAPER TAPE EQUIPMENT			
PC11	300 cps reader, 50 cps punch, and controller	4,200	38
PR11	300 cps reader and controller	2,600	22
PRINTERS			
LP11-VA	300 lpm, 132 column, 64 character printer plus controller	11,235 ~~10,500~~	72
LP11-WA	230 lpm, 132 column, 64 character printer plus controller	~~12,500~~ 13,375	72
LP11-RA	1200 lpm, 132 column, 64 character printer plus controller	~~31,500~~ 34,961	154
LP11-SA	900 lpm, 132 column, 96 character printer plus controller	~~34,780~~ 39,000	154
LS11-A	60 lpm, 132 column, 64 character printer plus controller Not Current	5,900	58
LV11-BA	500 lpm, 132 column, 96 character printer/plotter plus controller; plotting rate is 120K dots per second	~~12,480~~ 13,650	53
TERMINALS			
LA36-CA	DECwriter II; 30 cps, 20-mA interface	1,950	25
VT50-AA	DECscope; 75-9600 bps, 20-mA interface	1,250	22
LT33-DC	ASR-33; 10 cps, 20-mA interface	2,000	37
VT11-AA	17-inch CRT, processor, and light pen	9,500	69
VR-14	7 x 9 inch point plot display	3,400	19
COMMUNICATIONS EQUIPMENT			
DL11-A	20-mA serial synchronous interface; 8-bit characters plus 2 stop bits; 110-2400 bps	550	6
DL11-B	EIA/CCITT serial synchronous interface; 8-bit characters plus 2 stop bits; 110-2400 bps	575	6

DEC PDP-11 Family

EQUIPMENT PRICES

COMMUNICATIONS EQUIPMENT (Cont.)		Purchase Price	Monthly Maintenance
DJ11-AA	EIA/CCITT asynchronous 16-line multiplexer; includes panel with 16 connectors; customer specifications	$3,600	$32
DJ11-AC	20-mA asynchronous 16-line multiplexer; includes panel with 16 terminal strips; customer specifications	3,400	32
DH11-AA	EIA/CCITT or 20-mA asynchronous 16-line multiplexer and mounting panel; speed to 9600 bps; characteristics established by DM11 interfaces; EIA/CCITT or 20-mA lines may be mixed in 4-line groups	4,700	32
DM11-BB	16-modem multiplexer for Bell 103, 202, or equivalent; for DH11-AA	1,360	19
DM11-DA	20-mA 4-line adapter for DH11-AA	200	5
DM11-DB	EIA 4-line adapter for DH11-AA; includes 4 cables	530	5
DM11-DC	EIA/CCITT 4-line adapter with modem controls for DM11-BB	920	11
DH11-AD	Programmable asynchronous 16-line multiplexer; EIA/CCITT interface and modem controls; cables not included	6,000	56
DH11-AE	Same as DH11-AD above without modem controls	5,200	46
DU11-DA	Full/half duplex synchronous interface; programmable characteristics; speed to 9600 bps; interfaces Bell 200 or equivalent modem; data set controls included	950	5
DQ11-DA	Full/half duplex synchronous interface; programmable characteristics; speed to 10K bps; interfaces Bell 201, 208, 209, or equivalent modems; data set controls included	2,950	24
DQ11-EA	Same as DQ11-DA above except for Bell 303 or equivalent modems; speed to 1M bps	4,500	25
DQ11-KA	Crystal clock for DQ11-DA or DQ11-EA	200	1
DQ11-AB	CRC or LRC option for DQ11-DA or DQ11-EA	1,300	12
DQ11-BB	Protocol option for DQ11-AB; includes character recognition and sequence control	900	12
DV11-AA	EIA/CCITT synchronous 16-line multiplexer with internal CRC hardware; speed to 9600 bps full duplex; uses DV11-BA adapters	4,000	29
DV11-BA	8-line adapters for DV11-AA; maximum of 2	3,100	15
DJ11-AB	Asynchronous 16-line multiplexer; customer specifications; uses DC08	3,300	27
DH11-AB	Asynchronous 16-line multiplexer; programmable characteristics; speed to 9600 bps; uses DC08 interfaces	4,500	29
DC08-CS	Interface panel for 16 DC08-CM adapter; includes wired cabinet and control modules	2,300	4
DC08-CM	Dual line interface for DC08-CS; 2 lines	250	2
DN11-AA	Auto-dial system for 4 data sets; uses DN11-DA interfaces; includes wired cabinet	425	5
DN11-DA	Auto-dial interfaces for Bell 801 ACU; used with DN11-AA; maximum of 4	525	5
DF11-BA	103-type originate-only modem; 300 bps; includes cable for Bell DAA connection	530	11
DF11-BB	103-type answer-only modem; 300 bps; includes cable for Bell DAA connection	570	11
KG11-A	Check character option; computes LRC, CRC, and BCC characters; used with DU11 synchronous interface	950	6
DR11-B	DMA interface for customer devices; includes registers for word count, current address, and data	1,470	13
DR11-C	16-bit parallel general-purpose bidirectional Unibus interface for customer devices; includes interrupt, address, and control signals	490	5
SYSTEMS			
GT40-AA	Graphic Terminal System with programmable intensity and hardware vector, character, and point generation. System includes 11/10 processor with 8K memory, 12-inch CRT, light pen, keyboard, DL11-5 interface, and licensed FOCAL-GT software; in 10½ inch box	14,500	145
GT42-AA	Graphic Terminal System; same as GT40-AA except has 17-inch CRT and is mounted in short cabinet	17,500	151
GT44-AA	Graphic Display System with programmable intensity and hardware vector, character, and point generation. System includes 11/40 processor with 16K memory, LA36 terminal, two RK05 cartridge disks, bootstrap loader, 17-inch CRT, light pen, and two cabinets. RT-11 and BASIC licensed software with price	34,500	375
CABINETS AND HARDWARE			
H960-DH	Cabinet with one sliding drawer mounting box; provides mounting for 9 system units; includes power supplies for up to 64K words of core memory	3,000	16
H960-CA	Standard PDP-11 cabinet, 72 inches high; includes fans, power distribution panel, and front panels	850	27

DEC PDP-11 Family

EQUIPMENT PRICES

CABINETS AND HARDWARE (Cont.)		Purchase Price	Monthly Maintenance
H967-KC	Short PDP-11 cabinet, 50 inches high; same features as H960-CA above	750	—
BA11-ES	Expansion box; provides mounting for 6 system units; requires H720 power supply	550	—
BA11-KE	Expansion box; provides mounting for 5 system units	1,950	16
H720	Power supply for BA11-ES	750	11
H744	+5V Regulator, 25 Amperes	395	—
H952-HA	Free-standing table	275	—
DD11-A	Peripheral Mounting Panel; includes Unibus connections for 4 small peripheral controllers	275	—
DB11-A	Unibus repeater; allows additional 18 unit loads	1,300	5

SOFTWARE PRICES

		License Fee
QJ100	PTS-11; includes editor, absolute assembler, relocatable assembler, linker, absolute loader, debugging tool, I/O executive	$ 100
QJ006	FOCAL paper tape system; includes FOCAL language processor	300
QJ900	BASIC paper tape system; includes BASIC language processor	500
QJ180	CAPS-11; includes monitor, relocating assembler, linker, editor, debugging tool, and PIP file utility	300
QJ910	BASIC/CAPS; includes BASIC/CAPS language processor; requires QJ180	500
QJ003	RT-11 disk operating system; includes F/B monitor, single-job monitor, editor, MACRO assembler, linker, librarian, debugging tool, and PIP file utility	750
QJ925	FORTRAN/RT11; includes FORTRAN/RT-11 compiler and run-time system; Requires QJ003	700
QJ920	BASIC/RT-11; includes BASIC/RT-11 language processor; Requires QJ003	500
QJ250	DOS/BATCH-11 with FORTRAN; includes monitor, editor, MACRO assembler, linker, librarian debugging tool, PIP file utility, disk initializer, FORTRAN IV compiler and object-time system, file compare, verify and dump, magnetic tape EBCDIC to ASCII conversion, and device-to-device fast copy program	1,700
QJ252	DOS/BATCH-11 without FORTRAN; same as QJ250 above without FORTRAN IV compiler	1,000
QJ253	Device Driver Package	500
QJ035	DOS/BATCH FORTRAN; Requires QJ252	700
QJ031	FORTRAN compiler	500
QJ033	FORTRAN object-time system	500
QJ550	RSX-11A multi-tasking executive; requires QJ250 or QJ252	750
QJ620	RSX-11M real-time, disk-based operating system; includes executive, MACRO assembler, task builder, editor, on-line debugging, librarian, PIP file verification, dump, and exchange programs, FORTRAN IV compiler and run-time system	3,000
QJ621	RSX-11M utility programs	5,000
QJ622	RSX-11M FORTRAN compiler	500
QJ580	RSX-11D real-time, disk-based, multiprogramming system; includes executive, MACRO assembler line editor, task builder, debugging tool, PIP file utility, file exchange program, FORTRAN compiler and object-time system; for PDP-11/35 or larger systems	12,500
QJ586	RSX-11D operating system plus FORTRAN compiler (for RP04 systems)	5,000
QJ585	RSX-11D executive and I/O programs	5,000
QJ583	RSX-11D utility programs	7,000
QJ584	RSX-11D FORTRAN compiler	500
—	RSX-11S execute-only executive ($600 without support)	1,200
QP101	FORTRAN IV-Plus; includes FORTRAN IV-Plus compiler and run-time system; for PDP-11/35 or larger systems	3,000
QP100	FORTRAN IV-Plus compiler; requires QJ580 or QP210	500
QP010	COBOL-11: includes COBOL-11 compiler and run-time system, report generator, sort, and reformat programs; for PDP-11/35 or larger systems; requires QJ580 or QP210	7,000
QR430	RSTS/E resource sharing time-sharing operating system; includes monitor, utilities, and BASIC-Plus language processor; for PDP-11/35 or larger systems	5,000
QP210	IAS interactive application system for PDP-11/70 or large 11/45 systems; includes executive, MACRO assembler, editor, task builder, debugging tool, file utilities, and text output utility	7,800
QP240	BASIC/IAS time-shared BASIC system, includes BASIC language processor	NA
QP230	FORTRAN/IAS; includes FORTRAN IV compiler and run-time system	NA