Digital Equipment DECsystem-20

MANAGEMENT SUMMARY

The DECsystem-20, introduced in January 1976, augments Digital Equipment Corporation's powerful and flexible DECsystem-10 line. In functionality, this newest line from DEC's Large Computer Group occupies the area between the PDP-11/70 minicomputer and the DECsystem-10. The larger forerunner was designed specifically for large-scale interactive time-sharing operations, and has been so well received by its users that it has taken top honors for the past three years in Datapro's annual survey of User Ratings of General-Purpose Computer Systems (Report 70C-010-50). The DECsystem-10 (Report 70C-384-01) is a medium-to-large-scale system that has found its place in commercial time-sharing (service bureaus, etc.), educational time-sharing, and scientific time-sharing applications.

Functionally, the DECsystem-20 is similar to the -10. It is intended for interactive time-sharing applications, but in a different environment. The -20 is intended primarily for in-house time-sharing systems where networks of several dedicated minicomputer systems would be too expensive in terms of hardware cost, and too risky because of untried networking software. More specifically, the DECsystem-20 is aimed at large commercial users who require both data base and computational systems, with multi-language program development and batch processing capabilities, in addition to the time-sharing features of the system.

Basic design changes that should enhance the DECsystem-20's acceptability in this new environment include limited configurability to increase reliability, an operating system that does not require a full-time operator or a systems programmer, and an operating system interface that allows any user to control the system. In contrast, the DECsystem-10 permits a great variety of ▷

The DECsystem-20 is intended as a smaller, limited-configurability version of the medium-to-large-scale DECsystem-10. This newer family of computers has most of the functionality of the DECsystem-10, but has been packaged in significantly less space by the inclusion of both memory and I/O controllers in the same cabinet as the CPU. The TOPS-20 operating system features many new innovations that permit virtually unattended operation.

CHARACTERISTICS

MANUFACTURER: Digital Equipment Corporation, Large Computer Group, 200 Forest Street, Marlborough, Massachusetts 01752. Telephone (617) 481-9511.

MODELS: DECsystem-20 Models 2040 and 2050.

DATA FORMAT

BASIC UNIT: 36-bit word. In core storage, each word location includes one additional parity bit. The processor handles halfwords, but parity bits are not associated with halfword data representation. Variable-length bytes from 1 to 36 bits in length are also handled.

FIXED-POINT OPERANDS: Either 36-bit words or 18-bit halfwords for add and subtract instructions. The multiply instruction produces a double-word product, and the divide instruction uses a double-word dividend. There are also integer multiply and divide instructions which involve only single words. All arithmetic operations are performed in binary mode.

FLOATING-POINT OPERANDS: Standard floating-point hardware is included in the KL20 processor. Single-precision floating-point uses one word, consisting a 27-bit plus-sign fraction and an 8-bit exponent. Double-precision operands have 62-bit fractions and 8-bit exponents, including a sign. The first 36-bit word of a double- ▶
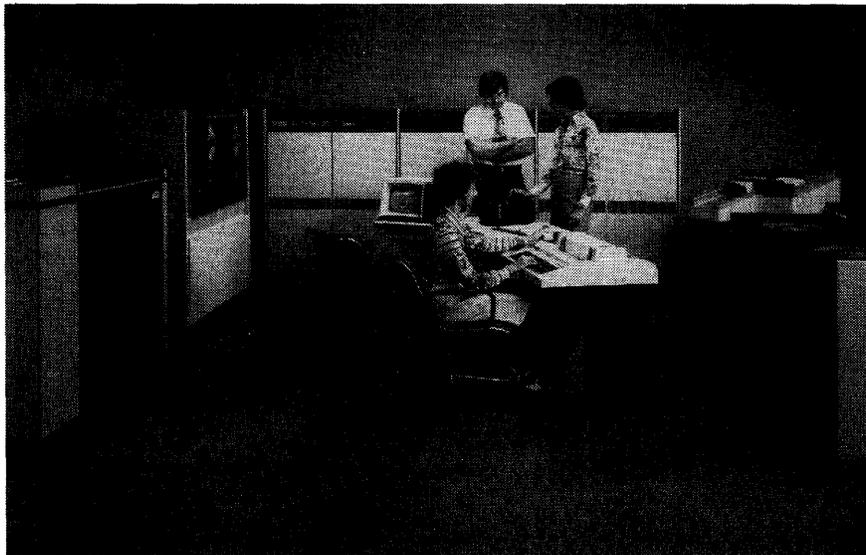
The DECsystem-20, requiring much less space than a similarly configured DECsystem-10, incorporates CPU, memory, mass storage controllers, and communications controllers in the same central system package. The system shown includes a DECsystem 2040 (background) with 128K words of main memory, eight asynchronous communication lines, two RP04 20-million-word disk drives, two TU45 9-track magnetic tape drives, an LP20-F 1200-lpm line printer, one LA36 DECwriter II console terminal, one CD20-B 1200-cpm card reader, and a VT52 CRT user terminal. This system can be expanded to over 1.6 billion 7-bit characters of disk storage and up to 64 user terminals. Purchase price for the configuration shown is $427,495.

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configurations, requires a full-time operator, and requires operator training to successfully control the system.

Basically, the DECsystem-20 *is* a DECsystem-10. It starts with the KL20 microprogrammed processor, which is quite similar in characteristics to the KL10 processor used in the DECsystem 1080 and dual-processor 1088 systems. The KL20, like the KL10, features an optional cache memory system with a four-word-wide data path between core memory and cache memory. It is constructed from very fast emitter-coupler-logic (ECL) circuitry, and represents an enhancement in performance over earlier DECsystem-10 models. The KL20 CPU offers a set of business-oriented instructions that perform double-precision addition, subtraction, division, and multiplication on fixed-point operands, and also a string manipulation instruction that performs nine different function including decimal/binary conversions and editing functions.

There are two models of the DECsystem-20: the 2040 announced in January 1976, and the 2050, announced in November 1976.

The minimum 2040 system configuration includes 128K words of 1-microsecond core memory; one dual-ported 20-million-word disk drive; one 9-track, 75-ips magnetic tape transport; two integrated controllers for the tape and disk subsystems; eight asynchronous communications lines; and one LA36 DECwriter II console terminal. The purchase price for this system is $315,000. Maximum configuration for a DECsystem-2040 is 256K 36-bit words of memory in 32K-word increments, four 20-million-word disk drives or two 40-million-word drives, up to four tape transports, two line printers, one card reader, and up to 64 communications lines implemented through four 16-line asynchronous multiplexers. Two additional integrated controllers (tape or disk) can also be added; these are not supported by the operating software at this time, but will be fully supported in the spring of 1977.

The 2050 is the newest DECsystem-20, and its most notable enhancement is the addition of cache memory between the CPU and main memory. The cache memory system is the same as the one used in the DECsystem-10 and consists of 512 blocks of four words each. Access time for the cache memory is 160 nanoseconds. DEC estimates that 90 to 95 percent to all memory requests will reference information already in cache, yielding effective memory cycle times in the neighborhood of 244 nanoseconds.

To make the cache system more efficient, there is no automatic "write-through" into main memory. Writing to memory is selective and controlled by the TOPS-20 monitor. Data that is going to change frequently is not written into main memory until it becomes stable, reducing the number of main memory cycles required.

precision floating-point operand consists of the 18-bit exponent-and-sign and the most significant 27-bits of the fraction. The second word contains a sign bit and the 35 least significant bits of the fraction.

INSTRUCTIONS: For all but I/O, each instruction consists of one word with a 9-bit operation code, a 4-bit accumulator or flag address, and 23 bits for development of the effective address. The effective address field uses one bit to specify the type of addressing. 4 bits as an index register designator, and 18 bits to reference a memory location. In I/O instructions, the first 3 bits identify the instruction as I/O, and the next 7 bits address an I/O device, with 2 more bits as an operation code. The next 23 bits are used to develop an effective address just as in the non-I/O instructions described above.

INTERNAL CODE: Seven-bit ASCII. Each 36-bit word is used to represent five 7-bit bytes, with one unused bit per word. Bytes from 1 to 36 bits in length can also be recognized and manipulated.

MAIN STORAGE

STORAGE TYPE: Magnetic core.

CAPACITY: See table.

CYCLE TIME: See table.

CHECKING: Parity bit with each 36-bit word is generated with writing and checked with reading.

RESERVED STORAGE: Two 512-word pages are reserved by the TOPS-20 software for the Executive Process Table (EPT) and the User Process Table (UPT). The EPT includes channel status information and is used for communications between the KL20 CPU and the front-end PDP-11 minicomputer. The UPT includes an arithmetic overflow vector address and contains the output from memory and instruction processor clocks. For the overflow vectors, only the user incurring the overflow is affected, leaving the system unaffected.

STORAGE PROTECTION: The KL20 CPU includes storage protection as a standard feature. A paging system reserves up to 256K 36-bit words of memory in as many as 512 pages of 512 words each. The individual pages need not be located in contiguous memory locations, thus eliminating the need to shuffle program segments in memory to counteract checkboarding. The paging registers effectively permit addressing of 4 million words of memory through use of special hardware. Three bits are used to denote the type of access possible for each page, such as read/write, read-only, proprietary, or denial of access.

CENTRAL PROCESSORS

There are two CPU's in the DECsystem-20, the KL20 and a PDP-11/40 front-end processor that is used to control all low-speed peripherals and also to initialize the system. System initialization is accomplished through a dual-access disk drive that contains the system microcode. When the system starts, th PDP-11 performs a brief system checkout, after which it configures memory and loads the microcode into the KL20. The system software is then loaded into the DECsystem-20 main memory and normal operation begins.

The front-end processor also controls all communications lines to user terminals, including the operator console, which is treated as any other user terminal. In addition to the initializing functions and low-speed peripheral control, the front-end processor is interfaced to all KL20

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CHARACTERISTICS OF DECSYSTEM-20 AND LATEST DECSYSTEM-10 MODELS

	1090	2040	2050
SYSTEM CONFIGURATION			
CPU	KL10B	KL20	KL20
CPU's supported by standard software	2 (1099)	1	1
Date of announcement	Nov. 1976	Jan. 1976	Nov. 1976
Date of first delivery	2nd qtr. 1977	Feb. 1976	—
Typical system purchase price	$1,210,000	$375,000	$595,000
MAIN MEMORY			
Minimum capacity, 36-bit words	256K	128K	256K
Maximum capacity, 36-bit words	4096K	256K	512K
Increment size, 36-bit words	256K	32K	64K
Memory cycle time, microseconds	1.0	1.0	1.0
Words accessed per cycle	4	1	4
Storage Interleaving	2-way	2 or 4-way	2 or 4-way
Memory ports	8	4	4
Cache memory	Yes	None	Yes
Effective memory cycle time, microseconds	0.244	1.0	0.244
CENTRAL PROCESSOR			
Number of instructions	386	386	386
I/O CONTROL			
Type of controllers	Integrated and External	Integrated	Integrated
Maximum number of controllers	—	4	4
Maximum I/O rate, 36-bit words/sec.	1,000,000	1,000,000	1,000,000
Buffering	Optional, 16 words	16 words	16 words
System capacity, users	512	64	128

▷ A cache sweep feature allows only selected portions of cache to be written into main memory.

Four words are fetched for each read request. The actual word requested is always the first brought out of main memory, and the next three words in sequence are simultaneously read out. Data in the cache is replaced on a least-recently-used basis.

Users can upgrade 2040 systems to 2050 status, but the modification requires more than the addition of a new backplane and cache memory subsystem. DEC feels that for a system to truly benefit from the enhanced processing capabilities, additional mass storage must also be added.

In addition, main memory and communications line capacities are increased in the 2050: up to 512K words of core memory, in 64K word increments, and up to 128 communications lines. The basic 2050 hardware configuration includes 256K 36-bit words, two 20-million-word disk drives (one dual-ported); one 9-track, 75-ips magnetic tape transport, 16 asynchronous communications lines, and one LA36 DECwriter II console terminal. The cost of this basic system is $485,000.

Software is also included in all DECsystem-20 packages, as well as 50 days of on-site consulting for the ▷

► control and data lines and constantly monitors these. In the event of failures, the PDP-11 reports the problem through the console terminal. The front-end processor is connected to the KL20 by the DTE-20 interface. The front-end processor then directly accesses the KL20 internal structure concurrently with normal processing activities. Through the DTE-20 interface, maintenance personnel may interrupt, examine and deposit data in registers, change data in main memory or registers, or transfer data during time-sharing operations.

REGISTERS: The KL20 processor has 128 integrated-circuit general-purpose registers, contained in 8 blocks of 16 registers each, that can be used as accumulators, index registers, or for other high-speed memory functions. Register blocks are assigned to the operating system and to individual user programs to provide for rapid context switching. Program switching between register blocks is estimated to be 500 nanoseconds for the KL20.

In addition, the KL20 has five clock registers that are used for accounting and performance evaluation. These include the interval timer, the time base, the performance analysis counter, and two accounting meters. The interval timer is a programmable interrupt source with an interval range from 10 microseconds to 4096 milliseconds; the time base is a one-microsecond-based time-of-day clock used by the monitor for system accounting; the performance analysis counter monitors either the duration or rate of occurence of designated hardware conditions; the two accounting meters are the instruction processor meter, which measures the amount of instruction processor time used, and the memory reference meter, which measures user-program accesses to memory. ►

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▷ purpose of application software development. Included in the system software package is the TOPS-20 operating system, the GALAXY batch processing system, the macro assembler, the linking loader, the editor, and other utilities. Programming languages and the SORT-20 utility are separately priced at charges ranging from $2500 for the SORT package to $25,000 for the DBMS data base management system.

The most significant distinction between the DECsystem-20 and its forerunner, the DECsystem-10, is packaging. The DECsystem-20 incorporates the CPU, memory, and up to four mass storage controllers in the same enclosure, providing a substantial hardware cost saving. In contrast, the DECsystem-10 is built up from separately housed components that are based on earlier technologies. Since the DECsystem-20 has been packaged more compactly, configurability suffers somewhat, although this is to the user's advantage in that it should provide increased system reliability. What's more, the peripheral equipment offered with the -20 is consistent with the needs of the target market. In other words, DEC has limited the peripheral complement of the DECsystem-20 to just that equipment required for in-house time-sharing and batch processing. There are no provisions for real-time interfaces or other exotic equipment.

Another difference between the DECsystem-10 and -20 systems is the role played by the PDP-11 front-end processor. In the DECsystem-10, the PDP-11 is used for initialization and to provide a maintenance interface to the CPU. Initialization is performed from the system disk drive. This drive has a dual-access interface, one side connected to the DECsystem-10 massbus and the other side connected to the PDP-11 Unibus. At start-up time, the PDP-11 accesses the system software on the disk and loads it into the DECsystem-10 main memory. The PDP-11 also interfaces the various registers and control circuitry of the CPU, providing the functions of an on-line front panel. Through this arrangement, maintenance personnel can examine or alter the contents of registers or memory locations during normal processing activities (providing these activities don't crash the system). Selected control lines can also be monitored and altered through the PDP-11.

In the DECsystem-20, the role of the front-end PDP-11 has been expanded to include control of all low-speed peripherals and communications lines and, perhaps more important, to provide extensive diagnostic facilities to the DECsystem-20. When not performing I/O control for the system, the PDP-11 is constantly monitoring the data paths and control lines of the KL20 CPU. The DECsystem-20 includes a special diagnostic bus that permits tests that could not be run using conventional interfacing techniques. Since the terminals are also under control of the PDP-11, maintenance engineers are presented with printed diagnostic messages and can avoid the time-consuming process of reading indicators and "fat-fingering" quickie test routines. Also included is an additional dedicated asyn- ▷

▶ INSTRUCTION REPERTOIRE: The KL20 CPU has 386 standard instructions, all of which are one word in length. The instruction set can be summarized by category as follows:

Boolean	64
Byte manipulation	5
Fixed-point arithmetic	24
Floating-point arithmetic	44
Full-word data transmission	18
Half-word data transmission	18
Input/output	8
Program control	9
Stack	4
Shift and rotate	6
Arithmetic testing	66
Logical testing and modification	64

In addition, the business instruction set includes four double-precision, fixed-point operations and a STRING instruction that can be used for nine separate functions including editing, decimal to binary conversion, binary to decimal conversion, character detection, string compare, and string move.

ADDRESSING: Programs are capable of directly addressing 256K words through the 18-bit address field in each instruction. These addresses can be indexed through any of 16 accumulators in each register set. Multi-level indirect addressing can be combined with indexing (preindexing).

INSTRUCTION TIMES: See table below. All times are in microseconds and are for the executive mode, using direct addressing without indexing and assuming no effects for multiprogramming such as segment relocation, etc.

Fixed-point add/subtract (36 bits)	0.7
Fixed-point multiply	2.4
Floating-point add/subtract (single precision)	1.9
Floating-point multiply (single precision)	*
Floating-point add/subtract (double precision)	5.0
Floating point multiply (double precision)	*
Jump	0.5

*Timing not available.

CACHE: The 2050 system includes a fast-access MOS cache memory with a 160-nanosecond access time. The cache, which is 2,048 words in size, actually consists of four caches, each with a capacity of 512 words (or one page) that operate in parallel. Each cache is a two-dimensional array consisting of 128 horizontal lines and 4 vertical columns containing one word of data each. In addition, the cache addresses a list of physical page addresses calculated by the memory-mapping hardware that correspond to the four columns of program data. For each processor fetch operation, a simultaneous search is performed of all four cache pages to determine whether the data is present in the cache. If not, the referenced data must be retrieved from main memory. Data is loaded into the cache from main memory four words at a time, thereby providing an instruction look-ahead feature.

DEC estimates that data being written to or read from main memory is typically found in the cache from 90 to 95 percent of the time, resulting in an effective access time of ▶

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▷ chronous line interface for maintenance purposes. If desired, this line can be connected, through a modem, to a remote service center for diagnostic services by DEC personnel.

The DECsystem-20 also features memory mapping to extend the addressing range of the KL20 CPU beyond the 256K-word limitation. The mapping system employed is the same as that used by the KL10 CPU and increases the addressing range to 4096K words of physical memory.

Physical memory is divided into 512-word pages. A 512-entry page address map is contained in CPU hardware. Eighteen-bit effective addresses are translated into 22-bit physical addresses by appending a 13-bit entry from the page table to the low-order nine bits of the effective address. The page entry also includes a 3-bit protection code that indicates what type of accesses can be made to this page (no entry, read-only, read-write, written, etc.). Two page tables exist, one for user mode and one for executive mode.

In the event of a page fault, hardware exists to determine the required page mapping. Two registers in the CPU point to either the monitor's or active user's page maps in main memory. These page maps contain mapping information for entire programs, unlike the hardware page maps that contain paging information only for those pages resident in main memory. From these maps, the required page is accessed from disk storage and brought into main memory. The page maps in main memory also contain control bits, including a read-only bit, a bit to indicate that no physical page is assigned to the virtual address, and a "used" or "written" bit that indicates whether a page has been altered while in main memory. If the page has not been altered, no rewrite to disk is required and a disk access is saved.

Operating software for the DECsystem-20, while functionally resembling its DECsystem-10 counterpart, has many enhancements to improve system performance. TOPS-20 is a multi-user, multi-mode, virtual memory operating system that supports multi-language interactive processing plus multi-stream batch processing. Multiple batch jobs can be run concurrently with interactive processing, due to the use of the same command language for both time-sharing and batch operations. Since the same command language is used for both types of processing, batch jobs appear as time-sharing jobs and can be run by the same monitor. The GALAXY batch processing software runs as a job under TOPS-20.

The list of programming languages supported by TOPS-20 is extensive. Included in the list are IBM-compatible COBOL, BASIC, ALGOL, three versions of FORTRAN, IBM-compatible APL, DEC's version of PL/1 (called CPL-20), a CODASYL-compatible data base management system (DBMS), and an interactive query language (IQL). ▷

▶ 244 nanoseconds. The cache uses a least-recently-used algorithm to identify the oldest cache entry, and that entry is removed to provide space for new data. Physical memory addresses, in contrast to logical user addresses, are maintained by the cache to facilitate context switching and the use of re-entrant code. A "written" bit is activated each time a user program has written a location in the cache, but the entry is not "written through" to main memory until it becomes necessary to provide cache space for newly accessed data. When an entire user program is swapped out by the Monitor, a "cache sweep" feature writes all altered pages in the cache associated with that program back to main memory before the program is swapped out of main memory.

PAGING: The KL20 processor provides a mapping capability from physical memory addresses of up to 4 million words (which require 22 bits for representation) to shorter effective addresses contained in 18 bits. The most significant half of the 18-bit effective address is used as an index to a page table which contains up to 4096 physical page numbers. The referenced physical page number is concatenated with the low-order 9 bits of the effective address (which indicates one of the 512 words on a page) to produce a 22-bit main memory address that can reference any of the 4 million words.

PROCESSOR MODES: The KL20 processor has two modes: User Mode and Executive Mode. The Monitor operates in the Executive Mode, in which addresses are not relocated and all memory locations are accessible. User programs execute in the User Mode, and are relocatable and subject to memory protection restrictions. The Exec Mode is further divided into the Supervisor Submode and the Kernel Submode. Kernel Submode is used for the most frequently preformed segments of the TOPS-20 Monitor, which handle system I/O and any functions which affect all users of the system. The rest of the Monitor executes in the Supervisor Submode and performs general management of the system and functions which affect only one user at a time. All instructions are permitted for use in the Exec Mode.

User Mode permits the execution of all instructions except those which would cause interference with other users or the integrity of the TOPS-20 Monitor. User Mode is subdivided into the Public Submode and the Concealed Submode. Concealed Submode protects any program in that category from being copied or modified, even by the program itself, and is normally used for proprietary software. Concealed Submode programs can read, write, execute, and transfer to any Public location, while Public programs can access addresses in Concealed programs only by transferring to locations which have ENTRY instructions. In User Mode, a program can access up to 256K words.

INTERRUPT STRUCTURE: The KL20 has seven standard prioritized channels associated with the I/O bus that transfers interrupt signals between system devices and the I/O Bus. Twenty-one additional channels can be added for a maximum of 28. Assignment of the channels to specific devices is under user program control, and may be altered during processing. The processor itself is treated as a device, and internal oveflow or priority checks can cause signals to be sent to the user program. Any number of devices can be connected to a single channel, and some devices may use two channels to transfer interrupts indentifying different conditions, such as device ready for data transmission or error condition encountered.

In addition to the seven-level interrupts, up to 135 Programmed Trap Instructions are available. The trap instructions can be executed in the same address space as the instructions which caused the trap. This allows user ▶

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▷ All but one of the compilers are the same as those offered with the DECsystem-10. Since the KL20 and KL10 CPU's are not object code-compatible, a compatibility package has been developed. This software package occupies a large enough block of main memory to require an extra 32K words in order to guarantee adequate user space. The one exception, the recently released BASIC+2-20, is available for the DECsystem-20 only and appears to run in native mode. All language processors are sharable and re-entrant under TOPS-20. Like the command language, all compilers are compatible under batch and time-sharing.

TOPS-20 supports a demand-paged virtual memory system that provides each process with a unique addressing space of up to 256K 36-bit words. Each job in the system can be considered as requiring one or more processes. In demand-paged mode, portions of active programs are moved into main memory in 512-word pages. This virtual memory system is different from the one employed in the DECsystem-10. In that system, all programs, including the compilers, are divided into two categories: pure code and impure code. The pure code section contains all program steps and data that will not change, and can be shared by any number of users. The impure code section contains all parameters and data peculiar to each user's program, and is not sharable between programs. In the DECsystem-20, there is no pure/impure code division. Instead, all programs, including the operating system, are assumed to be sharable. When a user program causes changes to a page, the system brings in a private copy for that program, leaving the remaining active programs to share the original copy.

To the user, the most visible difference between the DECsystem-10 and DECsystem-20 is the command processor interface. Under the older system, operators must exactly specify each system command along with its associated parameters. Any deviation from the required input results in a rejected command. The new DECsystem-20 operator interface with the command processor was developed from concepts employed in the TENEX operating system, an advanced, interactive, communications-oriented system developed under partial U.S. government sponsorship for use with PDP-10 systems on the ARPA network. The improved command processor interface is highly interactive, providing prompting at any time during the specification of a system command. Users need only have a vague recollection of the various system commands in order to successfully initiate a job or task. After logging on to the system, users can query the system to find what commands are possible. The system responds with a menu list of all the system commands. After choosing the appropriate command, the system, if requested, will also supply promptings that indicate the nature of other parameters required to complete the system commands.

The command processor interface also permits users to use abbreviated commands to speed up interactive operations. The user enters enough of a command to enable it to be uniquely identified, and the system completes it. If ▷

▶ programs to handle their own interrupts by directing the monitor to place a jump to a user routine in the trap location. Up to 40 programmed traps may be specified which execute in the executive area. These trap routines are loaded into the system at monitor generation time. Interrupts are decoded with one instruction.

INPUT/OUTPUT CONTROL

I/O CHANNELS: The DECsystem-20 uses integrated channel controllers for tape and disk drives. These connect to the internal channel bus and operate either synchronously or asynchronously. Each controller has a 16-word buffer for input operations. The channel bus is a physically short, high-speed data path between the memory control unit and the integrated controllers. It has a peak I/O bandwidth of 6 million 36-bit words per second, and operates synchronously in a time-division multiplexing mode, permitting multiple concurrent memory accesses by the mass storage controllers.

The basic DECsystem-20 is provided with two integrated controllers, each capable of handling either disk or magnetic tape. Up to eight disk or tape drives can be connected to a controller. Four TU45 tape drives can be connected to a tape controller. In turn, two tape controllers can be connected to a tape channel, thereby placing up to eight tape drives on a single channel.

Software limitations, imposed by the original release of the TOPS-20 operating system, limit disk configurations to four RP04 (20-million-word) or two RP06 (40-million-word) disk drives. The restrictions will be lifted during the second quarter of 1977, after which time the system capacity will be increased to 8 disk drives of either type for the 2040 and 16 disk drives for the 2050. In addition, four 4-drive tape subsystems will be allowed on a single system.

Only high-speed mass storage devices are connected to the internal channel bus. All low-speed devices interface the DECsystem-20 through the PDP-11 front-end processor that is incorporated in the system. Low-speed devices offered with the DECsystem-20 include line printers (maximum of two), a card reader, and up to 64 communications lines for the 2040 and up to 128 lines for the 2050. A card punch, paper tape reader/punch, and plotter are also offered.

SIMULTANEOUS OPERATIONS: Each of the four integrated controllers is capable of transferring data to or from memory through direct memory access. DECsystem-20 main memory is single-ported, but the memory control unit has four ports, permitting queueing of four independent memory requests. Main memory can be four-way interleaved, providing simultaneous access by up to four devices through the four ports of the memory control unit.

Memory interleaving also permits instruction look-ahead, causing the next sequential instruction to be accessed from memory and decoded while the previous instruction is still being executed.

MASS STORAGE

RHP04 DISK SYSTEM: Provides large-capacity random access storage. Includes a controller and from one to four RP04 disk drives, each with a storage capacity of 20 million 36-bit words. A maximum of two controllers, each with a maximum of four disk drives, can be connected to a DECsystem-20 for a total of 160 million 36-bit words (or 800-million 7-bit characters). Average seek time is 28 milliseconds, average rotational delay is 8.3 milliseconds, and data transfer rate is 178,571 36-bit words (or 892,855 7-bit characters) per second. Rotational speed is 3600 rpm. ▶

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▷ the abbreviation is not sufficient to complete the command, typing the question mark brings promptings to help complete the information. The interface also "remembers" command strings and permits the use of an abbreviation to specify an entire command, including the last specified parameters.

DEC's initial entry into the large-scale computer business was made in 1964 with the 36-bit PDP-6, which was succeeded in 1967 by the PDP-10. Some 25 PDP-6 systems were delivered, followed by about 175 PDP-10 installations. Since the announcement of the DECsystem-10 family in September 1971, DEC has doubled its annual volume of business in large-scale computer systems, and has installed well over 500 DECsystem-10's.

In January 1976, the DECsystem-20 was introduced to capture another segment of the time-sharing market, in-house business systems. This new family is quickly gaining acceptance, and DEC reports an acceleration of orders for DECsystem-20's since the announcement of the 2050.

Between the DECsystem-10 and DECsystem-20 lines, DEC's Large Computer Group offers a range of computational capability that is comparable to that of the IBM System/370 line from the Model 125 through the Model 158. The DECsystem 2050 was introduced to meet competition from IBM's recently announced 370/138 and 370/148. The KL20 central processor utilized in the 2040 and 2050 systems is estimated to surpass the internal performance of an IBM System/370 Model 158 in scientific processing environments and to approximately equal the performance of a 370/158 in business-oriented processing—at equipment prices estimated to be about one-half those of their IBM counterparts.

One key reason why the DECsystem models are so much less expensive than functionally comparable IBM systems is that DEC competes only in systems environments which favor the DECsystems' particular strengths. Those strengths are largely derived from the excellent applicability of the DEC operating systems to a "multi-mode" environment, inlcuding on-line processing plus local batch plus remote batch plus computer network requirements. In order for IBM, as an example, to satisfy these requirements, a full-scale OS or OS/VS system with the Time-Sharing Option (TSO) and a host of other ancillary software support products is needed. Even where part of the DEC software is now separately priced, the difference in the cost of the required hardware (main and auxiliary storage plus high-performance processor) usually leads to a sizable overall advantage for DEC.

To support the marketing plans for its DECsystem-20 family, DEC is counting on the expanding market for in-house time-sharing systems. In addition, DEC is looking for substantial growth in commercial environments, particularly in applications in which the strengths of the DECsystem-20 can be put to good use in interactive program development and in communications networks (DECNET). To provide momentum for its marketing ▷

▶ The RHP04 Disk System uses an industry-standard IBM 3336-type disk pack that contains 12 disks and uses 19 recording surfaces. Data is organized into 128 words per sector, 20 sectors per track, 19 tracks per cylinder, and 411 cylinders per pack. Error detection and correction circuitry permits detection and correction of bursts up to 11 bits in length under control of the operating system. Instruction retry is also supported. In addition to a rotational position-sensing capability, the RHP04 controller also permits overlapped head positioning on two or more disk drives under control of the operating system software. Additional reliability features include an offset head capability to facilitate read recovery and the ability to dynamically eliminate track sectors with unrecoverable errors from use by the system. The RP04 drive is manufactured by ISS.

RHP06 DISK SYSTEM: A double-density version of the RHP04 Disk System, each RHP06 disk drive has a storage capacity of 40 million 36-bit words (or 200 million 7-bit characters). A maximum of two channel subsystems, each with up to four disk drives, can be connected to a DECsystem-20 for a total of eight disk drives and 312 million words. Average seek time is 28 milliseconds, average rotational delay is 8.8 miliseconds, and data transfer rate is 178,571 36-bit words (or 892,855 7-bit characters) per second. A dual-port capability on each drive permits overlapped head positioning to occur on two or more drives. The RHP04 controller, permitting RHP04 and RHP06 disk drives to be intermixed on the same control unit. The RP06 drive is manufactured by ISS.

TU45 MAGNETIC TAPE SYSTEM: A 9-track, 75-ips unit with program-selectable recording densities of 800 bits per inch, NRZI, or 1600 bits per inch, phase-encoded. The transports employ vacuum-column tape buffers. Up to four TU45 transports can be connected to the integrated tape controller. Currently, only two controllers can be included with any DECsystem-20, due primarily to software limitations. During the second quarter of 1977, the maximum number of controllers that can be connected to either a 2040 or 2050 system will increase to four.

PC20 PAPER TAPE READER/PUNCH: Reads paper tape at 300 cps, using a photo-electric reader, and punches tape at 50 cps. The PC20 is an option on all DECsystem-20 models.

CD20A CARD READER: A tabletop-mounted card reader manufactured by Documation. The unit reads 80-column cards from a 550-card input hopper and features a riffle air-stream that separates cards and prevents jam created by cards becoming stuck together. Rated speed is 300 cards per minute. To minimize card wear, the CD20A employs a vacuum picker and optical reader station using light-emitting diodes (LED's). Stoppages are reduced by an automatic retry mechanism that causes the reader to make six attempts before generating a pick error. The CD20A is recommended for use in remote batch entry applications. The controller for the CD20A is built into the unit and interfaces the Unibus of the PDP-11 front-end processor.

CD20B CARD READER: A free-standing unit, manufactured by Documation, that reads 80-column cards from 2200-card input hopper at 1200 cpm. The unit features the same mechanism as the CD20A card reader and differs only in the card-handling rate and the mounting. The controller for the CD20B mounts in the unit and interfaces the Unibus of the PDP-11 front-end processor.

LP20A AND LP20B LINE PRINTERS: These are both versions of the Dataproducts 2230 line printer, a drum-type printer featuring a choice of either 64- or 96-character drums. Using the 64-character drum, the printer operates at 300 lpm, but when the 96-character drum is specified, the printing speed becomes 240 lpm. Both models are 132- ▶

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thrust, DEC has assembled a field organization of nearly 200 sales and software engineers and close to 300 field engineers dedicated to selling and servicing DECsystem installations.

They won't, however, be calling on the typical batch-oriented computer user whose processing requirements are concentrated on conventional business applications. Instead, Digital's DECsystem-20 market target includes "the top manufacturing and service companies" where the system can complement the processing capabilities of an already existing large computer installation.

Many potential customers in DEC's targeted market segments are conditioned to acquiring their computers through rental agreements. Although the overwhelming majority of DECsystem computers are acquired by outright purchase, DEC does arrange both full-payout lease and monthly rental agreements with customers who elect to acquire their equipment through these arrangements. Full-payout lease prices are estimated at approximately 2.5 percent of the system purchase price per month, and five-year rental rates average approximately 3.2 percent of the system purchase price per month. Exact rental prices, however, are not available from DEC, and rental and lease agreements are negotiated individually with each customer.

DEC's fundamental approach to the marketplace for the DECsystems is to avoid head-on encounters with IBM except upon DEC's terms. These terms specify a sophisticated user (generally in the top 20 to 30 percent of current computer installations) and one who generally meets the criteria outlined earlier. (For example, general-purpose commercial batch-oriented installations are definitely not sought after, if not actually discouraged.) Furthermore, DEC has historically been conservative in accepting business that is predicated upon heavy systems responsibility. This approach has resulted in a very high level of customer loyalty and has contributed to steady if not rapid growth for DEC's large-scale systems business. In this regard, DEC's current business plan remains essentially unchanged from previous years, and the company's realistic approach seems likely to yield continued market acceptance of the DECsystem-20 at a pace satisfactory to DEC.

USER REACTION

Datapro contacted seven DECsystem-20 users in January 1977 to record their opinions of the system. Each of the users had one system. The survey group consisted of a large engineering firm, three distributorships with multiple remote offices, one secondary school system, one college, and a large retail store chain. The seven systems had an average installed life of six months. Four of the systems had been purchased from DEC, while the remaining three were being acquired through 5-year full-payout leases.

Memory sizes for the various configurations averaged 150K words, ranging from 96K to the maximum 256K

position printers that feature programmable vertical format units. Switches on the units permit line spacing of either six or eight lines per inch. Users have a choice of either EDP or scientific character fonts for both the 64- or 96-character models. Up to two line printers of any type can be connected to the DECsystem-20 through the PDP-11 front-end processor.

LP20F AND LP20H LINE PRINTERS: These are similar to the LP20A and LP20B printers above. They are versions of the Dataproducts 2440 line printer, which is a drum-type unit featuring a choice of either 64- or 96-character drums. Using the 64-character drum, the printer operates at 1250 lpm, and with the 96-character drum, at 925 lpm. Both models are 132-position printers with standard 12-channel tape-controlled vertical format units. Swtiches on the units permit line spacing of either 6 or 8 lines per inch. Users have a choice of either EDP of scientific character fonts for both the 64- and 96-character models. Up to two line printers of any type can be connected to the DECsystem-20 through the PDP-11 front-end processor.

LP200B LINE PRINTER: A Dataproducts 2250-Charaband-type unit, this printer provides the flexibility and interchangeability of the train printer mechanism but is said to eliminate the problems caused by the metal-to-metal friction inherent in that design. The Charaband is composed of a number of rods mounted on a steel-clad polyurethane belt. The assembly looks like a machine gun cartridge belt. A replaceable cap, with two print characters, is placed on the ends of each rod to make a two-character print head. The entire Charaband passes horizontally past the paper in the same manner as a train printer. The second set of replaceable print caps can serve as spares, or they can have a different character font. The Charaband mechanism is less expensive than a drum and can be refurbished merely by replacing the print caps. In addition, the Charaband enables greater printing speeds than those attainable from drum printers.

The LP200B printer is a 1500-lpm unit with either 64- or 96-character fonts. Users have a choice of four Charabands, and both the 64-character and the 96-character set can be included on the same Charaband. Other features of the LP200B include a 12-channel paper tape-controlled vertical format unit and operator-selectable line spacing (6 or 8 lines per inch). Users may optionally specify special character fonts. Like the LP20 lint printers, the LP200B also interfaces the DECsystem-20 through the PDP-11 front-end processor.

XY10 INCREMENTAL PLOTTER SYSTEM: Includes the XY10 plotter controller and a Calcomp 565 drum-type plotter. The XY10 controller connects to the PDP-11 front-end processor and supports one plotter. The Calcomp 565 has a 12-inch drum and can produce charts up to 120 feet long. Plotting speed is 300 0.01-inch steps per second.

COMMUNICATIONS EQUIPMENT

All terminals, including the operator console terminal, connect to the system through the PDP-11 front-end processor. The DC20 communications subsystem interfaces all system terminals.

DC20 COMMUNICATIONS SUBSYSTEM: Supports up to 64 asynchronous lines on a 2040 system, and up to 128 lines on a 2050 system. The DC20-AA multiplexer terminates 8 asynchronous lines and can be expanded to 16 lines by the addition of one DC20-DA 8-line expander. Two expanded DC20-AA's can be incorporated in the basic 2040 or 2050 for a total of 32 lines. Two more expanded DC20-AA's can be added, using a DC20-EC communications expansion cabinet, for a total of 64 lines

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▷ words. The 20-million-word RP04 disk drive was install-ed on six of the seven systems, the exception being a newly converted 2050 system that had been upgraded to three 40-million-word RP06 drives when converting from 2040 status. Typically, two RP04's were found in the systems, although one user required only a single drive. Four of the users had added an extra tape transport to their systems.

Line printers included three 300-lpm units, three 1200-lpm units, and one 1500-lpm Charaband unit. All systems used the 300-cpm tabletop-mounted card readers. The number of communications lines implemented in the systems varied from 4 (a user just getting started) to the full 64. Typically, the number of lines fell between 16 and 24.

Applications being developed and executed on the seven systems included engineering calculations, statistical anal-yses, and simulations; order entry, report generation, standard accounting functions such as accounts receiv-able, accounts payable, payroll, general ledger, and in-ventory control; municipal accounting; school accounting and student records; and educational time-sharing. One of the users helped defray the cost of the system by selling unused time and user lines to other municipal agencies.

The list of equipment replaced by the DECsystems included a Burroughs B 1700, an IBM 370/135, an IBM 370/125, and an IBM 360/30.

The survey evoked a broad spectrum of user ratings, which are tabulated below.

	Excellent	Good	Fair	Poor	WA*
Ease of operation	5	2	0	0	3.7
Reliability of mainframe	6	0	1	0	3.7
Reliability of peripherals	4	3	0	0	3.6
Responsiveness of maintenance service	5	1	1	0	3.6
Effectiveness of maintenance service	2	4	1	0	3.1
Technical support	3	2	1	1	3.0
Operating system	4	3	0	0	3.6
Compilers and assemblers	2	3	2	0	3.0
Ease of programming	6	1	0	0	3.9
Ease of conversion	4	1	1	0	3.5
Overall satisfaction	3	3	1	0	3.3

*Weighted Average on a scale of 4.0 for Excellent.

On the positive side, everyone was pleased with the ease of operation, particularly the ease of start-up and the system's power fail/restart capabilities. The mainframe and peripheral reliability also rated high, though with some qualifications in the category of peripheral relia-bility. The reservations stemmed almost entirely from early problems with the TU45 magnetic tape subsystem.

Maintenance responsiveness also received a high rating, with most of the users stating that there are relatively few DECsystem-20's installed and generally enough service personnel to respond quickly to maintenance calls. How-ever, the survey group rated the effectiveness of mainte- ▷

▶ on the 2040. For the 2050, three 32-line DC20-EC expan-sion cabinets can be added, providing up to 128 asynchro-nous communications lines.

The DC20 system is scanner-based. Each input and output line is double-buffered. Received characters are appended to the line with an appropriate line number and then buffered in a 64-level first-in/first-out buffer memory. The front-end PDP-11 periodically empties the buffer memory and places the characters in main memory.

On transmission, characters are loaded into each line buffer from the PDP-11 memory along with a byte count and memory address. The DC20 then continues to cycle-steal the outgoing message from the PDP-11 memory. Optional modem controls are also available for the DC20.

LA36 DECWRITER II KEYBOARD TERMINAL: Pro-vides electromechanical impact printing at a rate of 30 characters per second in a "60-character-per-second-mode." Printable characters are stored in a buffer during carriage return and line feed, allowing subsequent bursts at 60 characters per second while multiple characters are stored in the buffer. Prints in rows of 132 print positions on forms ranging from 3 to 14⅞ inches in width. Up to six-part forms can be handled. The LA36 keyboard generates a set of 128 ASCII characters, including 96 upper and lower case letters and numbers and 32 control characters. Characters are formed in a 7-by-7 dot matrix and are printed at a horizontal pitch of 10 characters per inch and a vertical spacing of 6 lines per inch. The keyboard layout conforms to the most recent ANS standard. The LA36 features quietized operations to enhance its suitability for office environments.

LA37 DECWRITER II APL TERMINAL: Identical in mechanical characteristics to the LA36, but features a full APL keyboard as well as standard alphanumeric charac-ters.

VT50 DECSCOPE INTERACTIVE VIDEO DISPLAY TERMINAL: Announced in August 1975, the VT52 is upward-compatible with the VT50 Interactive Video Ter-minal and incorporates a number of enhancements. The VT52 has an 8.3-by-4.1-inch display of up to 24 lines of 80 characters each, for a total of 1920 characters. The displayable characters consist of a 96-character upper and lower case, numeric, and punctuation ASCII subset. The terminal includes a 63-key typewriter keyboard plus an auxiliary 19-key keypad for entering numerals, controlling cursor movement, and invoking up to three user-defined functions. The cursor can be moved up or down one line, right or left by one character, to home position, or to fixed tab stops every eight spaces. The cursor can also be moved to any position on the screen under program control. Other functions include: erase the display from the cursor position to the end of the screen, scroll up, and scroll down. Transmission is in ASCII in either full-duplex or full-duplex with local copy mode. Transmission speeds are switch-selectable and can be 75, 110, 150, 300, 600, 1200, 2400, 4800, or 9600 bits per second.

SOFTWARE

The DECsystem-20 is provided with a virtual-memory, multi-mode operating system and an extensive repertoire of programming languages and utilities. Included among the languages are FORTRAN, COBOL, ALGOL, APL, BASIC, a version of PL/1, and a macro-assembler. The operating system, TOPS-20, includes features that sup-port full-language time-sharing for program development and for interactive and terminal-oriented applications, as well as concurrent multi-stream batch processing. ▶

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▷ nance substantially lower for the same reason. The systems are relatively new and many of the maintenance engineers are not really comfortable with the system. The users did, however, mention that the DEC representatives seemed to become familiar with the systems very rapidly, so that this problem will probably resolve itself in the near future.

Continuing on the positive side, the TOPS-20 operating system was very enthusiastically received. The only reason it did not receive a perfect 4.0 rating was because of characteristics of the time-sharing accounting system. The accounting module does not require valid account numbers for entry to the system, and, in fact, will permit users access to the system without an account number. Some users even liked this aspect. But those wishing to keep accurate usage records for cost allocation were not particularly happy and were consulting with DEC on the development of a more stringent accounting package.

Although the DECsystem-20 compilers were not as highly rated, the more general ease of programming category was accorded a near-perfect rating of 3.9. Programming ease was rated high due to the large number of programming languages available. Most of the users we surveyed were using three or more languages concurrently. They rated the compilers somewhat lower because they are DECsystem-10 compilers and must be executed with a special compatibility package. Most users felt this was an inconvenience that took away user space and also slowed down their response times. Six of the seven stated that they did not have any quantitive data about the extent of performance degradation. One user, however, claimed to have researched the effect of the compatibility package and stated that it actually caused very little, if any, system degradation. The problem is expected to become academic when DEC releases native-mode compilers that do not require this compatibility package.

The category receiving the greatest criticism was technical support. Although most of the users felt that the quality of the support was quite good, and rendered within a reasonable length of time, these same users complained of being charged for software consulting services for problems they felt were DEC's responsibility. Some of the problems cited were bugs, but others were software characteristics that did not fit into users' requirements and did not represent failures. Typical of these characteristics was the fact that TOPS-20 does not require a valid account number to gain access to the system, and the operating system's automatic shutdown for maintenance after 96 hours of operation. These and other problems had generally been noted after the 90-day warranty period, but the users still felt that the manufacturer should absorb the costs for consulting services that were incurred while identifying the problems.

The group of users who awarded lower ratings to the category of technical support included those who had been dealing with IBM prior to acquiring a DECsystem-20. IBM, in general, markets a different type of ▷

▶ **OPERATING SYSTEM:** A single operating system and highly interactive command control language are provided for all DECsystem-20 models. Unlike TOPS-10, its DECsystem-10 counterpart, TOPS-20 has been designed to function as a stand-alone system with minimal operator requirements. Any remote or local user terminal can function as the operator console simply by identifying itself as the console, and more than one terminal can perform console functions. The system treats all terminals equally, and relies on passwords from users to determine authority rather than accepting commands only from designated privileged terminals. This feature permits complete remote diagnostic capabilities since the required passwords are all that is needed to perform maintenance operations.

TOPS-20 was constructed from TENEX (developed by Bolt, Beranek, and Newman) and is a full virtual-memory, process-structured monitor. The interface to the command processor is highly interactive, providing prompting at any point during the specification of a task or job. After a user has successfully logged onto the system, typing a question mark will cause the system to produce a menu listing of all the operations possible. If the exact name of the desired function is not known, inputting the first letter followed by a question mark produces a list of the commands beginning with that letter. The user must, however, know the basic function performed by each command. After the user has determined the command to be performed by the system, subsequent question marks will produce additional promptings that indicate parameters and other required input data to complete the system command.

Another user service provided by the interactive interface to the command processor is the abbreviating of commands to speed up interactive operations. Using this feature, users merely input enough characters to uniquely identify a particular valid command and type an ESCAPE character. The interface will complete the command and await further input, such as parameters, etc. If the user input is not enough to uniquely identify the command, the system requests more information. If the user cannot supply the needed parameters, inputting the question mark will produce prompting to aid in completing the command.

The interface can also recognize abbreviated command strings. When an abbreviated command is entered, the system checks back to the last used sequence and supplies the entire string, including the supplied parameters. This mode of operation will continue until a new command string is supplied.

Another notable, but less visible, difference between TOPS-20 and TOPS-10 is memory space reduction. Significantly greater portions of the TOPS-20 operating system,

including the command processor, are non-resident and are brought into main memory through demand paging in the same manner as user programs. The system also makes use of re-entrant program modules, but still can generate private, dedicated copies of pages within modules whenever integrity is threatened.

The major portions of TOPS-20 include the following components:

● **Service Request Handler:** Accepts requests for allocation of system resources such as main memory, processor time, and I/O device availability. Includes the cyclic Command Decoder, which is responsible for validity checking and interpreting user requests and passing them to the appropriate system program. ▶

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▷ product than DEC, choosing to include more services with the hardware and software, but at the cost of higher purchase and lease prices. One or two of the users felt the problem was a result of misunderstandings on both sides, and that each would have to make some accommodations.

The category of overall satisfaction, although well above the 3.0 level, would have been even higher were it not for the late delivery of some portions of the operating software. Two users had counted on using one particular module that was not delivered until October 1976. This module is now installed and working satisfactorily, but the delay, coupled with minor start-up problems, were cited as the reasons behind the reduced rating.

Despite its DECsystem-10 origins, the DECsystem-20, during its first year on the market, was still a new product and subject to all the problems encountered in new products. It is conceivable that DEC sales personnel emphasized the DECsystem-10 lineage a little too strongly, and led users to expect the same initial level of performance as that attained with the veteran system. Most of the criticisms cited by the survey group, while valid, were typical of newly released systems. It is noteworthy that all the problems that involved actual failures within the system had been already solved, while those remaining were ones that involved a need for modifications, rather than corrections. No matter how much development time has been spent on a system, including its forebears, there will still be some problems inherent in the new system. And when these are eliminated, as most appear to be, the DECsystem-20 is likely to rival the DECsystem-10's three-year leadership in Datapro's annual user ratings of general-purpose computers. □

► ● **Sharable Resource Allocator:** Distributes system resources to individual users in accordance with messages from the service request handler. Includes two cyclic programs: the Scheduler and the Swapper. The Scheduler determines which user program is to be run during a given time-slice, using a round-robin queue monitor as well as the Core Allocator (to provide access to sharable system resources) and the Context Switcher (for saving and restoring program conditions when swapping). The Scheduler is activated by the system clock 60 times per second, and user jobs are given time-slices of one-half second for execution. Jobs which do not issue I/O requests during their one-half second time-slice are considered to be compute-bound, and are placed in a different queue where they get 2-second time-slices at less frequent intervals. The Swapper transfers jobs between drum/disk and main memory after determining which user programs must be present in core for a job to run and which programs must be removed from core in order to make room for the run.

● **I/O Service Routines:** These routines process user program requests for I/O devices, and consist of three non-cyclic routines. The Programmed Operator Handler traps user service requests to the operating system and is the only means by which the user can switch to Exec Mode for operating system service. Input/output routines are initiated by the Programmed Operator

Handler to manage data transfers between peripheral devices and user programs in core memory. The disk I/O service routine includes optimization techniques for disk accesses, which according to DEC result in 25 to 50 percent faster disk throughout than would otherwise be possible under the same loading conditions where the controller is saturated with transfer requests. The I/O System permits the use of symbolic device names and allows the user to have device independence. The File Handler permits users to define protected output files for permanent storage.

The DECsystem-20 Monitor allows three basic concurrent modes of operation: interactive time-sharing, batch and remote communications. Up to 128 interactive terminals can be handled by the Monitor. The DECsystem-20 Monitor, as well as the Command Language for the Monitor, is common to all modes of operation. This hierarchy of capabilities within one operating system, as well as the flexible hardware boundaries between the models, permits relatively simply upward growth without extensive retraining or reprogramming.

Time-sharing users have the same command languages available to them as do multiprogramming batch users, allowing time-sharing terminals to initiate batch jobs. Commands are available to let terminal users manipulate files and control their own programs from creation through execution. Individual peripherals can be dedicated to a user for his exclusive use on a given job, or he can create and access files on peripheral devices shared with others. File protection schemes allow sharing of files among multiple designated users, with differing degrees of access authorized to each. Mass storage devices can be exclusively dedicated to an individual user.

In multiprogramming mode, users are scheduled on a modified round-robin basis by the queue manager program, using disk to hold swapped-out segments. Control information is passed through the Executive Bus to initiate swapping or memory transfers. This device attachment scheme permits independent overlapped operation between the swapping of one program and the execution of another program in memory. The re-entrant or sharable nature of many monitor segments, as well as the sharable code segments produced by the sharable compilers, results in additional core utilization by minimizing swapping.

Multiprogramming batch mode allows operation of up to 14 jobs concurrently with time-sharing. The batch user places his program in an input stream which is loaded into the system through an input device: cards, tape, or disk. EBCDIC card input will automatically be handled by the stacker program and passed through a code conversion. Tapes, however, are currently required to be ASCII and must be converted through a DEC "Filter" program prior to input. The Stacker program collects batched input data in the job stream and accumulates it onto different individual files depending upon data type. Individual alternating inputs resulting from multiple data acquisition processes cannot be gathered by the system on a common input spool for subsequent processing by applications programs.

The batch controller system accepts parameters specified by the user, such as start and deadline times, which then are used by the queue manager to modify the basic round-robin scheduling algorithm inherent in the system. At installation time, default conditions can be established providing standard parameters to be inserted unless otherwise specified by individual users. During concurrent operation with time-sharing, batch jobs may occupy any available area in main memory. No partitions are set up to separate main memory into areas exclusively reserved for time-sharing or batch processing. ►

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Remote communications hardware and software capabilities will permit simultaneous use of multiple remote stations with other modes of operation. Asynchronous full-duplex communications between small remote computer stations allows remote users to send or receive data. The remote batch terminals may have printers, card readers, etc., locally attached, and may also support additional remote terminals.

TOPS-20 provides a demand-paged virtual memory environment that allows each job a unique 256K-word address space in 512-word pages. The system divides the pages of each active job into two groups, the working set and the balance set. The working set consists of all pages that have been referenced within a particular recent time interval. The virtual memory system dynamically adjusts the time interval according to the assumption that, when the job next becomes active, memory references will probably occur to the same pages. The number of pages contained in a job's working set is determined by the program's characteristics. The balance set consists of those jobs whose working set will fit into main memory. Interactive jobs are given higher priority than compute-bound batch processing, unless the latter has been blocked for a long time. The balance set is controlled by the scheduler and is periodically redefined. Working sets are also monitored, and pages that have not been recently referenced are swapped out. Generally, the system administrative controls attempt to provide a nearly equal percentage of the processor to all users, but, at the same time, to optimize the use of all resources. File input and output are also demand-paged.

Memory mapping and page-level access protection are provided through hardware and microcode. These features permit page sharing between programs and reduce context switching overhead. Page status and age information are maintained in tables and are automatically updated for each page in main memory by microcoded routines. The system is supported by two hardware registers in KL20 CPU that contain pointers to locate the physical pages in memory which contain mapping information for the operating system and the currently active user. These pages, referred to as the User Page Table (UPT) and the Monitor Page Table (MPT), contain page pointers for mapping information between the user's and the monitor's address space and the actual pages of physical memory being used by these elements.

There are three types of pointers—immediate, shared and indirect.

Immediate mode signifies that entries in the User Page Table refer directly to physical pages in main memory.

Shared mode indicates that two or more users are sharing the same page of coding. In this case, the pointers in the UPT direct the system to a shared pages table, in which the physical address of the shared page is contained. The location of the shared pages table is contained in another CPU register. Page sharing relieves the system of the need to provide multiple copies of the same code or data block to separate tasks or jobs performing similar operations. If the shared page is modified by one of the jobs, a separate copy is created for that user, leaving the other jobs still sharing the unmodified copy.

Indirect mode uses the shared pages table, but the entry in the table points to a second user page table. The entry in this second UPT then points to the physical pages.

GALAXY MULTIPROGRAMMING BATCH PROCESSING SYSTEM: Enables the DECsystem-20 to execute multiple batch jobs with time-shared jobs. GALAXY is executed as a single-user job and uses the same command

language as time-shared programs. Batch users can enter jobs using traditional card decks, with control cards defining the command options for a job, or create and submit a control file through a user terminal. This control file is then intercepted by the batch system and processed in the same manner as a job submitted on cards. Since the batch and time-sharing systems use the same command language, system overhead is reduced by the ability to have only one control processor resident in main memory. The system administrator can assign a guaranteed percentage of CPU time for batch jobs.

GALAXY also provides automatic line printer and card reader spooling plus job accounting functions. Jobs can be run in any order, and the user may specify the number of times each job is run.

Special commands for error handling are provided. These commands are copied into the control file by the input spooler and specify the actions to be taken in the event of a fatal error. If the user has not provided for error recovery, the batch controller automatically initiates a core dump of the user's area and terminates the job.

DATA BASE MANAGEMENT SYSTEM: DBMS-20 is a full-scale data base organization and management system that uses both COBOL and FORTRAN as its host languages and provides a data management language (DML) based largely upon the April 1971 CODASYL Data Base Task Group (DBTG) specifications. DBMS-20 supports hierarchical data structures in simple tree format or in more complex network structures and provides a high degree of data independence from physical devices as well as user application programs. Owner and member relationships are defined by chained pointers. DBMS-20 permits access to data through the DIRECT, CALCULATION, or VIA set location modes, permitting clustering of records normally accessed in groups. In addition to the Schema, multiple subschemas can be associated with the Schema to minimize the program modifications required due to the addition of data and new relationships to the files. A temporary subschema area is used to permit program testing on data without jeopardizing the integrity of the data base.

The Data Base Control System module is composed of re-entrant routines that permit concurrent retrievals to the same data areas. Data areas can be subjected to an exclusive update provision that grants exclusive update rights of a data area to a given processing program. The protected update option permits concurrent retrievals from a data area but proscribes concurrent updating activities. Concurrent updates to the same data area can be performed by a multiple-update queuing mechanism. Privacy of data within the data base is provided by privacy locks of up to 30 characters in length which are associated with the schema, subschemas, and data areas. Data base support utilities include initialization, print, schema update, and statistics logging routines. Recovery files are maintained for each file each time it is opened for protected update. The COBOL extension module, LIBOL, provides an interface to an on-line communications network. DBMS-20 is a separately priced program product. DEC claims that current users of TOTAL, from Cincom Systems, or IDMS, from Cullinane Corp., can migrate to DBMS-20 with only minor changes.

IQL-20: The DEC Interactive Query Language is an information retrieval and report writing system that uses English-like requests to read a file or group of files and process data contained in those files. IQL-20 extracts, summarizes, reorganizes, and copies file information, and produces reports in specified formats. It interfaces both the file management system of the TOPS-20 operating system and DBMS-20. Data files can be sequential or index-sequential with fixed and/or variable record length. IQL-20 can perform sorting; conditional processing; computation, including multiply and ▶

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▶ divide; perform built-in functions, such as tallies, totals, and averages; generate multiple reports in nine or more formats; perform matrix reporting through manipulation of summaries or individual items; define, modify and examine dictionaries for the pre-storing of files, records, or items; and operate in either interactive or batch mode.

COBOL-20: A complete implementation of American National Standard COBOL X3.23 (Level 4) with compilation speeds, according to DEC, which vary from 2,000 to 6,000 statements per minute. DEC also claims sort speeds of 1,000 to 5,000 records per minute for the COBOL Sort statement, which uses the disk as intermediate storage by default but may assign intermediate files to tape or drum. An ISAM package is also included in the compiler to allow access to data files which may employ a variety file organizations. The COBOL Compiler may be used for line-by-line compilation or for batch compilation. The standard recording mode for COBOL is ASCII, in either 6-bit or 7-bit bytes; however, IBM-compatible EBCDIC code can also be read or written on magnetic tape after a code conversion to or from the internal ASCII code representation. The COBOL Compiler has 7K words of "pure" (re-entrant) code and a minimum of 10K words for each user's portion. The minimum hardware requirement is any DECsystem-20 with 96K words of memory.

A separately priced SORT-20 package, for use with COBOL, can reduce sort times for disk data sets with more than 1000 records by about half.

FORTRAN-20: A FORTRAN compiler that contains both extensions to the ANS FORTRAN-IV standard and global and local optimization capabilities for improving execution times. DEC says that even without the global optimization capability, FORTRAN-20 object code executes significantly faster than that compiled with DEC's earlier FORTRAN IV compiler, and that compilations require only half of the CPU time required by DEC FORTRAN IV. When global optimization is invoked, DEC estimates that compilation speed will decrease slightly but that the resulting object code will execute up to 40 percent faster than unoptimized code.

Language extensions in FORTRAN-20 include a PARAMETER statement that allows specification of compile-time constants; an INCLUDE statement that permits the inclusion of source code from files other than the primary source file; OPEN/CLOSE file specification statements; N-dimensional arrays; ENCODE/DECODE statements; Boolean operators; NAMELIST and list-directed I/O that provide format-free input and output operations; and compatibility with IBM-type declaration statements.

Users may reference any I/O device. Devices are normally specified by logical assignments so that physical device selection need not be made until run-time. Those devices corresponding to the special I/O statements READ, PRINT, ACCEPT, and TYPE are also assignable at run-time.

FORTRAN-20 supports FORDDT, an interactive debugging aid allows breakpoints to be set on any line, allows array elements to be referenced by name, and permits interactive run-time recovery of file and device selection errors.

BASIC+2-20: Compatible with the BASIC+2 compiler developed for the DEC PDP-11 minicomputers. Some of the features included in this latest BASIC compiler include program manipulation commands that permit saving, running, and retrieving BASIC programs; immediate mode statements to simplify debugging; optional automatic line-by-line syntax checking; up to 30-character variable names; IF/THEN/ELSE programming constructions; string handling operations including string arrays; a full matrix operations package; extensive program editing facilities; and access to system files.

The minimum hardware required for BASIC+-20 is 128K words of main memory and allocation of 50K words of permanent file storage.

BASIC-20: An extended BASIC interpreter implemented in re-entrant coding for time-shared operations. Enhancements to the language are in four areas:

● Editing facilities for adding or deleting lines, renaming files, resequencing line numbers, combining two files, and listing any portion of a file on the line printer or a user terminal.

● User-controlled peripheral assignments for input or output files, including disk.

● Output format controls allowing terminal output to include tabs, spaces, and columnar headings.

● Expanded command set including matrix manipulation operators and a macro capability.

The minimum hardware required for BASIC-20 is a 96K-word system.

ALGOL-20: Consists of a one-pass, single-phase compiler capable of processing up to 5000 ALGOL lines per minute, according to DEC; this speed assumes disk I/O with 24 unpacked significant symbols per line. Features of ALGOL-20 include a full range of diagnostics, extended-precision floating-point representation, byte-string manipulation capability, "while" and "for" statements for iterative procedures, and independent program and procedure compilation. DECsystem-20 ALGOL is limited by the following restrictions labels are not allowed, all formal parameters must be specified, and ALGOL-60 identifiers are restricted to 63 symbols. Use of the compiler requires a 13K-word re-entrant segment in memory and a non-sharable user segment consisting of 2K words plus an amount of core dependent upon the size of the user's ALGOL program. The ALGOL-20 object-time system provides a basic I/O system including teletype I/O default with 16 logical channels, storage management, on-line de-bug tools, and a library of attachable routines including FORTRAN interface, byte-string manipulation, bit-field manipulation, single- and double-precision mathematical functions, etc. ALGOL-20 also features a built-in debug utility. DEC claims this is the only ALGOL compiler available with such a feature.

The minimum hardware required for ALGOL-20 is a 96K-word system.

APL-SF: A conversational programming language that is particularly well suited for operating on numeric and character array-structured data, the DEC APL system runs under the DECsystem-20 time-sharing Monitor. DEC's APL closely resembles the IBM APL/360 implementation, but provides additional features. DEC offers both basic and extended versions of APL, each of which can have double-precision arithmetic facilities. Extended APL includes the Divide-Quad, Execute, Quote, and Dyadic Format for performing matrix inversions, solving linear equations, and evaluating character strings, plus user-level file access to standard ASCII sequential files, internal format random-access and sequential files, and immediate I/O to any peripheral through an OUTPUT command.

Extended APL, with or without double-precision arithmetic, occupies 24K words of re-entrant code plus 7500 characters of user code area and a 5K or 6K user workspace. Basic APL, with or without double-precision arithmetic, requires 20K words of re-entrant code plus 7500 characters of user code area and a 5K to 6K user workspace. APL is a separately priced program product. ▶

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The minimum system requirements for APL-SF include a 128K-word system, with at least 45K words available in user space, and at least 50K words of pertinent file storage space.

CPL-20: DEC's Conversational Programming Language is an interpreter supporting a subset of the ANS PL/1 language. CPL is designed for beginning programmers or even nonprogrammers. It provides users with the option of immediately executing statements or saving them in a file for later execution.

CPL includes the following PL/1 functions: ALLOCATE, ASSIGNMENT, BEGIN, CALL, CLOSE, DECLARE, DEFAULT, DELETE, DO, END, FORMAT, FREE, GET, GOTO, IF, NULL, ON, OPEN, PROCEDURE, PUT, READ, RETURN, REVERT, SIGNAL, STOP, and WRITE. CPL supports the FIXED, FLOAT, CHARACTER, CHARACTER VARYING, BIT, BIT VARYING, and POINTER data types in both single-dimension and arrays. The AUTOMATIC, STATIC, CONTROLLED, and BASED storage classes are also provided for.

In general, nearly all PL/1 arithmetic, mathematical string-handling, array, and storage control functions are supported by CPL-20. The minimum hardware requirement for CPL-20 is a 128K-word system, with at least 50K words available as user space and 50K words of permanent file storage space.

MACRO ASSEMBLER: This two-pass symbolic assembler is device-independent, allowing the user to select I/O devices for source program entry, program listing output, and object code storage. Powerful macro capabilties permit creation of user-defined language extensions for frequently used coding sequences. The pure, re-entrant code for the macro assembler occupies 7K words of main storage, and each user's portion of the assembler requires a minimum of 1K words.

EDITS: This page- and line-oriented file editor permits blocks of data to be transferred within files and allows lines or complete pages of data to be copied from one file to another. Other facilities provided by EDITS include string searches and substitutions, the capability to modify text within a line and to complete a line, and the ability to save edited material by issuing one command. EDITS requires 8K words of main storage, and each user's portion requires a minimum of 5K words.

USER GROUP: The worldwide DEC Users' Society (DECUS) was founded in 1961 and currently has more than 10,000 members in over 40 countries. This group is directly supported by DEC and schedules two meetings annually in addition to publishing a bi-monthly newsletter, DECU-SCOPE. The DECUS Program Library Catalog lists more than 500 programs written by DEC users, most of which are available at no charge, or in some cases for a nominal handling fee. DECUS Membership is limited to DEC users, although some meetings are opened to general attendance. Inquiries should be directed to:

DECUS Executive Director	DECUS European Secretary
Digital Equipment Corp.	DECUS International Office
146 Main Street	81 Route de L'Aire
Maynard, Mass. 01754	1227 Carouge
	Geneva, Switzerland

PRICING

CONTRACT TERMS: DEC offers a purchase agreement for immediate ownership of the DECsystem-20, and full-payout accrued-equity lease contracts. The most common of these is a five-year accrued-equity contract that yields DEC a full payout in four years. An end-of-contract option permits the direct purchase of the system for the then-fair market value, which DEC estimates will be 10 percent of the original purchase price. The monthly charges for accrued-equity contracts for new DECsystem-20 systems are negotiated on an individual basis in order to reflect prevailing interest rates. There are no extra-use charges for the equipment, although maintenance contracts may be negotiated for any amount of daily maintenance from 8 to 24 hours. Liberal educational discounts are given to qualified institutions.

SOFTWARE: A system software package is included with each system. This package includes the TOPS-20 operating system with the GALAXY batch processor; the linking loader, editor, and other utilities; and the macro assembler. All other language processors and the SORT utility are licensed separately. License fees are listed in the Software Prices section of this report.

SUPPORT: Included with the price of each system is a consulting services package that provides up to 50 days of applications consulting support to users to aid them in developing their applications programs. These 50 days must be used within one year of installation.

Ninety days of installation support are provided at no charge following delivery of a system. Thereafter, systems integration assistance and field support by DEC's Systems Engineering Group are available at several prices, depending upon the level of support provided. The Customer Software Maintenance Service, in addition, provides remedial action for software bugs occurring at participating installations plus limited on-site support for critical malfunctions, and is priced at $3,500 per year. The On-Site Customer Maintenance Service offers, in addition to the above services, scheduled monthly visits of up to one full day by a DEC software support representative for consultation on software plus seminars on new Monitor releases, and is priced at $7,000 per year.

Customized software support beyond that supplied in the three support packages is charged for at $45 per hour, with a $75 minimum per call. The charge for a "resident" DEC Systems Engineer spending 40 hours per week at a customer site is $4,800 per month on a six-month term and $4,300 per month on a twelve-month term. A monthly consulting arrangement that provides the services of a DEC Systems Engineer for 160 hours during a four-week period is available for $6,000 per month.

EDUCATION: Each DECsystem-20 user is entitled to 13 man-weeks of training. On-site training, including course materials, is provided for specialized customer requirements at individually arranged rates.

UPGRADE POLICY: DEC offers a trade-in policy giving credits toward the purchase of more advanced DECsystem devices. Older PDP-10 equipment or slower DECsystem equipment may be upgraded to higher-performance devices. Traded-in equipment must be in generally good condition (i.e., DEC-maintained by Field Service) or is subject to a refurnishing charge. Allowances depend upon device type and vary widely from about 20 to 50 percent of the original purchase prices.

EQUIPMENT: The following systems are representative of the types of DECsystem-20 configurations that are normally used and supported by the TOPS-20 operating system. All necessary controllers, processor features, and interfaces are included in the indicated prices.

MINIMUM DECSYSTEM 2040: Consists of a 2040 CPU with 128K words of MA20 memory; one RP04 20-million-word disk drive; one TU45 9-track, 800/1600-bpi tape transport; one LA36 DECwriter II console terminal; one DC20 8-line asynchronous multiplexer; the TOPS-20 operating system including the GALAXY batch system, linking loader, ▶

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▶ editor, and utilities; the macro assembler; installation and 90-day warranty; and 50 days of application software consulting. Purchase price is $315,000, and monthly maintenance charge is $1,603.

MINIMUM DECSYSTEM 2050: Consists of a 2050 CPU with 2048 words of 160-nanosecond cache memory and 256K words of MA20 memory; two RP04 20-million-word disk drives; one TU45 9-track, 800/1600-bpi tape transport; one LA36 DECwriter II console terminal; one DC20 8-line asynchronous multiplexer with 8 expansion lines (16 lines total); the TOPS-20 operating system including the GALAXY batch system, linking loader, editor, and utilities;

the macro assembler; installation and 90-day warranty; and 50 days of application software consulting. Purchase price is $485,000, and monthly maintenance charge is $2,460.

TYPICAL DECSYSTEM 2040: Includes the minimum 2040 configuration as specified above plus an additional 128K words of MA20 memory (256K total), three additional RP04 20-million-word disk drives, one DC20-DA 8-line expander plus one DC20-AA 8-line multiplexer (24 lines total), 21 VT52 CRT user terminals, and one LP20-F 1200-lpm line printer. Purchase price is $531,365, and monthly maintenance charge is $3,413.■

EQUIPMENT PRICES

		Purchase Price	Monthly Maint.* 8-hour	Monthly Maint.* 12-hour
BASIC SYSTEMS				
	DECsystem 2040 systems include the KL20 CPU with 128K words of 1-microsecond memory and two integral data channels, one TU45 magnetic tape subsystem, an LA36 DECwriter II console terminal, eight asynchronous communications lines, TOPS-20 operating system plus utilities, macro assembler, installation, 90-day parts and labor warranty, software updating services for one year, 10 training credits, and the consulting services package.			
2040-A	DECsystem-2040 with one RP04 20-megaword disk drive	$315,000	$1,603	$1,811
2040-C	DECsystem-2040 with one RP06 40-megaword disk drive	325,000	1,603	1,811
	DECsystem 2050 systems include the KL20 CPU with 160-nanosecond cache memory, 256K words of 1-microsecond main memory, and two integral data channels; one TU45 magnetic tape subsystem; an LA36 DECwriter II console terminal; 16 asynchronous communication lines; TOPS-20 operating system plus utilities; macro assembler; installation; 90-day parts and labor warranty; software updating services for one year; 10 training credits; and the consulting services package.			
2050-A	DECsystem-2050 with two RP04 20-megaword disk drives	485,000	2,460	2,780
2050-C	DECsystem-2050 with two RP06 40-megaword disk drives	503,000	2,460	2,780
MEMORY				
MA20-A	Basic memory module; 32K words, 1 microsecond, for expansion above 128K words; max. 2 per system; uses MA20-E modules for expansion to 128K words	15,750	130	147
MA20-E	Expansion memory module, for use with MA20-A above; max. 3 per MA20-A	15,750	100	113
MASS STORAGE				
RPT04-A	20-megaword disk drive and integrated controller for 2040 or 2050; single-access, includes one RP04-A drive and disk pack, can support up to 3 additional RP04-A's, max. 1 per system	37,700	215	243
RPT04-B	20-megaword disk drive and integrated controller; dual-access version of RPT04-A above	42,800	234	265
RP04-A	20-megaword add-on single access disk drive for use with integrated controllers on 2040, 2050, or RPT04-A; max. 3 per subsystem	27,200	190	125
RP04-B	20-megaword add-on disk drive; dual-access version of RP04-A above, max. 3 per subsystem	32,340	210	237
RP04-C	Dual-access kit; converts one RP04-A single-access to RP04-B dual-access drive	5,150	20	22
RPT06-A	40-megaword disk drive and integrated controller for 2040 or 2050; single-access, includes one RP06-A drive and disk pack, can support one additional RP06-A, max. 1 per system	47,150	215	243
RPT06-B	40-megaword disk drive and integrated controller; dual-access version of RPT06-A above	56,290	235	265
RP06-A	40-megaword add-on single-access disk drive for use with integrated controllers on 2040, 2050, or RPT06-A above; max. 3 per subsystem	36,650	190	215
RP06-B	40-megaword add-on disk drive, dual-access version of RP06-A above; max. 3 per subsystem	41,790	210	237
RP06-C	Dual-access kit; converts one RP06-A single-access drive to RP06-B dual-access drive	5,150	20	22
INPUT/OUTPUT DEVICES				
TU45B-E	Magnetic tape transport and integrated controller for 2040 or 2050; includes one TU45A transport, can support 3 additional TU45A's, max. 2 per system	25,200	180	203
TU45A-E	Add-on magnetic tape transport for use with TU45B-E above, max. 3 per TU45B	14,700	120	136
LP20-A	Line printer and controller; 132 positions, 64-character, EDP or scientific font; 300 lpm	21,530	160	181
LP20-B	Line printer and controller; 132 positions, 96-character, EDP or scientific font; 230 lpm	22,580	160	181
LP20-F	Line printer and controller; 132 positions, 64-character, EDP or scientific font; 1200 lpm	46,200	260	294
LP20-H	Line printer and controller; 132 positions, 96-character, EDP or scientific font; 925 lpm	48,300	260	294
LP200-B	Line printer and controller; 132 positions; Charaband-type mechanism; includes software, long line interface, and diagnostics; does not include Charaband; 1500 lpm	59,000	340	384
LP07-Y	Charaband for LP200-B line printer; dual-sided; choice of 64- and 96-character EDP fonts, two 64-character EDP fonts, two 96-character EDP fonts, or customer-specified font	4,000	—	—

*Based on 5-day week.

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		Purchase Price	Monthly Maint.*	
			8-hour	12-hour

INPUT/OUTPUT DEVICES (Continued)

CD20-A	Card reader and controller; tabletop mounting, 300 cpm	$ 6,170	$ 66	$ 75
CD20-B	Card reader and controller; free-standing, 1200 cpm	19,250	100	113
PC20	Paper tape reader/punch and controller; includes interface, power supply, cabinet, software, and diagnostics	20,810	108	122
XY20-A	XY plotter and controller; includes software and diagnostics, step size 0.004 inch; 2.0 ips	31,500	50	57

COMMUNICATIONS DEVICES

DC20-AA	Basic asynchronous multiplexer; 8 lines, can be expanded to 16 lines with one DC20-DA expander, max. 7 per system	5,280	70	79
DC20-DA	Expansion group for use with DC20-AA above; 8 lines, max. 1 per DC20-AA	1,580	60	68
DC20-EC	Communications Expansion Cabinet; required for over 64 communications lines, includes one DC20-AA basic 8-line group, max. 1 per system	11,000	115	130
DF01	Acoustic Coupler	760	11	12

TERMINALS

LA36-H	DECwriter II hard-copy terminal; 64 ASCII characters, 30 cps	2,580**	25	28
LA37-P	DECwriter II hard-copy terminal; APL/ASCII character set, 30 cps	3,440**	25	28
VT50-A	CRT display/keyboard; 12 lines x 80 characters, 64 ASCII characters, EIA interface	1,450**	22	25
VT52-A	CRT display/keyboard; 24 lines x 80 characters, 96 ASCII characters, EIA interface	2,200**	20	23

*Based on 5-day week.

**Single-quantity price; quantity discounts are available for these items without standard DEC Quantity Discount Agreement.

SOFTWARE PRICES

		Single-use license	Annual update
QT001-AP	FORTRAN-20; includes SPR service for one year	$ 8,250	$ 950
QT002-AP	ALGOL-20; includes SPR service for one year	8,250	750
QT003-AP	COBOL-20 V.10; includes SPR service for one year	8,250	950
QT004-CP	BASIC-20	5,500	—
QT007-AP	SORT-20 V.2; includes SPR service for one year	2,750	350
QT008-AP	DBMS-20 V.4; includes installation, on-site remedial coverage for 90 days, and SPR service for one year	27,500	2,500
QT009-AP	CPL-20; includes SPR service for one year	5,500	650
QT011-AP	COBOL-20; includes SORT-20	11,000	1,300
QT012-AP	APL-20/SF; includes SPR service for one year	24,750	1,500
QT014-AP	APL-20 Basic; includes SPR service for one year	8,250	900
QT025-AP	Upgrade APL-20 Basic to APL-20/SF	15,000	1,500
QT015-AP	IQL-20; includes SPR service for one year	13,200	1,000
QT016-AP	IQL-20 Extended; includes SPR service for one year	16,500	1,100
QT046-AP	Upgrade IQL-20 to IQL-20 Extended	3,300	1,100
QTK02	TOPS-20; current release software	5,500	—
QTK01-KP	Update service for QTK02	4,000	—