Digital Equipment DECsystem-20

MANAGEMENT SUMMARY

The DECsystem-20, introduced in January 1976, has remained a strong product line for Digital Equipment Corporation. Since its inception with the Model 2040, the family has twice been augmented, first with the Model 2050 (dropped in April 1979 with the advent of all MOS memory versions) and then in February 1978 with the Models 2020 and 2060.

Functionally, the DECsystem-20 is similar to the DECsystem-10. It is intended for interactive time-sharing applications, but in a different environment. 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. The DECsystem-20 is intended primarily for in-house time-sharing systems. More specifically, the DECsystem-20 is aimed at 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 configurations; more functionality in networking with multipathing, terminal concentration, and route through; requires a full-time operator, and operator training to successfully control the system.

The DECsystem-20 family consists of three models, sold as packaged systems and built around two different processors. Featuring the functionality of the DECsystem-10 and the advantages of recent technology developments, the low-end DECsystem-20 Model 2020 can be purchased for between $200,000 and $300,000 for a typical configuration. On the high end, a typical DECsystem-20 Model 2060 can be purchased for between $600,000 and $1,000,000.

CHARACTERISTICS

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

DEC is a worldwide corporation and the world's largest manufacturer of minicomputer systems. In addition, the company is directly involved in interactive timesharing and production of medium and large scale computer systems. The company employs about 38,000 persons and maintains sales and service offices in all major U.S. cities and in major cities throughout Canada and the Western world.

MODELS: DECsystem-20 Model 2020, 2040, and 2060.

DATE ANNOUNCED: See table.

DATE OF FIRST DELIVERY: See table.

NUMBER INSTALLED TO DATE: See table.

The low-end DECsystem-20 Model 2020 is in the price/performance range of an IBM 370/115. It is targeted at DEC's traditional mainframe markets in education; government, including civilian agencies and the department of defense; industrial research labs and consulting engineers; and commercial companies in computer services, finance, distributing, and manufacturing.

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Most of the DECsystem-20 family is built on variants of the DECsystem-10 KL10 processor; the Model 2040 on the L10-E and the Model 2060 on KL10-EE. Only the Model 2020 was built from "the ground up" with a new processor, the KS10-A.

The minimum DECsystem-20 for any model configuration includes 256K words (36 bits) of memory, a single or dual ported disk drive, a tape drive, 16 asynchronous communications lines, and an I/O console. Maximum configurations include up to 1536K words of memory, 56 disk drives, a card reader, a card punch, 2 printers, 16 magnetic tape drives, and up to 128 asynchronous communications lines. The same KL10 hardware running TOPS-10 can offer up to 464 asynchronous lines with the addition of three universal front ends.

One of the most notable features of the DECsystem-20 family is the use of cache memory, which is the same as the one used in the DECsystem-10 and consists of 512 blocks of four words each (one block on the 2020). Access time 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 221.4 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. 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 field upgrade from 2040 to 2060 systems, 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.

Software is included in all DECsystem-20 packages, as well as on-site consulting for application software development. Included in the system software package is the TOPS-20 or TOPS-10 (Model 2020 only) 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 $3,000 for the SORT package to $30,000 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 Models 2040 or 2060 incor-

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 of 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-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: See table.

CAPACITY: See table.

CYCLE TIME: See table.

CHECKING: Parity bit with each 36-bit word is generated with writing and checked with reading in all systems except 2020. Error correcting memory, which detects and corrects all single bit errors and detects all double bit errors, is employed in the 2020. Error correcting memory uses a Hamming code and special algorithm as the method of detecting bit errors.

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 KL10 CPU and the front-end PDP-11 minicomputer (2040 and 2060). 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 KL10 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

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CHARACTERISTICS OF DECSYSTEM-20 FAMILY

	2020	2040	2050*	2060
SYSTEM				
Number installed to date	175	190	125	—
Date of announcement	Feb. 1978	Jan. 1976	Nov. 1976	Feb. 1978
Date of first delivery	July 1978	July 1978	May 1977	July 1979
Maximum On-line disk storage, megawords	316.8	633.6	1267.2	2217.6
Maximum communications lines:				
Asynchronous	32	128	128	128
Synchronous	2	4	6	6
2780/3780	—	4	6	6
DECnet	1	1	1	1
Maximum card readers	1	1	1	1
Maximum card punches	0	1	1	1
Maximum paper tape units	0	1	1	1
Maximum printers	1	2	2	2
Maximum magnetic tape drives	4	16	16	16
CPU	KS10-A	KL10-E	KL10-E	KL10-EE
Number of instructions	386	386	386	386
System capacity, no. of users	32	64	128	128
Concurrent jobs	20	50	40	120
Relative CPU performance	1.0	2.0	3.0	6.0
MEMORY				
Minimum capacity, 36-bit words	256K	256K	256K	256K
Maximum capacity, 36-bit words	512K	1536K	512K	1536K
Increment size, 36-bit words	64K, 128K, 256K	64K	64K	256K
Memory control unit ports	—	4	4	4
Words accessed per cycle	—	1	4	4
Memory type	ECC MOS	ECC MOS	Core	ECC MOS
Memory cycle time, microseconds	1.05	1.05	1.2	1.05
Read access time	—	0.467	—	0.467
Read cycle time, 1 word; microsec	—	0.667	—	0.667
Read cycle time, 4 words; microsec	—	1.267	—	1.267
Memory interleaving (software selectable)	—	2- or 4-way	2- or 4-way	2- or 4-way
Cache memory, words	512	—	2048	2048
Access time, microseconds	0.160	—	0.160	0.160
Effective memory cycle time, microsec.	0.420	—	0.2214	—
Writable control store, words	2K x 96 bit	1280 x 75 bit	1280 x 75 bit	1280 x 75 bit
Cycle time, microseconds	0.3	—	—	—
I/O CONTROL				
Type of controllers	Integrated	Integrated	Integrated	Integrated
Maximum DMA transfer rate, 36-bit words	16 million/sec.	16 million/sec.	16 million/sec.	16 million/sec.
Max. I/O transfer rate, 36-bit words	500,000/sec.	500,000/sec.	500,000/sec.	500,000/sec.
Maximum number of controllers	3	5	7	10
Buffering	16 words	16 words	16 words	16 words

*No longer actively marketed, but listed here for historical perspective.

porates 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 (Models 2040 or 2060) 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 DEC-

be located in contiguous memory locations, thus eliminating the need to shuffle program segments in memory to counteract checkerboarding. 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 three processors employed in the DECsystem-20. The 2040 and 2060 use the KL10 CPU and a PDP-11/40 front-end processor, which provides control for all low-speed peripherals and system initialization.

The third CPU, the KS10 central processor, is used exclusively with the 2020 system.

System initialization on the 2040 and 2060 is accomplished through a dual-access disk drive that contains the system microcode. When the system starts, the PDP-11 performs a brief system checkout, after which it configures memory and loads the microcode into the KL10. 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

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system-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 KL10 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 asynchronous 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 2020 does not feature a front-end processor. All peripherals except the console are attached via a Unibus/Unibus adapter combination. Mass storage interfaces to the Unibus via a RH11-C Massbus Adapter.

The DECsystem-20 also features memory mapping to extend the addressing range of the CPU beyond the 256K-word limitation. The mapping system employed is the same as that used by the DECsystem-10 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

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 control and data lines and constantly monitors these. In the event of failures, the PDP-11 reports the problem through the console terminal, and allows module-level diagnosis. The front-end processor is connected to the KL10 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.

On the 2020, system initialization is accomplished through the console. In addition the operator can perform microcode load and check, perform memory modification and examination, start and stop the CPU clock, single step the CPU clock, execute a given instruction and start the machine at a given location.

In addition to system initiation, the KS10 differs from the KL10 in that the KS10 employs a microprocessor-based simulator of the larger 36-bit KL10 processor. The KS10 processor is built from AMD 2901 bit-slice microprocessors and is implemented on four printed circuit boards. In comparison, the KL10 processor requires 52 printed circuit boards.

The KS10 processor, because it is a simulator, is slower than the KL10 processor, giving the DECsystem-2020 about one-half the internal performance of the DECsystem-2040. The KS10 also includes a smaller cache memory than the KL10 (512 words compared to 2048 words), and the cache replacement algorithm implemented in the KS10 is not as sophisticated as the one implemented in the KL10 processor.

The actual processor employed in the 2040 is the KL10-E. The 2060 employs the KL10-EE, a slightly modified KL10-E, designed to handle MOS memory.

CONTROL STORAGE: See table.

REGISTERS: The KL10 and the KS10 processors have 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 KL10 and nanoseconds for the KS10.

In addition, the KL10 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 occurrence 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.

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 (pre-
indexing).

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DECsystem-20 Operating Systems Summary

	TOPS-10	TOPS-20
Operating system design level	Large, multi-user, multi-programming system with multi-stream batch capabilities	Multi-user, multi-language, virtual memory, interactive processing system with multi-stream batch capabilities
Interactive users support	16 to 128*	8 to 100 simultaneously
Batch users supported concurrent with multiprog.	*	74
System disk units	RP04 or RP06	RM03, RP04, or RP06
System load devices (magtape)	TU70, TU72	TU45
Minimum memory required (in words)	256K	256K
Maximum memory supported (in words)	512K	1536K
CPUs on which operational	2020	2020, 2040, and 2060
Languages supported:		
ALGOL	Optional, ALGOL-10	Optional, ALGOL-60
APL-Basic	Optional	Optional
APL-SF	Optional	Optional
BASIC	Optional, BASIC-10	—
BASIC Plus-2	—	Optional
COBOL	Optional, COBOL-10	Optional, COBOL-20
CPL	Optional CPL-10	Optional, CPL-20
FORTRAN	Optional, FORTRAN-10	Optional, FORTRAN-20
Macro Assembler	Included with TOPS-10	Included with TOPS-20
Communications software supported		
DECnet	Optional, DECnet-10	Optional, DECnet-20
DECsystem 2780/3780 Multileaving	Optional	Optional
Traffic	—	Optional, Traffic-20
Sort/Merge	Optional DECsystem-10 Sort/Merge	Optional DEcsystem-20 Sort/Merge
DBMS	Optional, DBMS-10	Optional, DBMS-20
IQL	Optional, IQL-10	Optional, IQL-20

*175 jobs total.

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, as it does under TOPS-10.

Also available for the 2020 is a version of TOPS-10, complete with compilers, sort/merge, and DBMS. This version of TOPS-10 does not have the full functionality of DECsystem-10 TOPS-10, particularly in the area of communications. Communications enhancements will be offered by third quarter 1980.

The list of programming languages supported by TOPS-10 and TOPS-20 is extensive. Included in the list are IBM-compatible COBOL, BASIC, ALGOL, 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).

INSTRUCTION REPERTOIRE: The KL10 and the KS10 CPUs have 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.

INSTRUCTION TIMING: In the tables below, all timings 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 and Floating Point for 2040 and 2060

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)	**2.2**
Floating point multiply/divide (double precision)	**4.8/10.2**
Jump	**0.5**

Fixed and floating point instruction times on the 2020 are not presently available.

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Equivalent versions of all but one of the compilers (BASIC) is offered on both the DECsystem-10 and DECsystem-20. 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 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.

CACHE: The 2020, 2050, and 2060 systems include a fast-access MOS cache memory with a 160-nanosecond access time. The cache is 2,048 words on the 2060 and 512 words on the 2020. On the 2060, CACHE 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 221.4 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 KL10 and KS10 processors provide 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 KL10 and KS10 processors have 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.

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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 1000 mainframes worldwide.

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 115 up. The 2020 also competes with the IBM System 138, Honeywell Level 62, and the Univac 90/30.

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, including 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 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.

INTERRUPT STRUCTURE: The KL10 and KS10 have seven standard prioritized channels associated with the I/O bus that transfers interrupt signals between system devices and the I/O Bus. The KL10 has an additional priority level (0) of higher priority than the seven programmable levels. This interrupt level is reserved for the front end processor. 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 overflow 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 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 integrated controllers, capable of handling either disk or magnetic tape. Depending on the model, up to eight disk or tape drives can be connected to a disk 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.

Only high-speed mass storage devices are connected to the internal channel bus. On the 2040 and 2060, all low-speed devices interface through the PDP-11 front-end processor that is incorporated in the system. On the 2020, all devices are interfaced through a Unibus/Unibus adapter except the I/O console. Lowspeed devices offered with the DECsystem-20 include line printers, a card reader, and communications lines. A card punch and paper tape reader/punch are also offered and are connected through a separate I/O interface.

SIMULTANEOUS OPERATIONS: Each of the 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.

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Exact rental prices 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

Detailed below is a summary of the information obtained from seven DECsystem-20 users over the past few months. Four users responded to Datapro's annual survey of computer users; the rest were interviewed by telephone. Included in the survey were two 2020's, two 2040's, two 2050's, and two unspecified DECsystem-20's. Memory on the systems in the survey varied from 256K words on a 2020 up to 768K words on a 2060. Users had migrated to the DECsystem-20 from such varied sources as a COBOL time-sharing service, a DSC Meta/4 (IBM 1130 emulation), and an IBM 370/168. Average time of installation was about 2 years. Earliest installation was July 1976, and latest January 1979. Users were widely split as to prime language. APL, FORTRAN, COBOL, and BASIC were all being utilized. The number of interactive terminals varied from a low of zero terminals to a high of 150 terminals. On-line disk storage varied from a low of 120 megabytes to a high of 600 megabytes with an average of 340 megabytes.

Applications being developed and executed on the seven systems included financial reporting; standard accounting functions such as accounts receivable, accounts payable, payroll, general ledger, and inventory control; report generation; and interactive educational instruction.

User ratings are tabulated in the table below:

	Excellent	Good	Fair	Poor	WA*
Ease of operation	6	1	0	0	3.8
Reliability of mainframe	4	2	1	0	3.4
Reliability of peripherals	3	4	0	0	3.4
Responsiveness of maintenance service	6	1	0	0	3.8
Effectiveness of maintenance service	3	2	2	0	3.1

*Weighted Average on a scale of 4.0 for Excellent.

CONFIGURATION RULES

2020: Devices integral to the processor cabinet in addition to the KS10-A processor include up to 512K words of MS10 memory (256K words are optional), the console subsystem and two Unibus adapters. The first RM03 or RP06 disk drive is bundled in the system package. RM03's and RP06's may be mixed on the same system. Maximum configuration is 8 disk drives per system. Disk drives are attached to the 2020 via the RH11-C Massbus Adapter, which connects to one of the two Unibus/Unibus adapters.

A TAU45 Master Tape Drive must be ordered with each package system as field service contracts require one tape drive. Maximum configuration is 4 tape drives per system. The LP20A/B and LP20C/D are the only line printers supported on the 2020 at this time. DEC Field Service contracts require a hard copy printer device. Maximum configuration is one line printer per system. The DNHXX Expansion Cabinet is required and used only for the card reader controller. Maximum configuration is one card reader per system. The first 16 asynchronous EIA communication lines are bundled in the system package. Maximum configuration is 32 asynchronous lines per system. The additional 16 lines are provided by DZ11-AA (8 lines) and DZ11-BA (8 lines). Up to two synchronous lines may be attached through DN20-BA (one line) and DN20-BB (one line). Synchronous lines operate under TOPS-20 only. The magnetic tape subsystem, printer, communications lines, and punched card equipment are all attached through the second Unibus/Unibus adapter.

2040: Devices integral to the processor cabinet in addition to the DL10-E processor include up to 1536K words of MB20 memory (1280K words are optional), front-end utility processor, optional synchronous front end, massbuses (one tape and one disk standard, one disk optional, and one tape or disk optional), and optional DIB20 I/O Interface.

Three TU45A-EH/EJ Tape Drives can be added to a TU45A-EC/ED Magnetic Tape Subsystem for a total of four drives per TU45A-EC/ED. Two TU45A-EC/ED's allowed per system. On a second channel up to eight TU70 or TU72 Tape Drives can be added to a TX02-E controller for a maximum of eight drives per system.

Disk Drives may be added to a maximum of 16 drives on 2040's. Eight drives are allowed per channel. The first RP06 is a dual ported drive and is bundled with the system. It is attached to both the disk massbus and the front-end utility processor. A Line Printer is required with each DECsystem-20 connected through the front-end utility processor. Up to 2 line printers may be connected to a 2040. A maximum of one paper tape unit or card punch, connected through DIB20 is allowable per 2040. The I/O console and all communications lines except synchronous lines are connected through the front-end utility processor. See also the table following 2060 configuration rules. The DN20-C Synchronous Communications Front End handles up to two DN21-BA Synchronous Line Controllers (each accommodating one 19.2K to 56K bps synchronous line) and one DN20-BA Synchronous Line Controllers (handling four 2.4K to 19.2K bps lines).

2060: Components integral to the processor cabinet, in addition to the KL10-EE processor, include up to 1536K words of MF20 memory (1280K words are optional), cache memory, front end utility processor, optional synchronous front end, eight massbuses (one tape and one disk standard, one tape or disk optional, and five disk optional), and optional DIB20 I/O Interface. Rules for attachment of communications lines and peripherals are the same as for the 2040 with one exception; the maximum number of RP06 drives is 56.

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Representing opposite ends of the scale, the DECsystem-20 Model 2020 and the Model 2060 cover a price, performance, and capacity range of 10 to 1. All three models in the family can operate under the same operating system and high level language processors. Additionally, the 2020 can operate under a version of the more mature TOPS-10 operating system and related software.

	Excellent	Good	Fair	Poor	WA*
Technical support	3	3	1	0	3.3
Operating system	6	0	1	0	3.7
Compilers and assemblers	3	4	0	0	3.4
Ease of programming	3	2	2	0	3.1
Ease of conversion	2	4	0	0	3.3
Overall satisfaction	4	3	0	0	3.6

*Weighted Average on a scale of 4.0 for Excellent.

In comparison with the January 1977 survey, ratings went up in six categories, remained the same in one category, and went down in four categories. Significantly, ratings went down in reliability of mainframes and peripherals. Just as significantly, ratings went up in maintenance service responsiveness and effectiveness as well as technical support. It appears that in the view of the users, the reduction in reliability of the equipment has been made up somewhat by the improvement in service.

Users felt system strengths were in time sharing capability, backup systems, file security, documentation and debugging. System weaknesses were listed as availability of parts, not enough well trained field support personnel (even though maintenance and field support ratings were good) and lack of a software hotline. Datapro's comment on field support personnel has been stated many times before: can there ever be enough support staff?

Ratings for the DECsystem-20 are better than good in every category surveyed. DEC's record of satisfaction

The rules for asynchronous communications on the 2040 and 2060 are contained in the following table.

Async. Lines	Features required DC20-AA	DC20-DA	DC20-CC	DC20-EC/ED
16	1	1	---	---
24	2	1	---	---
32	2	2	---	---
40	2	2	1	1
48	2	3	1	1
56	3	3	1	1
64	3	4	1	1
72	4	4	1	1
80	4	5	1	1
88	5	5	1	1
96	5	6	1	1
104	5	6	1	2
112	5	7	1	2
120	6	7	1	2
128	6	8	1	2

On all DECsystem 20 processors, hardware internally is EIA with support for EIA lines and terminals only. All 20 ma current loop terminals must be converted to EIA for use with DECsystem 20. For asynchronous speeds up to 2400 bps, cabling must not exceed 1000 feet; for asynchronous speeds up to 9600 bps, cabling must not exceed 250 feet.

MASS STORAGE

RP06 DISK PACK DRIVE: Provides large-capacity random access storage. RP06 disk drive has a storage capacity of 39.6 million 36-bit words (or 176 million 8-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.

The drives rotate at 3600 rpm, resulting in an average rotational delay of 8.3 milliseconds. The peak data transfer rate is 357,142 36-bit words per second. Track to track, average, and maximum head movement times are 10, 30, and 55 milliseconds, respectively.

The RP06 drive uses an industry-standard IBM 33 36-11-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 815 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 RP06 controller also permits overlapped head positioning through optional porting 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.

RM03 DISK PACK DRIVE: This drive employs a technology similar to that of the IBM 3330 through the use of a track-following servo system. In this system, one disk surface of each pack is dedicated to servo control and tracking information. The pack contains five platters, with the top and bottom platters employed for protection. Recording is on five surfaces at 6038 bits per inch and 384 tracks per inch. Data is recorded on 823 tracks per surface (including 15 spare tracks). Formatted capacity is 67 megabytes. The drives rotate at 3600 rpm, resulting in an average rotational delay of 8.3 milliseconds. Track-to-track, average, and across-all-tracks head positioning times are 6, 30, and 55 milliseconds, respectively. Head positioning is performed by a closed-loop proportional servo system driving a voice-coil actuator. Data transfer rate is 0.3 megawords per second.

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from users has been consistent from the introduction of the DECsystem-20 and has not been often matched. The problems that do exist are not insurmountable. If DEC shows the same determination and skill in the future, ratings should be maintained if not improved. With competition growing stronger, the task for DEC is clearly defined and well within the realm of solution.□

INPUT/OUTPUT UNITS

TU45A MAGNETIC TAPE DRIVE: A 9-track, 75-ips unit with program-selectable recording densities of 800 bpi; NRZI, or 1600 bpi, phase-encoded. The transports employ vacuum-column tape buffers; dual-gap, read after write magnetic heads; and up to 10.5 inch reels. The TU45A may operate in read mode in either forward or reverse direction. Handling on the TU45A is by direct drive reel motors, servo-controlled single capstan, filtered positive pressurized tape compartment, and vacuum type tape cleaner. On the 2040 and 2060, up to eight drives per controller are possible. On the 2020, up to four drives are permitted. The TU45A is manufactured by Pertec.

TU7X MAGNETIC TAPE DRIVE: The TU70-A drives are 9-track, 200-ips units with program-selectable recording densities of 800 bpi, NRZI or 1600 bpi, phase-encoded. The TU72-E drives are 9-track, 125 ips units with program-selectable recording densities of 6250 bpi group encoded or 1600 bpi in PE mode. The TU7X employs up to 10.5 inch reels for up to 2400 feet of tape. Both drives use direct-drive reel motors, and servo-controlled, single capstan vacuum tape buffer columns with constant tape winding tension.

Up to eight drives per TX02-E controller are possible. The TX02-E/TU7X can be configured on any 2040 or 2060 system via the DX20 Data Channel.

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. When printing on either the LP20A or LP20B, paper 4 to 16.8 inches wide may be employed. Both models are 132-position printers (10 characters per inch) 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 Models 2040 and 2060. Through the PDP-11 front-end processor, one line printer is available on the 2020, connected through its controller to the Unibus.

LP20C AND LP20D LINE PRINTERS: These are similar to the LP20A and LP20B printers above. They are versions of the Dataproducts 2290 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 900 lpm, and with the 96-character drum, at 660 lpm. Both models are 132-position printers (10 characters per inch) with a 12 channel direct access vertical format unit containing its own memory loaded from the main memory via normal data lines. Switches 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. Interfacing of these units is the same as for the LP20A and LP20B.

LP200-B 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 LP200-B printer is a 1500-lpm unit with either 64- or 96-character fonts. This line printer provides 132 print positions at 10 characters per inch. The user has a choice of numerous paper widths from a minimum of 5.13 inches to a maximum to 18.75 inches. 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 LP200-B 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 Models 2040 and 2060 through the PDP-11 front-end processor.

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 jams 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 on all but the 2020 where the interface is to the Unibus of the processor.

CD20C 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. Like the CD20-A, the controller for the CD20-C mounts in the unit and interfaces to the DECsystem-20 in the same fashion as the CD20-A.

CP20-C CARD PUNCH: A free-standing unit capable of punching at 160 columns per second (100 cpm if all 80 columns are punched up to 285 cpm if 1 column is punched). Two hoppers are provided; the first provides space for up to 100 rejected cards and the second provides space for up to 1000 standard punched cards. Error detection is by automatic verification utilizing echo checking. The CP20-C is interfaced to the DIB20 External I/O BUS Interface on the 2040 and 2060.

PC20 PAPER TAPE READER/PUNCH: Reads 8-channel paper tape at 300 cps, using a photo-electric reader, and punches tape at 50 cps by electromechanical means. The PC20 is an option on all DECsystem-20 models except the 2020 and is interfaced the same as the CP20-C.

LA36 DECWRITER II HARD-COPY KEYBOARD TERMINAL (AND CONSOLE): Provides 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,

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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 characters.

LA38 DECWRITER IV HARD-COPY TABLE-TOP TERMINAL: The LA38 is designed for entry-level applications with a maximum print speed of 30 characters per second. This model is an addition to the DECwriter IV series and features serial printing by 9-by-7 dot matrix, horizontal tab spacing, selection of any of 4 different character sizes in the 10- to 16.5-character-per-inch range, a 128-character buffer, and communication speeds of 110 or 300 bps. In the LA38, paper movement is by use of tractor feed. The unit prints 128 ASCII upper- and lower-case characters. The LA38 also has a 19-key pad for rapid entry of numerical data. Like other new terminals from DEC, the LA38 is microprocessor based and incorporates a self-check feature as standard.

LA120 DECWRITER III: This terminal has a maximum print speed of 180 characters per second. It is designed for pedestal mounting as a console terminal in high-speed and/or highly interactive time-sharing applications. The standard character set features 128 ASCII symbols, uses a 7-by-7 dot matrix bidirectional printing mechanism, and a tractor paper-feed. The LA120 uses 132 print positions, features adjustable tractor feed and accommodates 6-part, continuous pin-fed forms from 3 to 14⅞ inches wide. Although intended primarily for 1200-bps operation, the LA120 will accept data at 15 standard rates between 50 and 9600 bps; a 100-character buffer is standard, with 4000 characters optional. The unit can be set up for horizontal and vertical tabs, up to 6 different line spacings, and 8 different character sizes ranging between 5 and 16.5 characters per inch. The LA120 is microprocessor based and incorporates a self check feature as standard. The LA120 uses a typewriter-style keyboard with optional 14-key numeric pad. The keyboard generates any of 128 ASCII character codes. Control functions include Line Feed, Return, Break, Escape, Repeat, Caps Lock, Tab, Delete, Bell, Space, Backspace, Shift, and Control Shift. The keyboard also contains a cluster of 8 function keys and 5 status indicators.

LA180 DECPRINTER RECEIVE-ONLY TERMINAL: A serial impact printer that uses a mechanism similar to that of the LA36 terminal but can print characters at the rate of 180 characters per second. The LA180 is a matrix unit that prints the full 128-character ASCII set using a 7-by-7 dot matrix. It prints rows of 132 characters and can accommodate 6-part forms in widths from 3 through 14⅞ inches. Horizontal spacing is 10 characters per inch, and vertical spacing is 6 lines per inch. A switch permits the operator to select 11 different forms lengths. The LA180 will accept data at standard rates between 110 and 9600 bps. Operation can be full duplex, half duplex or echoplex. The LA180 is manufactured by DEC.

VT61 BUFFERED VIDEO DISPLAY TERMINAL: The VT61 is an upper and lower case ASCII terminal with a 1920-character display, 19-key function pad, 12 user-defined function keys and a typewriter style keyboard. The VT61 can transmit in either block or character mode. It also features a blinking cursor, direct cursor addressing, and built-in editing commands that permit character and line insertion and deletion, text justification, reverse video, and protected forms plus other editing features not available on the now inactively marketed VT50 and VT52 terminals. The VT61 displays a 128-character set using a 7-by-8 dot matrix. Transmission speeds are switch-selectable and can be 75, 110, 150, 300, 600, 1200, 2400, 4800, or 9600 bits per second. The interface may be EIA or 20 ma current loop. The VT61 is manufactured by DEC.

VT62 MICROPROCESSOR DRIVEN VIDEO DISPLAY TERMINAL: A block mode terminal specifically designed for commercial data capture and retrieval applications. The VT62 is an upper and lower case ASCII terminal with a 24 line by 80 character display (1920 characters). The keyboard is typewriter style with a 10 function keys, 15 user defined function keys, and a 19 key numeric pad.

Features of the VT62 include local input checking for card correction of user errors without host computer intervention, program controlled split screen layout (display and form areas) with split screen scrolling, menu selection displayed in reverse video, multidrop block-mode communication with DDCMP protocol. The VT62 can be connected to the DECsystem-20 in multipoint and single-point configurations with either an EIA or 20ma interface. The 20ma asynchronous and EIA asynchronous interface (up to 9600 bps) are used for direct radial (single-drop) connection to a host as high-speed local terminals. The EIA synchronous interface (up to 4800 bps) is for use with a synchronous modem as a stand-alone multi-drop or single-point terminal. Implementing the DDCMP protocol, a terminal with an EIA interface can be used in conjunction with commercially available modem-sharing devices to allow multiple terminals to be serviced by one communication line.

The VT62 features an interface port allowing the connection of an LA180 hard copy terminal. This output-only terminal shares the VT62 microprocessor and line interface, but otherwise looks like a separate and independent output-only device. This option can be used as a low cost, error free, remote forms-oriented printer. The VT62 is manufactured by DEC.

VT100 VIDEO DISPLAY TERMINAL: Contains a 12-inch, 1920-character display and detachable typewriter keyboard with 18-key numeric/function keypad. The VT100 features a 7x9 dot matrix character font displayed on a 10x10 space. Standard features include 44, 66, 80, or 132 characters per line, line-selectable, double-width and double-height characters, line drawing graphic characters, bidirectional scrolling, split screen, tabulation, and highlighting attributes including dual intensity, normal or reverse video on a character by character basis, blinking, and underline. Advanced video adds selectable blinking, underline, and dual intensity characters (in any combination) to the existing reverse video attribute. Data rates range from 50 to 19,200 bps. The asynchronous terminal is equipped with an EIA RS-232C (VT52 compatibility mode only) or 20-ma current loop interface. All operating parameters are established via the keyboard in the Set-Up mode. The VT100 is manufactured by DEC.

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

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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 on the 2040. For the 2050, three 32-line DC20-EC expansion cabinets can be added, providing up to 128 asynchronous 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.

DZ11 ASYNCHRONOUS LINE INTERFACE (for the 2020 only): These devices offer hardware selectable data rate, character size and stop element length, and parity check generation through hardware switches or straps. Each of the eight lines can be individually programmed through software control to one of 15 line speeds between 50 and 9600 bps. Maximum throughput is 19,200 cps in full duplex mode. The DX11 does not offer DMA facilities. However, the DZ11 includes enough modem controls to operate a 300-bps data set (Bell 103 or 113). Interrupts can be programmed to occur for each character or after 16 characters. The DZ11 is transparent to data, but can report parity errors and framing errors. Input characters are buffered with identification hardware in a first in/first out (FIFO) buffer or in DEC terms "silo". The DZ11-A features EIA/CCITT line interface while the DZ11-B is an expansion unit for the DZ11-A.

DN20-C DATA COMMUNICATIONS FRONT END: Supports TOPS-20 Digital Network Architecture and bisync protocols and allows DECnet processing along with the host in 2040 and 2060 systems. DN20-C supports 2780/3780 remote terminals and communications with IBM systems. Under the TOPS-20 Operating System, support is for synchronous lines only.

The DN20-C is a PDP-11/34A based processor configured with 32K words of core memory. Up to six bisync (2780/3780) lines are supported under TOPS-20. When running under TOPS-20 communications software, up to four low speed (2.4K bps to 19.2K bps) and two high speed (19.2K bps to 56K bps) synchronous lines or six low speed and one high speed synchronous line are allowed. High speed synchronous lines cannot be configured if the system supports 2780/3780 communications. DECnet-20 may be run over only one high speed or one low speed synchronous line.

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 support full-language time-sharing for program development and for interactive and terminal-oriented applications, as well as concurrent multi-stream batch processing.

OPERATING SYSTEMS: In addition to TOPS-20, the operating system designed for DECsystem-20, Model 2020 operates under a version of TOPS-10, the DECsystem-10 counterpart.

Unlike TOPS-10, 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.

- 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 ac-

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cess 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 thoughput 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.

- TOPS-20 File System: Provides up to 4000 user accounts/directories per structure on a 2020 or 2040 and up to 12,000 on the 2060. The file system provides a multilevel directory structure and interuser security through directory and file access protection mechanisms. The user group definition facility of the file system allows arbitrary definition of user-groups desiring to have common access to files. This facility also provides simultaneous update capabilities within a file, allowing two or more cooperating users concurrent access to a file. The file system also provides user-level disk space quotes for space management, automatic space allocation and deallocation during program run time for file creation and deletion, automatic optimized file placement and I/O, a centralized file name parsing and look-up monitor facility, and centralized file operations monitor facilities.

- RSX-20 Operating System Version VB12-12: This feature of TOPS-20 controls the front-end processor of the 2040 and 2060.

- TOPS-20 Exec: Implements the system command language for interactive and batch processing. The Exec also provides file handling, and operator level, and system information commands.

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.

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.

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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 the KS10 and KL10 CPUs 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.

TOPS-10 (for the DECsystem 20 version 6.03): Consists of a resident portion and a nonresident portion. The resident operating system, in turn, consists of 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.

- 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 Memory 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 ½ second for execution. Jobs which do not issue I/O requests during their ½-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 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 25-50% faster disk throughput 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 resident portion of TOPS-10 requires from about 20K to 40K words of main memory, depending upon the processor model.

The non-resident portion of TOPS-10 is stored on disk and includes the language processors, debugging programs, and operating system support programs. Standard languages available for the DECsystem-10 include COBOL, FORTRAN IV, ALGOL-60, BASIC, APL, and the Macro Assembler. Each language processor consists of a "pure" or re-entrant portion and a user portion which contains parameters defining a specific user job. The language processors produce sharable, re-entrant user programs.

TOPS-10 allows four basic concurrent modes of operation: single interactive time-sharing, real-time processing, single batch, multi-programming and remote communications. Up to 32 interactive terminals on the 2020 can be handled by the Monitor. The terminals may be video displays or others which operate at speeds from 110 to 9600 bps.

TOPS-10 facilities allow the user through the command language to control spooling to the printer. Spooling to disk is not available with this version of TOPS-10. Unlike other TOPS-10 versions, TOPS-10 (6.03A) has integrated virtual memory support. The system administrator may optionally control this feature, deciding which user may implement it. Controls are also provided for the user of virtual memory support, allowing fine tuning of the system to his needs.

The virtual memory option on the 2040 and 2060 supplies a system Page Fault Handler that works in conjunction with the central processor hardware Swapper to effect a demand paging mode of operation for designated user programs. When a page fault is detected by the Swapper, control is transferred to the Page Fault Handler, which specifies the pages to be swapped out to make room for currently referenced data. As an alternative, a user-written Page Fault Handler can be embedded in a user program to provide optimized demand paging based upon its specific characteristics.

Any user program can be made to run in the virtual-memory mode without modification by specifying "virtual core" in the SET job control command that allocates memory to the program. The REACT administrative control program permits each installation to restrict the use of the virtual memory option to specified users, to set limits on the amount of physical and virtual storage allocated to user programs, and to establish installation standard paging rates for all virtual-memory programs. Option provides a limited fail-soft facility in the event of a partial memory failure by permitting jobs to be reloaded to execute in the virtual memory mode of operation.

The TOPS-10 monitor, as well as the command language for the monitor, is common to all modes of operation.

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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 cannot 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 or drum to hold swapped-out segments. The swapping device is usually connected directly to main memory via a high-speed data channel. Control information is passed through the I/O 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 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 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 monitor generation time, default conditions can be established providing standard parameters to be inserted unless otherwise specified by individual users. During concurrent operation with time-sharing, a batch job 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.

Real-time applications are handled by the TOPS-10 monitor using the system facilities available for time-sharing and multiprogramming, as well as the additional features of guaranteed residence, where user programs are locked into core, and the programmable interrupt system, which can link a real-time sensor or activator device to one or more assigned priority interrupt levels.

Real-time devices may be serviced in single mode or block mode. Single mode service runs the user's interrupt program each time the device interrupts. Block mode allows an entire block of data to be read from the real-time device before the interrupt program is executed. In either mode, execution of the interrupt program causes the status of all operations to be preserved and restored upon completion of the interrupt processing.

TOPS-20 or TOPS-10 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 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.

TOPS-20 LINK: Besides the standard loading functions, Link provides a single region tree-structured overlay facility; load-time defined overlay structure independent of FORTRAN, COBOL, or ALGOL programs; a diagramming facility to portray the program overlay structure; and relocatable overlays.

TOPS-20 SORT/MERGE and TOPS-10 SORT/MERGE: A disk sort utility which operates stand-alone or in configuration with COBOL-68 and FORTRAN-IV. Sort/Merge reorders the records of ASCII files, sixbit files, EBCDIC files, and binary files produced by COBOL and FORTRAN in a sequence determined by the sorting parameters prepared by the user. Sort/Merge automatically controls the use and allocation of disk work space with user specified memory limits. The merging of files into a single sorted file can be invoked either stand alone or via the COBOL MERGE verb. Optional support of magnetic tape for input or output is provided by Sort/Merge.

ALGOL-60 (under TOPS-10 and TOPS-20): Consists of a one-pass, single-phase compiler capable of processing up to 5,000 ALGOL lines per minute, according to DEC; this speed assumes disk I/O with 24 unpacked significant symbols per line. Advanced features of DECsystem-10 ALGOL include a full range of diagnostics, extended-precision floating-point representation, bytes-string manipulation capability, "while" and "for" statements for iterative procedures, and independent program and procedure compilation. DECsystem-10 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-60 object-time system provides a basic I/O system including teletype I/O default with 16 logical channels, storage management, on-line debug tools, and a library of attachable routines including FORTRAN interface, byte-string manipulation, bit-field manipulation, single- and double-precision mathematical functions, etc. ALGOL-60 on the DECsystem-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-BASIC AND APL—SF (under TOPS-10 and TOPS-20): 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 close-

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ly 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 and 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-BASIC and APL-SF differ primarily in the APL-SF support of file I/O. APL-SF provides user level file access to standard ASCII sequential files, internal format random access files, internal format sequential files, binary random-access files, and immediate-mode I/O via any supported output device through the OUTPUT command.

APL-SF provides system functions that perform file operations, including ENQ/DEQ; allow creation of local functions; and return information about names in the active workspace.

BASIC (under TOPS-10): Provides 13 commands for full BASIC language capabilities plus enhancements 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 pure, re-entrant code for BASIC occupies 12K words of main storage, and each user's portion requires a minimum of 2K words.

BASIC PLUS-2 (under TOPS-20): Compatible with the BASIC PLUS-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; record I/O, supporting sequential and relative (direct) access to files; and access to system files.

The minimum hardware required for BASIC PLUS-2 is 128K words of main memory and allocation of 50K words of permanent file storage.

COBOL-68 (under TOPS-10 and TOPS-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.

The Sort/Merge, included with COBOL, can reduce sort times for disk data sets with more than 1000 records by about half.

CPL (under TOPS-10 and TOPS-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. The minimum hardware requirements for CPL is a 256K-word system, with at least 50K words available as user space and 50K words of permanent file storage space.

FORTRAN (under TOPS-10 and TOPS-20): A new FORTRAN compiler that contains both extensions to the ANS 1966 FORTRAN-IV standard and global and local optimization capabilities for improving execution times. DEC estimates that even without the global optimization capability, object code executes 5 to 10 percent 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 under TOPS-10 and TOPS-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 under TOPS-10 requires a 96K-word DECsystem-20.

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Both versions of FORTRAN support FORDDT, an interactive debugging aid that 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.

MACRO ASSEMBLER (under TOPS-10 and TOPS-20): 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 capabilities 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.

DECNET-10 AND DECNET-20: Actually a number of specific products aimed at several broad markets. Announced in April 1975 as a series of hardware and software extensions to standard systems, DECNET permits users to create communications networks merely by adding appropriate software and hardware to existing computer systems.

DECNET allows customers to:

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

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

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

DDCMP performs the physical line control only for the interfaces noted in the Communications Hardware Interfaces table as DECnet-supported. DDCMP performs line scanning, error detection and error recovery. On half-duplex lines, DDCMP controls the direction of traffic, while on full-duplex lines, DDCMP controls bidirectional traffic; on multi-point lines DDCMP performs the polling function. Outgoing transmissions are enveloped with control characters mainly to enable the receiving device to perform error detection. The CRC-16 polynomial checking technique is employed in creating an error detection code. Incoming transmissions are stripped of control characters after passing error detection checks. To accommodate the relatively long transit times for satellite-destined messages, DDCMP can support the transmitting of up to 255 messages before halting transmission to await acknowledgements for the previously transmitted messages.

DECnet software to handle the DDCMP protocol line handling is intended for use with low or medium-speed communications systems. The software will perform the function for both the program-interrupt and the DMA types of communications hardware interfaces. When volume increases substantially and begins to consume too much central processor overhead, or when high-speed communications lines are used, the DMC11 interface can be employed. Containing a dedicated microprocessor, the DMC11 will perform, via firmware, the line handling function, thus relieving the central processor's DECnet software of this time-costly burden. With the DMC11, a user could employ DDCMP protocol without using the other functions of DECnet.

When NSP receives a message for transmission from a program, NSP affixes the receiving program's identifier and sends it to the appropriate physical link for DDCMP protocol line handling. Incoming messages are stripped of their enveloped characters and given to the appropriate program. When two remotely located programs must talk to each other by passing a high volume of a particular type of data (as in remote program loading), NSP can establish a Dynamic Logical Link between the programs, and will pass only the specified type of data through the link.

When a remotely located program wants access to a file, NSP does not supply the request to a user program, but to the DAP DECnet module. This module goes through the same steps a local user program would take to get at data from mass storage. Namely, it issues an open and a read/write command to the File Management System. If the remote command was a Read, DAP would obtain the data and pass it to NSP for transmission. NSP will treat the data as just another outgoing message from just another user. DAP will also interface with the Device Handler software that controls unit record equipment and locally attached terminals.

A goal for the set of DEC products has been to provide as general an interconnection mechanism between specific products as possible, limited only by the technology and cost considerations which constrain each individual member of DECnet. Those latter constraints make totally general interconnectability impractical.

DEC recently extended the range of its DECnet communications software to include networking among most DEC operating systems and processors ranging from the LSI-11 microcomputer to the DECsystem-20.

Changes have been made to the Network Service Protocol (NSP), Data Access Protocol (DAP), and Digital Data Communications Message Protocols (DDCMP) within DEC's Digital Network Architecture. Among the changes are improved support for various systems under DAP and the ability to prevent network overloads under NSP.

Basically, the new and revised DECnet programs are designed to simplify network configuration and generation and to provide computing networks for industrial, commercial, scientific, and educational markets. The programs allow "dynamic reconfiguration," the ability to switch lines without interrupting service in case of malfunction. A full point-to-point interconnect capability allows disk-to-task communications by which programs running on separate networks can exchange data. Remote resources access for use

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of peripherals at another node and remote sequential I/O files are also supported.

DECnet-20 is a phase II network product and as such has these phase II features: allows a suitably configured DECsystem-20 to participate as a Phase II DECnet system in point-to-point computer networks; offers task-to-task communications using the DIGITAL Network Architecture (DNA) protocols; and communicates with adjacent systems over synchronous communications lines. Access to DECnet-20 is made via Macro-20 system calls.

For message exchange, two user programs can be on the same or adjacent DECnet systems. (Adjacent systems control opposite ends of a point-to-point communication line. The DECsystem-2040/2060 with its required communications front-end processor, is defined as a DECnet system). If adjacent systems, the second system can be any Phase II DECnet system that supports synchronous communication lines. However, DECnet networks that include systems other than DECsystem-2040/2060, can also include only one DECsystem-2040/2060; e.g., two DECsystem-2040s may be connected via DECnet; but a DECnet network containing a DECsystem-2020 or DECnet-11M, for example, can also include only one DECsystem-2040/2050/2060.

DECnet-20 supports (DDCMP) for full-duplex transmission in point-to-point operation using serial synchronous facilities.

DECnet-20 implemented on a DECsystem-2040/2060 supports one point-to-point synchronous link. On a DECsystem-2020, two point-to-point synchronous links may be supported with the proper hardware configuration. Only one physical link may connect any pair of nodes.

The synchronous line units interface to Bell System 208A modems for operation at speeds up to 4.8K bps to ICC COMLINK II modems for speeds up to 1.92K bps, and to Bell 303 modems (using a CCITT V.35 converter), for speeds in excess of 19.2K bps. Equivalent modems may also be used.

DECnet-20 is implemented as an ancillary process under TOPS-20 with DIGITAL-supplied monitor-level components and user-level utilities. DECnet-20 is implemented in two forms: For the DECsystem-2040/2050/2060, DECnet-20 resides in part in the central processor and in part in a dedicated communication front-end, the DN20; for the DECsystem 2020, DECnet-20 resides entirely in the central processor.

TOPS-20 2780/3780/Multileaving: Emulates and/or terminates Model 76 Data 100 units, or equivalent. It enables a DECsystem-20 equipped with a DN20 communications front end to submit 2780/3780 remote entry jobs to an IBM 360/370 and to process jobs submitted from 2780/3780 terminals.

In emulation mode, the TOPS-20 2780/3780 connects a DECsystem-20 to an IBM 360 or 370. The DECsystem-20 appears to the IBM system to be a Data 100 emulating an IBM 2780 or 3780 remote job entry station. The IBM 360 or 370 systems must be running one of the following: OS/VS2 (SVS) HASP II Version 4; OS/VS2 (MVS) with JES2; OS/MVT HASP II Version 3.1; OS/MVT ASP Version 3.1; or OS/VS2 (SVS) ASP 3.2.

A DECsystem-20 user can submit a disk file containing IBM JCL and ASCII data to the IBM system as a batch job. The TOPS-20 2780/3780 translates the data to EBCDIC before transmitting the job to the IBM system. Any output data returned to the DECsystem-20 is translated into ASCII and printed. In emulation mode, the DN64 does not handle special forms.

When connected to an OS/VS2 (SVS) HASP II Version 4 or OS/VS2 (MVS) with JES2 system, the TOPS-20 2780/3780 allows the DECsystem-20 user to route output from the IBM system to a given disk area on the DECsystem-20.

In termination mode, the TOPS-20 2780/3780 connects a DECsystem-20 to a Data 100 unit with 2780/3780 (or equivalent) terminals. (It is the user's responsibility to demonstrate 2780/3780 equivalency.) The 2780/3780 remote station user submits a DECsystem-20 batch control file from the remote station's card reader. The DN64 returns any job output to the remote station for printing on its printer.

The TOPS-20 2780/3780 supports a maximum aggregate termination rate of 40K bps from up to 6 synchronous communication lines. The lines can range in speed from a minimum of 2.4K bps to a maximum of 19.2K bps. The lines can interface to: Bell System 301C modems at 2.4K bps; Bell System 208A or 208B modems at 48K bps; Bell System 209A modems at 9.6K bps; or ICC COMLINK II modems at 19.2K bps.

TRAFFIC-20 (TRANSACTION ROUTING AND FORM FORMATTING IN COBOL): A collection of CRT screen formatting and program-to-program communications subroutines available to DECsystem-20 COBOL programs. Traffic-20 includes a set of Transaction Formatting Routines; a set of Transaction Routing Routines, and a stand-alone utility program for defining and saving CRT screen format descriptions. The Transaction Formatting Routines enable a COBOL program to send formatted CRT displays to and receive data messages from user terminals. The Transaction Routing Routines enable a COBOL program to send and receive packets to and from cooperating COBOL programs.

DATA BASE MANAGEMENT SYSTEM: DBMS-10 and DBMS-20 are full-scale data base organization and management systems that use both COBOL and FORTRAN as their host languages and provide a data management language (DML) based largely upon the April 1971 CODASYL Data Base Task Group (DBTG) specifications. DBMS-10 and DBMS-20 support hierarchical data structures in simple tree format or in more complex network structures and provide a high degree of data independence from physical devices as well as user applications programs. Owner and member relationships are defined by chained pointers. DBMS-10 and DBMS-20 permit 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 reentrant 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-10 and DBMS-20 are separately priced program products. DEC claims that current users of TOTAL, from Cincom Systems, or IDMS, from Cullinane Corp., can migrate to DBMS-10 or DBMS-20 with only minor changes.

A detailed analysis of DBMS-10 and DBMS-20 can be found in Report 70E-384-01.

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IQL-10 AND 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-10 and IQL-20 extract, summarize, reorganize, and copy file information, and produce reports in specified formats. The language interfaces both the file management system of the operating system and DBMS-10 or DBMS-20. Data files can be sequential DBMS data bases, or index-sequential with fixed and/or variable record length. IQL-10 and IQL-20 can perform sorting; conditional processing; computation, including multiply and 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-sorting of files, records, or items; and operate in either interactive or batch mode.

IQL-10 and IQL-20 contain a DBMS interface. In interactive mode, IQL operating under control of a terminal front-end module can define dictionaries reflecting schema files for DBMS data bases.

PRICING

CONTRACT TERMS: DEC offers a purchase agreement for immediate ownership of the DEC system-20, conditional sales agreement, and full-payout accrued-equity lease contracts. The conditional sales agreement is used primarily by non-profit institutions and state and local governments. This agreement carries a three- to seven-year term and is noncancelable with the title passing to the user, DEC retaining a security interest. The most common 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. These full payout leases may extend from three to seven years and are noncancelable. Five years is typical. 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 (see below). 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 or the TOPS-10 operating system 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.

Software maintenance service is available on a yearly basis and includes binary updates for bug fixes and for enhancements; a subscription to Software Dispatch, a monthly technical journal for resolution of customer software problems; Autopatch, providing, machine readable software patches; and update license only, enabling customers to copy updates to their supported system for use on their license-only systems. For bundled software, the annual maintenance is $4,000. The software notebook set plus one year of update service is priced at $975. The software notebook update service annual maintenance fee is $550. The Software Dispatch subscription is $440 annually.

USER GROUP: The worldwide DEC Users' Society (DECUS) was founded in 1961 and currently has more than 33,800 members in over 40 countries. This group is directly supported by DEC and schedules two international meetings annually in addition to publishing a bi-monthly newsletter, DECU-SCOPE. DECUS is composed of four chapters (listed below), special interest groups (such as the DECsystem 10/20 Group), local users groups, and national users groups. Symposia are held throughout the year in each of the DECUS chapters. The DECUS Program Library Catalog lists more than 2,600 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 Australia
P.O. Box 491
Crows Nest
New South Wales 2065 Australia
61-2-439-2566

DECUS Canada
P.O. Box 11500
Ottawa, Ontario
K2H 8K8 Canada
613-592-5111 Ext. 2115

DECUS Europe
12 Avenue des Morgines
C.P. 510
1213 Petit-Lancy 1
Geneva, Switzerland
022-93-33-11

DECUS U.S.
One Iron Way
Marlboro, Massachusetts 01752
617-481-9511 Ext. 4100

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 (warranty) are provided at no charge following delivery of a system on an 8 hours per day, 5 days per week basis. More intensified coverage over a shorter period of time is also available (for example 24 hours per day, 7 days per week for 50 days). 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 DECservice agreement provides on-call remedial maintenance between 8 a.m. to 5 p.m. and preventative maintenance between 8 a.m. and 8 p.m., both Monday through Friday. There is no additional charge for remedial service begun during the contracted hours of coverage but which must extend beyond these coverage hours. There is a guaranteed four hour response for service calls placed during the contract period and on-call maintenance on a best effort basis at per call rates with no charge for materials outside the contract period. The following table gives premiums to be added to regular rates (Monday-Friday, 8 a.m.-8 p.m.) for service outside the standard contract period.

	16 hours	24 hours
Daily Mon. through Fri.	8%	16%
Saturday or Sunday	11.2%	13.6%

The Basic service agreement provides maintenance between 8 a.m. and 5 p.m. Monday through Friday and priority response (typically next day) during hours of coverage. Extended coverage rates for Basic service agreements can be obtained by adding the premiums in the following table to standard Basic service rates.

	12 hours	16 hours	24 hours
Daily/no weekends	13%	26%	43%
Sat. & Sun.	10%	13%	17%

The Customer Software Maintenance Service, in addition, provides remedial action for software bugs occurring at

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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 4 hour 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.

Currently available courses include DECsystem 20 User Course, Administration Course, Assembly Language Programming, Programming, Operating System, COBOL, and Operator Course.

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 2020: Consists of KS10-A CPU with 256K words of MS10 Error Correcting MOS memory; a 14.89 megaword (67 megabyte) RM03 Disk Drive; a TU45 Magnetic Tape Subsystem; an LA36 DECwriter II Console Terminal; an LP20-A Line Printer; a DC20 8-line asynchronous multiplexer; the TOPS-20 operating system including the GALAXY batch system, link loader, editor, and utilities; the macro assembler; installation and 90-day warranty; and 50 days of application software consulting. Purchase price is $181,080 and monthly maintenance charge is $1,502.

MINIMUM DECSYSTEM 2040: Consists of KL10-E CPU with 256K words of memory; a RP06-B Disk Drive, word disk drive; a TU45 9-track, 800/1600-bpi tape subsystem; an LP20-A Line Printer; an LA36 DECwriter II console terminal; 16 asynchronous communications lines, asynchronous multiplexer; 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 $374,360 and monthly maintenance charge is $2,926.

MINIMUM DECSYSTEM 2060: Consists of a KI10 CPU with 2048 words of 160-nanosecond cache memory and 256K words of memory; a RP06-B 39.6 million-word disk drive; a TU45 9-track, 800/1600 bpi tape subsystem; an LP20-A Line Printer; an LA36 DECwriter II console terminal; 16 asynchronous communications lines; the TOPS-20 operating system including the GALAXY batch system, linking loader, editor, and utilities; the maxro assembler; installation and 90-day warranty; and 50 days of application software consulting. Purchase price is $448,860 and monthly maintenance charge is $3,379.■

EQUIPMENT PRICES

PACKAGED SYSTEMS**

DECsystem 2020 Systems include the KS10-A CPU with 256 word virtual address cache memory, 256K words of 1.05-microsecond MS10 MOS Memory, and one integral data channel; an LA36-C DECwriter II Console Terminal; 16 asynchronous communications lines; 10 training credits; hardware installation and 90-day warranty and one-year software updating services; five sets of manuals; 25-day consulting services package; utilities; and macro assembler:

		Purchase Price	Monthly Maint.*
2020-PA/B	DECsystem 2020 with one RM03 Disk Drive and TOPS-20 Operating System	$129,800	$ 859
2020-PC/D	DECsystem 2020 with one RM03 Disk Drive and TOPS-10 Operating System plus sources	129,800	859
2020-SA/B	DECsystem 2020 with one RP06 Disk Drive and TOPS-20 Operating System	144,800	859
2020-SC/D	DECsystem 2020 with one RP06 Disk Drive and TOPS-10 Operating System plus sources	144,800	859
2020-GE/GF	DECsystem 2020 with two RM03 Disk Drives, one TU45-Tape Drive and TOPS-20 Operating System	198,000	1,385
2020-GH/GJ	DECsystem 2020 with two RM03 Disk Drives, one TU45-Tape Drive and TOPS-10 Operating System plus sources	198,000	1,385
2020-GK/GL	DECsystem 2020 with two RP06 Disk Drives, one TU45-Tape Drive and TOPS-20 Operating System	228,000	1,450
2020-GM/GN	DECsystem 2020 with two RP06 Disk Drives, one TU45-Tape Drive and TOPS-10 Operating System plus sources	228,000	1,450

DECsystem 2040 Systems include the KL10-E CPU with 256K words of 1.05-microsecond MF20 MOS Memory, and two integral data channels; an LA36-C DECwriter II Console Terminal; 16 asynchronous communications lines; TOPS-20 Operating System plus utilities and macro assembler; 10 training credits; hardware installation and 90-day warranty, software installation with 90-day warranty and one year software updating services; five sets of manuals; and 50-day consulting services package:

2040-SA/SB	DECsystem 2040 with one RP06-B Disk Drive	324,600	2,173

*Monthly maintenance is 5-day, 12 hours per day DECservice except for 2020 packages and terminal products: MS10-BA, MS10-HA, MS10-LA, RM03-A, TAU45-EC/ED, DZ11-AA, DZ11-BA, DF01-A, LA36-C, LA36-H, LA37-C, LA37-P, LA38-G, LA38-H, LA120-BA, LA180-EA/ED, LA180-P, VT61-A, VT62-A, VT100-A and VT1XX-A. For 2020 products, the quoted figure is DECservice for an eight hour day, 5 day week. For terminal products the quoted figure is the eight hour Basic maintenance. Maintenance figures in parentheses are for 2020 only.

**All minimum systems require a magnetic tape subsystem and a line printer in addition to the basic package.

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EQUIPMENT PRICES

		Purchase Price	Monthly Maint.*
PACKAGED SYSTEMS (Continued)**			
DECsystem 2060 Systems include the KL10-EE CPU with 160 nanoseconds cache memory, 256K words of 1.05-microsecond MF20 MOS Memory, and two integral data channels; an LA36-C DECwriter II Console Terminal; 16 asynchronous communications lines; TOPS-20 Operating System plus utilities and macro assembler; 10 training credits; hardware installation and 90-day warranty, software installation with 90-day warranty and one year software updating services; five sets of manuals; and 50-day consulting services package:			
2060-PA/PB	DECsystem 2060 with one RP06-B Disk Drive	399,100	2,626
SYSTEM UPGRADES			
2060-UA/UB	2040 to 2060 Upgrade; includes MCA20 and TOPS-20 with extended features; may also include KLPV	100,000	—
2060-UC/UD	2050 to 2060 Upgrade; TOPS-20 with extended features; may also include KLPV	10,000	—
MEMORY			
MS10-BA	MOS memory modules for 2020 (error correcting):		
	64K words	8,000	65
	128K words	15,000	125
	256K words	27,000	250
	Memory for 2040:		
MB20-GC/GD	Expansion unit (second backplane)	27,000	169/unit
MB20-E	Core memory modules (3 max. per backplane)		
	64K words (1 unit)	27,000	130
	128K words (2 units)	54,000	260
	192K words (3 units)	63,000	390
	256K words (4 units)	72,000	520
	320K words (5 units)	80,000	650
	384K words (6 units)	88,000	780
	448K words (7 units)	96,000	910
	Memory for 2060:		
MF20-LC/LD	Expansion controller (first backplane) with 256K-word memory module	65,000	559
MF20-LC/LD	Expansion unit (second backplane) with 256K-word memory module	65,000	364/unit
MF20-LH/LJ	External expansion controller (first backplane) with 256K-word external memory module	65,000	581
MF20-LK/LL	External expansion unit (second backplane) with 256K-word external memory module	65,000	285
MF20-E	MOS memory modules (two max. per backplane)		
	256K words (1 unit)	65,000	221
	512K words (2 units)	113,750	442
	768K words (3 units)	162,500	663
	1024K words (4 units)	195,000	884
MASS STORAGE			
RP06-A	39.6-megaword Add-On Single-Access Disk Drive for use with integrated controllers on 2020 and DH20 Controller on the 2040 or 2060	34,000	247
RP06-B	39.6-megaword Add-On Disk Drive, dual-access version of RP06-A above; max. 3 per subsystem	39,140	273
RP06-C	Dual-access kit; converts one RP06-A single-access drive to RP06-B dual-access drive; not for 2020	5,150	26
RM03-A	14.89-megaword Disk Drive for 2020; max. 8 per system	19,000	182
RH20	Massbus Controller for disk or tape	10,500	32
MAGNETIC TAPE EQUIPMENT			
TU45A-EC/ED	Magnetic Tape Subsystem with tape controller and TU45A Tape Drive; for 2040 or 2060	26,400	305
TU45A-EH/EJ	Add-On Tape Drive for TAU45-EC/ED and TU45A-EC/ED; 75 ips, 800/1600 bpi, NRZI/PE; maximum of three	14,700	227
TAU45-EC/ED	Magnetic Tape Subsystem with tape controller and TU45A Tape Drive; for 2020	29,500	273
TAU77-EC/ED	Magnetic Tape Subsystem with tape controller and TU77 Tape Drive; for 2020	28,000	338
TU77-AF/AJ	Add-On Tape Drive for TAU77-EC/ED and TU77-CB/CD; 125 ips, 800/1600 bpi, NRZI/PE; maximum of three	19,500	227
TU77-CB/CD	Magnetic Tape Subsystem with tape controller and TU77 Tape Drive; for 2040 and 2060	28,000	305
TX02-EE/EF	Magnetic Tape Controller and DX20 Channel for TU72 Series Tape Drives; requires RH20; for 2040 or 2060	90,500	588
TU72-E	Add-On Tape Drive for TX02-E; 200 ips, 1600/6225 bpi, PE/GCR	33,000	195
TX03-A/B	Two Channel Switch for TX02-EE/FF	6,000	13
TX03-EE/FF	Two channel switch option and DX20 channel for TX02-E	51,000	244
TX03-FB	Two channel switch option for two TX02-E	12,000	26
TX05-B	2 x 16 Tape Switch for TX02-EE/FF	12,000	13
TX05-EC/ED	Two control unit tape switch option and one TX02-E; requires one TX02-E	69,500	370
TX05-FB	Two control unit tape switch option; requires two TX02-E	24,000	26
PRINTERS			
LP20-A	Line Printer and Controller; 132 positions; 64-character, EDP or scientific font; 300 lpm	16,500	279
LP20-B	Line Printer and Controller; 132 positions; 96-character; EDP or scientific font; 230 lpm	17,500	279
LP20-C	Line Printer and Controller; 132 positions; 64-character; EDP font; 900 lpm	34,125	321
LP20-D	Line Printer and Controller; 132 positions; 96-character; EDP or scientific font; 660 lpm	35,385	321
LP200-BA/BB	Line Printer and Controller; 132 positions; Charaband-type mechanism; includes software, long line interface, and diagnostics; does not include Charaband; 1500 lpm; not for 2020	51,000	499
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, 64- and 96-character OCR-A fonts, two 96-character scientific fonts, 96-character EDP and scientific fonts, two 96-character Swedish/Finnish fonts, 64- and 96-character British fonts, two 64-character open Gothic fonts, or customer specified character fonts	4,000	—

*Monthly maintenance is 5-day, 12 hours per day DECservice except for 2020 packages and terminal products: MS10-BA, MS10-HA, MS10-LA, RM03-A, TAU45-EC/ED, DZ11-AA, DZ11-BA, DF01-A, LA36-C, LA36-H, LA37-C, LA37-P, LA38-G, LA38-H, LA120-BA, LA180-EA/ED, LA180-P, VT61-A, VT62-A, VT100-A and VT1XX-A. For 2020 products, the quoted figure is DECservice for an eight hour day, 5 day week. For terminal products the quoted figure is the eight hour Basic maintenance.

**All minimum systems require a magnetic tape subsystem and a line printer in addition to the basic package.

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EQUIPMENT PRICES

		Purchase Price	Monthly Maint.*
PUNCHED CARD EQUIPMENT			
CD20-A	Card Reader and Controller; tabletop mounting; 300 cpm	6,170	115
CD20-C	Card Reader and Controller; free-standing, 1200 cpm	21,800	198
CP20-C	Card Punch; 100 cpm, requires external I/O bus interface DIB-20; not for 2020	34,500	301
PUNCHED TAPE EQUIPMENT			
PC20-C	Paper Tape Reader/Punch; includes cabinet and power supplied; requires external I/O bus interface DIB-20; not for 2020	14,500	140
DIB-20	External I/O Bus Interface	5,500	49
ASYNCHRONOUS COMMUNICATIONS DEVICES			
DC20-AA	Basic Asynchronous Multiplexer; 8 lines, can be expanded to 16 lines with one DEC20-DA expander, max. 7 per system; for 2040 or 2060	5,280	91
DC20-DA	Expansion group for use with DC20-AA above; 8 lines, max. 1 per DC20-AA	1,580	78
DC20-EC/ED	Communications Expansion Cabinet; required for over 64 communications lines, includes one DC20-AA basic 8-line group, max. 1 per system; for 2040 or 2060	11,000	156
DC20-CC	Cables and Distribution Cabinet; for configuration between 32 and 128 lines	2,200	—
DZ11-AA	Asynchronous Line Interface and Distributor Panel; for 8 lines; required when more than 16 lines are ordered	2,310	32
DZ11-BA	Asynchronous Line Interface; for 8 lines; required when more than 8 or 24 lines are ordered; requires DZ11-A	1,800	27
SYNCHRONOUS COMMUNICATIONS DEVICES			
DN20-CA/CB	Data Communications Front End; requires DN20-BX synchronous line units and software; for 2040 or 2060	28,200	189
DN20-BA	Synchronous Line Controller; one allowed per DN20-C; includes DN20-BB; for all processors	3,580	35
DN20-BB	Synchronous Line Unit; for expansion of DN20-BA; max. of 3 DN20-BB per DN20-BA	1,380	14
DN21-BA	Synchronous Line Controller and Interface for speeds between 19.2K and 56K bps; for 2040 or 2060	3,050	35
DN22-AA/BB	IBM 2780/3780/HASP Multileaving Emulator/Terminator for 2020	12,500	151
TERMINALS			
DF01-A	Acoustic Telephone Coupler	760	14
LA36-C	DECwriter II Hard Copy Terminal; 30 cps; KSR; 132 positions, 20 ma current loop, 14 position keypad	2,100	24
LA36-H	With EIA Interface	2,200	24
LA37-C	LA36-C with dual APL/ASCII character set and 20 ma current loop	2,950	28
LA37-P	With EIA Interface	3,050	28
LAXX-LG	EIA Interface with modem control	110	—
LA38-G	DECwriter IV Hard Copy Table-Top Terminal; 30 cps; KSR; 132 positions, EIA interface, 14 position keypad	1,600	20
LA38-H	With Universal power supply	1,700	20
LAX34-CL	20 ma Current Loop Interface for LA38	120	3
LA120-BA	DECwriter III; 180 cps, numeric pad, EIA interface	2,600	32
LA12X-AL	20 ma Current Loop Interface for LA120	120	—
LA180-EA/ED	DECprinter; 180 cps, serial, EIA interface	3,770	71
LA180-P.	DECprinter for hardcopy use with VT61; parallel interface	3,240	65
VT61-A	Buffered Video Display Terminal; 24 lines by 80 characters, 128 ASCII character set; 20 ma current loop for EIA interface	4,030	42
VT62-A	Microprocessor Driven Video Display Terminal; designed for transaction processing; 20 ma current loop or EIA interface	3,150	65
VT100-A	CRT Terminal with detached keyboard, EIA keyboard, EIA interface supported in the VT52 compatible mode only	1,900	22
VT1XX-AA	20 ma Current Loop Interface for VT100	120	3
HARDWARE			
DNHXX-A	Expansion Cabinet for 2020	7,500	—
H956	Option Cabinet	1,575	—
844	Power Control for H956 cabinet	665	—

*Monthly maintenance is 5-day, 12 hours per day DECservice except for 2020 packages and terminal products: MS10-BA, MS10-HA, MS10-LA, RM03-A, TAU45-EC/ED, DZ11-AA, DZ11-BA, DF01-A, LA36-C, LA36-H, LA37-C, LA37-P, LA38-G, LA38-H, LA120-BA, LA180-EA/ED, LA180-P, VT61-A, VT62-A, VT100-A and VT1XX-A. For 2020 products, the quoted figure is DECservice for an eight hour day, 5 day week. For terminal products the quoted figure is the eight hour Basic maintenance.

**All minimum systems require a magnetic tape subsystem and a line printer in addition to the basic package.

*Monthly maintenance is 5-day, 12 hours per day DECservice except for 2020 packages and terminal products: MS10-BA, MS10-HA, MS10-LA, RM03-A, TAU45-EC/ED, DZ22-AA, DZ11-BA, DF01-A, LA36-C, LA36-H, LA37-C, LA37-P, LA38-G, LA38-H, LA120-BA, LA180-EA/ED, LA180-P, VT61-A, VT62-A, VT100-A and VT1XX-A. For 2020 products, the quoted figure is DECservice for an eight hour day, 5 day week. For terminal products the quoted figure is the eight hour Basic maintenance.

Digital Equipment DECsystem-20

SOFTWARE PRICES

TOPS-10	TOPS-20		One-Time License Fee	Annual Maint. Fee
QH500-XM	QT002-AM	ALGOL-60; binaries and source code supplied	$10,000	$ 750
QH0702-AM	QT014-AM	APL; same as APLSF, but without file I/O; binaries only supplied	10,000	900
QH0701-AM	QT012-AM	APLSF; binaries only supplied	10,000	750
QH502-XM	—	BASIC-10; binaries and source supplied	6,000	900
—	QT027-AM	BASIC-Plus-2; binaries only supplied	10,000	1,100
QH508-XM	QT011-AM	COBOL-68 with Sort/Merge; binaries and source supplied	13,000	1,300
QH099-XM	QT099-AM	COBOL-74 plus QT011-AM; binaries and source supplied	13,000	1,300
QH060-AM	QT009-AM	CPL (ANS-76 PL/1 subset interpreter; binaries only supplied)	6,000	650
QH500-XM	QT001-AM	FORTRAN-66; binaries and source supplied	10,000	950
QH300-XM	QT007-AM	Sort/Merge; binaries and source supplied	3,000	350
QH101-AM	QT008-AM	DBMS; binaries only supplied	30,000	2,750
QH045-AM	QT016-AM	IQL extended with DBMS interface, both ISAM and sequential; binaries only supplied	17,000	1,200
QH074-AM	QT025-AM	APL to APLSF upgrade	10,000	—
—	QT028-AM	BASIC to BASIC-Plus-2 upgrade	4,500	—
QH509-XM	QT024-AM	Sort/Merge to COBOL-68 Sort/Merge	10,000	—
QH681-XM	—	DECnet-10 Task to Task; binaries and source supplied	15,000	2,500
—	QT042-XM	2780/3780 Software for 2040, 2050, or 2060 (TOPS-20); binaries and source supplied	7,500	1,500
—	QTD01-AM	DECnet-20 for 2040, 2050, or 2060; binaries only supplied	5,000	1,000
—	QTD20-AM	DECnet-20 for 2020; binaries only supplied	5,000	1,000
—	QT037-AM	Traffic-20; binaries only supplied	6,000	1,000
ZH008-CM	ZH008-CM	Maintenance Programs for the KL10-E	44,000	—
ZT001-YM	ZT001-YM	Maintenance Programs for the KS10-A	22,000	100
QT046-YM	QT046-YM	KS10 Microcode	44,000	500
	Source Code			
QT029-EK/EL	QT029-EK/EL	TOPS-20 Front End Source Code on RP04 or RP06 Disk	20,000	2,500
—	QT030-EM	TOPS-20 Monitor Source Code on 9-track tape	25,000	3,000
—	QT038-EM	TOPS-20 Executive Sources (Command Scanner) on 9-track tape	7,000	1,000
—	QT040-EM	TOPS-20 Source Package; includes QT030, QT029, QT038; supplied on RP04 or RP06 Disk	40,000	4,000

Digital Equipment DECsystem-20

New Product Announcement

DEC has quietly made several enhancements to the DECsystem-20 product line in recent months. Included in these enhancements are MOS external memory for the 2040 and 2060, new tape drives for the entire DECsystem-20 line, and IBM 2780/3780/HASP multileaving for the 2020.

EXTERNAL MEMORY: The DECsystem-20 2040 and 2060 can now be expanded to include up to 12 megabytes (3072K words) of main memory. As before, the first 6 megabytes (1536K words) are housed in the CPU cabinet. In the CPU cabinet, the first and second backplanes hold 3 megabytes (768K words) of memory apiece. The first megabyte (256K words) comes with the backplane. The other 2 megabytes (512K words) are added via 256K word MF20-E Memory Increments. The new external memory cabinet holds the additional six megabytes of main memory on two backplanes. Each backplane holds three megabytes of memory in the same fashion as memory housed in the CPU. External memory requires TOPS-10 Version 7.01 or TOPS-20 Release 4. Delivery of the new MF20 Series External Memory is scheduled for the third quarter of 1980. Pricing for external memory can be found in the price list which preceeds this NPA.

NEW MAGNETIC TAPE SUBSYSTEMS: Two versions employ the same drive, but a different controller. The TAU 77-EC/ED Magnetic Tape Subsystem is specifically for the 2020, while the TU77-CB/CD is tailored for the 2040 and 2060. Either controller can be configured with up to four drives. The TU77 Magnetic Tape Drive is a 9-track, 125 ips unit with program selectable recording densities of 800 bpi NRZI or 1600 bpi PE. The TU77 employs up to 10.5 inch reels for up to 2400 feet of tape. Pricing for the new magnetic tape units appears in the price list which preceeds this NPA.

IBM 2780/3780/HASP MULTILEAVING EMULATOR/TERMINATOR (DN22-AA/AB): Designed to enable a 2020 with either TOPS-10 Version 7.01 or TOPS-20 Release 4 to act as a remote station to an IBM host in emulation mode. DN22 also allows the 2020 to act as a host and communicate with 2780, 3780 or HASP-multileaving style terminals in termination mode. With DN22, two communications lines are provided in any mix of emulation or termination. DN22 requires one DN20-B synchronous line from the 2020 with either synchronous modems for remote use or a single synchronous null modem for local use. Pricing for DN22 appears in the price list preceding this NPA. □