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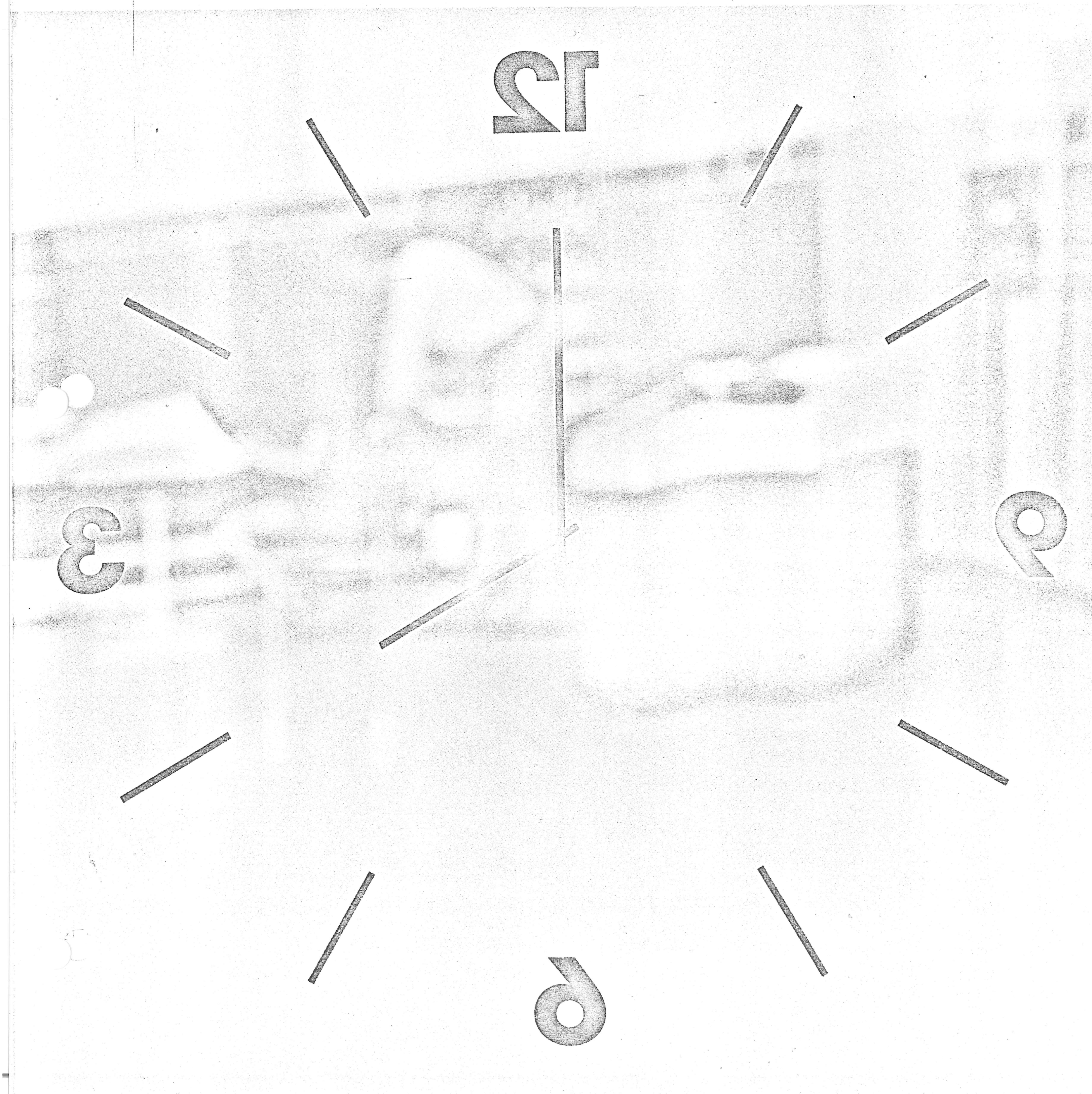
PDP-10 Real-Time Systems



DEC offers real-time system designers a complete system capability...including real-time software, custom hardware, and satellite computers...timesharing for on-line calculations or program development...and multiprogramming and remote batch processing with immediate turn-around and big computer power.

THE PDP-10

PDP-10 computers have proven highly successful in meeting the needs of many diverse real-time applications. Large-scale PDP-10 systems may be found in physics and chemistry laboratories, in hybrid computing centers, in computer science departments, and in industrial process control and information systems.

Typically, a large-scale, real-time system should answer three important needs. It must be able to satisfy the response requirements of real-time tasks. It must provide on-line interactive capabilities for the user so that real-time processes may be monitored and controlled as required. And it must be able to handle a substantial processing or computational load.

PDP-10s have the hardware needed to do these jobs—multiprogramming hardware, multi-level interrupt hardware, high-speed input/output busses, real-time clocks, high-speed random access disks, and on-line interactive terminals. But equally important, PDP-10s also have the requisite software for these jobs. In fact, the TOPS-10 operating system is unique in that it supports the entire multi-functional operation of the PDP-10. Moreover, because of the high degree of sophistication invested in the TOPS-10 operating system, all functions can be carried on simultaneously, and without interfering with one another.

The interactive timesharing and batch processing functions of the system proceed under the supervision of a background scheduling algorithm. The scheduling algorithm determines which job is to run, considering job running time, job size, and job priority.

Up to 14 batch jobs may be active simultaneously. As any job becomes unrunnable because, for example, it is doing I/O, another job will be picked up and run. When jobs become unrunnable, they are not swapped out of core unless their core space is needed. If swapout is necessary, it is automatic.

Batch jobs may also be run from remote stations under the multiprogramming batch monitor of the TOPS-10 operating system. Operating through a high-speed synchronous interface, a typical remote batch station consists of a small DEC computer, a line printer, card reader and assorted other peripherals. Optionally a remote batch station can be set up to concentrate 16 lines from remotely located console users.

Another special PDP-10 feature is that no memory partitions are required between timesharing and batch processing jobs. This means that the full amount of core memory is available to all users. Similarly, all languages and utility processors are available to all users, and batch jobs have access to data files and libraries on an equal basis with timesharing and real-time users.

The TOPS-10 operating system has also optimized file handling and storage. A sophisticated file handler communicates with specialized disk service routines, providing:

- named storage of files
- storage which cannot be accessed or altered without authorization
- controlled file sharing among authorized users
- an administrator-specified set of storage hierarchies
- a quota system for allocating storage to users
- accounting information
- defaults making it unnecessary for the user to know the physical location of his files.

REAL-TIME SOFTWARE

With the introduction of a new real-time monitor module, PDP-10 systems offer timesharing, batch processing, and real-time capability—all at the same time. Among the features of the real-time software are: fast response, high throughput, and no fixed memory partitions. Both single and dual processor systems are supported.

Every demand for system resources, ranging from the most time-critical real-time task to batch processing and timesharing, is handled efficiently. Real-time programs may be written in FORTRAN or MACRO-10 (assembly language).

In order to obtain fastest response a job may be driven directly in response to the priority interrupt system and be run in Executive mode, providing response times limited only by the ability of the hardware to respond to interrupts (typically under 10 microseconds).

Response times of 100 microseconds may be obtained by programs running in User mode by means of the Real-Time Trap monitor call providing fast response while simultaneously offering protection to the rest of the system.

Response times of a few milliseconds or less may be assured by placing the program in any one of 15 high priority queues maintained by the system scheduler.

Using this mechanism, system response may be biased to favor real-time tasks, batch processing or any other program or group of programs—a very useful tool for the system administrator or batch operator.

Through a series of monitor calls, jobs may be run on a periodic basis under control of the system clock. Also, one job may request that another be run—a feature useful when a block of data has been input and an analysis job on the disk system is selectable. High priority queue assignments allow the system to be tailored to optimize performance.

SOFTWARE FEATURES

Real-time programmers are able to call upon unique TOPS-10 monitor features for various privileges and services.

Fast Response to Interrupts—Real-time programmers may dynamically connect and disconnect their time critical real-time equipment and tasks to the PDP-10 priority interrupt system.

Response to interrupts is immediate. Real-time programs run at interrupt level in either Privileged User or Executive hardware modes. A spectrum of real-time privileges is provided to be administered by the system manager.

The interrupt service time for each data word in fast block mode is 6.4 microseconds and in normal block mode, 14.6 microseconds. User programs can get control in 3.1 microseconds, "super" executive mode; in less than 10 microseconds, executive mode; and in 100 microseconds with maximum security privileged user mode. In all cases, the real-time code is completely protected from the coding errors or program bugs of timesharing and batch processing users.

Core Management Control—The real-time programmer by means of a monitor call can cause his program to be "locked" into core and thereby to become protected against being "swapped" or rolled out onto the disk (drum). Prior to performing the "lock" the monitor positions the real-time code so as ensure the efficient use of core by maximizing contiguous space in the remaining core area.

Job Priority Assignments—PDP-10 programmers, with privileges granted by the system administrator, can assign any of fifteen priorities to their job(s). The system may be biased to favor real-time, timesharing, and/or batch jobs of special interest. An analogous console command allows a terminal user to make these assignments. The job scheduler always scans high priority queues first and in descending priority order.

Jobs May Share A Common Data Area—Programs (more than one job) may share a common area in core. Thereby, a data collection or filtering program can pass data to a more extensive analysis program for processing. This technique, provided by the PDP-10 protection and relocation hardware, allows one to lock the smaller program in core, with the large analysis program remaining disk resident until needed.

Jobs May Go to Sleep Until Awakened—When a program is not needed until another task has been completed or until a specified length of time has passed, it may declare that it wishes to "hibernate." If a time is specified it will awaken when that period has elapsed. If no time is given, the job will wait indefinitely until called by another job. "Waking" a suspended job is accomplished by executing the monitor call, WAKE, with the job number specified. Waking is immediate if the hibernating job has previously been given highest priority.

Real-Time Jobs Are Completely Protected From Background

Exec, privileged user, and user hardware modes, plus memory protection and relocation hardware, provide protection from coding errors and program "bugs."

Protection Against Loss Of Data Files

Redundant recording of file retrieval information ensures against loss of data files.

Protection Against Loss Of Power

Power Failsafe hardware provides system security against loss of power.

No Fixed Memory Partitions

PDP-10 dual memory protection and relocation hardware provides absolute address protection and relocation of jobs throughout core memory—dynamically.

Reentrant Systems Software

Conserves core space in the PDP-10 multiprogramming environment. Jobs may share core space.

Dual Processor System

Master-slave dual processor systems supported by system software.

Unified Job Control Language

One job control language for real-time, batch, and timesharing users.

Higher Level Language Control of Real-Time Tasks

FORTRAN routines provided for real-time system usage.

Dynamic Scheduler

Does not use fixed time slot or round robin algorithm.

HARDWARE FEATURES

The following PDP-10 hardware features result in fast, flexible and efficient operation, whether the system is being used in a dedicated or a true multiprogramming real-time environment.

Sixteen General-Purpose Registers

Whether implemented as 150 nsec cycle time TTL integrated circuit registers or as the first 16 locations of core memory, these 16 general-purpose registers are addressable as accumulators, index registers and memory locations. They may even contain executable code. An important speed advantage is obtained when interactive program loops are executed from fast memory.

Fifteen Index Registers

The right half of each general-purpose register 1 through 15 may be used as an index register. Indexing may take place to any level.

Multilevel Indirect Addressing

The calculations of an effective address for any instruction may involve any depth of indirect addressing, with indexing at each level if specified.

Immediate Mode Addressing

An immediate mode is provided in any of the instruction classes, including floating point instructions. In the immediate mode, the result of the effective address calculation, which may involve indirect addressing and indexing to any depth, is used directly as an operand.

Sixty-Four Programmable Operators

The PDP-10 provides 64 "programmable operators," codes which trap to fixed locations with the effective address calculation performed. Half of these programmable operations are interpreted by the

monitor. Such monitor-interpreted calls accomplish a variety of functions, including all input/output. The remaining half of the programmable operators trap to the user's own area and may be user defined.

Multilevel, Hardware Implemented, Priority Interrupt System

The PDP-10 priority interrupt system is designed to meet the dynamically changing requirements of the typical real-time environment. Seven levels of hardware priority are standard (28 are available). Devices may be assigned to any hardware priority through the execution of assignment I/O instructions. It is not necessary, as with other systems, to rearrange cables in order to accomplish this function. Under program control it is possible to enable (or disable) individual levels, individual devices, or the system as a whole.

I/O devices may make use of the BLKI/O (Block-In—Block-Out) feature which, in one step requiring no programmer attention, will automatically:

- Identify the source of the interrupt
- Update word count and data memory address
- Transmit or receive a word of information
- Dismiss the interrupt or, if the last word in the block has been transmitted, execute an instruction transferring control to the appropriate end of transmission subroutine

Interrupts may be generated by appropriate instructions. This is often desirable in order to simulate the presence of real-time hardware which, for some reason, might be unavailable. Also software interrupt generation capability is desirable to enable the high priority recognition of real-time device interrupts yet permit lengthy related computations to be executed at a lower level.

Dynamic Memory Protection and Relocation

To protect the overall system from possible errors in the code of the currently running task and to provide for dynamic allocation of core among jobs, dual memory protection and relocation registers are provided. Each user mode program is assigned one or two segments of memory. One segment may be write protected to protect critical data from errors committed by the user himself. One segment may be shared with other users or other programs. Segments are a multiple of 1024 words, can be located anywhere in core, and may contract or expand as required.

Core management techniques employed by the monitor ensure the efficient use of core. System programs are reentrant, thus a single sharable copy of FORTRAN IV, for example, is sufficient for all users.

Should a program attempt to reference memory outside of its assigned limits, a hardware trap occurs and the running program is stopped in favor of another.

Multiplexed I/O Bus

The PDP-10 multiplexed I/O bus provides a 36-bit, full-word parallel path between memory and an I/O device controller. Each data transmission instruction will move one word of data between memory and the device controller buffer.

Certain multifunction BLKI/O instructions will automatically move a block of data to or from a device without further programmer attention. The maximum data rate of the bus is 200 KHz words.

Memory Interleave/Overlap

All memories and processors are capable of asynchronous, overlapped operation. Memories are equipped with two-way interleave switches which, when used, cause consecutive memory address to be located in alternate physical memories. The resulting memory overlap often can increase the execution speed of a given program by reducing the effective cycle time of memory.

High-Speed Channel

One or more high-speed selector channels may be included in any system. Each channel will service up to eight devices. The data paths for both channel commands and data transmission are 36-bit word parallel. Data transmission rates are limited only by memory speeds; i.e., 1M words per second per memory.

Direct Addressing

The entire core memory, up to 262,144 words, is directly addressable without resort to base registers, displacement addressing or indirect addressing.

Optimum Instruction Format

The 36-bit PDP-10 instruction word provides for 512 operation codes, of which 366 are wired instructions and 64 are programmable operators. The remaining codes are reserved for future expansion and act as no-ops. In all but eight instructions, one of 16 accumulators may be specified. The eight exceptions are I/O instructions, which do not reference an accumulator but, in these, one of 126 I/O devices is specified. All instructions contain an indirect bit through which indirect addressing may be carried to any depth. All permit the specification of one of 15 index registers. All are capable of addressing a full 262,144 words of memory or, alternatively, the address field may contain immediate operands up to 18 bits.

Logically Complete Order Code

366 basic instructions divide logically into specific classes and are easily learned. Instruction mnemonics are modular; that is, the characters comprising them are concatenated to form the various instruction mnemonics. Many instructions operate in several modes, with the mode defining the direction of data transfer, where a result is to be left, or defining the condition of test in any of the 128 arithmetic and logical test instructions.

Variable Length Byte Manipulation

In addition to the instructions which manipulate 36-bit words, there are 64 half-word instructions and a set of 5-byte manipulation instructions which operate on bytes of any size. (Byte sizes are not restricted to submultiples of the word length.) The hardware permits automatic packing, unpacking and sequential access of any size bytes. Characters are represented throughout the system in ASCII, which is a 7- (not 8) level code. Five characters pack conveniently into a character set (as in the representation of symbols). In this case, 6-bit characters are stored six to a word.

Push-Down Stack Operations

The PDP-10 incorporates instructions for storage and retrieval of data on push-down lists. Even more importantly, there are subroutine call and return instructions which preserve and restore the program counter and the state of the machine flags using a push-down list. These instructions are valuable in implementing reentrant and recursive procedures.

Floating Point Hardware

Every PDP-10 has full floating point hardware with which the PDP-10 36-bit word length gives a precision of 8 decimal digits in single precision.

Power Fail Safe

Every PDP-10 is equipped with a power failure detection circuit which, if enabled, will cause an interrupt should power go out of limits. The program can then save all volatile registers.

Temperature Protection

Strategically placed thermostats detect overly high temperature conditions and can trigger logic which will generate an interrupt.

LANGUAGE PROCESSORS

FORTRAN IV

PDP-10 FORTRAN is a super set of the ASA Standard. The Compiler operates under any of the PDP-10 monitors. Temporary storage devices are not required during compilation and users can specify I/O devices. The FORTRAN library contains all scientific functions specified by ASA standards, along with utility programs such as DUMP, PDUMP, DATE and TIME.

BASIC

Advanced BASIC* is a conversational, problem-solving language for scientific, business, and educational applications. BASIC produces machine language directly and runs at high speed in minimal core. BASIC, a reentrant compiler, has internal editing and debugging capabilities, provides 13 commands for easy matrix computation and handles single alphabetic, numeric, and alphanumeric strings. The user can also store and access information on any mass storage device and request teletype output in desired formats.

*BASIC is the trademark of Dartmouth College.

COBOL

Based upon the August 1968 ANSI level 2 specifications, the PDP-10 COBOL compiler contains features which improve its usefulness for timesharing. For instance, user-developed programs are reentrant, and the timeshared terminal may be used during compilation to enter programs and control information or to obtain instructions from the compiler or monitor. The terminal may also be used as an input/output device for remote storage and retrieval. PDP-10 COBOL contains a separate Report Generator Program written in COBOL.

ALGOL

The ALGOL compiler is a complete subset of ALGOL 60 with a number of added features which include string handling facilities via a formal string mechanism, byte manipulator, double precision floating point facilities, assignments within expressions, facilities for separate compilation of procedures, modulus operator, and octal constants.

MACRO-10 is a powerful two-pass assembler which provides direct access to the PDP-10's 366 instructions. It is completely device independent, allowing the user to specify input and output devices at run time. MACRO-10 contains complete macro facilities, conditional assembly features, concatenation of completely general argument strings, indefinite repeat operations, and unlimited nesting of macros.

AID

AID is an easy-to-use language for solving engineering and scientific problems. Based on the JOSS* language, AID allows the user to state his problem as formulae and receive results in symbolic form. AID provides facilities for editing, program storage and recall on disk, and the ability to create new programs by combining existing program segments.

*JOSS is the trademark of the Rand Corporation

UTILITY PROGRAMS

TECO

TECO is an extremely powerful and concise text editing language with more than 30 commands for inserting, deleting, appending, searching, and displaying text. Editing is performed on a character, line or variable-character string basis. In addition to conventional editing operations, it also performs interactive string search, match, and substitution operations.

EDITOR

EDITOR is an easy-to-use line editor that produces or modifies MACRO, FORTRAN, or other source files from a teletype. It contains commands for inserting, deleting, printing, and sequencing lines of text. Versions of EDITOR are available for use with either DECtape or disk storage.

PIP

PIP transfers files between standard input/output devices, eliminating the need for a satellite computer. PIP also can perform merging, editing, sequencing, and syntax checking.

DDT-10

This widely copied DEC program applies more than 50 commands to the conversational on-line debugging of any MACRO-10, FORTRAN IV, or COBOL program. The user can stop the running program and examine or modify data and instructions in terms of his own symbols or FORTRAN statement numbers. DDT is also used to search a program for a particular instruction, data, or effective address.

Other utility programs for the PDP-10 include a monitor system builder, a file updating system, and programs for cross-reference listing, code translation, and source and binary comparisons. Additional programs allow the user to obtain a summary of file system status, receive an on-demand summary of system status on his teletype, and save or retrieve selected disk files on a backup magnetic tape.

LOADER

LOADER assigns consecutive core space and loads independently assembled or compiled programs prior to execution. Core occupied by the LOADER program is recoverable after loading. Special options include chaining facilities, storage map listing, and automatic library searching.

DIAGNOSTIC PROGRAMS

System operation is checked by a comprehensive set of diagnostic routines supplied with each PDP-10 system. In many cases, the diagnostic programs operate under control of the timesharing monitors and may be run without system downtime.

LANGUAGES AVAILABLE FROM DECUS*

LISP

LISP is a general-purpose programming language which utilizes a list-structure storage scheme for both program and data. It is primarily suited for manipulation of symbolic quantities, although it offers arbitrary precision arithmetic as well. LISP functions may be recursive. This package is a current version of LISP 1.6 and includes LISP compiler and editing sub-system.

SNOBOL-10

With only minor exceptions, SNOBOL-10 is compatible with Version 2.0 of SNOBOL-4 as released by Bell Telephone Laboratories. SNOBOL is a symbol manipulation language and is a useful tool in compilation, machine simulation, symbolic mathematics, text preparation, and language translators.

SCHOLAR/TEACH

Compared to many systems for computer-assisted instruction, "SCHOLAR/TEACH" requires fewer hours for lesson preparation. An instructor should be able to devote more time to the content and quality of his lesson and less to coding and pre-structuring. Neither does he need to spend as much time initially in familiarizing himself with the system.

GASP II

GASP II is a discrete simulation language which consists of a set of FORTRAN subprograms.

APL**

A Programming **L**anguage was conceived and developed by Dr. Kenneth Iverson. The language is based on a consistent unification and extension of existing mathematical notations, and upon a systematic extension of a small set of basic arithmetic and logical operations to vectors, matrices and trees.

CSMP

CSMP is a continuous system modeling program written in FORTRAN.

*Digital Equipment Computer Users Society

**Currently under development

CUSTOM DESIGN

DEC provides custom peripheral equipment and custom PDP-10 systems. These customized systems and equipment are fully tested and carry the standard DEC warranty. All custom equipment designed by DEC can be included in standard service contracts, if desired, at the expiration of the warranty period. Custom equipment and test routines for it are fully documented.

We recognize that our multiprocessor systems present particularly stringent hardware and software design requirements. Consequently, a team of specialists experienced in multiprocessor applications is available to provide assistance in system configuration and design, program design, system testing, documentation and installation. Factory assembly of multiprocessor systems before delivery and close liaison with customers during testing assure a smooth installation and minimize the time required to get the system up and running.

INTERPROCESSOR UNITS

Peripheral Switch (DT01C)

The peripheral switch is an electronic switch which enables two PDP-10 central processors to share peripherals. Each processor can request use of the switch, and when the request is granted, the processor has exclusive access to the peripherals. The switch contains a 36-bit register which is used as an interprocessor buffer accessible by both processors and serves as a means for control and communication. The DT01C is used to link together a chain of peripherals which can then attach to the I/O bus of the processor having switch control. All peripherals in the chain can be accessed by this processor. The other processor is locked out from the peripheral chain until it requests and is granted control of the switch. Peripherals which are used exclusively by only one processor are positioned on its I/O Bus and not attached to the switch.

Memory Bus Switch (DT04C)

The memory bus switch is an electronic switching element which allows sharing of peripherals that use direct memory access. The switch is under program control thru the I/O busses of both processors. It is normally used in conjunction with a DT01C unit to allow simultaneous switching of both the I/O bus and the memory bus.

Peripheral Switch Control (DT03C)

The peripheral switch control will control up to eight peripheral switches for the purpose of sharing peripherals between two processors. It offers more flexibility of configuration than the DT01C. Each peripheral to be switched must include two DT03 switches.

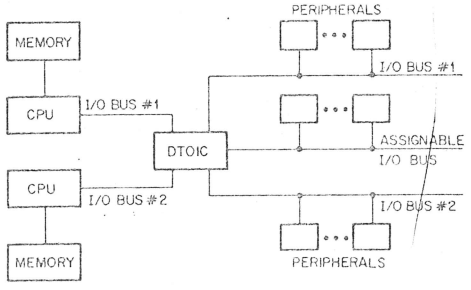


Figure 1 PERIPHERALS SWITCH

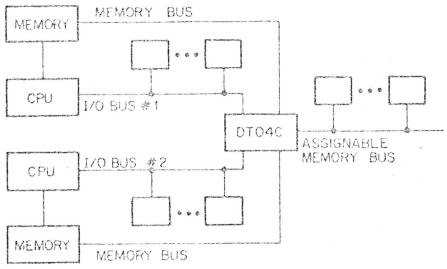


Figure 2 MEMORY BUS SWITCH

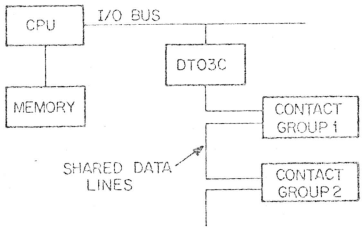


Figure 3 PERIPHERAL SWITCH CONTROL

DATA COMMUNICATIONS

Data Line Scanner* (DC10)

This unit provides a timesharing, two-way interface between the PDP-10 and a maximum of sixty-four serial asynchronous lines. Any device using 5- or 8-level teletype code can be handled by the DC10 at speeds up to 100KB. Standard software supports ASCII. Data lines to the devices are serviced either on demand or under program control, but servicing is controlled by the central processor on a priority interrupt basis. In operation, the DC10 continually scans the eight possible 8-line groups looking for a flag that is set. Once found, it scans within the group for the appropriate line and then causes a program interrupt on the program interrupt channel assigned to the data line scanner.

Data Communications System* (DC68A)

This system handles communications from up to 63† lines at speeds of 110, 150, and 300 Baud. The system is built around a rack-mounted 4K PDP-8/I and DA10 interface for interconnecting the processors.

Extended Memory Interface

The extended memory interface allows a PDP-11 to directly address PDP-10 memory. A DA11C provides the level conversion and major control for up to four PDP-11s with each PDP-11 having an additional piece of controlling hardware. Additional documentation is available.

I/O Bus to Synchronous Modem* (DS10)

The I/O bus is fully software supported and connects a PDP-10 to a synchronous full-duplex data line operating at voice-grade rates. The software supports use of the DS10 in conjunction with a DC71 (PDP-8/I) remote batch terminal.

In addition to providing the units listed above, DEC has the capability to interface any network of PDP computers to other types of processors. A number of special purpose interfaces also exists for linking the PDP-10 to many of the very large computer systems now in use.

* Standard PDP-10 Product
† Performance at 110 Baud

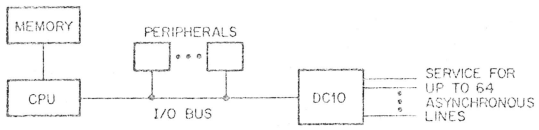


Figure 4 DATA LINE SCANNER

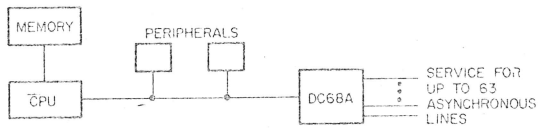


Figure 5 DATA COMMUNICATIONS SYSTEM

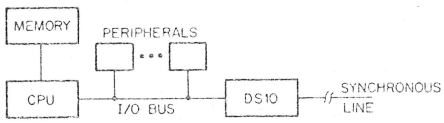


Figure 6 I/O BUS TO SYNCHRONOUS MODEM

INTERPROCESSOR CONNECTIONS

Extended Memory Interface (DA15C)

The DA15C is an interface between a PDP-10 and a PDP-15. It extends the addressing space of the PDP-15 beyond its physical memory size by allowing the PDP-15 to read and write directly into PDP-10 memory. Two 18-bit PDP-15 words are stored in each PDP-10 location. The interface connects to the memory and I/O busses of both processors. Control and status information are transferred under program control to activate or deactivate the interface. Protection and relocation registers in the interface allow the blocks of PDP-10 memory addressable by the PDP-15 to be dynamic; i.e., under monitor control the interface can be deactivated, the block moved within memory, and the registers updated. The monitor then reactivates the interface to resume normal operations. Block size can be chosen in 1K increments by setting the interface protection register through PDP-10 program control.

Memory-to-Memory Interface (DA25)

This direct memory-to-memory interface between a PDP-10 and PDP-8, PDP-12, or PDP-15 allows block transfers of data in a single-cycle break mode. Hardware design allows for a combination of sixteen processors to be connected directly to the PDP-10 memory. Block transfers in either direction are initiated under program control and the processors are immediately freed to continue program execution. The interface associates a unique device number with each satellite processor, which can be addressed to connect the satellite to the PDP-10. When the connection is free, the PDP-10 end is placed in a scan mode to check for any satellite

requesting service. Data is sent by a request/response method. Because of the asynchronous nature of this link, bus lengths of a few thousand feet can be accommodated. (Line drivers are required for distances over 100 feet.)

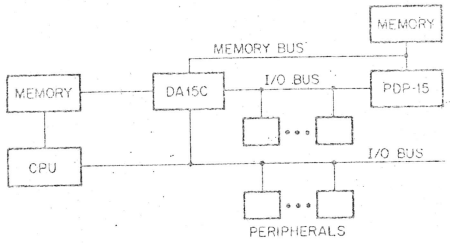


Figure 7 EXTENDED MEMORY INTERFACE

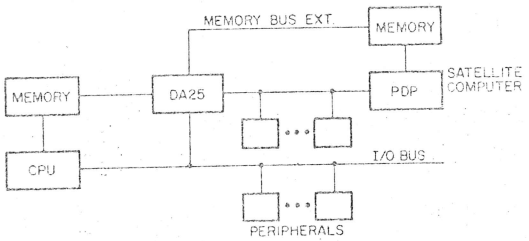


Figure 8 MEMORY-TO-MEMORY INTERFACE

DISPLAY EQUIPMENT

Interactive Graphics Terminal (VB10C)

The graphics terminal is a highly interactive display for the PDP-10. It was designed to allow complete user freedom and flexibility under normal PDP-10 timesharing.

Its basic hardware consists of a display connected directly to PDP-10 memory through a special memory interface. Several important features included in the display are memory protection and relocation, character mode operation, vector mode, and subroutining. To allow complete user-display interaction, the graphics terminal has a function box, lightpen and a Rand tablet as options.

A most important feature of the display is the extensive software control package available from DECUS. This package permits a user unfamiliar with the hardware instructions for the display to generate and manipulate display pictures from FORTRAN or LISP.

The software package contains all of the basic routines for displaying vectors, points, and text, and for controlling the scale and intensity of the picture. The user can define his own number space or sets of number spaces and the viewports on the display CRT where the pictures are to be displayed.

Any part of a picture which falls outside of the user's number space or window will not be displayed. Pictures can be generated as a set of sub-pictures or nested sub-pictures. Sub-pictures and pictures can be blanked from the display and unblanked at a later time. The package also contains all of the routines necessary to create three-dimensional pictures. The user can rotate the picture or zoom in or back off from a picture by changing the viewport value. Core space used by a picture can be released and reused for generating new pictures.

The graphics terminal provides several levels of user interaction. Simple data inputs can be entered through the function box to the teletype. The identification of lines or points within a picture can be accomplished with the lightpen. Perhaps the most important interactive feature of the terminal is that a user can input graphic data through the Rand tablet and "see" that data on the CRT in real-time. An architect, for example, could draw new structures, a mathematician could input new curves, an electrical engineer could add new connections during circuit design, all with no more difficulty than drawing on a piece of paper.

ANALOG TO DIGITAL CONVERTERS

The analog input subsystem combines a reliable solid state multiplexer with a high resolution analog-to-digital converter for data acquisition and reduction of time-dependent analog voltage signals from laboratory devices such as gas chromatographs.

PHA/ADC Interfaces

DEC will interface any of several nuclear physics oriented analog to digital converters to PDP-10 and/or other PDP computers. The ADC's are supplied by the customer and shipped to our factory for installation in the system. Connection may be made to the PDP-10 over the I/O bus, direct-to-memory, or through a small computer. Data input may take the form of a list of conversions stored in alternate buffer areas in core or of a memory increment mode where the ADC word specified a memory address and the content of that memory location is incremented by one. Both singles and coincidence modes are available.

One attractive concept is to interface the ADCs to a PDP-15 and interface the PDP-15 directly to PDP-10 memory with a DA15C.

DIGITAL INPUT UNITS

Flag Input Unit (FI10)

This 36-bit pulse input unit generates a program interrupt request whenever one or more of the lines connected to it changes from a zero to a one. The central processor will respond to this interrupt by reading in the entire 36-bit word and then locating the bits which are ones. The PDP-10 instruction JFFO (find first one and jump) is particularly useful in performing this function.

The flag input unit recognizes the absolute voltage changes on the input lines (variations in rise times are unimportant). The unit contains a 3-bit hardware register to allow its assignment to one of the seven PDP-10 priority levels. The data register is double-buffered to allow synchronization and thus avoid loss of information.

Contact Interrogation Unit (DS03C)

One of the significant costs incurred in the scanning of multiple contacts can be the cost of wiring. To minimize this expsnse, the DS03C uses a bus system in which the

contacts are interrogated and the data lines are shared, thereby reducing the number of lines needed to transmit the data to the central processor. This contact interrogation approach dictates that both sides of the contact must be available. Each interrogation provides up to 36-bits of contact status information.

Up to 128 words of contact information can be handled by the control section of a DS03C. Each word is both sequentially and randomly addressable.

TYPICAL INSTALLATIONS

Computer Science

An artifical intelligence laboratory uses a dual processor PDP-10/PDP-6 system that includes shared memory and an I/O bus switch which allows sharing of peripherals. Currently, the PDP-6 controls the motions of a mechanical arm through a digital servo network, while the PDP-10 operates a color display built by DEC.

Dual processor software is under development by laboratory personnel. A type 340/346 display is used to study system loading and observe the passage of jobs through the system. The various job queues and their occupancy—maintained by the scheduler—may be displayed.

A chess playing program of national fame has been developed for the PDP-6/10 by laboratory personnel. They have also produced a music compiler capable of producing compiled output for six simultaneous voices. With this compiler, tempo, pitch, key, and musical note embellishments are all programmable. Unlike normal instruments, the computer is self-tuning. The chess and the music compiler are available from DECUS.

Physics

A national laboratory has established a National Neutron Cross Section Center based on a PDP-10 timeshared computer and a high speed CRT display system. The PDP-10 provides large-scale graphic systems with the support, maintenance, and simultaneous access of a data base by multiple users. In addition, it provides high speed data busses, a powerful instruction set, and timesharing and interactive languages.

At the same laboratory an on-line data facility was set up within the Physics Department to perform high energy counter and spark chamber hodoscope on-line computer experiments. The equipment, together with a dual processor PDP-10/PDP-6 system, is in vans located in the main experimental hall of the synchrotron accelerator.

Since mid-1965, the facility has been running five to ten real-time jobs simultaneously. With the addition of the PDP-10, the number will increase. Thus the timesharing aspects of the PDP-10 are of significant importance.

This on-line use of a powerful computer in high energy physics has demonstrated that research can be much more efficient than the traditional off-line analysis of bubble chamber film (PEPR), especially when the experiment has high data rates and low cross section.

The PDP-10 at a Department of Nuclear Physics in the United Kingdom operates with a PDP-7 in nuclear research. The PDP-7 supports three vector displays and monitors a linear accelerator, while the 48K PDP-10 provides computational power for complex mathematical modeling. The PDP-7 also includes customer-built interfaces to devices of other manufacturers.

The physics laboratory of a German university uses a PDP-10 for nuclear physics research. The 32K timesharing system operates a 10/40 monitor with a PDP-8/I for data acquisition. A direct memory interface (DA25) couples the PDP-10 and PDP-8.

Communications software to support the interface was also provided by DEC. The software allows high speed transfers in both directions so that data acquired by the PDP-8/I can be passed to the PDP-10 for processing, and formatted data can be sent back to the PDP-8/I for real-time CRT display.

The A/D converter data is collected in the PDP-8/I memory using a double buffering scheme. When one buffer is filled, the A/D converter starts filling the second buffer as the PDP-10 empties the first one. The PDP-10 is used to analyze the incoming data and create real-time display information which is displayed by the PDP-8 concurrently with data acquisition.

Pulse height analysis software was supplied with the system by a vendor employed by the University, and tested by DEC prior to shipment of the PDP-8/I system. The application software allows data acquisition in both singles and group mode from four A/D converters as well as various types of PHA display formats with lightpen routines to permit moving of marker, locating peaks, etc.

FORTRAN data reduction programs developed at the tandem laboratory of a New York university will be used to process the data and to obtain final results.

As an additional benefit the PDP-8/I teletype can be used as a PDP-10 terminal for program development. The PDP-8 programs can be assembled by the PDP-10 using PAL-10 and, after assembly, may be loaded into the PDP-8/I for execution.

The system includes a KA10 processor with fast registers and dual memory protection and relocation registers, 32K of MB10 memory, 2 DECtapes, 2 magtapes, the memory-to-memory interface (DA25), the PDP-8/I with 8K of memory, CRT data break display with a VR12, a data break multiplexer, 10-MD A/D converters, 8 scalers, even registers and A/D converter configuration selection switches.

Medical

A government medical research laboratory in Bethesda, Maryland, has installed a large PDP-10 swapping system to serve as the hub of a laboratory-wide computer complex. In addition to providing timesharing services, the PDP-10 is coupled to a powerful CRT display processor for research in biomedical image processing.

The display processor is highly interactive and operates directly on the PDP-10 memory bus. Laboratory personnel have written a complete software package containing all the routines needed for generating

vectors, points, and text. With display service routines—supplied by DIGITAL—added to the swapping monitor, the system provides dynamic displays in real-time simultaneously with timesharing.

The software package lets the users generate and manipulate display files from FORTRAN and LISP; there is no need to understand display hardware. A Rand tablet, for the input of graphical data, is supported by a complete software package that links the tablet input with user display files. Complete software documentation is available from DECUS.

The installation includes 64K of core memory, a line printer, a card reader, two swapping disks, 6 DECtapes, and 3 magnetic tapes.

Located in the computing center of a medical research laboratory, a PDP-10 performs statistical analysis of data stored in massive magtape files as well as other computing functions under timesharing. Future plans call for links between the system and PDP-8 terminals located up to 150 miles away.

The laboratory is currently developing an information storage and retrieval system so that the procedure of maintaining records and scheduling appointments for several thousand blood donors may be automated. When fully implemented, a computer local to the blood bank will be interfaced to blood analyzers and communicate over a high speed link with the PDP-10. Remote terminals will be concentrated by the blood bank's computer so that operating personnel can interact directly with the PDP-10 and its data files.

A university is using a PDP-10 for biomedical image processing in chromosome studies, but hopes to branch out to other areas such as X-ray processing and X-ray enhancement.

An automatic microscope locates slide-mounted blood cells in metaphase (a stage in cell division when chromosomes are most easily observed) and signals a PDP-7 which digitizes the image with a flying spot scanner. The PDP-7 then signals the PDP-10 which accepts the data, stores it on disks and performs the analysis.

The system has 32K of core memory of mixed speeds, DECtape, a card reader and a line printer. A swapping monitor is used although only three terminals are employed, one of them being the console teletype on the PDP-7. The PDP-7 software operates in two modes: local PDP-7 mode and PDP-10 terminal mode.

Manufacture

A system at the engine division of a world renowned manufacturer uses a PDP-10 in conjunction with PDP-8s and two ICL computers. The PDP-8s monitor and control the test beds for the Concorde's jet engine as well as other engines readied for on-line testing. The data they collect is fed to the PDP-10 which, in turn, routes it to the ICL machines which provide the computational power. Results of the engine analyses are stored in files managed by the PDP-10 and easily accessible to researchers using timesharing terminals. The terminals can also be used to change the parameters of the tests by initiating appropriate commands to the PDP-8s.

A PDP-10 monitors the structural testing of the Concorde supersonic commercial transport. The results of these tests will lead to the craft's certificate of airworthiness. The project has been labeled one of the "most elaborate structural tests ever carried out."

The tests dynamically apply loads to the fuselage of the plane, under continuous computer control, and continuously monitor the stress effects. The test program will continue throughout the service life of the Concorde.

The testing system also uses two of DEC's PDP-8/I computers, one to control the operation of the loading jacks and the other to monitor operations.

A DEC CRT display will be used to examine accumulated data and assist technical personnel in their efforts to analyze and interpret test results. The display includes a high speed lightpen, remote slave display and hardware for generating vectors, characters, and increments. The display is interfaced directly to memory and is fully capable of generating images without processor overhead. DEC provided the monitor software to drive the display. A package which allows the user to program the display in FORTRAN IV is available from DECUS.

Hybrid Computation

A PDP-10 at the plant of a helicopter manufacturer is interfaced to an Applied Dynamics AD-4 100 V analog computer and is used to perform helicopter design simulations. Software for the hybrid interface was supplied by Applied Dynamics and written by Applied Programming Technology, Sudbury, Massachusetts.

A consulting firm in Houston, Texas, has interfaced a Hybrid Systems, Inc., SS-100 general-purpose analog computer to a PDP-10. The interface was designed and implemented by the consultant's personnel.

At rates exceeding 1000 per second, the system provides interactive solutions to differential equations encountered in the chemical, oil, and steel industries, in oceanographic and biomedical research, and in engineering and construction. The system is also used in simulation and optimization studies.

A/D and D/A data are transferred directly to and from PDP-10 memory and the SS-100 while control and command information is transmitted and received over the PDP-10 I/O bus. FORTRAN IV callable subroutines, written by the consultants, complete the package.

A PDP-10 in the Electrical Engineering Department's "Hybrid Computing Laboratory" is interfaced to an EAI 680 analog computer. The PDP-10 functions as a logic controller for the analog computer, and serves in simulation studies—for research and instruction—performed under timesharing.

Engineering applications of the system include high-speed analog data conversion from tape and remote inputs, control optimization studies, system simulation, network design, biomedical simulation, pattern recognition, and solution of complex systems of partial differential equations.

The system is also being used to research such diverse subjects as weather forecasting, human performance, building design, ionosphere wave propagation, and mining systems.

For instructional purposes, the system can be operated from 8 console booths, each with a KSR-33 teletype. Through timesharing, students can work on a common problem previously set up on the analog plugboard, supplying parameters and conditions of their own choice. Or, the students may work on different problems by using various sections of the plugboard. The students, who are required to have previous analog and digital (FORTRAN) programming experience, work on such problems as parameter optimization, Monte Carlo methods, and difference approximations to partial differential equations.

The system includes 16K of core memory, a 346/340 display with a lightpen, DECtape, a teleprinter, 8 teletypes, and the hybrid interface.

The hybrid interface, together with the MACRO subroutines callable from FORTRAN IV, were supplied by EAI. The interface is an EAI 693 system with 24 A/D channels (multiplexed), 14 bits with 20 μsec conversion time and 8 D/A (4 multiplying type), 15 bits with 40 μsec conversion time.

Manufacturing Control

A PDP-10 at a metal manufacturing facility in Ohio acts as a timeshared management information system. Its major functions are to: maintain a central data bank, perform manufacturing control functions (including production scheduling, demand forecasting, order shipment, etc.), provide management reports, and perform miscellaneous management and engineering calculations.

Through timesharing, management has immediate access to the status of any order, process, or inventory. At the same time, this data is available to programs which control, schedule, or forecast plant needs. The system eliminates manual record keeping by collecting, on-line, the data needed for sound management decision making.

Orders, schedules, etc. are updated directly from console teletypes and from an on-line data collection system tied directly into plant processes. Plant personnel using the teletypes are requested to enter specific data in a fixed format. Thus the system is self-tutoring and does not require extensive employee training. Response is so fast that each operator appears to have exclusive use of the computer.

The on-line data collection sub-system includes relay contacts to determine the status of plant devices and a multiplexed low-level integrating digital voltmeter to read the voltages of a variety of measuring instruments. The relay contacts are interfaced to the PDP-10 via the Contact Interrogation Unit, which can be expanded to 4608 individual contacts. The status of 36 of these contacts may be read by a single PDP-10 instruction.

System control functions include production scheduling, demand forecasting and shipping. Like the data acquisition programs, the control programs run under the timesharing monitor; they are resident in core only when active. The programs may be written in any PDP-10 programming language—FORTRAN IV, COBOL, BASIC, or MACRO-10. Control programs may have access to the central data file as data upon which to base control decisions. Control programs also have access to all system peripherals such as line printers, DECtape, and disk.

The management reporting system is implemented in the same manner as the system control functions, via user-level programs written by plant personnel. The system is designed to provide specific information upon request or when exceptional conditions exist which require management decisions. Its basic philosophy minimizes the volume of reports and maximizes the value of information generated; overall emphasis is upon management control by exception.

CUSTOMER SERVICE AND SUPPORT

The DEC Team

Account Representative

The account representative—the leader of the account team—is the primary contact with DEC and has ultimate responsibility for the success of PDP-10 systems. It is his job to understand needs and to supply technical, pricing, and delivery information.

Software Specialist

The team's software specialist provides technical assistance to analysts and programmers concerning DEC-supplied software. He supplies technical advice to improve the effectiveness and efficiency of an installation.

Field Service Representative

The team's field service representative provides continuing PDP-10 maintenance on either an on-call or resident engineer contract. Local, immediate service is the trademark of DEC field service representatives.

PDP-10 Marketing Staff

The PDP-10 marketing staff has a wealth of information on PDP-10 configurations and applications at a large number of colleges and universities. Inquiries should be made through a DEC account representative or directly to:

PDP-10 Marketing
Digital Equipment Corporation
146 Main Street
Maynard, Massachusetts 01754
617/897-5111

Training

The following PDP-10 courses are given regularly at DEC's Maynard, Massachusetts, Training Facility. The current schedule is available from DEC account representatives.

The Programming Course, which covers the fundamentals of PDP-10 machine language programming, is designed to acquaint the student with the most effective use of PDP-10 hardware and software (two weeks).

The Monitor Course demonstrates PDP-10 monitor

systems and the methods of modifying them to meet specific needs (two weeks).

The Maintenance Course familiarizes the student with system logic of PDP-10 hardware including the processor, memory, and DECtape systems (five weeks). Other peripherals are covered in a supplementary course. If demand warrants, these courses can be taught at individual customer locations.

Documentation

Much of the success of any computer system is a function of the quality and availability of documentation. To meet customers' varying needs, DEC supplies three types of PDP-10 documentation: software notebooks, handbooks, and applications software bulletins.

PDP-10 customers receive copies of a looseleaf software notebook, a complete reference source that is amended quarterly with updates and improvements. In addition to providing reference material in easy-to-update form, the notebook allows customers with special requirements to print their own manuals*. Notebook contents are printed on high quality paper in 8-1/2" x 11" format.

*Permission for reprinting must be granted by DEC.

Handbooks, the second type of PDP-10 documentation, compile what were formerly individual manuals into groups for convenient customer use. For example, the PDP-10 Reference Handbook provides the systems programmer with all the necessary reference material to communicate with the monitor and to write, edit, debug and operate machine language programs.

Another handbook, the PDP-10 Timesharing Handbook, is intended for the timesharing terminal user, providing him with the information and instruction to write and operate programs in most of the higher level languages.

The third type of documentation, the PDP-10 Applications Software Bulletin, is meant to serve as a catalog of application software available on the PDP-10 in addition to standard DEC supported software. The bulletin is divided into two groupings: (1) DECUS contributions, and (2) PDP-10 software for trade or sale.

Copies may be obtained from the DEC account representative or large orders may be purchased at quantity discounts from: Direct Mail Department, Digital Equipment Corporation, 146 Main Street, Maynard, Massachusetts 01754.

DECUS

Digital Equipment Computer Users Society (DECUS) is a voluntary, non-profit users group supported by DEC. Its 9,000 members from the United States and 40 foreign countries constitute one of the most active users groups in the world. DECUS publishes DECUSCOPE, a bimonthly newsletter, and sponsors symposia each spring and fall in the United States and once a year in Europe, Canada and Australia. The DECUS Program Library contains a wide variety of programs for all DEC products from special executive routines to editors, debugging systems, and games. These programs are contributed by the users and a catalog listing the programs is available.

DECUS also encourages the subgrouping of users with special interests. For example, PDP-6/PDP-10 users have formed a special group which meets at DECUS symposia to exchange information through technical papers and discussions.

Individual application forms are available from local DEC offices or from the DECUS Executive Director, Digital Equipment Corporation, 146 Main Street, Maynard, Massachusetts 01754.

DEC Supplies

DEC has a complete line of operating supplies, which includes DECtape, LINCtape, standard magnetic tape, paper tape, tape storage racks and accessories, or printer paper and ribbons, and miscellaneous items.