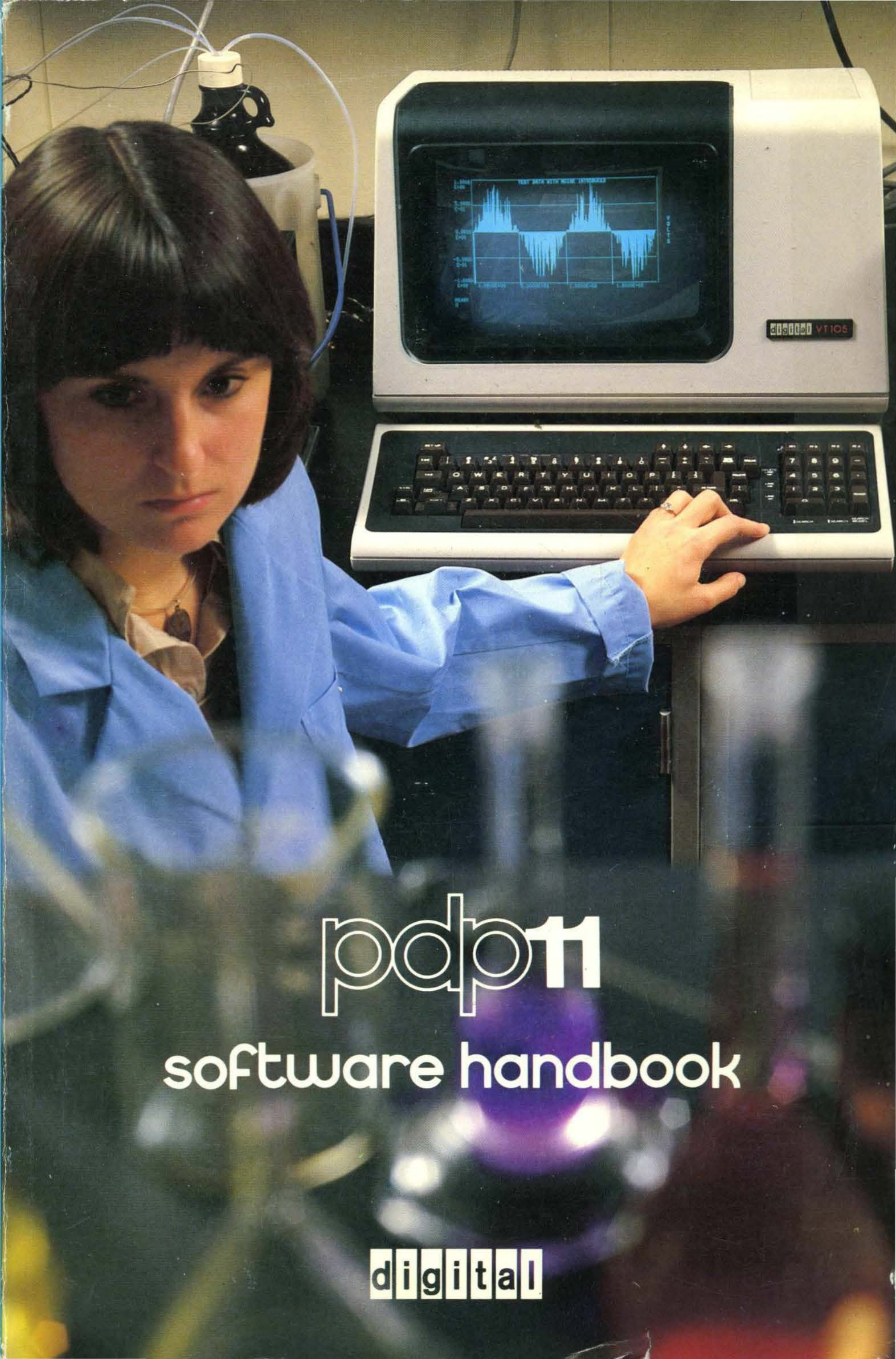

pdp11 software handbook

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DIGITAL Facility, Maynard, Massachusetts

CORPORATE PROFILE

Digital Equipment Corporation designs, manufactures, sells and services computers and associated peripheral equipment, and related software and supplies. The Company's products are used world-wide in a wide variety of applications and programs, including scientific research, computation, communications, education, data analysis, industrial control, timesharing, commercial data processing, word processing, health care, instrumentation, engineering and simulation.

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PREFACE

This Handbook is intended for a spectrum of customers with varying expertise; so, if you are reading about computer software for the first time or if you are an expert, you will be able to learn something new, and to make better informed decisions about DIGITAL operating systems and associated software.

It is not necessary to read straight through this Handbook to get a view of PDP-11 software. Whether you are interested in the higher-level programming languages, the user level utilities, the data managers, networks, or the operating systems themselves, you will find a concise description and an explanation of the benefits to be derived from each software product. The Table of Contents gives details of the chapters and should help you find material of interest. For example, if you are reading about computers for the first time, you will probably want to read Chapters 1 and 2. Operators and users may want to go directly to the chapters that describe programming languages, operating systems, file management, database management, and distributed processing and networks.

The goal of this Handbook is to introduce the system software without delving into the degree of technicality one finds in the user documentation delivered with the system. A glossary of software terms, an alphabetic listing of most commonly used abbreviations, and a thorough index are included for the convenience of the reader. There is also an appendix on the resources of DECUS, the Digital Equipment Computer Users Society, from which members can obtain specialized software developed by other members.

DIGITAL is constantly improving existing products and introducing new ones. Your best source for the latest word on software is your sales representative, who can keep you up to date on recent releases and enhancements to traditional products.

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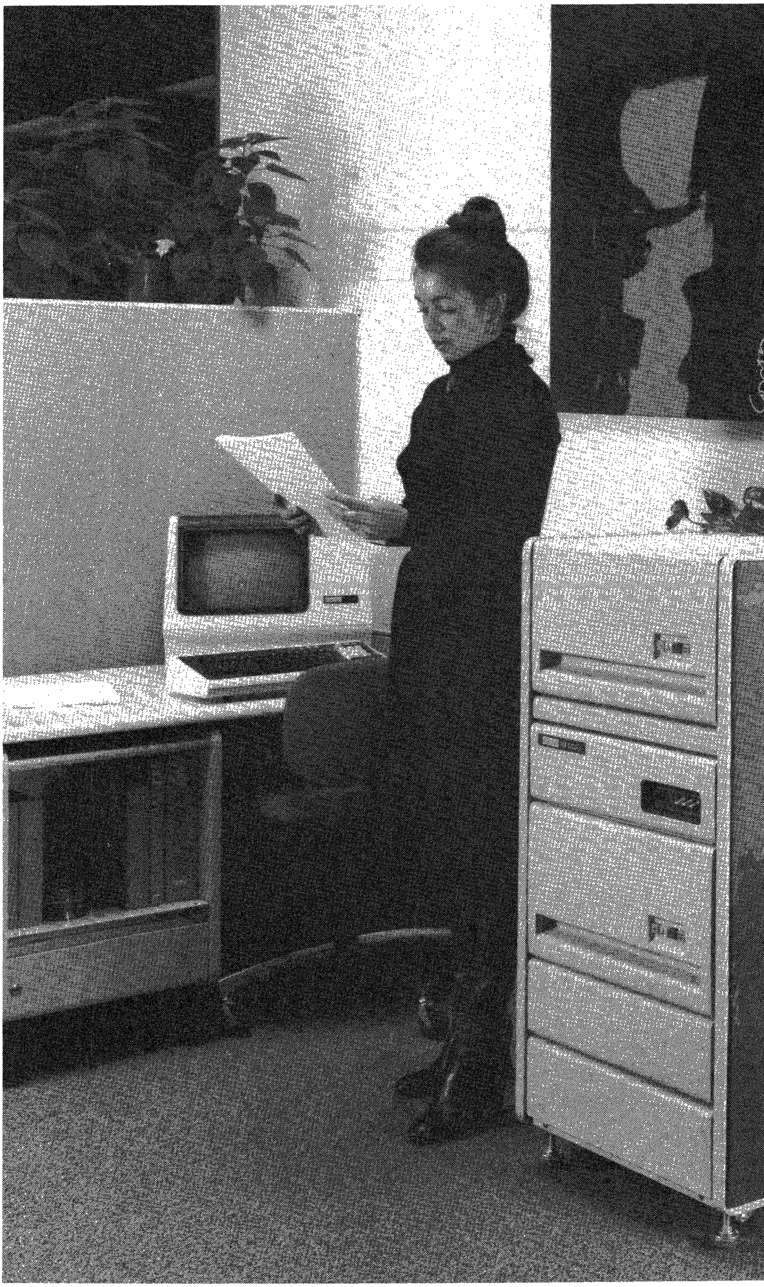


CHAPTER 1
INTRODUCTION TO PDP-11 SOFTWARE

HARDWARE/SOFTWARE SYSTEMS

The PDP-11 computer family is a wide range of compatible processors complemented by a variety of peripheral devices, software, and services.

This Handbook discusses the major software available for the PDP-11 family of computers, and explains its features and benefits. **Software** is the collection of programs or routines that allow people to use computer hardware. Generally speaking, **programming** creates and changes software, while engineering design alters hardware.

Since your computer hardware is only as useful as the software operating in conjunction with it, you should understand certain software concepts. This chapter and the next introduce basic concepts, at the same time briefly showing how DIGITAL implements those ideas.

Compatibility is a key feature of both hardware and software in the PDP-11 world. Small systems can grow easily into larger ones as your data processing needs increase. Your software can run in different PDP-11 hardware environments. For example, some operating systems can run on several processors, and all can grow to accommodate new languages, peripherals, and other improvements.

While a few of the characteristics of software may vary from application to application, compatibility helps guarantee that personnel and programs can move among systems with a minimum of trouble.

For example, the FORTRAN IV programming language runs on several operating systems, and a person who has learned FORTRAN IV could, with little difficulty, write programs that would run in several environments. Likewise, a FORTRAN IV application program can be readily transported to any DIGITAL PDP-11 system that supports the language.

The flexibility of PDP-11 hardware/software systems allows you to select both the most appropriate hardware for your particular application needs, and the operating system and languages that can serve your immediate requirements and still allow for possible growth.

COMMUNICATIONS SOFTWARE

DIGITAL produces powerful technology that permits the linking of computers and terminals into flexible configurations called networks. Networks can vastly increase the efficiency and cost-effectiveness of data processing operations. Chapter 24 outlines the gamut of PDP-11 networking and distributed processing capabilities.

OPERATING SYSTEMS

An operating system not only provides access to the features of a processor, it also organizes a processor and peripherals into useful tools for a certain range of applications. For example, there are systems that manage one user's task at a time. There are others that accept many tasks, and allocate use of the central processor according to a scheme of priorities, privileges, and time quotas. Some systems support realtime applications, that is, applications in which the computer is required to respond within given time limits to an external message, make a decision, and respond quickly (e.g., flight simulator control; power plant management; laboratory experiment supervision).

The operating systems featured in this Handbook are:

RSTS/E and CTS-500	Resource-Sharing Timesharing System/Extended Operating System for PDP-11 Processors A moderate to large-sized timesharing system, expressly designed to optimize the interplay between people and system; RSTS/E is used in a variety of multiuser applications ranging from business data processing to academic instruction.
RSX-11M	Realtime System Executive Operating System for PDP-11 Processors A small- to moderate-sized realtime multiprogramming system that can be generated for a wide range of application environments—from small, dedicated systems to large, multipurpose realtime application and program development systems.
RSX-11M-PLUS	Realtime System Executive Operating System-PLUS for high-end PDP-11 Processors A large realtime system meant to take advantage of enhanced hardware features and larger memory available on the PDP-11/44 and PDP-11/70 processors. RSX-11M-PLUS is a superset of RSX-11M.

RSX-11S	Realtime System Executive Operating System for PDP-11 Processors A small, execute-only member of the RSX-11 family for dedicated realtime multiprogramming applications (requires a host RSX-11M, RSX-11M-PLUS, IAS, or VAX/VMS system).
RT-11 and CTS-300	Realtime Operating System for PDP-11 Processors A small, single-user foreground/background system that can support a realtime application job's execution in the foreground and an interactive or batch program development job in the background.
DSM-11	DIGITAL Standard Mumps Operating System for PDP-11 Processors A small- to large-sized timesharing system that offers a unique fast-access data storage and retrieval system for large database processing; originally designed for medical record management and now available for similar database applications.

Chapter 2 of this Handbook defines and illustrates the concept of an operating system.

PACKAGED TOGETHER VS. SOLD SEPARATELY

Some software products are packaged with other products and sold together as a unit. The RSTS/E operating system includes a BASIC-PLUS language processor; MUMPS-11 language is inseparable from the DSM operating system. Similarly, one form or another of the Record Management Services (RMS) is included in each operating system that supports them.

Separately sold products, on the other hand, are distinct options, not necessarily included as part of any other software. Special application software packages (such as stress analysis, statistical analysis, or general accounting) are sold separately from the operating systems they work with.

The flexibility produced by this approach aids in tailoring a system to your specific needs, without sacrificing or omitting vital routines and utilities.

DIGITAL's operating systems support a considerable variety of software products, both those that are packaged together and those that are sold separately, along with numerous central processors and peripherals. The three tables which follow, compare the processors on which PDP-11 operating systems run, the languages supported under each system, and the configurations of typical systems.

Since both hardware and software are continually evolving and being improved, these tables are meant to be used as guides to what is currently available.

Table 1-1 Processors

Operating Systems	Processors								
	PDP-11 Family								
	LSI-11/2 Based	11/03L	11/23	11/23-PLUS	11/04	11/24	11/34	11/44	11/70
RT-11–foreground/background or single-job operating system	X	X	X	X	X		X	X	
DSM-11–multiuser data base management system			X			X	X	X	X
RSX-11S–execute only real-time, multiprogramming system	X	X	X	X	X	X	X	X	X
RSX-11M–small to moderate sized real-time, multiprogramming system			X	X	X	X	X	X	X
RSX-11M-PLUS–moderate sized real-time, multiprogramming system				X		X		X	X
RSTS/E–general-purpose timesharing system				X		X	X	X	X
IAS–multipurpose, multiprogramming system							X	X	X

Table 1-2 Languages

Languages	Operating Systems						
	PDP-11 Family						
	RT-11	DSM-11	RSTS/E	RSX-11M	RSX-11M-PLUS	RSX-11S	IAS
MACRO Assembler	X		X	X	X	X[1]	X
BASIC-11	X			X	X		X
BASIC PLUS			X				
MU BASIC	X						
BASIC-PLUS-2			X	X	X		X
PDP-11 COBOL			X	X	X		X
COBOL-81			X	X	X		
FORTRAN-77			X	X	X	X[1]	X
FORTRAN-IV	X		X	X	X	X[1]	X
Standard MUMPS		X					
CORAL 66				X		X	X
PEARL				X			
MICROPOWER/PASCAL	X						

[1] Task Execution only.

Table 1-3 (cont.) Typical System

TOPIC	DSM-11
SYSTEM TYPE:	Data management timesharing facilities for up to 63 simultaneous users which includes interactive users and detached jobs
CPU:	PDP-11/34 with KY11-LB PDP-11/23/24/44 PDP-11/70
TYPICAL SYSTEM DEVICES:	RL01 Cartridge disk drive RL02 Cartridge disk drive RK07 Cartridge disk drive RM02 Disk pack drive RM03 Disk pack drive RM05 Disk pack drive RP06 Disk pack drive
TYPICAL LOAD DEVICES:	RL01 Cartridge disk drive RL02 Cartridge disk drive RK07 Cartridge disk drive TS11 Magtape TE16 Magtape
MINIMUM MEMORY (bytes):	96K
MAXIMUM MEMORY SUPPORTED (bytes):	248K (PDP-11/23/34) 1M (PDP-11/24/44/70)
HIGH-LEVEL LANGUAGES:	ANSI STANDARD MUMPS
COMMUNICATION CAPABILITIES:	DMC11 (opt.) DMR11 (opt.)

Table 1-3 Typical System

TOPIC	RSTS/E
SYSTEM TYPE:	General timesharing; up to 63 simultaneous users, which includes interactive terminal users, detached jobs and batch processing.
CPU:	PDP-11/24 through PDP-11/70 with memory management and EIS
TYPICAL SYSTEM DEVICES:	RL02 Cartridge disk drive RK07 Cartridge disk drive RP06 Disk pack drive RM02 Disk pack drive RM03 Disk pack drive RM05 Disk pack drive
TYPICAL LOAD DEVICES:	TE16 Magtape TU77 Magtape RL01 Cartridge disk drive RL02 Cartridge disk drive RK07 Cartridge disk drive TS11 Magtape & Controller
MINIMUM MEMORY (bytes):	128K (without RMS) 248K (with RMS)
MAXIMUM MEMORY SUPPORTED (bytes):	248K (except PDP-11/44 and PDP-11/70) 1024K (PDP-11/24 and PDP-11/44) 3840K (PDP-11/70)
HIGH-LEVEL LANGUAGES:	BASIC-PLUS (inc.) FORTRAN IV (opt.) FORTRAN-77 (opt.) PDP-11 COBOL (opt.) COBOL-81 (opt.) BASIC-PLUS-2 (opt.)
COMMUNICATION CAPABILITIES:	RSTS/E-2780 (opt.) RSTS/E High Performance 2780/3780 Emulator (opt.) DECnet/E (opt.) RSTS/E 3271 PE (opt.) DX/RSTS (opt.)

Table 1-3 (cont.) Typical System

TOPIC	RSX-11M
SYSTEM TYPE:	Compact, efficient real-time multiprogramming applications and development system
CPU:	Any UNIBUS PDP-11 Processor and PDP-11/23, or PDP-11/70
TYPICAL SYSTEM DEVICES:	RK07 Cartridge disk drive RL02 Cartridge disk drive RP06 Disk pack drive RM02 Disk pack drive RM03 Disk pack drive
TYPICAL LOAD DEVICES:	RL01 Cartridge disk drive RL02 Cartridge disk drive RK07 Cartridge disk drive TE16 Magtape TS11 Magtape
MINIMUM MEMORY (bytes):	32K without concurrent program development 48K with concurrent program development and application execution
MAXIMUM MEMORY SUPPORTED (bytes):	56K (without memory management) 3840K (with memory management)
HIGH-LEVEL LANGUAGES:	FORTRAN IV (opt.) FORTRAN-77 (opt.) PDP-11 COBOL (opt.) COBOL-81 (opt.) BASIC (opt.) BASIC-PLUS-2 (opt.) CORAL-66 (opt.) PEARL-11 (opt.)
COMMUNICATION CAPABILITIES:	DECnet-11M (opt.) RSX-11 2780/3780 Emulator (opt.) RSX-11M/3271 PE (opt.) RJE/HASP (opt.) UN1004/RSX (opt.) MUX200/RSX-IAS (opt.) RSX-11M/SNA PE (opt.) RSX-11 PSI/FR (opt.) RSX-11 PSI/CAN (opt.) RSX DLX-11 (opt.) DX/11M (opt.)

Table 1-3 (cont.) Typical System

TOPIC	**RSX-11M-PLUS**
SYSTEM TYPE:	Moderate sized real-time multiprogramming system that is optimized for large multipurpose real-time applications and program development systems
CPU:	PDP-11/23-PLUS, 11/24, 11/44, 11/70
TYPICAL SYSTEM DEVICES:	RL02 Cartridge disk drive RK07 Cartridge disk drive RM02 Disk drive RM03 Disk drive RM05 Disk drive RP06 Disk drive
TYPICAL LOAD DEVICES:	RL02 Cartridge disk drive RK07 Cartridge disk drive TE16 Magtape TU77 Magtape TS11 Magtape
MINIMUM MEMORY (bytes):	256K
MAXIMUM MEMORY SUPPORTED (bytes):	3840K
HIGH-LEVEL LANGUAGES:	BASIC (opt.) BASIC-PLUS-2 (opt.) FORTRAN IV (opt.) FORTRAN-77 (opt.) PDP-11 COBOL (opt.) COBOL-81 (opt.)
COMMUNICATION CAPABILITIES:	DECnet-11M-PLUS (opt.) RSX-11 PSI/FR (opt.) RSX-11M/3271 PE (opt.) RSX-11 2780/3780 Emulator (opt.) RSX-11M-PLUS RJE/HASP (opt.)

Table 1-3 (cont.) Typical System

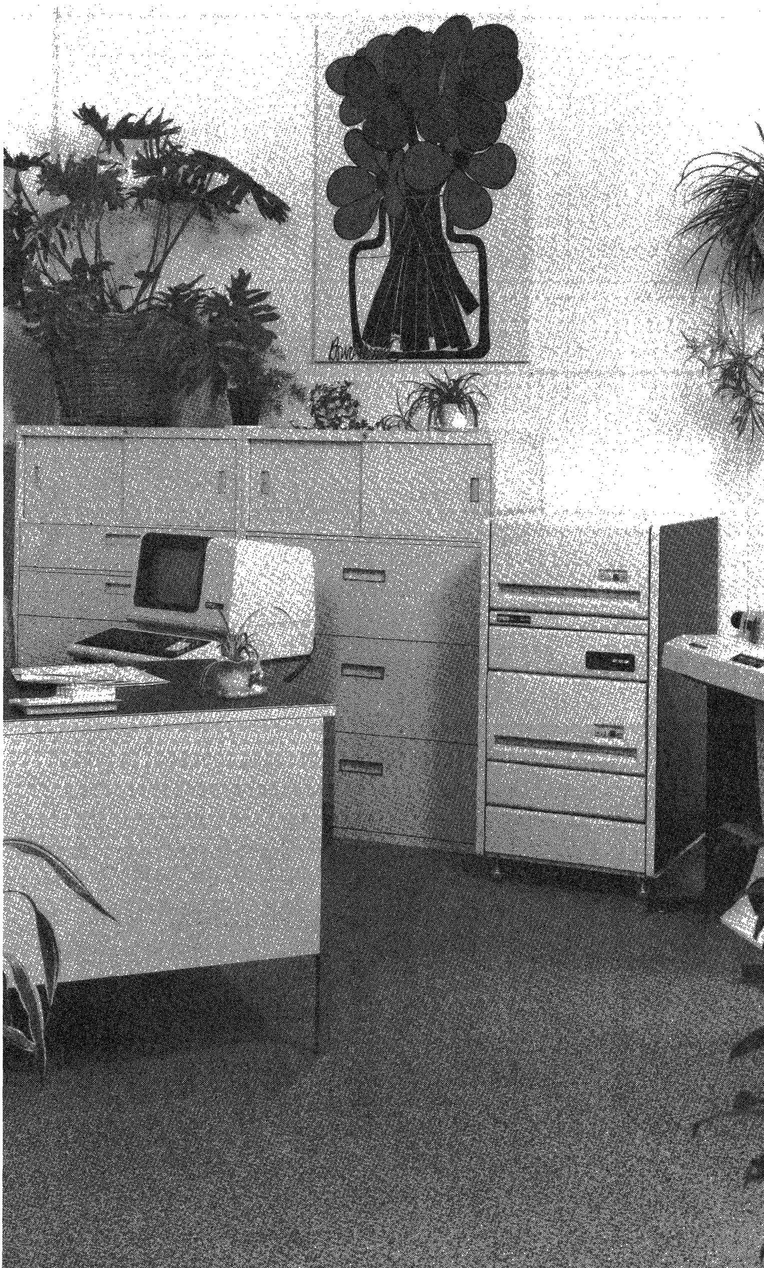
TOPIC	RSX-11S
SYSTEM TYPE:	Execute-only real-time multiprogramming applications system; requires RSX-11M, RSX-11M-PLUS, or VAX/VMS system for generation and program development
CPU:	All PDP-11 processors (LSI-11 based to PDP-11/70)
TYPICAL SYSTEM DEVICES:	None required
TYPICAL LOAD DEVICES:	TE16 Magtape TS11 Magtape
MINIMUM MEMORY (bytes):	16K 32K for on-line task loading or execution of tasks written in FORTRAN
MAXIMUM MEMORY SUPPORTED (bytes):	56K (without memory management) 3840K (with memory management)
HIGH-LEVEL LANGUAGES:	No compilers supported, but tasks are developed on host system using FORTRAN IV, FORTRAN-77, or CORAL 66
COMMUNICATION CAPABILITIES:	DECnet-11S (opt.) RSX DLX-11 (opt.)

Table 1-3 (cont.) Typical System

TOPIC	IAS
SYSTEM TYPE:	Large, multiuser timesharing system; supports concurrent interactive, batch and real-time applications
CPU:	PDP-11/34 through PDP-11/70 with memory management
TYPICAL SYSTEM DEVICES:	RL01 Cartridge disk drive RK07 Cartridge disk drive RP06 Disk drive RM03 Disk drive RM05 Disk drive
TYPICAL LOAD DEVICES:	TE16 Magtape RL01 Cartridge disk drive RL02 Cartridge disk drive
MINIMUM MEMORY (bytes):	96K
MAXIMUM MEMORY SUPPORTED (bytes):	248K (PDP-11/34) or 3840K (PDP-11/44/70)
HIGH-LEVEL LANGUAGES:	FORTRAN IV (opt.) FORTRAN-77 (opt.) PDP-11-COBOL (opt.) BASIC (opt.) BASIC-PLUS-2 (opt.) CORAL-66 (opt.)
COMMUNICATION CAPABILITIES:	DECnet-IAS (opt.) IAS/2780 (opt.) RSX-11M/IAS RJE-HASP (opt.) MUX200/RSX-IAS (opt.)

Table 1-3 (cont.) Typical System

TOPIC	RT-11
SYSTEM TYPE:	Single user, real-time application Foreground/Background program development or batch job
CPU:	All PDP-11 processors (LSI-11 based products through the PDP-11/44) except the PDP-11/70 or VAX Family
TYPICAL SYSTEM DEVICES:	RL01 Cartridge disk drive RL02 Cartridge disk drive RK07 Cartridge disk drive RX01 Floppy disk drive RX02 Floppy disk drive
TYPICAL LOAD DEVICES:	RL01 Cartridge disk drive RL02 Cartridge disk drive RX01 Floppy disk drive RX02 Floppy disk drive TE16 Magtape TU58 Cartridge tape
MINIMUM MEMORY (bytes):	24K Single job 32K Single job with BATCH or MACRO 32K Foreground/Backgound
MAXIMUM MEMORY SUPPORTED (bytes):	60K for systems running the SJ or FB monitor 248K for systems running under the XM monitor
HIGH-LEVEL LANGUAGES:	BASIC (opt.) Multiuser BASIC (opt.) FORTRAN IV (opt.)
COMMUNICATION CAPABILITIES:	DECnet/RT (opt.) RT-11/2780/3780 PE (opt.)



CHAPTER 2
OPERATING SYSTEMS

INTRODUCTION

An operating system is a collection of control programs and routines designed to make computer hardware devices easy to use. Operating systems vary greatly in the kinds of hardware with which they are compatible, the range of complexity of tasks they handle, the degree of adaptability to special user purposes, and the programming languages which they support.

Operating systems not only provide a way by which a user's specific program can run on the computer, but they can also have a set of utilities and routines which manage such resources as printers and terminals, detect errors in programs, keep user accounts, protect information, warn the operator of failures—and much more.

COMPONENTS AND FUNCTIONS

Operating systems are collections of programs that organize a set of hardware devices into a working unit. Figure 2-1 illustrates the relationship between users, operating system, and hardware.

PDP-11 operating systems consist of two sets of software: the monitor (or executive) software and the system utilities.

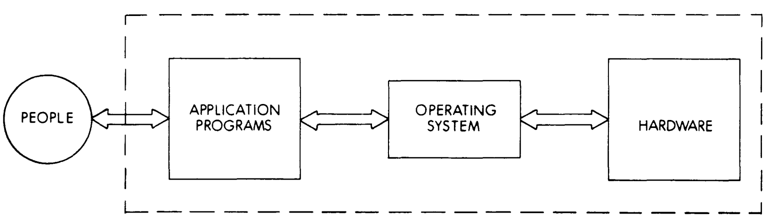


Figure 2-1 Computer System

The **monitor** (an integrated set of routines) acts as the primary interface between the hardware and a program running on the system, and between the hardware and the people who use the system. The monitor's basic functions can be divided among the following services:

- User interface
- Programmed processing services
- Device and data management

- Memory allocation
- Processor time allocation

In general, a monitor can have two distinct operating components: a memory resident portion and a temporarily resident (called "transient") portion. Typically, the operating system is delivered on a hardware medium, called the system device, such as a disk or magnetic tape. In order for any useful work to be done, the monitor must be transferred ("loaded") into the memory part of the hardware processor. When the monitor is loaded into memory and started, all of the monitor is resident. Its first duty is to communicate with the person running the system—the operator. The monitor simply waits until an operator requests some service, and then it performs that service. In general, such services include loading and starting programs, controlling program execution, modifying or retrieving system information, and setting system parameters. In most systems, these functions are serviced by transient portions of the monitor. By being able to move back and forth—between memory and the system device—the transient portion of the monitor can make room for programs that need memory space, thereby improving the size-to-performance ratio of the computer. Movements of this sort occur in time spans measured in milliseconds.

The memory resident portion remains in memory to act on requests from the program, which generally include input/output (I/O) services such as file management, device-dependent operations, blocking and unblocking data, allocating storage space, and managing memory areas. In large systems, these services might also include intertask communication and coordination, memory protection, and task execution scheduling.

In some cases, the user can adjust the size of the monitor by eliminating features that are not needed in an application environment. RSTS/E, RSX-11M, and RSX-11S are examples of such systems. RT-11 offers several monitors of varying size and capability; monitors can be customized to add features. The RSX-11S system monitor (called an **executive**) is always memory resident when the system is operating. In this case, the user concerned with size can remove routines that perform unneeded operations. In general, all PDP-11 operating systems are designed to be flexible enough to operate in a relatively wide range of hardware environments.

System Utilities

System utilities are the individual programs supplied by DIGITAL that are run under control of the monitor to perform useful system-level operations. System utility programs enhance the capabilities of an operating system by providing users with commonly performed general services. There are three classes of system utilities: those used for program development; those used for file management; and those used to perform special system management functions.

In the first category are the text editors, assemblers, compilers, linkers, program librarians, and debuggers. A whole section of this Handbook is dedicated to programming languages and program development, and another section introduces some utilities—such as editors and screen formatters—that are useful both in program development and in other contexts. File management utilities include file copy, transfer, and deletion programs, file format translators, and media verification and clean-up programs. For more detailed information on these, see the Handbook section on file and data management. System management utilities vary from system to system, depending on the purpose and functions the system serves. Some examples are system information programs, user accounting programs, error logging, and on-line diagnostic programs.

PROCESSING METHODS

Interactive processing—as opposed to batch processing—permits "dialogs" between the computer and the user. People typing commands at terminals and getting quick response, and people writing and editing programs at video terminals, are working interactively with the operating system. In batch processing, however, the whole program must be supplied, along with all necessary data, before any response can be obtained from the computer. Note that all DIGITAL operating systems support interactive processing. Some support batch processing, as well.

The basic distinction among DIGITAL operating systems is the processing method each uses to execute programs. The key distinctions among PDP-11 systems are:

- Single-user vs. multiuser
- Single-job vs. foreground/background
- Foreground/background vs. multiprogramming
- Timesharing vs. event-driven multiprogramming

A **single-user** operating system receives demands upon its resources from a single source. It has only to manage the resources based on these demands. As a result, these systems do not require account numbers to access the system or data files. They usually provide no protection from user programs for the operating system. RT-11 is a single-user operating system.

A **multiuser** operating system receives demands for its resources from many different individuals and/or programs. The system must manage its resources based on these demands. For example, several users may want sole control of a device at the same time. The system handles access to the device. In addition, people may be using the system for different purposes, so that some privacy must be maintained. As a result, a multiuser system normally has an account system to manage different users' files. The RSTS/E, RSX-11M, and RSX-11M-PLUS systems are all multiuser systems, and all provide device allocation control and file accounts. In the case of the RSTS/E and RSX-11M systems, the file account structure is also used to keep track of the amounts of system resources an individual uses. Furthermore, the RSTS/E, RSX-11M, and RSX-11M-PLUS systems extend privacy by protecting individual users at a system level from the effects of any other users of the system.

An RT-11 system can operate in two modes: as a **single-job** system or as a **foreground/background** system. In a foreground/background system, memory for user programs is divided into two separate regions. The foreground region is occupied by a program requiring fast response to its demands and priority on all resources while it is processing (for example, a process-control or data acquisition application program). The background region is available for a low-priority, pre-emptable program, for example, one doing numerical analysis or program development.

Two independent programs, therefore, can reside in memory, one in the foreground region and one in the background region. The foreground program is given priority and executes until it relinquishes control to the background program. The background program is allowed to execute until the foreground program again requires control. Thus two programs effectively share the resources of the system, for when the foreground program is idle, the system does not go unused. Yet, when the foreground program requires service, it is immediately ready to execute. Input/output (I/O) operations, such as the input of data from the realtime process, or the output of accounting files to the lineprinter, are processed independently of the requesting job to ensure that the processor is used efficiently, as well as to enable fast response to all I/O interrupts.

The basis of foreground/background processing is the sharing of a system's resources between two tasks. An extension of foreground/background processing is **multiprogramming**. In multiprogrammed processing, many jobs compete for the system's resources. While it is still true that only one program can have control of the central processor (CPU) at a time, concurrent execution of several tasks is achieved because other system resources, particularly I/O device operations, can execute in parallel. While one task is waiting for an I/O operation to complete, another task can have control of the CPU. Timeslicing (see below) can also manage multiprogramming environments.

The RSX-11 family of operating systems employs multiprogrammed processing based on a priority-ordered queue of programs demanding system resources. In this case, memory is divided into several regions called partitions, and all tasks loaded in the partitions can execute in parallel. Program execution, as in the RT-11 foreground/background system, is event-driven. That is, a program retains control of the CPU until it declares a "significant" event—normally meaning that it can no longer run, either because it has finished processing, or because it is waiting for another operation to occur. When a significant event is declared, the RSX-11 executive gives control of the CPU to the highest priority task ready to execute. Furthermore, a high-priority task can interrupt a lower-priority task if it requires immediate service.

The RSTS/E and DSM systems also perform concurrent execution of many independent jobs. RSTS/E and DSM, however, process jobs on a **timesharing** rather than an event-driven basis, since this is best suited for a purely interactive processing environment.

In a timesharing environment each job is guaranteed a certain amount of CPU time (a **time slice**). Jobs receive time one after another, in a round-robin fashion. The system itself manages timesharing processing to obtain the best overall response, depending generally on whether jobs are compute-intense or I/O-intense. The system manager or privileged users can also specify the minimum guaranteed time for a particular job when it gets service, as well as modify its priority.

SYSTEM GENERATION

System generation is the tailoring of an operating system to a customer's particular hardware configuration and software services. Such structuring is necessary because each installation is unique, and each requires a different combination of the capabilities potential in the system when it is first supplied. For example, your installation may not have a lineprinter, but may have extra disk drives or expanded memory. It would be wasteful to reserve valuable memory space for the code necessary to lineprinters. In addition, the system must be configured so that it can use the facility of the disk drive. This is accomplished at system generation (**SYSGEN**) time. Some operating systems, such as RT-11, provide several monitor options, so that many customers find they don't have to do a system generation at all.

System generation is also the point at which the system manager decides upon the inclusion, allocation, or definition of various utilities and system-wide parameters. In an RSX-11M system, for example, the manager could decide whether both event-driven and time-slice scheduling for realtime tasks should be available.

Finally, some layered software products are "added on" at sysgen time. (Other layered products might have been added after system installation, but before system generation.) If a RSTS/E manager wants to have the PASCAL compiler available to users, for example, it is during system generation that the choice to add the compiler is implemented.

Systems may, of course, be re-sysgened as needs change; for example, if the system grows, hardware is expanded or additional compilers are added. Usually system generation is a routine procedure that involves a menu and a dialog between the system and the manager or DIGITAL software specialist. In some situations the sysgen can occur while the system is running; in others it may be necessary to bring the system down for the small time the operation requires.

DATA MANAGEMENT

Computers deal with binary information. Of course, most people find it inconvenient to "think" in binary codes, so DIGITAL's operating systems are programmed to translate easier-to-understand programming languages into binary. The way in which people interpret and manipulate the binary information is called **data management**.

This section describes PDP-11 software data management structures and techniques, from the physical storage and transfer level to the logical organization and processing level. (For definitions of words you are unfamiliar with, see the Glossary.) Contents of the following sections include:

- ASCII and binary storage formats—how binary data can be interpreted
- Physical and logical data structures—the difference between how data storage devices operate and how people use them
- File structures—how physical units of data are logically organized for easy reference
- File directories—how files are located and retrieved
- File protection—how files are protected from unauthorized users
- File naming conventions—how files are identified

Physical and Logical Units of Data

Computers—at their most fundamental level—understand only binary information. **Physical units** of data are the elements which computers use to store, transfer, and retrieve binary information. A **bit** (binary digit) is the smallest unit of data that computer systems handle. An example of a bit is the magnetic core, used in some processor memories, that is polarized in one direction to represent the binary number 0 and in the opposite direction to represent the binary number 1.

In PDP-11 computers, a **byte** is the smallest memory-addressable unit of data. A byte consists of eight binary bits. An ASCII character code can be stored in one byte. Two bytes constitute a 16-bit **word**. Some machine instructions are stored in one word.

The smallest unit of data that a record-oriented I/O peripheral device can transfer is called its **physical record**. The size of a physical record is usually fixed and depends on the type of device being referenced. For example, a card reader can read and transfer 80 bytes of information at a time, stored on an 80-column punched card. The card reader's physical record length is 80 bytes. (Character oriented devices—paper tapes and terminals—can obviously transfer a single character at one time.)

A **block** is the name for the physical record of a mass storage device such as disk or magnetic tape. An RK05 disk block consists of 512 contiguous bytes. Its physical record length is 512 bytes.

Physical blocks can be grouped into a collection called a device or a physical **volume**. This collection has a size equal to the capacity of the device medium. The term physical volume is generally used with removable media, such as disk packs or magnetic tape.

Logical units of data are the elements manipulated by people and programs to store, transfer and retrieve information. The information has logical characteristics; for example, data type (alphabetic, decimal, etc.) and size. The logical characteristics are not device dependent; they are determined by the people using the system. It is the job of the operating system to correlate physical and logical data units. This frees the programmer or user from worrying about manipulation and allows him to concentrate on solving an application problem.

A **field** is the smallest logical unit of data. For example, the field on a punched card which contains a person's name is a logical unit of data. It can have any length necessary, as determined by the programmer who defines the field.

A **logical record** is a collection of fields treated as a unit. It can contain any logically related information, in any one of several data types, and it can be any user-determined length. Its characteristics are not device dependent, but they can be physically defined. For example, a logical record can occupy several blocks, or it can reside in a single block, or several logical records can reside in a single block. Its characteristics are determined by the programmer. A record could contain all of the status information about an item in inventory or about a loan applicant.

A **file** is a logical collection of data that occupies one or more blocks on a mass storage device such as a disk or magnetic tape. A file is a system-recognized logical unit of data. Its characteristics can be determined by the system or the programmer.

A file can be a collection of logical records treated as a unit. An example is an employee file that contains one logical record in the file for each employee. Each record contains an employee's name and address and other pertinent information. If the logical record length is 50 bytes and there are 200 employees, the complete employee file could be stored in 20 512-byte blocks. Depending on the file structure used in the system, the blocks could be scattered over the disk, or could be located one after the other.

A **logical volume** is a collection of files that reside on a single disk or tape. It is the logical equivalent of a physical device unit (a physical volume) consisting of physical records, such as a disk pack. The files on a volume may have no specific relationship other than their residence on the same magnetic medium. In some cases, however, the files on a volume may all belong to the same user of the system.

Figure 2-2 illustrates some of the kinds of physical and logical units of data that PDP-11 computer systems handle.

Data Storage and Transfer Modes

All PDP-11 operating systems use two basic methods of data storage: ASCII and binary. Data stored in ASCII format conform to the American Standard Code for Information Interchange, in which each character is represented by a 7-bit code. The 7-bit code occupies the low-order seven bits of an 8-bit byte. The high-order bit is normally zero for PDP-11 systems. Text files are examples of data stored in ASCII format.

Binary storage always uses all eight bits of a byte to store information. The significance of any bit varies depending on the kind of information to be stored. Machine instructions (2's complement integer data), and floating point numeric data are some examples of data stored in binary format.

Figure 2-3 illustrates the way in which binary data can be interpreted as either ASCII data or machine instructions. The figure shows examples of a word of storage containing a sequence of bits, interpreted first as two ASCII characters and second as a machine instruction.

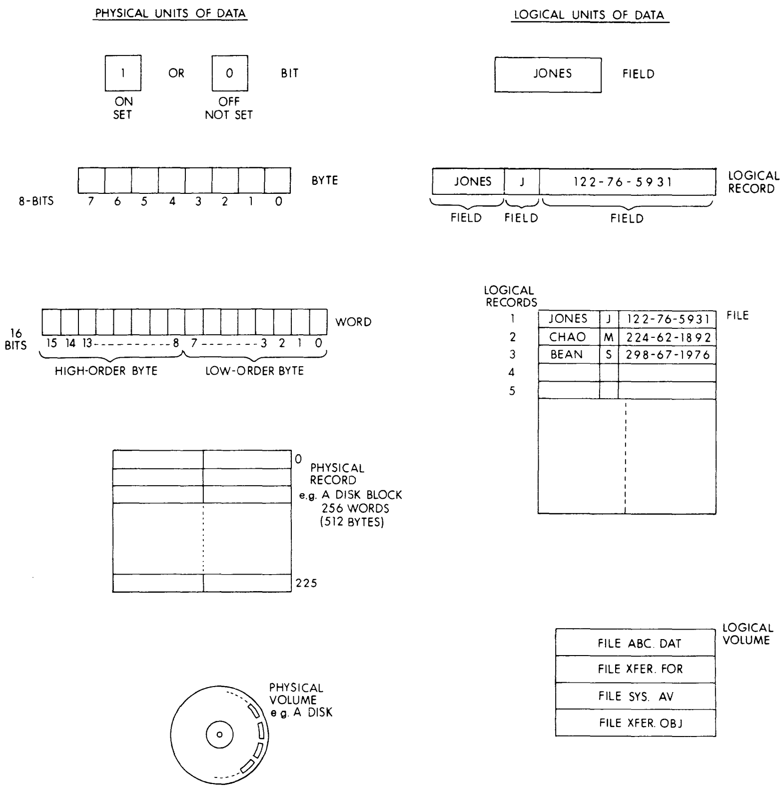


Figure 2-2 Physical and Logical Data Storage

In large, sophisticated systems such as RSTS/E, RSX-11M, and RSX-11M-PLUS, the way in which data are stored on the byte or bit level is rarely a concern of the application programmer. The operating system handles all data storage and transfer operations. In smaller systems such as RT-11, the programmer can become involved in data storage formats, although this is not generally a necessity. A particular application may require the selection of a particular storage format.

The data storage format is related to the way in which data are transferred in an I/O operation.

Formatting can also be applied at a higher level to define the type of data file being processed. In the RT-11 system, there are four types of binary files; each type signifies that a special interpretation applies to

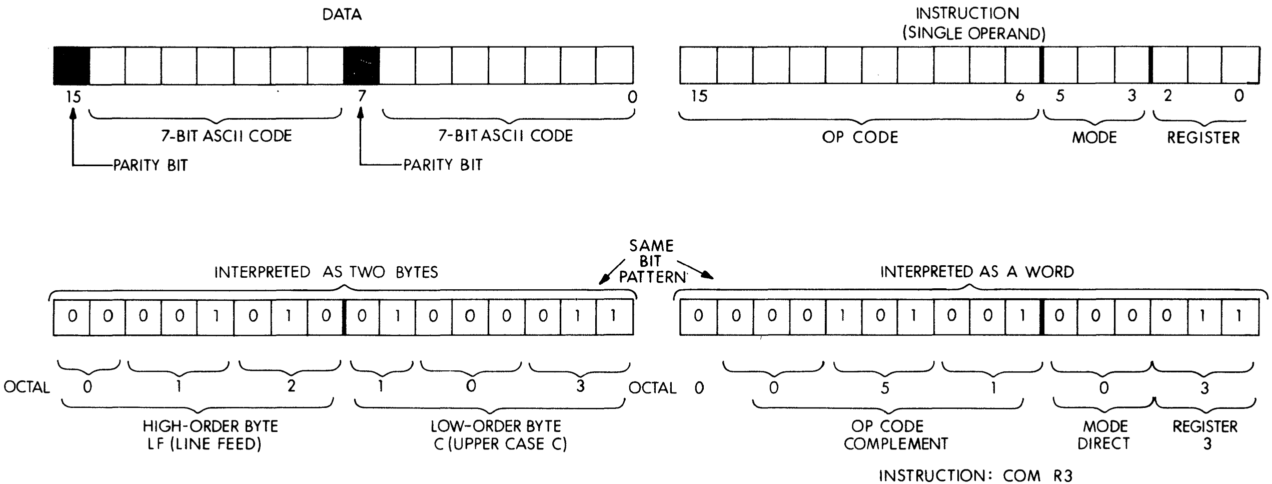


Figure 2-3 ASCII and Binary Storage

the kind of binary data stored. For example, a memory image file is an exact picture of what memory will look like when the file is loaded to be executed. A relocatable image file, however, is an executable program image whose instructions have been linked as if the base address were zero. When the file is loaded for execution, the system has to change all the instructions according to the offset from base address zero.

I/O Devices and Physical Data Access Characteristics

In a PDP-11 computer system, data moves from external storage devices into memory, from memory into the CPU registers, and out again. The window from external devices to the CPU is called the I/O page. Each external I/O device in a computing system has an I/O page address assigned to it. Figure 2-4 illustrates the data movement path in a PDP-11 computing system.

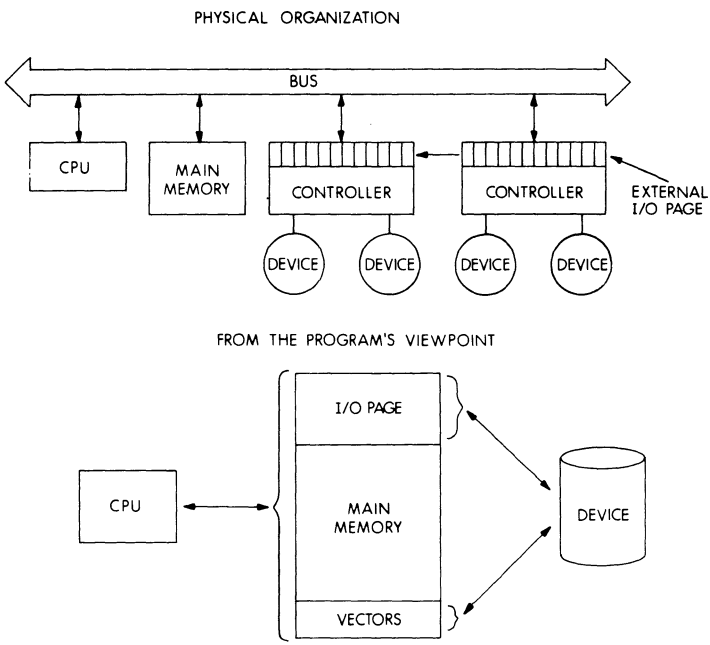


Figure 2-4 Memory and I/O Devices

Although all external devices are controlled similarly, devices differ in their ability to store, retrieve or transfer data. Almost all PDP-11 operating systems provide device independence between devices that have similar characteristics and, where possible, between differing devices in situations where the data manipulation operations are functionally identical. Primarily, PDP-11 operating systems differentiate between:

- File-structured and non-file-structured devices
- Block-replaceable and non-block-replaceable devices

Terminals and lineprinters are examples of devices that do not provide any means to store or retrieve physical records selectively. They can transfer data only in the sequence in which they occur physically.

In contrast, mass storage devices such as disk and tape have the ability to store and retrieve physical records selectively. For example, an operating system can select a single file from among many stored on the medium.

Mass storage devices are called file-structured devices since a file, consisting of a group of physical records, can be stored on and retrieved from the device. Terminals and lineprinters are called non-file-structured devices because they do not have the ability to selectively read or write the physical records constituting a file.

Finally, mass storage devices differ in their ability to read and write physical records. Disk devices are block-replaceable devices because a given block can be written without accessing or disturbing all the other blocks on the medium. Magnetic tape is not a block-replaceable device.

A device's physical data access characteristics determine which data transfer methods are possible for that device. Non-file-structured devices allow sequential read or write operations only. Block-replaceable devices allow both sequential and random read or write operations. Figure 2-5 summarizes the read/write capabilities of each category of I/O device.

Physical Device Characteristics and Logical Data Organizations

One of the most important services an operating system provides is the mapping of physical device characteristics into logical data organizations. You do not have to write the programs needed to handle input and output to any standard peripheral devices, since appropriate routines are supplied by DIGITAL with the operating system.

There are generally two sets of routines provided in any operating system, depending on its complexity: 1) device drivers or handlers; 2) file management services.

Device drivers or handlers perform operations to relieve the user of

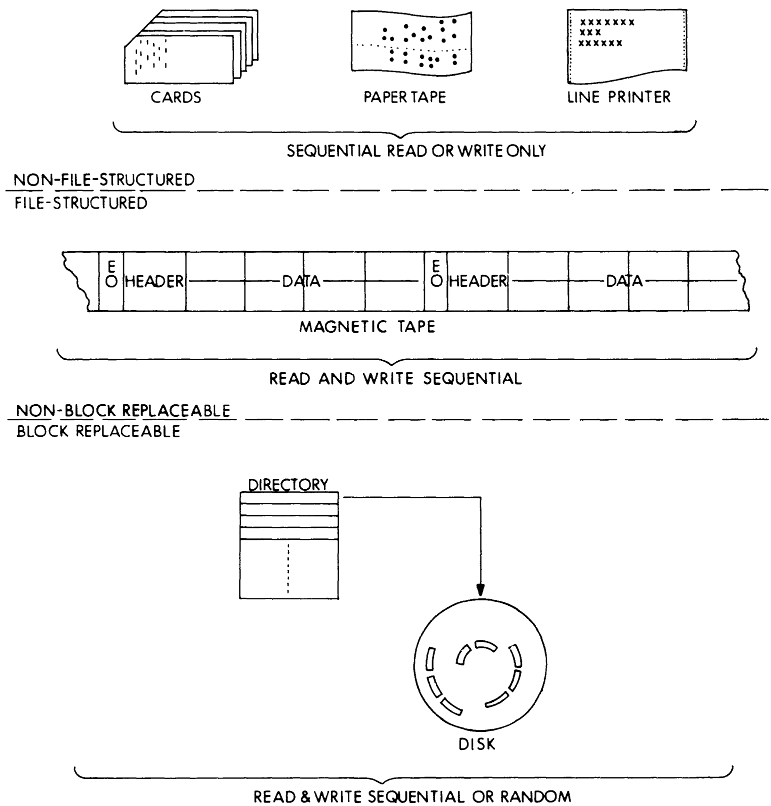


Figure 2-5   I/O Device Read/Write Capabilities

the burden of I/O services, overlapping I/O considerations, and device dependence. They can:

- Service I/O devices
- Provide device independence
- Block and unblock data records for devices, if necessary
- Allocate or deallocate storage space on the device
- Manage memory buffers

An operating system can also provide you with a uniform set of file management services. For example, the RT-11 system provides file management services through the part of the monitor called the User Service Routine (USR), which loads device handlers, opens files for read/write operations, and closes, deletes and renames files.

In summary, an operating system maps physical device characteristics into logical file organizations by providing routines to drive I/O devices and to interface with user programs. Figure 2-6 illustrates the transition between the user interface routines and the I/O devices.

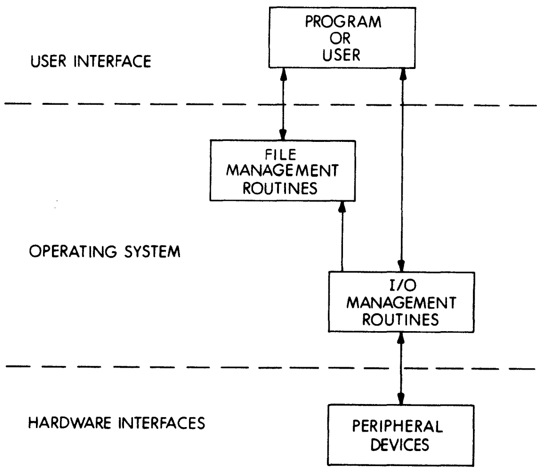


Figure 2-6 Device Control and File Management Services

As an example of the mapping of physical characteristics into logical organizations, the RSX-11 system's device driver and handler and file management services allow the user program to treat all file-structured devices in the same manner. That is, all of these devices appear to the user program to be organized into files consisting of consecutive 512-byte blocks which are numbered from block zero of the file to the last block of the file. In reality, the blocks may be scattered over the device and, in some cases, the device's actual physical record length may not be 512 bytes.

In RSX-11 terminology, the actual physical records on the device (for example, the sectors on a disk) are called physical blocks. At the device driver or handler level, the system maps these physical blocks into logical blocks. Logical blocks are numbered in the same relative way that physical blocks are numbered, starting at block zero—as the first block on the device—and ending at the last block on the device. At the user interface level, the operating system maps logical blocks into virtual blocks. Virtual block numbers become file relative values, while logical block numbers are volume relative values.

Figure 2-7 illustrates the mapping between physical, logical and virtual blocks in an RSX-11 system. The figure shows two disk device types which have different physical record lengths. In this case, the blocks constituting a file are scattered over the disk. The file is a total of 5 blocks long. At the logical block level, the operating system views the file as a set of non-contiguous blocks. At the virtual block level, the user software views the file as a set of contiguous, sequentially numbered blocks.

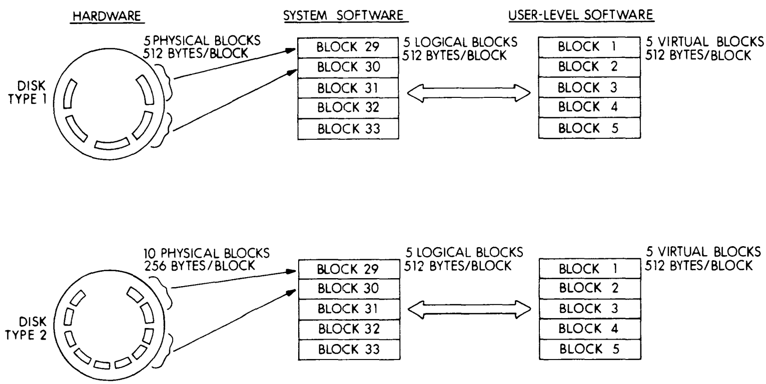


Figure 2-7 Physical, Logical and Virtual Blocks

File Structures and Access Methods

A file structure is a method of organizing logical records into files. It describes the relative physical locations of the blocks constituting a file. The file structure or structures that a particular operating system employs is a product of the way in which the system views the particular I/O devices and the kinds of data processing requirements the system fulfills.

File structure is important because a file can be effective in an application only if it meets specific requirements involving:

SIZE	Growth of the file may require a change in the file structure or repositioning of the file.
ACTIVITY	The need to access many different records in a file or frequently access the same file influences data retrieval efficiency.
VOLATILITY	The number of additions or deletions made to a file may affect the access efficiency.

An **access method** is a set of rules for selecting logical records from a file. The simplest access method is sequential: each record is processed in the order in which it appears. Another common access method is direct access: any record can be named for the access. A non-block replaceable device such as magnetic tape, can only be processed sequentially. A block-replaceable device, such as disk, can be processed by either access method, but direct access takes greatest advantage of the device characteristics.

PDP-11 operating systems provide a variety of file structures and access methods appropriate to their processing services. All PDP-11 file structures are, however, based on some form of the following basic file structures:

FILE STRUCTURE	ACCESS METHODS
Linked	Sequential
Contiguous	Sequential or Direct Access
Mapped	Sequential or Direct Access

Linked files are a self-expanding series of blocks which are not physically adjacent to one another on the device. The operating system records data blocks for a linked file by skipping several blocks between each recording. The system then has enough time to process one block while the medium moves to the next block to be used for recording. In order to connect the blocks, each block contains a pointer to the next block of the file. Figure 2-8a shows the format of a linked file.

Linked file structure is especially suited for sequential processing in which the final size of the file is not known. It readily allows later extension, since the user can add more blocks in the same way the file was created. In this manner, linked files make efficient use of storage space. Linked files can also be joined together easily.

The blocks of **contiguous** files are physically adjacent on the recording medium. This format is especially suited for random (direct access) processing, since the order of the blocks is not relevant to the order in which the data is processed. The system can readily determine the physical location of a block without reference to any other blocks in the file. Figure 2-8b shows the format of a contiguous file.

Mapped files are virtually contiguous files; they appear to the user program to be directly addressable sets of adjacent blocks. The files may not, however, actually occupy physically contiguous blocks on the device. The blocks can be scattered anywhere on the device. Separate information, called a file header block, is maintained to identify all the blocks constituting a file. This method provides an efficient use of available storage space and allows files to be extended easily, while

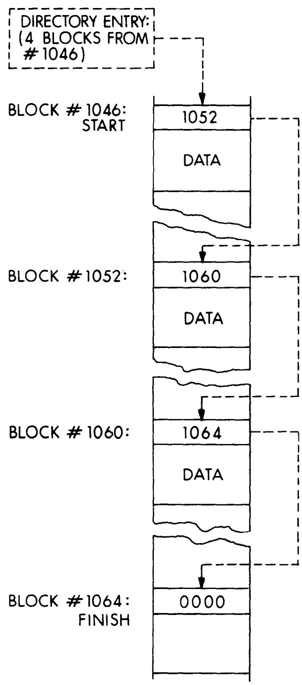


Figure 2-8a Linked File Structure

still maintaining a uniform program interface. Figure 2-9a illustrates a mapped file format.

If desired, a mapped file can be created as a contiguous file to ensure the fastest random accessing, in which case it is both virtually and physically contiguous.

The basic file structures discussed above can be modified or combined to extend the features of each type for special-purpose logical processing methods. Some examples are indexed files and global array files.

For the most generalized and flexible file structure, you can use indexed files, which are actually two contiguous files. One file acts as an ordered map of a second file containing the target data. The index portion or map contains either an ordered list of key data selected from the target data records or pointers to data records in the second file, or both.

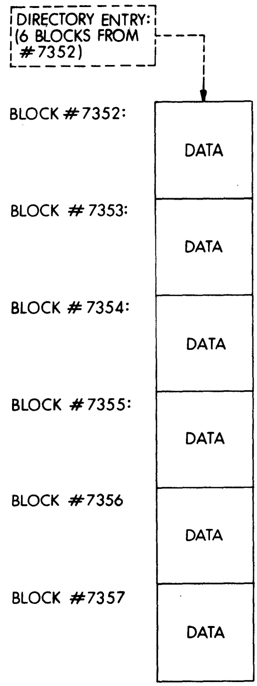


Figure 2-8b Contiguous File Structure

The target data records can be processed in the order of the index portion, or the target data records can be selected by searching through the index portion for the key data identifying the records. These methods of logically processing the target data are called **indexed sequential access** and **random access by key**, respectively.

The Digital Standard Mumps (DSM) operating system provides another special file structure, called **global array files**, a version of the linked file structure. The arrays themselves are a logical tree-structured organization consisting of one or more subscripted levels of elements. All elements on a particular subscripting level are stored in a single chain of linked blocks. At the end of each block in the chain is a pointer to the next block in the chain. The levels of the array (all the block chains) are linked together through pointers in the first block of each chain. This file structure ensures that the time it takes to access any element of the array is minimal. Figure 2-9C shows the DSM global array structure.

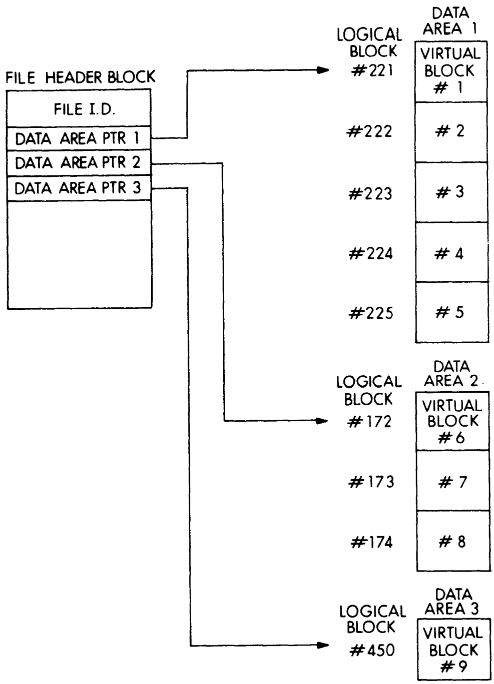


Figure 2-9a Mapped File Structure (Non-contiguous File)

Directories and Directory Access Techniques

Just as file structure and access methods are required to locate records within files, directory structures and directory access techniques are required to locate files within volumes.

A directory is a system-maintained structure used to organize a volume into files. It allows the user to locate files without specifying the physical addresses of the files. It is a direct access method applied to the volume to locate files.

RT-11 supports the simplest kind of file directory. When disk and tape media are initialized for use, the system creates a directory on the device. Each time a file is created, an entry is made in the directory that identifies the name of the file, its location on the device, and its length. When access to the file is requested thereafter, the system examines the directory to find out where the file is actually located.

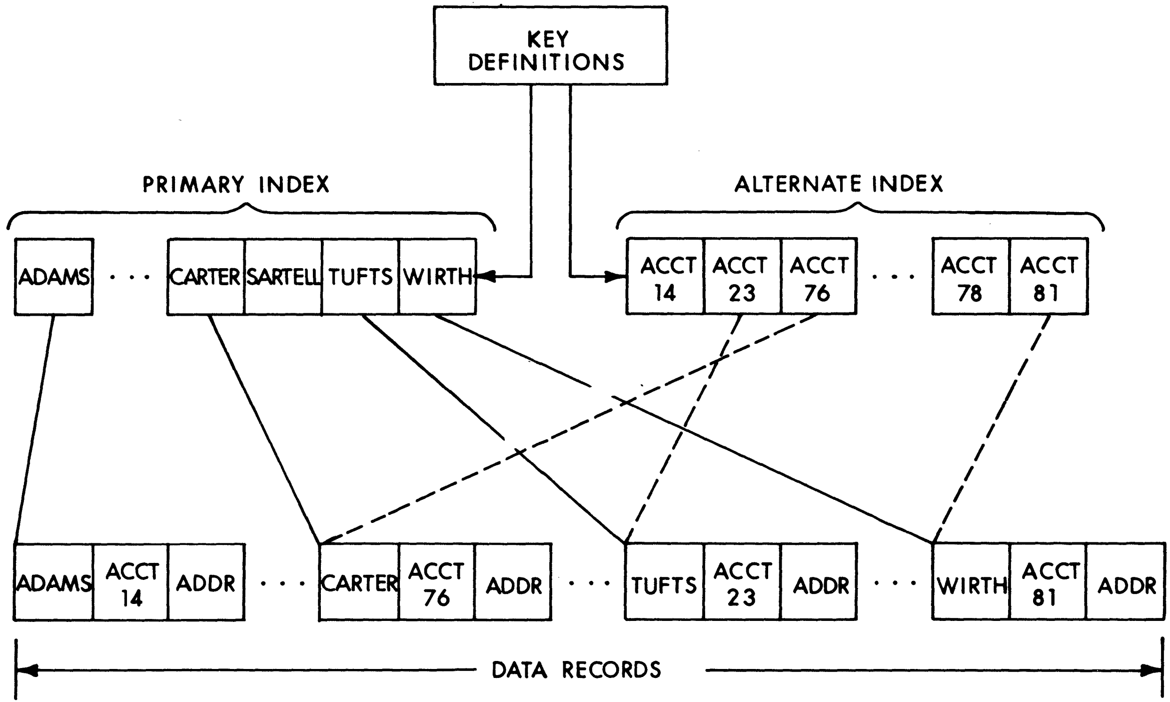


Figure 2-9b Indexed File Structure

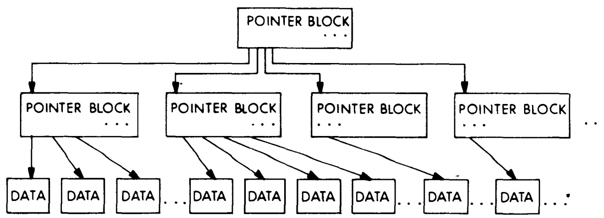


Figure 2-9c DSM Global Array Structure

The system can access the file quickly without having to examine the entire device.

In multiuser systems such as RSTS/E and RSX-11M, two different kinds of directories are used to enable the system to differentiate between files belonging to different users. They are the Master File Directory (MFD) and the User File Directories (UFD). These directories are maintained as files themselves, stored on the (physical) volume for which they provide a directory.

The MFD is a directory file containing the names of all the possible users of a particular device. The UFD is a directory file containing the names of all the files created by a particular user on a device. The system first checks the MFD to locate the UFD for the particular user, and then checks the UFD to locate the file. Figure 2-10 illustrates the use of the Master and User File Directories.

Though the directories are important in the operation and access of the system, most users need not worry about them. The system maintains directories on behalf of all users. Of course, as with most system services, privileged users may do their own directory creation and maintenance.

File Protection

RT-11 provides the simplest form of file protection with a one-bit "protected" designation. Files so named cannot be accidentally deleted. Under RT-11 no system of user numbers or accounts is needed. Directories form the basis for file access protection in multiuser systems. Unauthorized users cannot access a file unless they know the account under which it is stored and can obtain access to that account. Account systems and file access protection techniques are related.

Multiuser systems identify the individuals who use the system by account numbers called User Identification Codes (UIC), which are

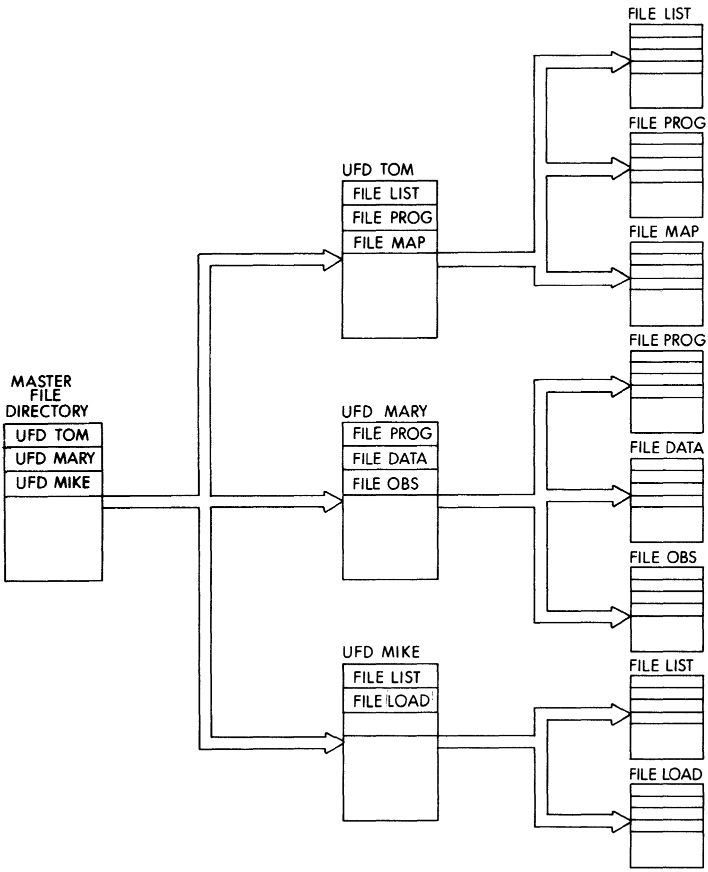


Figure 2-10 Master and User File Directories

normally assigned by the system manager. In general, a UIC consists of two numbers: the first number is used to identify a related group of users; the second number is used to identify an individual user in the group.

In RSTS/E systems, an individual file can be protected against read access or write access where distinctions are made on the basis of the UIC account number under which a file is stored. For example, a file can be read protected against all users who are not in the same account group and write protected against all users except the owner.

The RSX-11 file system provides a protection scheme for both volumes and files. It is possible to specify protection attributes for an entire volume as well as for the files in the volume. A file or an entire volume can be read-, write-, extend- or delete-protected. Distinctions are made on the basis of account number, where the system recognizes four groups of users: privileged users, owner, owner's group, and all others.

File Naming

The most common way users communicate their desire to process data is through file specifications. A file specification uniquely identifies and locates any logical collection of data which is on-line to a computer system.

A language processor, for example, needs to know the name and location of the programming language source program file that it is to compile; it also needs to know the name that the user wants to use for the output object program and listing files it produces. Most PDP-11 operating systems share the same basic format for input and output file specifications.

Typically, the file specification includes a device name (given by an abbreviation mnemonic) for the device where the file resides, a unit number, the file name itself, and a file type—a group of one to three characters that conventionally tells what kind of file it is. (For example, .FOR as a file type says the file is a source program in the FORTRAN language.) In multiuser systems, the file specification might also include the UIC of the user and the file version number. If a network application is being run, the file specification would include the node name of the node where the file is, if other than the host system.

In most cases, the user does not have to issue a complete file specification. The PDP-11 operating systems use default values when a portion of a file specification is not supplied. The filename extension defaults, for example, depend on the kind of operation being performed.

The device name, if omitted, is normally assumed to be the system device, and most systems also allow the user to omit the unit number. If omitted, the unit number is assumed to be unit number 0.

In addition to relying on defaults in the file specification, the user can also put an asterisk in place of a file name, file name extension, account number, or version number to indicate a class of files. The asterisk convention, also called the **wildcard convention**, is commonly used in PDP-11 operating systems when performing the same operation on related files. For example, the file specification DP1:[2,1]PROG.* refers to all files on DP1: under account [2,1] with a file name PROG and any extension. The file specification DK:[*,*] FILE.SAV refers to the files under all accounts on drive unit 0 named FILE.SAV.

USER INTERFACES

User interface refers to both the software that passes information between an operator and a system and the language that a system and an operator use to communicate. In the latter sense, a user interface consists of commands and messages. Commands are the instructions that the user types on a terminal keyboard (or gives to a batch processor) to tell the system what to do. Messages are the text that a system prints on a terminal that tells the operator what is going on; for example, prompting messages, announcements, and error messages. This section discusses commands, the portion of the user interface that tells the system what to do, and prompting messages, the messages the system prints when it is ready to receive commands or information.

There are basically four types of commands used in PDP-11 operating systems:

- Monitor or command language commands—used to request services from the system as a whole
- I/O commands—used to direct any kind of I/O operation (often a part of monitor commands)
- Special terminal commands—these use keys on a terminal for special functions
- System program commands—commands used in system programs that perform operations relevant only for the individual program

Since system program commands are relevant only for individual system programs, and not for operating systems in general, this section discusses only monitor and command language commands, I/O commands and special terminal commands.

Special Terminal Commands

Special terminal commands involve a set of keys or key combinations that, when typed on a terminal, perform special functions. For example, a user normally types the carriage return key at the end of an input command string to send the command to the system, which responds immediately by performing a carriage return and line feed on the terminal. The key labeled RUBOUT or DELETE is used to delete the last character typed on the input line.

The most significant special terminal commands are those used with the key labeled CTRL (control). When the CTRL key is held down (like the shift key) and another key is typed, a control character is sent to the system to indicate that an operation is to be performed.

For example, a line currently being entered (whether as part of a command or as text) will be ignored by the system if you type a CTRL/U combination. A new input line can then be entered. The CTRL/U function is the same as typing successive RUBOUT keys to the beginning of a line. CTRL/U is standard on PDP-11 operating systems.

Another example is the CTRL/O function. If, during the printing of a long message or a listing on the terminal, you decide you are printing the wrong file, you can type a CTRL/O to stop the terminal output. If you wish to stop and then resume output to a terminal, you type CTRL/S to stop it and then CTRL/Q to resume. CTRL/O, CTRL/S, and CTRL/Q are standard functions on PDP-11 operating systems.

I/O Commands

Users communicate their intentions to process data files by issuing I/O commands consisting of at least one file specification. Normally, the I/O commands used in a system are standard throughout that system; in addition, most PDP-11 operating systems share the same basic I/O command string format.

Three command string formats are generally available; the older, less convenient Command String Interpreter (CSI), the newer, easier Concise Command Language (CCL), and DIGITAL Command Language (DCL) formats. Under CCL and DCL, the command, input and output file specifications and options may all be entered in a single line in response to the system prompt.

- COPY MYFIL YOURFIL

Omitted information will be prompted for by the system until the command is complete in its general format:

- COMMAND input filespec output filespec/option

Because CCL and DCL use English-like commands and options, they are easy to learn and use.

The older CSI requires several more steps: in response to the system prompt, the user enters a RUN command and the name of a program to be run, e.g., PIP (Peripheral Interchange Program). The response is a command level prompt for file specifications:

- RUN PIP
  * YOURFIL = MYFIL.

The general format, including single-letter switches, is:

- RUN Program
  * output filespec = input filespec/switch

To return to the monitor level, the user types ↑C.

Command string switches are simply ways of appending qualifying information to an I/O command string. The switches used vary from program to program. They are not usually required in an I/O command string, since most programs assume default values for any switch.

Monitor and Command Language Commands

The primary system/user interface is provided in PDP-11 operating systems by either monitor software or special command language interface programs that run under the monitor. The monitor software and command languages allow the user to request the system to set system parameters, load and run programs, and control program execution.

An input command line consists of the command name (an English word that describes the operation to be performed) followed by a space and a command argument. For example, the command to run a program is the word RUN followed by the name of the file containing the program. If the command name is long, it can usually be abbreviated.

In the RT-11 system, a monitor component called the keyboard monitor performs the function of notifying the user that the monitor is ready for input by printing a period at the left margin. The user enters a command string on the same line and terminates the command string by typing the carriage return key.

In the RSTS/E system, there are four keyboard monitors which share the responsibility for interpreting commands. The four standard keyboard monitors are DCL, BASIC-PLUS, RSX, and RT-11. All of these interpret sets of system commands, that is, words followed by optional command parameters. These system commands allow users to perform all the fundamental functions required to use the RSTS/E system, such as logging on and off, and running programs.

DIGITAL Command Language (DCL)

DIGITAL Command Language is a quickly learned command language that can be used by both interactive and batch-processed jobs for:

- Interactive program development
- Device and data file manipulation
- Program execution and control

Commands are composed of English words; command parameters such as file name specification and options can follow the command on the same line, or can be printed on subsequent lines in response to the system prompt.

In order to make DCL friendlier, DIGITAL has supplied it with extensive HELP facilities that both guide the user on the proper operation of the commands and supply explanations of system messages. In addition, through the use of defaults, DCL relieves programmers of many routine decisions and much redundant typing in order to complete parameters and options. Of course, the programmer may override the defaults in any command by the use of simple command options. Abbreviations also speed up the command typing procedure, allowing the programmer to use the shortest unique form of both commands and parameters. File specifications for DCL can be as simple as the name of the file only, or as detailed as a full listing of network, node device (including type, controller, and unit), directory, file name, file type, and version number.

Though there are more than a hundred DCL commands, the programmer may also program and store commands of his own, and then use them just as the DIGITAL-supplied commands are used.

DIGITAL Command Language (DCL) is a DIGITAL company standard that makes movement from one DIGITAL system to another easier by providing consistent formats and syntax. It is now available on RT-11, RSX-11M, RSX-11M-PLUS, RSTS/E, and VAX/VMS operating systems.

A **Concise Command Language** (CCL) command is used to run and pass arguments automatically to designated programs stored in the system library. The programs can be system utilities supplied with the operating system, or can be user-written console routine programs that perform application operations specific to your job.

CCL commands not only provide an easy-to-use command interface, but they can also provide protection from unauthorized use of certain programs. For example, if a particular program performs several operations, some of which should not be available to unauthorized users, the system manager can prevent those users from issuing the RUN command to run the program, but can allow them to perform the safe operation subset by using CCL commands.

In the RSX-11 systems, an additional command interface called the Monitor Console Routine (MCR) allows the user to perform system level operations. There are two kinds of commands that MCR accepts: general user commands and privileged user commands. General user commands provide system information, run programs, and mount and dismount devices. Privileged user commands control system operation and set system parameters.

RT-11's version of the CCL is the set of keyboard monitor commands, whose features include wildcards, factoring (a simplifying method of string replacement), abbreviations, and prompts. Here is a short example of prompting:

COPY/CONCATENATE
From ?
DX1: (TEST.LST, TESTA.LST)
To ?
DX2: TEST.LST.

The system continues to prompt for input and output file specifications until you provide them. Keyboard monitor commands can be collected together into indirect command files.

PROGRAMMED SYSTEM SERVICES

All PDP-11 operating systems provide access to their numerous services through requests that programs or tasks can issue during execution. A **programmed request** inserted directly into the program provides the mechanism.

Under the RT-11 system, MACRO-11 programmers may use programmed requests to perform file manipulation, data transfer, and other system services such as loading device handlers, setting a mark time for asynchronous routines, suspending a program, and calling the Command String Interpreter (CSI).

In the RSTS/E system, users have access to the monitor's services through system function calls. The function calls allow a program to control terminal operation, to read and write core common strings, and to issue calls, in turn, to the system file processor. File processor calls, in turn, enable a program to set program run priority and privileges, scan a file specification, assign devices, set terminal characteristics, and perform directory operations. When the function operation is performed, the program continues execution.

The RSX-11 executive includes programmed services called executive directives. Directives can be executed in MACRO programs using system macro calls provided with the system. The directives allow a program to obtain system information, control task execution, declare significant events, and perform I/O operations. The RSX-11M operating system also includes programmed file control services which enable the programmer to perform record-oriented and block-oriented I/O operations.

SYSTEM UTILITIES

PDP-11 operating systems provide, in general, three kinds of system utility programs: program development utilities, file management utilities, and special system management utilities.

Most **system management utilities** included in an operating system are dependent on the function the operating system serves. For example, RSX-11M, RT-11, and RSTS/E include system error logging and report programs. RSTS/E, and RSX-11M-PLUS include user accounting programs. The chapters on specific operating systems will give you an idea of some of the system management utilities associated with each system. For details on **file management** utilities and **program development** utilities, see the pertinent sections of this Handbook.

CHAPTER 3
RSTS/E AND CTS-500

OVERVIEW

RSTS/E is the pre-eminent timesharing system for minicomputers, and reflects a decade's careful growth and development by DIGITAL. Many thousands of timesharing customers, from financial institutions and schools to manufacturers, insurance companies, and airlines, find RSTS/E a "blue chip" system: reliable, stable, friendly, and forgiving. CTS-500 is a commercial software system that includes all of RSTS/E plus appropriate languages and data management software needed for effective development, running, and maintenance of most commercial applications.

RSTS/E runs on a variety of DIGITAL processors, accommodating the complete range of peripherals, hardware and add-ons that any customer might need. RSTS/E is well-adapted to the growth of an individual system—as hardware and software are added—and is fully upward- and downward-compatible for applications being migrated across RSTS/E systems.

RSTS/E allows concurrent word processing and data processing using DECword/DP and can also communicate with stand alone word processors. Its built-in and layered functions reflect a DIGITAL commitment to keep the system easy for naive users and yet extremely powerful for users who want to write complex or innovative programs.

Some of the features of RSTS/E systems are listed in the pages that follow. All have as their goal the creation of a programming environment highly "available," so that programmer productivity is maximized, down-time is reduced to a minimum, and system operations are easy to learn and manage. RSTS/E provides excellent security, particularly useful in sensitive business applications such as bank transactions and stock transfers, where access to certain data must be severely restricted; or for educational institutions in which novice users must be prevented from bringing the system down by inexperience or intent.

Excellent communications software available for RSTS/E lets the computer link into distributed networks of DIGITAL computers (DECnets) or into flexible Internets with computers from other manufacturers. Also, thanks to the availability of a DCL subset with RSTS/E there is increased compatibility among RSTS/E, VMS, and RSX operating systems.

System accounting facilities included with RSTS/E give the system manager a detailed record of who used the various processor modes and for how long, so that both system management and billing for timesharing time can be done accurately.

There is an enormous amount of specialized software available for customers, from DIGITAL and from commercial developers who specialize in writing program packages for RSTS/E users in numerous industries. Resources of this sort help every customer who needs to enhance the operating system with software designed for financial accounting and general ledger, billing, forecasting, business simulation, materials control, a variety of banking transactions, freight tracking, insurance claim processing, and hundreds of additional timesharing applications.

Timesharing

Because computer hardware can really do processing of only one program or task at a time, it is important to determine, based upon the uses to which a computer is to be put, how that central processor is to be allocated. In timesharing environments, the processor is scheduled—usually in a round-robin fashion—among all the jobs that want it and are ready to do useful work. There may be levels of priority in timesharing so that, for example, agents who are confirming hotel reservations get served ahead of clerks who are doing inventory control programs; but every timesharing system accounts for all executable programs eventually.

From the user's point of view, the most important timesharing parameter to consider is computer response time which is the time that elapses between entering an instruction or field of data and the computer's response—computation, a ledger entry, an output operation to a printer or terminal.

RSTS/E systems provide excellent response time to users, who can number up to 127 at one time, and to jobs, which can number up to 63 at one time. A typical mix of users would include some people doing program development and working in a very interactive mode with the computer, some clerks doing data entry for delivery schedules or invoicing, some sales people entering transaction information, and perhaps even a batch job or two being run to complete the weekly salary. In addition, another computer owned by the company might be providing delivery status information via DECnet, or a mainframe from another computer manufacturer might be linked through Internet software from DIGITAL.

With such a diverse mix of users, we might find some people who know very little of the internal working of the computer, some who are programmers and expert in a language like COBOL or BASIC-PLUS-2, and some who are system-level programmers and system managers, capable of adapting the software to a variety of specific needs and of tuning the operating system for maximum performance. Under RSTS/E, all will get excellent response time, and all will feel as though they have unique control of the central processor and other resources of the computer.

Resources

Just about every kind of service you might want from an operating system is available with RSTS/E. Since high programmer productivity was an aim of DIGITAL in producing RSTS/E, the features of an easy, forgiving environment are included. User commands to the RSTS/E system are handled and interpreted by one of the run-time systems capable of acting as a keyboard monitor. The most popular languages for business and educational applications are available, including BASIC-PLUS-2, PDP-11 COBOL, COBOL-81, FORTRAN IV, FORTRAN-77, and DIBOL. This choice of languages lets you adapt your language to the function at hand, and lets you tap programming talent already trained in these popular languages. If you are familiar with traditional batch-mode program development requirements, you will be impressed by the ease and speed of developing applications under a RSTS/E system.

Text editors, particularly the DIGITAL standard editor (EDT), help speed program development and correction. EDT is a text editor that can be used to create a file, enter, and manipulate text in the file, and save or delete work done during edit sessions. It is easy to use and when used with DIGITAL'S terminals provides full screen video editing capabilities. In actual applications, the RSTS/E user can take advantage of features such as Record Management Services (RMS), software that supports building and accessing sequential, relative, and multikey indexed sequential file structures, and relieves programmers of many tedious tasks of I/O management. Calls from most of the various programming languages to RMS are sufficient to invoke the utility or access method desired.

FMS-11/RSTS Forms Management System is a software package that provides sophisticated screen formatting for application programs. FMS-11/RSTS allows non-programmers to design forms interactively on the video screen and eliminates tedious editing and recompiling of a forms program. The keypad-operated editor and the HELP facility are easy to learn. FMS-11/RSTS provides extensive field protection and validation features that help prevent data errors caused by typing errors.

Other features are described in more detail in sections that follow, and will be of interest to readers who want to know exactly what is available with RSTS/E, and what services it provides to users.

Timesharing Overview

RSTS/E tries to keep the CPU busy by running several jobs concurrently. Each user program be it a system utility, run-time system, or application program is a job. A job runs until it either enters an I/O wait state or exhausts its time quantum. At that point, the scheduler finds the next ready job and begins running that job. Meanwhile, the interrupt-driven I/O device handlers are processing requested data transfers. Upon completion of a transfer, the scheduler marks the job that requested the transfer as ready to run again and starts it from the point at which execution ceased.

RSTS/E attempts to keep as many jobs in memory as possible. When more memory is required to run a job than is available, the system temporarily swaps some jobs out of memory and stores them in a swap file. When it is the job's turn to run again, the job in the swap file is brought back into memory. Jobs waiting for more CPU time or keyboard input are most likely to be stored in the swap file, while jobs currently running or involved in disk or magnetic tape data transfers are necessarily in memory.

As the system processes each job, it maintains accounting information concerning that job. When the user logs off the system, all the information accumulated for all the jobs run by the user is used to update the accounting information stored on disk for that user account. This is particularly important to systems in which time is billed among various users.

To begin a timesharing session, a user logs into the system by entering an account name and a password (these are assigned by the system manager, the password is agreed jointly by the system manager and the user). The terminal is then under control of the keyboard monitor of the system default run-time system. The recommended default run-time system is DCL.

Whatever the default run-time system is, after the log in verification is complete and the system messages have been displayed, the user is in command mode. Each run-time system identifies itself by an identifying prompt. These are:

- DCL "$"
- RSX ">"
- BASIC "Ready"

- RT-11 "."

Commands are issued to the keyboard monitor of the run-time system. These commands cause the execution of Commonly Used System Programs (CUSP's) or application programs. The user is permitted to execute all the commands available to a non-privileged user. Privileged users have additional commands available for system management and maintenance.

A privileged user can detach the running job from the terminal, and run another job. The detached job continues to run unattended, but is still associated with the account number under which the user logged in. To retrieve control of a detached job, the user can log in on any free terminal and attach that job to the terminal.

The use of BASIC-PLUS is an important feature of the RSTS/E system. BASIC-PLUS can be run either from any default run-time system by issuing the BASIC command or it can be a run-time system itself. When BASIC-PLUS is entered it is in edit mode, to which it returns when program execution is completed or whenever a CTRL/C is typed. In edit mode, BASIC-PLUS examines each line typed by the user and determines whether that line is:

- A system or installation defined command
- An immediate mode statement
- A program statement

System and installation defined commands are executed immediately after being entered; immediate mode statements are first translated into an intermediate code, (placed in the user's job area) and are executed immediately by the run-time system. Program statements (lines of ASCII text preceded by the line numbers) are stored in their ASCII form in a temporary disk file under the user's account. Program statements without line numbers are immediately executed and not stored. This feature is provided for program debugging.

A user's job area is initialized by either executing the BASIC command or by logging in and being given a size of 2 KB or 4 KB, depending on the run-time system being used. The job area can grow in increments of 2 KB to a maximum size chosen by the system manager. When the user enters program statements in the edit mode, intermediate code created in the user's job area is not executed automatically. A copy of the intermediate code of the program can be transferred to disk storage or to an external storage medium.

You can change from edit mode to run mode by typing the RUN system command or the CHAIN immediate mode statement. In RUN mode, the run-time system interpretively executes the intermediate code stored in your job area. When a program finishes execution, the terminal returns to edit mode as signaled by the printing of the prompt "Ready." You can interrupt the BASIC-PLUS program by typing CTRL/C, which also returns the terminal to edit mode.

Management Commands

RSTS/E users can expect efficient operation because the operating system dynamically allocates processor time, memory space, file space, and peripherals to best suit changing demands. The system manager and designated privileged users have access to the RSTS/E system management commands either interactively using system utilities or under program control. Additional system commands and utility programs are also available to all users.

The RSTS/E file system provides a wide range of online processing capabilities. Files can be accessed randomly or sequentially, either through one of the keyboard command or utility programs or through the RSTS/E file system. Files can contain alphanumeric string, integer numeric, floating point numeric, or binary data; they can be created, updated, extended or deleted interactively either from the user's terminal or under program control, and can be sorted by the SORT-11 program. Files can be protected from access on an individual, group, or system basis; they can also be accessed by many users while being updated online.

Total or selective file backup and restore can be done online without disrupting users, or it can be done during periods when timesharing or application processing is not permitted. Private disk volumes may be used to limit user access. Removable disk media permit safe storage of valuable records at sites remote from the system.

RSTS/E is a high performance system, and it includes a variety of user tools to tune applications to perform even better. For example, with software disk caching (unrelated to CPU memory caching, which is also available), blocks of heavily used disk data are held in main memory to reduce the number of disk accesses. In addition, heavily used program segments can be held resident in main memory and shared among programs, saving memory space, reducing swapping time, and thus increasing performance. RMS data management code can also be shared for further memory savings. Use of common, shared, resident RMS also results in substantially reduced disk accessing for overlays and thus improves applications performance.

USER INTERFACE

User Command Language

The command language interpreter is interactive, comprehensive, easy to use, and very flexible. It enables the user to log into the system, manipulate files, develop and test programs, and obtain system information.

The four standard keyboard monitors are DCL, BASIC-PLUS, RSX, and RT-11. All of these interpret sets of system commands, that is, words followed by optional command parameters. These system commands allow users to perform all the fundamental functions required to use the RSTS/E system, such as logging on and off, and running programs.

Digital Command Language (DCL)
The DCL feature is based upon the DCL available on most PDP-11 and VAX/VMS operating systems. It is a subset of the DCL implemented on VAX/VMS. DCL is implemented as a run-time system or as an additional keyboard monitor. Its command set gives the user access to most RSTS/E system features.

Concise Command Language (CCL)
The RSTS/E system commands issued by the user at a terminal are familiar words or abbreviations. The system accepts both long and short command formats for inexperienced and experienced users. It responds with understandable statements and, if a command does not supply complete information, prompts the user for remaining data. CCL commands allow you to enter one command that runs a system utility and specifies a single command for the utility to execute. The number of CCL commands that can be defined varies from system to system, depending on the number of "small buffers" configured into the system. An average system probably includes a fairly standard set of CCL commands for certain RSTS/E utility programs. The system manager has the option of freely adding to, deleting from, or modifying the standard set of CCL commands.

SYSTEM CONFIGURATION AND OPERATION

RSTS/E system software exists as system code, language processing code, and system program code. The system code and language processing code are tailored at system generation time according to the hardware configuration on which the system runs and the software features which are chosen by the system manager. Once the system is generated, the system code and language processing code are frozen, and are alterable by patching or generating new code. The system program code exists in a library of programs executable by the system software or by individual users on the system. The library of programs is alterable and expandable during timesharing without requiring regeneration of the system.

System Code

The RSTS/E system code is stored on the system disk as a save-image library (SIL). A SIL, when loaded into memory, is immediately executable by the PDP-11 computer. The system code comprises many distinct elements which are either resident in memory or on disk during timesharing. Permanently resident elements are the following:

- Interrupt and trap vectors
- Small and large system buffers
- System information and data tables
- Disk and device drivers
- File processor modules

Optionally, the following are also resident modules:

- FMS/RSTS forms code in the terminal driver
- DECnet/E—Network Communications handler
- RJ2780—Remote Job Entry handler

The following elements are either permanently resident or disk resident (overlay) elements, the choice to be selected during system generation:

- File processor modules
- Infrequently used utility routines

System initialization code is loaded only during system start-up.

RSTS/E operations start when the system disk is bootstrapped. The bootstrap routine loads the initialization code which determines the hardware configuration and performs many consistency checks to ensure the integrity of the software. When checking is completed, the initialization code remains resident and allows many options.

Language Processing Code

DCL serves as the recommended default run-time system. However, any of the languages mentioned above may be used for applications programs. The auxiliary run-time system or object time system associated with a given language processor is loaded into memory only when a request is made to execute that language compiler or to execute a compiled program written in that language. The language processors reside on the system disk in machine executable form and can be either permanently resident in memory or temporarily resident (swappable). Usually the language compiler is swapped out to disk as required, just as any normal user job would be.

The run-time system may vary in size from 4 KB to 32 KB, and is generally shared among users.

FEATURES

System Generation

System generation is normally a one-time operation in which the system manager defines the hardware configuration and selects the basic software options. The system manager needs to perform a system generation only when the system is first installed or when the hardware configuration changes. Software options can be included in the system to tailor the system to the needs of the application.

In addition to defining the number and kinds of peripherals and processing hardware during system generation, the system manager defines special configuration options. Some of these options are discussed below.

Pseudo Keyboards — The system manager can define the system to have one or more pseudo keyboards. Using a pseudo keyboard as a communications device, you can write a program to control other jobs. In addition, each copy of the BATCH system program requires one pseudo keyboard to run jobs in a batch stream.

Multiple Terminal Service — The multiple terminal service option allows one program to interact with several users simultaneously by servicing their terminals on one I/O channel. This eliminates the need to run separate copies of the same program when several terminals must perform a similar function.

Floating Point Precision and Scaled Arithmetic — The system manager can select either single precision (2-word) or double precision (4-word) floating point numeric format. If the system has floating point hardware, the system manager can select a floating point math package that will increase processing speed by using the hardware instructions. The scaled arithmetic feature is included in all 4-word floating point math packages. Scaled arithmetic avoids loss of precision in floating point calculations; it is therefore very useful in calculating sums of money that cannot be manipulated easily as integer quantities.

System-Wide Logical Names — RSTS/E allows the system manager to assign up to 50 logical names on a system-wide basis. Any user can type a system-wide logical name to access the device (and, optionally, the account) it represents.

File Processor Buffering — The optional file processor (FIP) buffering module accelerates file processing on the RSTS/E system.

The module reduces the number of accesses to disk by maintaining more than one disk directory block in memory. The system manager can enhance FIP buffering by allocating additional memory to extended buffer space for use as a cache for disk directory blocks.

Data Caching

RSTS/E supports software disk caching of file directories and file data blocks.

Software disk cache is a dynamically allocated portion of main memory in which blocks of disk-accessed file data are stored. When a request is made to read a disk block, the operating system first checks the cache. If the block of data is there, a physical disk access is avoided. This results in faster program execution because disk accesses are minimized.

When the cache is full, new information is read into an area that contains the least recently used block of data. This automatic mechanism ensures that frequently-used blocks of data remain in the cache.

Cache size is determined by the system manager. The system manager can designate specific files for caching, or can specify that all files be cached. The system manager can also enable or disable caching of file data, independent of caching disk directory blocks. This system-level capability gives the system manager a powerful method of tuning system performance.

Systems Initialization

After generating the system, the system manager bootstraps the RSTS/E system to load the initialization (INIT) code into memory. The INIT code is a collection of routines used to create the file structures, system files, and start-up conditions required for normal operation of the RSTS/E system. The INIT code is essentially one large stand alone program with many functions. INIT includes routines which ensure the integrity of disk file structures and perform many checks on the hardware configuration. Options are provided which enable the system to function even when certain hardware elements are inoperative. Finally, the initialization code is responsible for loading the RSTS/E Monitor into memory for normal timesharing operations.

Once the default system initialization startup parameters are set up, the system manager does not have to repeat manual startup each time the system is started. Using the automatic restart feature, the RSTS/E system can recover and restart the timesharing session automatically after a system malfunction or power failure. When the system is started in automatic restart mode, control by-passes all parts of the startup code that call for operator intervention.

System Program Code
A library of programs is produced and stored on disk during the system library build procedures of system generation. Both the system and users execute these programs to perform system housekeeping and common utility functions. (Indeed, they are sometimes referred to as CUSP's, Commonly Used System Programs.) The system manager can use the programs to monitor and regulate system usage. Some library programs can be tailored by altering the source statements supplied by DIGITAL and recompiling to replace the current copy on the system disk.

System Management Utility Programs
RSTS/E includes system utility programs for both the system manager and general user. Some system management utilities are privileged programs and can be run only by the system manager or privileged users. Other utilities are not privileged and can be run by the general user, but have privileged features that can be executed only by the system manager.

System management utilities include: system initialization and maintenance programs, resource management and accounting programs, system error logging and analysis programs, operator services and spooling programs, and user communication programs.

System Accounts and Libraries
RSTS/E systems have three system accounts that are integral to the operation of the system and have auxiliary accounts for more efficient operation of the system. The Master File Directory (MFD) account is used on the system device and other disk devices in the system to control system access. The system library account is used by the RSTS/E system to manage a library of generally available and restricted use system programs and message and control files. A third special system account contains RSTS/E monitor files and routines which are critical to the operation of the system.

Of particular interest to the system manager is the accounting information maintained on each user account in the MFD on the system device. This accounting information is normally accessed through the system accounting utility programs. The system manager or privileged users can also access and change this information for programmers using the SYS monitor functions.

Privileged Capabilities and System Operation
Privilege is a special condition for a user job. With privilege, a job has capabilities not available to other, nonprivileged jobs. These capabilities are:

- Unlimited access on the system
- Ability to designate privileged programs
- Use of privileged aspects of system programs
- Use of privileged SYS system functions and the PEEK function

A job has privilege under one of the following conditions:

- It is a logged-out job (a job without an account)
- It is running under a privileged account
- It is running a privileged program

A logged-out job has privilege because the system must perform certain privileged operations to log a job into the system. The privilege remains in effect as long as the job remains logged out.

A job running under a privileged account has privilege, and the privilege remains in effect until it is logged out or changes to a nonprivileged account.

A privileged program is an executable file with a protection code of <192> (the sum of the privileged protection <128> and the compiled file protection <64>) or greater. The privilege is temporary unless the job is running under an account which itself has permanent privilege. The privilege remains until the program exits or until the program drops its temporary privilege. This temporary privilege allows a nonprivileged user to run a privileged program.

The following paragraphs summarize briefly privileged capabilities.

Unlimited Access

No file in the RSTS/E system can be protected against a privileged job. A privileged job can create and delete files under any account number on any disk. Such unlimited access does not generate the normal PROTECTION VIOLATION error.

Ability to Designate Privileged Programs

A program is privileged when it is an executable file and has a protection code of <192> or greater. Only the system manager or other users running under privileged accounts can create or modify privileged programs.

Use of Privileged Features of System Programs

If a program is designated privileged and is not protected against execution, any user can run the program with temporary privilege. Temporary privilege means that system operations normally reserved to a user of a privileged account can be executed while running under nonprivileged account.

The ability to designate a program as privileged allows the system manager to extend use of privileged functions to nonprivileged users. For example, the program TTYSET allows general users to change characteristics of their terminals. Such an action is a privileged system function; with temporary privilege, however, execution of the function by the owner of a nonprivileged account does not generate the normal PROTECTION VIOLATION error.

The same TTYSET program additionally allows a privileged user to change characteristics of other terminals. A check is built into the program to ensure that a user attempting to change the characteristics of a terminal other than his own is indeed a permanently privileged user. In effect, the execution of some privileged functions is made available to the nonprivileged user but other privileged features are available only to those users logged into the system under privileged accounts.

General System Utility Programs

RSTS/E provides several utility programs available to the general user. These programs include system information and terminal utility programs, file utility programs, and special service programs. Like the system management utilities, they are stored in the system library account and are called and executed by issuing the RUN system command or, if it is available, the appropriate CCL command.

The list of programs that follows is not exhaustive; it is only meant to suggest the range of utilities available under RSTS/E operating systems.

System Information Programs

SYSTAT	Provides current status of system jobs, devices, and buffers. Identifies active jobs in the system, accounts under which they are running, their size, their associated keyboard (if attached), and their current activity. Also identifies which devices are assigned and to which jobs.
QUOLST	Provides current system information, including number of free blocks remaining on the system structure, number of blocks used by an account, number of free blocks remaining in and disk quota of an account.
MONEY	Prints current account status, including amount of CPU time, connect time, kilo-core ticks and disk blocks used.

GRIPE	Allows the user to communicate with the system manager.
TTYSET	Allows a user to establish terminal characteristics. The user can call a macro command that establishes the standard characteristics for a selected type of terminal or can select an individual combination of characteristics.
INUSE	Prints the message "IN USE" at a terminal to allow a user to leave the terminal momentarily.
PIP	Allows the user to transfer files from one device to another, merge files, delete files, initialize a device directory or list a device directory.
COPY	Copies all the information on a disk, DECtape or magnetic tape device.
BACKUP	A package of programs which allow the user to preserve and recall files stored under one or more user accounts by transferring multiple files from the private or public disk structure to a private disk, DECtape, or magnetic tape.
DIRECT	Prints directories of selected file-structured devices.
FILCOM	Compares two text files line by line and prints any differences found.

Special Service Programs

MAC MACRO	Assemble MACRO-11 source code into object format. MAC operates under the RSX-11 run-time system; MACRO operates under the RT-11 run-time system.
LINK	Link object modules produced by FORTRAN or MACRO into an executable image which runs under the RT-11 run-time system.
TKB (Task Builder)	Builds an executable image by linking object modules produced by the MAC assembler or language processors other than FORTRAN. The resulting task image runs under the RSX run-time system specified by the user.
QUE	Creates jobs that are to be executed by spooling programs such as BATCH and SPOOL. It also

	lists pending requests and kills pending requests.
RUNOFF	Generates a formatted listing of a text file containing special RUNOFF text formating commands.

Batch Processing
The capability to execute a batch command allows the user to submit jobs to be run without terminal dialog. BATCH is particularly useful in executing large data processing operations for which interactive requirements are not a factor.

Batch input can be submitted from standard job control files on a random access file-structured device or from an I/O device. The input consists of elements of the batch control language and is collectively referred to as a **batch stream**. It is possible to execute multiple streams simultaneously by running multiple copies of the BATCH program. The capability to run more than a single batch stream is controlled by the system manager.

Logical Disk Structures
Access to all executable code and to system and user data on the RSTS/E system is accomplished through a logical structure of files.

The logical disk structure is divided into two types: public and private, but the file structure on a disk, whether public or private, is the same.

On a public disk, any user can create files. Every user has an account on a public disk. There is always at least one public disk on the system, which is called the "system disk." All public disks together on a system are called the "public structure" because the system itself treats all the public disks together as a unit. For example, when a program creates a file in the public structure, that file is placed on the public disk with the most space available. This is done to ensure proper distribution of files across the disks in the public structure.

The system disk contains the system code. Language processors and the library of system programs are also contained on the public structure. Storage of active user jobs which are temporarily swapped out of memory are in swapping files, at least one of which is on the system disk.

Any remaining disk drives in the RSTS/E disk structure can be devoted to private disk packs or disk cartridges. A private disk is one that belongs to a few user accounts, conceivably to a single user account. Files can be created only under these accounts, and can be read (or written) by other users only if the protection code of the file permits. A user who does not have an account on a private disk cannot create a file on it.

File Access Techniques

There are several file access methods available for the RSTS/E system:

- RMS-11
- BASIC-PLUS
- DMS-500

RMS-11 is the main file and record access method available on RSTS/E. It is used by BASIC-PLUS-2, PDP-11 COBOL, COBOL-81, FORTRAN-77, and optionaly on MACRO-11 and DIBOL-11. In addition, most of the utility programs and layered software products, e.g. SORT-11 and DATATRIEVE-11, will only work when using files maintained through RMS-11.

RMS-11 supports three file organizations:

- Sequential
- Relative
- Indexed

The indexed file organization allows each indexed file to have one primary key and up to 254 alternative keys. In addition to random access based on key values, programs can access records in an indexed file sequentially in ascending order by key values. Records are stored physically only in primary key order.

RMS-11 supports four record formats:

- Fixed length records
- Variable length records
- Variable length with fixed control fields
- Stream records

Indexed files are restricted to either of the two record formats: fixed or variable. The stream record format is restricted to sequential disk files only. Languages that do not use RMS (e.g. FORTRAN IV) cannot process RMS files unless the record format is stream.

User programs are provided with logical data record access to RMS files through extended language syntax statements. The form of the statements are dependent upon the application language interface. The functions provided are:

- OPEN
- CLOSE
- READ/GET
- WRITE/PUT
- REWRITE/UPDATE

- DELETE

In addition to the facilities provided for programming languages, there are a set of RMS-11 utilities that enable the user to create, load, maintain, and backup RMS-11 files.

BASIC-PLUS on RSTS/E provides three methods of file access:

Formatted ASCII	For standard sequential I/O operations.
Virtual Arrays	For random access of large data files. A virtual array is stored on disk and can contain string, integer and floating point matrices.
Record I/O	Allows the user to have complete control over I/O operations.

Formatted ASCII data files are the simplest method of data storage, involving a logical extension of the BASIC-PLUS PRINT and INPUT statements. The INPUT statement allows data to be entered to a running program from an external device, for example, the user's keyboard, a disk, DECtape, or paper tape reader. The PRINT statement causes the output of a specified string of characters to a selected device.

The PRINT-USING statement allows the user to control output formatting. A special set of formatting characters allows the user to format strings and numeric fields with tabs, special characters and punctuation. For example, the user can format check amounts with asterisk-fill for protection.

The RSTS/E virtual array facility provides the means for a program to operate on data structures that require fast random access processing yet are too large to be accommodated in memory at one time. To accomplish this, RSTS/E uses the disk file system for storage of data arrays, and maintains only portions of these files in memory at any given time.

Virtual arrays are stored as unformatted binary data. This means that no I/O conversions (internal form to ASCII) need to be performed in storing or retrieving elements in virtual storage. Thus, there is no loss of precision in these arrays, and no time is wasted performing conversions.

The third type of I/O, record I/O, permits a program to have complete control of I/O operations. Record I/O is a flexible and efficient technique of data transfer. Input and output to record I/O file is performed by the BASIC-PLUS GET and PUT statements. These statements allow the user to read or write specific blocks (physical records) of a file, where the block size is dependent on the type of device being accessed. For example, disk file blocks are always 512 bytes long, while records from a keyboard device are one line long, where a line is delimited by a carriage return or similar terminating character. With disk files, the program has the capability of performing random access I/O to any block of the file. Furthermore, using record I/O operations, the user can create a logical organization for file formats by controlling record length.

DMS-500 is a collection of BASIC-PLUS routines which are optional on RSTS/E systems and standard on the CTS-500 package. DMS-500 comprises a selection of routines which provide capabilities for organizing and processing data records stored in indexed, indexed sequential, and relative file structures. The optional DIBOL-11/DECFORM language package can use either RMS-11 or DMS-500.

The major components of DMS-500 include:

- ISAM/RAM (Indexed Sequential/Relative Access Method). Random access is either by means of a unique or duplicate ASCII key or by means of a relative record number.
- IAM (Indexed Access Method). A hashing technique is used to randomly store or retrieve a data record with a minimum number of disk accesses.
- DSORT (Extended Disk Sort) This method sorts disk resident multivolume files containing blocked, fixed-length records up to 512 bytes in length on up to 15 ascending key fields.

In addition to the basic RSTS/E file handling capabilities, DMS-500 IASM/RAM provides multi-volume disk file support by logically linking together multiple files.

Sys System Functions and the Peek Function

Many programs, particularly MACRO-11 assembly language programs are required to perform functions which directly affect the way in which the system handles such things as memory, I/O devices, runtime systems, etc. Rather than allow the application or system programmer to perform these manipulations in an uncontrolled way, the RSTS/E system provides a series of System Function Calls. These are calls from the program directly to the monitor that bypass the run-time system. The monitor performs the function, then returns to the calling program.

Some of the system function calls are privileged and can be issued only by privileged users or jobs, while others are available to all users. This ensures that the unprivileged user cannot gain access to system functions that could drastically change the way the system is supposed to operate.

System function calls are available to most of the high level languages available on RSTS/E. The calls are formatted for each language consistent with the general language syntax. One major note is that the calls are very system dependent.

The Peek system call is a privileged system call that allows any privileged job to examine any location in the monitor part of memory. This allows the user to read the monitor code, monitor data structures, including data structures of other users, and the file processor. This function does not allow a user program to examine the contents of another user's program.


RL02
PDP 11/23 PLUS

CHAPTER 4
THE RSX-11 FAMILY

INTRODUCTION

DIGITAL offers excellent realtime multitasking with its RSX-11 family of operating systems. Different members of the family are particularly suited to various classes of PDP-11 processors, but there is guaranteed compatibility across the family, so that programs written for one system will migrate easily to other systems. Upward and downward compatibility in the family assure that growth of the installation and changing requirements are easily accommodated.

RSX-11 systems offer:

- Fast response
- Numerous user and system utilities
- A wide range of programming languages
- Management of up to 250 priority levels
- Good program protection
- Low overhead
- Realtime leadership
- Interactive program development and execution
- Multiuser multiprogramming

The high-end RSX-11M-PLUS product can also handle batch job execution.

You can tailor your RSX-11 system to meet the requirements of any application. Of course, as your requirements change, the software can be reconfigured quickly to match the altered situation.

As the pioneer in distributed processing, DIGITAL has made sure that computers operating with RSX-11 can be linked together using the DECnet networking software. They can also be linked via Internets (protocol emulators) to certain computers from other manufacturers. In these ways, regardless of their geographical locations, tasks can communicate with, supply information to, and control one another. In fact, programs may be developed on one system and then loaded into and run on another. Operators at terminals can control peripherals and processors at other locations in the network.

RSX systems are highly reliable systems with built-in protection mechanisms in both hardware and software to ensure data integrity and system availability.

FAMILY MEMBERS

RSX-11M-PLUS

RSX-11M-PLUS is a multiuser system for both program development and application execution designed to run on PDP-11/23-PLUS, PDP-11/24, PDP-11/44 and PDP-11/70 computers. This operating system takes advantage of the expanded memory capability of these machines to provide the most flexibility and best performance of any member of the family.

RSX-11M

The RSX-11M operating system has a subset of the capabilities of RSX-11M-PLUS and is optimized to run on small and medium sized PDP-11s. It is designed to support factory automation, laboratory data acquisition and control, graphics, process monitoring, process control, communications, and other applications demanding immediate response. Its multiprogramming capabilities permit RSX realtime activities to execute concurrently with less time-critical activities such as program development, text editing, and data management.

Unique features of RSX-11M-PLUS include:

- User mode I/D space
- Multistream batch
- I/O request queue optimization
- Performance enhancements
- Dynamic dual path disk support
- Shadowed disk support
- Accounting

Features Common to RSX-11M-PLUS and RSX-11M

- Realtime multiprogramming
- DIGITAL Command Language (DCL)
- Generalized command line interpreter
- Memory management
- Cluster library support
- Error logger
- Power failure restart

RSX-11S

A memory-resident subset of RSX-11M is called RSX-11S. Since a file system is not part of RSX-11S, the file features of its parent, such as checkpointing and data management, are not supported. Instead, RSX-11S is used as a super-efficient execute-only system, generally under conditions in which a disk could not safely operate, for example, on the floor of a manufacturing plant. RSX-11S provides excellent on-line process control, because all programs are memory-resident, response is extremely fast. Tasks for an RSX-11S system are developed on DIGITAL computers with an RSX-11M, RSX-11M-PLUS, or VAX/VMS operating system. Such tasks are then loaded into the RSX-11S system image by using a supplied host utility, by using an RSX-11S utility known as the On-line Task Loader (OTL), or by down-line loading if both the host and the RSX-11S system have DECnet or the DECdataway running. RSX-11S runs on all PDP-11 computers, from the microprocessor LSI-11 to the high-end PDP-11/70.

FEATURES

RSX-11M-PLUS UNIQUE FEATURES

User Mode I/D Space

RSX-11M-PLUS supports separate I/D space hardware. This means that a user task has the ability to address up to 32K words of instruction and 32K words of data at the same time, giving a 64K word total. This simplifies the development and enhances performance of large application programs by reducing the need for overlays.

Multistream Batch

RSX-11M-PLUS has a multistream batch processing capability. The operations personnel can control the number of batch streams that can run. Batch jobs can be submitted by an interactive user, a program, or another batch job. When the number of batch jobs submitted exceeds the number of streams, the remainder of the batch jobs are held in a batch input queue. As with the spool queues, the operator can control the batch job queue by changing job priority, holding a job, or killing a job.

Volume mount commands issued in a batch job can request a generic device such as a disk or specific device unit such as disk-drive unit 2. The batch job waits until the operator satisfies the mount request, while other batch jobs proceed.

I/O Request Queue Optimization

This feature allows request queues for disks to be sorted by cylinder number of the request. The end result is that the average seek length is reduced, improving throughput as much as 30%. This is in addition to the enhanced performance already available through overlapped disk seeks.

Performance Enhancements
Overlapped disk seeks on RSX-11M-PLUS allow more disk accesses per unit of time. Communications microprocessors reduce the system load of interprocessor communications. Priority scheduling, the ability to lock tasks in memory, and other controls allow for further performance tuning.

Dynamic Dual Path Disk Support
RSX-11M-PLUS provides dynamic dual path support for RK06/07, RP04/05/06, and RM02/03/05/80 disks.

Shadowed Disk Support
In dual disk configurations, RSX-11M-PLUS supports disk shadowing where all disk information is written to both disks. This results in each disk being an exact duplicate of the other and enables the system to continue processing without interruption when one disk fails.

Accounting
For accounting purposes, the RSX-11M-PLUS system itself creates and maintains records of the use of system resources. These records are kept in an accounting log file.

Using the detailed accounting log records provided by the system, the system manager or a system programmer can establish programs for reporting on the use of system resources and for billing.

Because the users of the system resources are identified in two ways, reports on the use of system resources and bills for the use of system resources can easily be generated in either of two ways: by user name or by account name.

FEATURES COMMON TO RSX-11M-PLUS AND RSX-11M

Efficient Realtime Multiprogramming
Multiprogramming, the concurrent processing of two or more tasks residing in memory, is accomplished by logically dividing memory into a number of named partitions. Tasks are built to execute in a specific partition; all tasks in a given partition and all partitions in the system can operate in parallel. A task can be fixed in a partition to ensure immediate execution when it is activated, or it can reside on disk while it is dormant to make memory available to other tasks. This allows a number of programs to run simultaneously and maximizes the use of the central processor.

DIGITAL Command Language (DCL)
The DIGITAL Command Language is a useful tool for establishing and controlling the environment in which a process executes. A command

is a request directed from a terminal to the operating system for a specific action. Frequently used strings of commands can be built into command procedures. DCL provides you with an extensive set of commands for:

- Interactive program development
- Device and data file manipulation
- Interactive and batch program execution and control

Generalized Command Line Interpreter (CLI)
This feature provides the ability to write CLI as part of the application code without the need for internal operating system knowledge. No privileged "system" code is required for the new CLI implementation. There can be multiple CLI's on one system with the added feature that each terminal can be set for a unique CLI.

Memory Management
RSX-11 systems with hardware memory management provide automatic memory protection. The memory area assigned to a task is protected from other tasks executing in the system. Each task has a specific address range in which to execute. Very large programs can be executed using either disk or memory overlay structures.

The basis of event-driven task scheduling is the software priority assigned by your system manager to each active task. Realtime tasks require top priority on the system resources in order to be served properly. RSX-11 systems provide 250 software priority levels to allow concurrent processing of time-critical tasks, interactive terminals, and background computation. These software priority levels enable the user to compile/assemble, debug, and install tasks without affecting realtime task response. Software priority levels allow optimization of central processor use, as well as flexible performance options that can be tailored to specific application needs.

When a significant event occurs (such as I/O completion), the system Executive automatically interrupts the executing task and searches for the highest priority task that is ready to execute. It is possible to have several tasks assigned to the same priority. For part of the priority range, a given task will run until it needs to wait for an event. Then the next task at that priority will start executing. For the rest of the priority range, the tasks are rotated in the queue by a round-robin scheduler on a timeslice basis. The effect is to distribute the processor time evenly so that each task has its own turn at the top of the queue.

Once a task is in memory, the Executive normally allows it to run to completion even if memory is required for the execution of a higher priority non-resident task. An alternative with RSX-11 is to declare a task checkpointable. A checkpointable task currently active in a partition can be interrupted and swapped out of memory to disk when a higher priority task requests the partition. Later, after the higher priority task has completed its execution, the checkpointed task will restart execution where it was interrupted. With the checkpointing feature, more tasks can run concurrently in a given amount of memory, giving greater system throughput.

As an option in RSX-11 systems with hardware memory management, the RSX-11 Executive can dynamically allocate available memory in system-controlled partitions for more efficient use of memory. Effectively, this allows a task to be loaded anywhere there is room for it. The Executive keeps a list of the available areas of memory and loads tasks into it on a priority basis until either the requests are satisfied or there is no memory available in the partitions. When a task terminates, the memory it occupies becomes available again.

Cluster Library Support

With cluster libraries, only the library in use at any point in time is actually mapped to the task address space rather than the simultaneous mapping of all libraries. This leaves more task address space for application code.

Error Logger

The error logger features complete and easy to read reports, and includes error logging and reporting of customer added devices.

Power Failure Restart

Power failure restart is the ability of a system to smooth out intermittent short-term power fluctuations with no apparent loss of service or data. Power failure restart also maintains logical consistency within the application tasks and the system itself.

System Use

RSX-11 operating systems provide the facilities needed by users to implement efficient real time applications easily. The powerful Monitor Console Routine (MCR) command language connects the user to the RSX-11 system. MCR or the DCL command language include initialization commands, status, message, task control, and system maintenance commands. The MCR organization makes it possible for users to add commands to meet their own special application needs.

DIGITAL Command Language (DCL) is also available for interactive as well as batch processing. DCL is simple to learn and use, because it prompts users for missing arguments and provides a HELP facility to aid users who have forgotten command formats.

To increase program and system development accuracy, RSX-11 systems also have an indirect command file processor. An indirect command file is a text file containing a series of commands exclusive to, and interpretable by, a single task. The interpreting task is usually a system-supplied component of RSX-11M/M-PLUS, such as MCR, MACRO-11, or the Taskbuilder.

There are two types of indirect command files: indirect **task** command files and indirect **MCR/DCL** command files.

An indirect task command file is a sequential file containing a list of task-specific commands. Rather than retyping commonly used sequences of commands, you can type the sequence once and store it in a file. The indirect task command file is specified in place of the command line(s) normally submitted to the task.

An indirect MCR/DCL command file contains a list of MCR or DCL commands. It can, however, contain both normal commands and special commands to be interpreted by the processor itself and used to control command file processing.

In RSX-11 system multiuser environments, a number of terminals can operate concurrently, each running its own set of tasks. It is important to maintain data and system integrity in this kind of development and application environment. RSX-11 has user identification codes, privileged and nonprivileged accounts, password protection, and separate user directories; such multiuser protection allows you to monitor and control individual users of the system.

To reduce waiting time and accommodate more active terminals, RSX-11 provides print spooling, which allows programs to run to completion at full speed with print data going to a disk and without tying up memory resources waiting for the lineprinter. When a spooler finishes a job, it automatically selects the highest priority job from the queue for printing.

Under RSX-11M-PLUS, and as an additional option under RSX-11M, there is spooler support for multiple printers and print queues. Users of these systems do not have to compete with one another for access to the printer.

PROGRAM DEVELOPMENT TOOLS

RSX-11 has a comprehensive selection of application tools designed to shorten the program development cycle. Using the programming languages and the system utilities, users write, test, and execute programs quickly, interactively examine and evaluate the results of program execution, and modify and tune programs online. Compared to batch, interactive program development and testing is much faster and easier. If you are familiar with batch program development, you will be impressed with the ease of these interactive techniques.

RSX-11 Programming

RSX-11 systems offer an impressive range of programming languages so users can select the right language for their specific applications. For example, an organization that uses RSX-11 for a realtime process control application might use the same system to account for its Work In Process (WIP). The process control application could be written in FORTRAN IV, while COBOL might best suit the WIP program.

MACRO, a powerful assembly language supplied with RSX-11 systems, processes source programs and produces a relocatable object module. Its extensive features allow a programmer to code directly and efficiently in assembly language. Programmers can define individual macros that describe entire sequences of operations: the macro definition is required only once, but the operations can be used repeatedly in any program, simply by invoking the macro.

DIGITAL provides, under separate license, a complete series of higher level languages for RSX-11 systems: FORTRAN IV, the primary real time language; easy-to-use BASIC-PLUS-2; PDP-11 COBOL, the language for commercial applications; and CORAL 66, a British government prescribed language. For larger RSX-11M and RSX-11M-PLUS systems, DIGITAL offers performance-optimized FORTRAN-77.

RSX-11 SYSTEM UTILITIES, LANGUAGES, AND EDITORS

With these RSX-11 system features, users can create and edit source program files and data files, share programs and routines, and perform general system activities. RSX-11M/11M-PLUS systems give users:

- A choice of two editors, EDT or EDI
- A sophisticated task builder (TKB) to link modules and prepare executable programs
- System library routines to reduce program development time
- FMS-11/RSX Forms Management System
- Online debuggers (ODT) that allow users to examine, alter, search and execute programs
- Task patch programs (PAT)
- Record and file management utilities (RMS and FCS)

Editors

The RSX-11 editors are EDT, the standard editor offered on most of

DIGITAL's operating systems and EDI, a line-oriented text editor. Neither editor modifies the input file directly, so that if a user accidentally deletes a large amount of text, the original input is still available for quick recovery.

TKB Taskbuilder

The taskbuilder creates loadable memory images from assembled or compiled tasks. It links relocatable object modules and resolves any reference to global symbols, common areas, and shared libraries. The taskbuilder is used to specify a task's attributes, such as checkpointability, priority, etc. The taskbuilder is also used to create shareable commons. The taskbuilder provides an overlay descriptor language to construct task overlays. The overlay descriptor language simplifies the process of dividing tasks into overlaid segments and specifying load methods. If it is requested by the taskbuild command, a cross reference of all global symbols defined or referenced in the task may be obtained by the user. The taskbuilder also has the capacity to link an unlimited number of library files and up to seven virtual memory areas.

Librarian (LBR)

LBR provides the capability to create and maintain disk-resident libraries of object modules and user-defined macros. In addition, LBR may be used to create and maintain **universal libraries** (i.e., libraries whose entries may be any files legal under FILES-11: ASCII files, object files, executable task images, etc.)

Forms Management System (FMS-11/RSX)

Another feature available with RSX is FMS, an optional Forms Management System, which makes it easier for application programs to interact with users at video terminals. With FMS, programmers can create applications that use forms displayed on the terminal screen to handle user inquiry or response. The forms are easy to read, simple to fill in, and the data are moved quickly and efficiently through the application and the system.

ODT Online Debugger

ODT aids the user in debugging programs that have been assembled or compiled and taskbuilt. From the keyboard, the user interacts with ODT to:

- Print or change the contents of a location in the task
- Run the program using the breakpoint features to halt the program at specified points
- Search the program for a specific bit pattern

- Calculate offsets for relative addresses

Trace capability is also provided to aid in the debugging of FORTRAN programs.

Data Management Services

Data management services help you to better manage and work with the information in the computer system. RSX-11M/11M-PLUS data management includes:

- FILES-11, a file system that provides volume structuring and protection
- File Control (FCS) and Record Management Services (RMS) which have a variety of access modes for file storage, retrieval, and modification
- A record management services query language—DATATRIEVE
- A powerful database management system—DBMS

Each of these services has a more detailed description in a later chapter of this book, but each has a short description below.

FILES-11

FILES-11 oversees the storage and handling of both user and system files on volumes. Each volume contains its own set of file directories and information on the protection, size and location of the files on the volumes. The FILES-11 files can be manipulated with system utilities or user-written tasks.

FCS and RMS

The File Control Services (FCS) and Record Management Services (RMS) extend the programming languages by providing general-purpose file and record handling capabilities. They enable a programmer to choose the file organization and record access method appropriate for the data processing application. The file organization and record access methods are independent of the language in which they were programmed.

FCS, the basic file handling system on RSX-11M/M-PLUS systems, treats logical records as data units. These units can be retrieved from a file without requiring the user to know the format in which they were written. FCS supports sequential and random file access.

RMS, a superset of FCS, is compatible with FCS-written files. It adds important capabilities at a level above that of traditional file management services. RMS permits relative, sequential, and multikey indexed sequential file organizations. RMS allows access mode to be sequential, random, or according to Record File Address.

DATATRIEVE

Using DATATRIEVE, an optional inquiry language, data from RMS files can be rapidly extracted and updated. Users can also generate reports and create a directory containing command procedures. In order to perform query, display, report writing, and other activities, DATATRIEVE uses a special command language. The simple English-like commands are designed to be easy to use for every level of user.

DBMS

DBMS, an optional CODASYL database management system, extends the upper range of DIGITAL's data services software. It offers powerful and comprehensive facilities for the management of databases. By allowing the creation of one central database to act as a common resource to any number of application programs, DBMS reduces redundant data, provides data consistency and allows the database to be maintained more easily and with more security. Application programs are shorter, easier to code, and easier to debug.

Other Utilities

PIP Peripheral Interchange Program

PIP is used to copy files from one device to another, for example, from disk to printer; to rename files; to list files; and to delete files.

SLP Source Input Program

SLP is a noninteractive editing program used to create and maintain source language correction files on disk.

ZAP Task Patch

ZAP provides a facility for examining and modifying task image files and data files. With ZAP, permanent patches can be made to task image or data files without having to recreate the file.

PAT Object Module Patch

PAT allows patching or updating code in a relocatable binary object module.

BRU Backup and Restore Utility

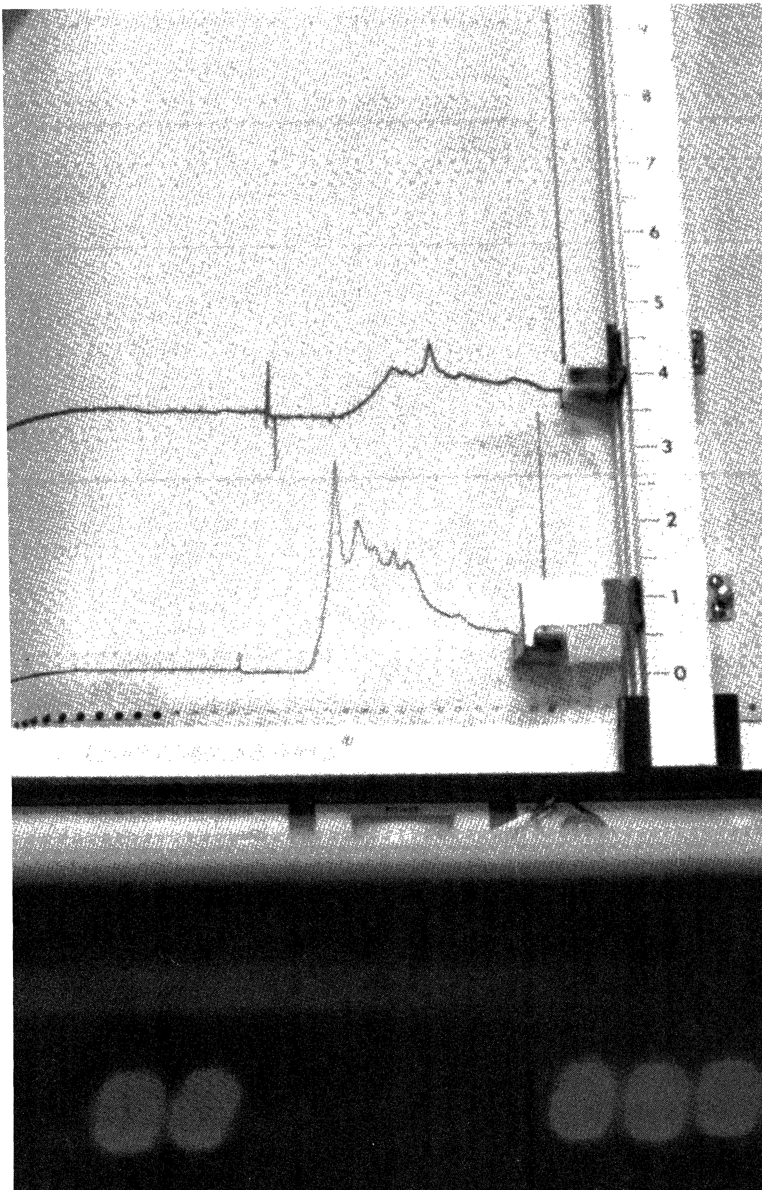
BRU is a high-performance, powerful backup/restore utility. For example, it is able to copy a 200 MB RP06 disk to tape in less than an hour. BRU also supports incremental backups (such as backing up only the files that have been modified since the previous backup), which greatly reduces the amount of time required for proper disk backup.

REALTIME SYSTEM HARDWARE INTERFACES

For applications handling a wide range of realtime processes—whether you need high speed data acquisition, fast response, monitoring and control of online processes, or the rapid reply to terminal inquiry—the flexible and powerful RSX-11 operating systems can do the job well.

To accommodate a wide range of uses, DIGITAL complements its RSX-11 systems with a comprehensive selection of off-the-shelf interfaces that connect realtime or communication equipment to the PDP-11 computer.

Ready-built for communication, industrial, and laboratory applications are asynchronous and synchronous interfaces, interfaces for analog-to-digital and digital-to-analog conversions, and interfaces for digital input/output. And, if it is needed, the RSX-11 operating systems provide a solid foundation and the tools necessary for building one's own interface.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CHAPTER 5
RT-11

INTRODUCTION

DIGITAL provides a compact operating system for realtime, single-user applications: RT-11. It is well suited to such applications as laboratory and factory instrument control, manufacturing process control, flight management, mapping problems, and numerous other technical jobs. RT-11 also finds widespread use in commercial applications, and RT-11 systems can be found doing word processing, medical record management, computerized estimating for general contractors, and typesetting for newspaper publications.

But despite its small size, RT-11 is far from primitive in either its services or its friendly environment. For example, RT-11 supports the standard DIGITAL Command Language (DCL), making access to system services as easy as typing English-like commands. Instead of having to manage system calls directly, you can call services through DCL commands that will prompt for any missing parameters, and will offer HELP if a problem or question arises.

The keypad editor, KED, is especially designed for a wide range of video terminals, and takes advantage of all their advanced features. Screen oriented editing lets you see immediately what effect your editing instructions have, and makes quick changes to correct errors or to accommodate altered program needs. KED is simple to use and easy to learn; even a novice can begin editing right away, since most common editing requirements use no more than two keystrokes, and the editing instructions themselves are clearly named to explain what they do.

Other software features are described later in this chapter to show you the full range of tasks RT-11 accomplishes in making the system accessible to both novice and experienced users alike.

MONITORS

The monitor is that part of the operating system which controls and allocates the services of the rest of the system. RT-11 systems give you a choice of any one of three different monitors. To accommodate the range of typical RT-11 users, DIGITAL supplies the system with:

- A single-job monitor, called SJ, that organizes the system for single-user, single-program conditions. SJ can run in configurations with as little as 24 Kbytes of memory, though in so doing it doesn't have to sacrifice access to system programs, services, or features (except extended memory and the use of a foreground or system job). Since the resident portion of the SJ monitor itself needs only 4 Kbytes of memory, it leaves lots of room for extensive program development. Also, because the monitor services interrupts very quickly, SJ systems are ideal for programs that require a high data transfer rate.

- A foreground/background monitor takes advantage of the fact that much central processor time is often spent waiting for external events such as I/O transfer or realtime interrupts. In FB monitor systems this waiting time is put to good use by allowing you to use the central processor for another (background) job while your principal job is pausing. For example, if your foreground monitor is running a laboratory sampling program, your background job could be a FORTRAN program development session, or an accounting file update. When the foreground pauses to receive data from the instruments, the background lets a programmer work on his coding, or update the file.

  In FB situations, the foreground job is always of higher priority than the background one, so that the system returns control to the foreground job when it is again ready to run. The FB monitor can set timer routines and send data and messages between the two jobs.

- Finally, there is an extended memory monitor, XM, which allows both foreground and background jobs to extend their effective logical program space beyond the 64 Kbyte space imposed by 16-bit addresses on PDP-11 computers. The XM monitor contains all the features of FB plus the capability of accessing up to 248 Kbytes of memory. Extended memory is managed by the monitor as a system resource and is dynamically allocated to programs as they need it. The extended memory overlay feature permits overlays to reside in extended memory rather than on disk; this results in faster execution time for overlaid programs.

These three monitors are upwardly compatible: FB provides all the services of SJ; XM provides all the services of FB. As system generation options, FB and XM monitors support error logging and system jobs.

You can access the monitor through either keyboard commands or programmed requests. With keyboard commands, you can load and run programs, start or restart programs at specific addresses, modify the contents of memory, and assign alternative device names to mention only a few of the services available. If you have a series of keyboard commands, you may create an **indirect command file**, a list of commands to be executed sequentially by the computer. Typically, you would write an indirect file for jobs that use a lot of computer time but do not need your supervision or intervention. Another possible use of indirect files is for command sequences that you use repeatedly and that are time-consuming to retype. Simply construct the indirect file and call it up when you want the monitor command procedures it includes.

Programmed requests to the monitor appear in a MACRO-11 source library and permit an assembly language program to access monitor services. Once a program is running, it communicates to the monitor through programmed requests. If your programs are written in FORTRAN IV, they can access the monitor services through the system subroutine library. Typical programmed requests manipulate files, perform input and output, and suspend or resume program operations.

SYSTEM UTILITIES

Though you may call most of the system services through keyboard monitor commands, the keyboard monitor itself does not perform the work. Instead, it passes the requests on to the appropriate system utility programs. By providing this simple interface, the monitor reduces the complexity of programming or operating the computer, and thus increases your productivity. Some of the utility programs and their functions are listed below.

Peripheral Interchange Program

The Peripheral Interchange Program (PIP) is a file transfer and file maintenance utility program. PIP is used to transfer files between any of the RT-11 devices and to merge, rename, and delete files. With PIP you can perform numerous operations simply and avoid the difficulty usually associated with file transfer and manipulation requirements.

PIP allows you to protect files against accidental deletion. File protection is indicated by the letter "P" next to the file size as listed in the file's directory. Files may be protected and unprotected only by using the RENAME keyboard command or the PIP utility.

Device Utility Program

The device utility program (DUP) is a device maintenance utility program. DUP creates files on file-structured RT-11 devices. It can also extend files on certain file-structured devices (disks and DECtape), and it can compress, scan for bad blocks, image copy, initialize, or boot RT-11 file-structured devices.

Directory Program

The directory program (DIR) performs a wide range of directory listing operations. It can list directory information about a specific device, such as the number of files stored on the device, their names, and their creation dates. DIR can list details about certain files, too, including their names, file types, and sizes in blocks. DIR can also print a device directory summary, and it can organize its listings in several ways, such as alphabetically or chronologically.

Command String Interpreter
The command string interpreter (CSI) is the part of the RT-11 system that accepts a line of ASCII input, usually from the user at the console terminal, and interprets it as a string of input specifications, output specifications, and options for use by a system utility program.

Librarian
The librarian utility program (LIBR) lets you create, update, modify, list, and maintain library files. A library file is a direct access file (a file that has a directory) that contains one or more modules of the same module type. The librarian organizes the library files so that the linker and MACRO assembler can access them rapidly. The modules in a library file can be routines that are repeatedly used in a program, routines that are used by more than one program, or routines that are related and simply gathered together for convenience.

DUMP
DUMP is the RT-11 program that prints on the console or lineprinter, or writes to a file, all or any part of a file in octal words, octal bytes, ASCII characters, or Radix-50 characters. DUMP is particularly useful for examining directories and files that contain binary data.

File Exchange Program
The file exchange program (FILEX) is a general file transfer program that converts files from one format to another so that they can be used with other operating systems.

Source Compare Program
The source compare program (SRCCOM) compares two ASCII files and lists the differences between them. SRCCOM can either print the results or store them in a file. SRCCOM is particularly useful when it is necessary to compare two similar versions of a source program. A file comparison listing highlights the changes made to a program during an editing session. SRCCOM can also produce (as output) a file of SLP commands that can be used later with SLP to patch an original file to match its edited version.

Binary Compare Program

The binary compare program (BINCOM) compares two binary files and lists the differences between them. You can direct BINCOM to print the results of the comparison at the terminal or lineprinter, or store them in a file. It can also create an indirect command file that invokes SIPP to patch one save file to match another version.

Resource Program

The resource program (RESORC) displays information about the system configuration.

Linker

The RT-11 linker (LINK) converts object modules produced by an RT-11 supported language processor into a format suitable for loading and execution. The linker processes the object modules of the main program and subroutines to:

- Relocate each object module and assign absolute addresses
- Link the modules by correlating global symbols that are defined in one module and referenced in another
- Create the initial control block for the linked program that the GET, R, RUN, and FRUN commands use
- Create an overlay structure if specified and include the necessary run-time overlay handler and tables
- Search libraries specified by the user, to locate any unresolved globals
- Automatically search a default system library to locate any remaining unresolved globals
- Produce a map showing the layout of the executable module
- Produce a symbol definition file

The linker runs in a minimal RT-11 system of 24 Kbytes of memory; it uses any additional memory to facilitate efficient linking and to extend the size of the symbol table. The linker accepts input from any random access device on the system; there must be at least one random-access device (disk or DECtape) for memory image or relocatable format output.

PROGRAM ALTERATION

Five RT-11 programs help you debug programs and make changes to programs that are already assembled. They are: the on-line debugging technique (ODT), PATCH, save image patch program (SIPP), the object module patching utility (PAT), and the source language patch program (SLP).

RT-11 On-Line Debugging Technique

RT-11 on-line debugging technique (ODT) is a program supplied with the system that aids in debugging assembly language programs. From the terminal, you can direct the execution of programs with ODT. ODT performs the following tasks:

- Prints the contents of any location for examination or alteration
- Runs all or any portion of an object program using the breakpoint feature
- Searches the object program for specific bit patterns
- Searches the object program for words that reference a specific word
- Calculates offsets for relative addresses
- Fills a single word, block of words, byte or block of bytes with a designated value

PATCH

The PATCH utility program is used to make modifications to any RT-11 file. PATCH can be used to examine and then change bytes or words in the file.

Save Image Patch Program

The save image patch program (SIPP) lets you make modifications to any RT-11 file that exists on a random-access storage volume. It is especially useful for maintaining .SAV image files. Using SIPP, you can examine locations within a file. You can use SIPP from the console, an indirect command file or a BATCH stream to patch all files created with the linker. SIPP can patch overlaid files created with the Version 4 linker, and nonoverlaid files created by previous linkers.

SIPP was designed to replace the former PATCH utility. However, PATCH is included in the Version 4 release so that patches that have been published prior to this release can be installed, and PATCH can patch overlaid files created with the earlier linker.

Object Module Patch Utility

The RT-11 object module patch utility (PAT) allows you to patch or update any code in a relocatable binary object module. PAT does not permit examination of the octal contents of an object module; that is a function of SIPP. An advantage to using PAT is that relatively large patches can be added to an object module without performing any octal calculation. PAT accepts a file containing corrections or additional instructions and applies these corrections and additions to the original object module.

Source Language Patch Program

SLP is a patching tool you can use for modifying source files. When used with SRCCOM, you can patch a source file so that it will match an edited version. SLP accepts as input a source file you wish to patch and a command file created by SRCCOM.

Text Editors

One of the most useful of all utilities is a text editor, since it makes the job of creating, correcting, and updating programs and files a simple matter of using commands at the terminal. RT-11 provides a selection of editors, including EDIT and KED.

EDIT is a program that creates or modifies ASCII source files and prepares them as input to other programs, such as compilers or assemblers. The EDIT program can read files from any input device and write them on any output device. It is a line-oriented editor, most useful for hard copy terminals.

EDIT performs four functions, exactly those you would expect an editing program to provide:

- Locates the text to be changed
- Executes and verifies the changes you command
- Lists a copy of the edited page on your terminal
- Outputs the page to the output file

In order to process text, EDIT thinks of a file as divided into logical units called pages of about 50 or 60 lines in length. Such a logical page corresponds roughly to a physical page in a program listing. One page at a time is read from the input file to the buffers, where it becomes available for editing.

KED is a video display editor meant for use with VT100 and VT100-compatible terminals. It takes advantage of the special keypad to the right of the terminal's keyboard. Keypad keys provide quick operation of various editing functions, such as moving the cursor left or right by a word or character. KED provides a HELP file in order to make keypad editing easy to learn and enjoyable to use.

BATCH

RT-11 BATCH is a complete job control language that allows RT-11 to operate unattended. RT-11 BATCH processing is ideally suited to frequently run production jobs, large and long-running programs, and programs that require little or no interaction with the user.

RT-11 BATCH permits you to:

- Execute a RT-11 BATCH stream from any legal RT-11 input device

- Output a log file to any legal RT-11 output device (except magtape or cassette)
- Execute the BATCH stream with the single-job monitor or in the background of the foreground/background monitor or with the extended memory monitor
- Generate and support system-independent BATCH language jobs
- Execute RT-11 monitor commands from the BATCH stream

ADDITIONAL SOFTWARE COMPONENTS

The RT-11 operating system supplies several other useful software components that help in the smooth operation of your computer. Two features available under RT-11 are the **System Jobs Feature** and the **Queue Package**.

The System Jobs Feature permits an FB or XM monitor created through system generation to run up to six extra jobs, in addition to the normal foreground and background jobs. DIGITAL provides two system jobs: the file queuing job, QUEUE, and the error logger, EL. If you generate a monitor with support for system jobs, you can run either or both of the supplied system jobs along with a foreground and background job (although this reduces memory available for foreground and background operation). Under the distributed FB monitor, you can run a system job as the foreground job.

With the file queuing package (QUEUE and QUEMAN), you can send files to any valid RT-11 output device. Although the Queue Package is particularly useful for obtaining hardcopy listings of files, queuing is not restricted to a lineprinter or to other serial devices. The QUEUE program runs with the FB or XM monitors, as either a foreground or system job. QUEMAN, the user interface to QUEUE, runs in the background.

Error Logger

The error logger (EL) monitors the hardware reliability of the system. It keeps a statistical record of all I/O operations on devices that call it. At intervals that you determine, the error logger produces individual or summary reports on some or all of the errors that have occurred. Support for the error logger must be obtained through system generation. The error logger runs with the FB or XM monitors, as either a foreground or system job, but is not supported under the SJ monitor.

SYSTEM SUBROUTINE LIBRARY

The RT-11 FORTRAN IV System Subroutine Library (SYSLIB) is a collection of FORTRAN-callable routines that allows a FORTRAN user to access various features of RT-11 foreground/background (FB) and single-job (SJ) monitors. SYSLIB also provides various utility functions, a complete character string manipulation package, and a two-word integer support. This library file is the default library that the linker uses to resolve undefined globals and is resident on the system device (SY:).

Some of the functions provided by SYSLIB are:

- Complete RT-11 I/O facilities, including synchronous, asynchronous, and completion-driven modes of operation. FORTRAN subroutines may be activated upon completion of an input/output operation.
- Timed scheduling of asynchronous sub jobs (completion routines). This feature is standard on FB and optional on the SJ monitor.
- Complete facilities for interjob communication between foreground and background jobs (FB and XM only).
- FORTRAN interrupt service routines.
- Complete timer support facilities, including timed suspension and time-of-day information. These timer facilities support either 50- or 60-cycle clocks.
- All auxiliary input/output functions provided by RT-11, including the capabilities of opening, closing, renaming, creating, and deleting files from any device.
- All monitor-level informational functions, such as job partition parameters, device statistics, and input/output channel statistics.
- Access to the RT-11 Command String Interpreter (CSI) for acceptance and parsing of standard RT-11 command strings.
- A character string manipulation package supporting variable-length character strings.
- INTEGER*4 support routines that allow two-word integer computations.

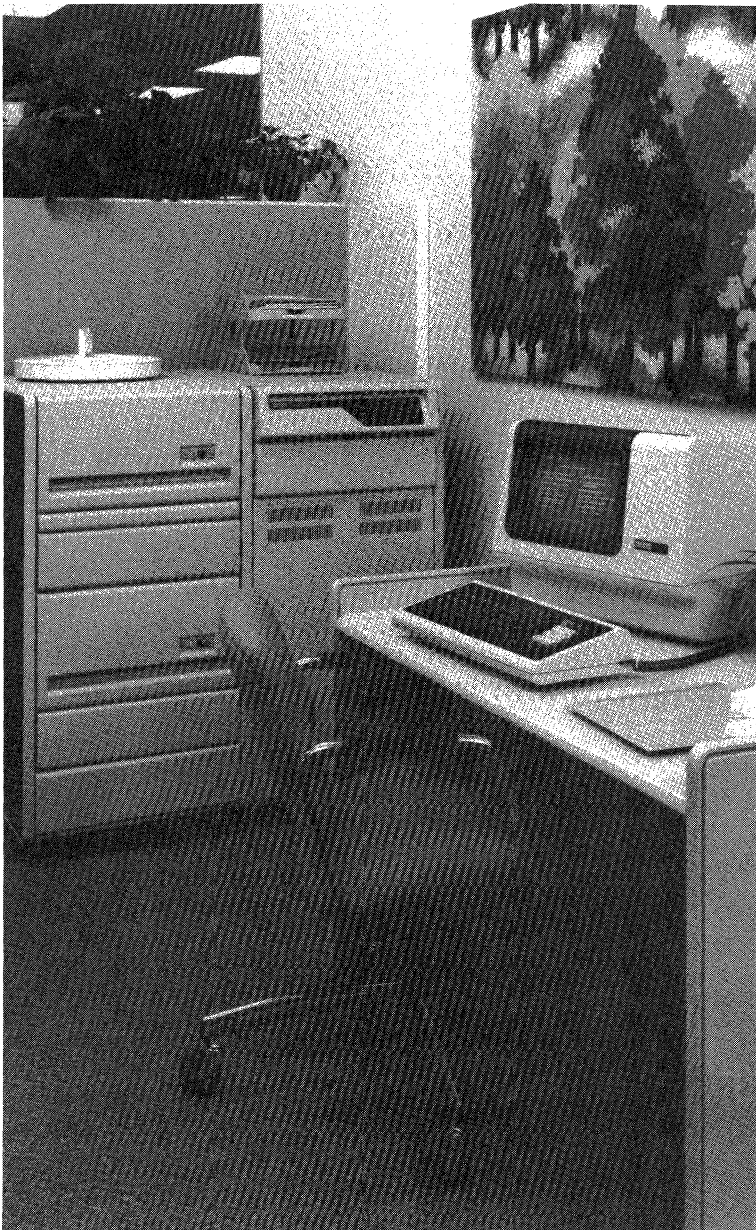
SYSLIB allows a FORTRAN IV user to write almost all application programs completely in FORTRAN IV with no assembly language coding.

RT-11 AUTOPATCH

RT-11 Autopatch is a software tool that automatically installs mandatory patches to modules on unaltered distribution kits of RT-11 and some of its layered products. Autopatch eliminates the need to install manually the patches published in the RT-11 Software Dispatch. The Autopatch kit also provides optional patches in machine-readable form so you do not have to type them. However, Autopatch does not automatically install these patches.

RT-11 Autopatch guides you through an interactive dialog. Your responses to the dialog questions supply Autopatch with information about which RT-11 products you want to patch and which devices you are using. Following the dialog, Autopatch automatically installs mandatory patches to the RT-11 operating system or layered products of your choosing. Autopatch tells you whenever you must switch volumes while the software is being patched. When Autopatch finishes installing the mandatory patches, you can use the optional patch files provided on the kit to install optional patches.

Autopatch is available to be purchased separately from the RT-11 system.



CHAPTER 6
CTS-300

INTRODUCTION

Where high reliability and flexibility are needed in a small business computer, DIGITAL's CTS-300 is a solution. It is based on RT-11, one of the most versatile of all operating systems, and uses DIBOL, a popular, friendly programming language especially designed for writing business applications.

CTS-300 is a complete software environment designed for small DIGITAL general purpose computer systems. It provides an operating system, a higher level programming language, system utilities, a text editor, a Sort/Merge program, and program development tools. Program development may be done in a time-sharing environment. CTS-300 is capable of supporting up to 12 users or up to 16 jobs simultaneously, depending on your application programs.

Depending upon hardware and system generation options, suitably configured Datasystem computers can accommodate a mix of application and program development terminals. In addition, if the hardware includes VT100 video terminals, the DECFORM screen handler running as part of CTS-300 will take full advantage of the VT100's wide range of features.

CTS-300 has a diverse customer base of more than 15,000 banks, retail stores, insurance offices, service bureaus, wholesalers, accounting firms, and business offices of numerous companies. Some users connect their Datasystems to distributed networks, some run them as stand alone computers.

CTS-300 provides you with immediate access to on-line information. Interaction with the system comes through high-speed video terminals, where the entire resources of the system are at your disposal for running programs. User programs may perform any data processing job from inventory control to accounts receivable.

Programs are not swapped in and out of memory while running, but reside in memory in dynamic partitions. This provides for two major benefits—fast terminal response time and a smaller resident operating system.

CONCURRENT PROGRAM DEVELOPMENT

A major capability of CTS-300 is made available through the CRT-oriented programming editor, DKED. With this feature, it is possible to create and modify DIBOL programs on-line, with multiple copies running under Extended Memory Time-Shared DIBOL (XMTSD). Further, one or more of the developers could be remote, using dial-up lines under XMTSD.

Concurrent program development and application execution provide excellent flexibility. XMTSD runs in either the background or in the foreground. In this latter case, the background partition is available for program development.

There are two ways of using the background. The first is with one application programmer occupying the background for program development using familiar utilities. Simultaneously, XMTSD can execute applications in the foreground. The second mix occurs when more than one programmer is developing in the foreground. This is accomplished by running DKED, the editor, in the foreground partition, as a job under XMTSD. When a program is ready for compiling and linking, it is then submitted to a command file in the background queue. Requests are executed in the order submitted: the queue will hold up to sixteen requests from various programmers.

EASE OF PROGRAMMING

The FLAGS subroutine permits a DIBOL application to select up to eight independent options at run time with one optional argument. During the running of an application, it is often desirable to change one of the eight options. This is accomplished by using an optional second argument to FLAGS.

In routine operator/CRT interaction, it is often desirable to time such things as messages displayed on terminals. For instance, information displayed as part of a program could take some length of time for an operator to read before the next application subset could occur. The SLEEP statement under TSD/XMTSD monitors will defer execution of a job for a specified period of time, thus allowing programmers to better utilize the scheduling of time among the other jobs.

The Print Utility provides programmers with a tool to produce simple, *ad hoc* reports from data files. This utility enables a search of a file index for report creation, while leaving the master file intact. It is unnecessary to sort the master file first, in a different order, then create a report; a small sorted index file will be sufficient. The enhanced Print Utility can improve programmer productivity.

The ISAM Utility allows end-user operators to create ISAM files without operator intervention. The autocreate feature can be initiated directly at a terminal or indirectly via chaining. Faster and easier file reorganization is the result.

The high-speed Sort/Merge utility permits users to easily define the parameters for sorting and merging data files. Users can specify up to eight key fields to control the ordering of the output records, in either ascending or descending sequence. A wide range of control over operating parameters, such as the number of work files to be used, is provided to enable users to achieve maximum sort efficiency. In addition, CTS-300 includes numerous utilities important in making system use easy. They are briefly explained below.

The Linker, an easy-to-use utility, converts the output from the DIBOL compiler into a run time format. The Linker allows a main program to be combined with many compiled external subroutines into a single executable job, and provides the ability to specify overlays. (Overlays allow the run time job to use less main memory than would otherwise be required.)

The Peripheral Interchange Program (PIP) allows either ASCII or binary files to be transferred among any RT-11 supported devices. It performs directory operations, renames files, extends the size of a given file, and consolidates empty files into one contiguous space. Segmented files can be merged during a PIP transfer, or multiple transfers may be executed in response to a single keyboard command.

The File Exchange (FILEX) Program provides a universal file format via floppy disks between Datasystem 300s and 500s. FILEX creates an IBM-compatible floppy in 3741 format that can be read by either IBM systems or other DEC Datasystems.

The Device Utility Program (DUP) performs general utility functions in support of disk devices. Among DUP functions are initializing devices, scanning for bad blocks, and compressing data on a disk.

The Directory Program (DIR) is used to list the file directories for disk devices. DIR allows directory listings to be sorted by file name, file type, date, size, or position.

The Librarian creates and maintains libraries of commonly used programs. Each library has a catalog, listing the sections with sufficient information to enable the Linker to find them. The Librarian's tasks include creating libraries, adding new modules to existing libraries, copying options, including selective deletion and replacement during the copy, and listing the catalogs of libraries.

COMMAND LANGUAGE

CTS-300 is designed for interactive use. The keyboard commands are consistent in format and easy to understand, and the high-level command language allows transition from source code to executing code with only one statement. CTS-300 also features indirect command files, which permit you to invoke a whole stream of system commands, similar to a BATCH stream, by issuing a single, one-word command. Unlike a BATCH stream, however, there is no complicated job control language to learn. Indirect command files accept the same monitor commands that users type at the terminal.

DATA MANAGEMENT SERVICES

Data Management Services for CTS-300 (DMS-300) provide capabilities for handling sequential, random, or ISAM structured files. DMS-300 also supports file sharing and multivolume files. Multivolume file support permits one file, extending over several disk drives, to be processed sequentially or by keyed access, without requiring special programming.

OPTIONAL SOFTWARE

RDCP (Remote Data Communications Package)

RDCP is a powerful batch data communications package which uses both IBM 2780 and 3780 protocols. It is easy to use, yet gives the data processing center the control necessary to manage a network of systems from a single location. It can be used to communicate with IBM processors as well as other DIGITAL Datasystems. Its key capabilities are as follows:

- Concurrent operation with other application programs, provided the system is configured with 28 KB of memory
- Unattended operation, depending on hardware configuration
- Batch command stream
- Recovery restart
- Data compression/decompression
- Transparent data
- Automatic calling, depending on hardware configuration
- Auto dial auto answer depending on hardware

DIBS-11 (Integrated Business System)

DIGITAL's DIBS-11 Integrated Business System is a multitask business application package that consists of six fully integrated modules—Order Entry/Invoicing, Inventory Management, Accounts Receivable, Accounts Payable, Payroll, and General Ledger. These modules may be utilized separately or as part of a totally integrated system that shares information between jobs. When integrated, information from the separate modules is posted automatically to General Ledger accounts in the system. Integration keeps information current and reduces operator time.

Collectively, the DIBS-11 modules answer the data processing requirements of most business users. If additional functionality is required, new software can be developed and easily integrated into the system. The modules can be selectively introduced into a business. This minimizes the disruption of on-going operations by allowing the user to make adequate preparations and to complete the necessary training in phases. As the modules are introduced, they can be easily integrated with one another, enabling the sharing of data resources and system capabilities. Each module is thoroughly documented by comprehensive manuals, and while all were designed to function together, each can be used independently of the others if desired.

To simplify the implementation and use of the DIBS-11 accounting software modules, we have designed them using a common framework of standard routines and programs. When used properly, the routines provide system security, file protection, and a means of chaining programs together into job streams. They also serve as a means of assuring consistency of documentation and maintenance for any new software which might be added to the basic modules.

A further aid to programmers is the inclusion of various "hooks" in each of the modules. These hooks can be used to customize or expand the functionality already provided. Many of the hooks are aready predefined, making the programmer's task even easier. For example, certain data fields have been defined even though they are not used by the application programs.

All of the modules use a common set of external subroutines to handle processes that are frequently encountered. This not only helps to simplify the programmer's task, it also minimizes program length and helps to maintain the consistency of system design. Some of these subroutines include printer, terminal, and disk I/O routines; commonly used algorithms such as day or date calculations; and routines specifically designed for the multiple-branch environment.

Whenever possible, general functions such as file protection in multiuser environments are handled in common routines. This, too, relieves the programmer of some design burden and allows concentration on the unique aspects of the problem at hand.

The DIBS-11 modules employ essentially the same design concept. In general, all data files are either standard indexed file access or a fixed length, sequential file format. In addition to the regular application files, DIBS-11 maintains a number of special-purpose files which contribute to system functionality. One is a menu processor that contains all of the screen prompts appearing in the user menus, along with associated program or menu names. Through the menu processor, screen formats and the sequence of program execution can be changed without having to write source code.

Others are a system file that in run time use allows an operator to select and use system peripherals without the need for special programming; a table file of miscellaneous application data used by the modules (e.g., sales code tables, price rules, branch names); a user file that keeps track of which program is running or about to run, and any messages passed between programs; a file that is updated with the current status of each data file and is the means by which data files are protected in multi-user environments.

Another important system feature is a subroutine which causes structures to be copied into source programs automatically. This allows common code (e.g., record layouts and procedure) to be shared by all application programs system-wide.

DIBS-11 is written in DIBOL. It is a customer-supported product which is distributed with source code.

DECtype-300

DECtype-300 is word processing software for CTS-300 which provides concurrent word and data processing. It is intended for use by organizations whose primary need is data processing. Systems equipped with DECtype-300 give users at every terminal word or data processing as needed.

DECtype-300 is a word processing application that produces documents. As you type text from a keyboard, DECtype-300 displays it on a video screen. Once the text is typed, DECtype files (saves) the document on a storage device, making it available for later use. At any time you can call the text back to the screen and use the keyboard to modify the document. You can tell DECtype-300 to print the document on any of several printers which may be attached.

DECtype-300 provides many options which let you produce documents that present your ideas as you intended them. You can highlight certain text by underlining or bolding it. You can type two or more characters in the same place on the paper, producing composite characters. You can use subscripts and superscripts for footnotes or mathematical formulas. You can right- or left-justify text, or center text between the margins. You can add space between words and margins and tab stops in any part of the document. You can indent paragraphs, switch between single-spacing and double-spacing, include tables in the text, and produce many other effects.

DECtype's "advanced features" make use of its general-purpose computer to meet applications other than word processing. You can: (1)

insert information from a list document into the blanks in a form letter, producing "customized" letters; (2) run it at the same time as other business applications; and (3) perform simple mathematical calculations.

DECtype is easy for the new operator to use and understand. Wherever you must make major choices, DECtype-300 displays a "menu," describing all the options and indicating which letters to type to select each option. Before deleting information, DECtype either asks for confirmation or gives you a "second chance" to recover the information. When you give DECtype-300 an invalid command, it displays an understandable message telling you how to correct the problem.

DECtype is also optimized for the experienced user. The actual keystrokes required to invoke an option are minimal and easily memorized. DECtype-300 automatically wraps text so that lines of text will fit within the indicated margins, freeing you to look at the source document instead of the screen. If you should later change the margins, DECtype-300 automatically refits the text to conform to the new margins. DECtype ensures that questions of formatting do not slow down an experienced user during text entry.

QUILL

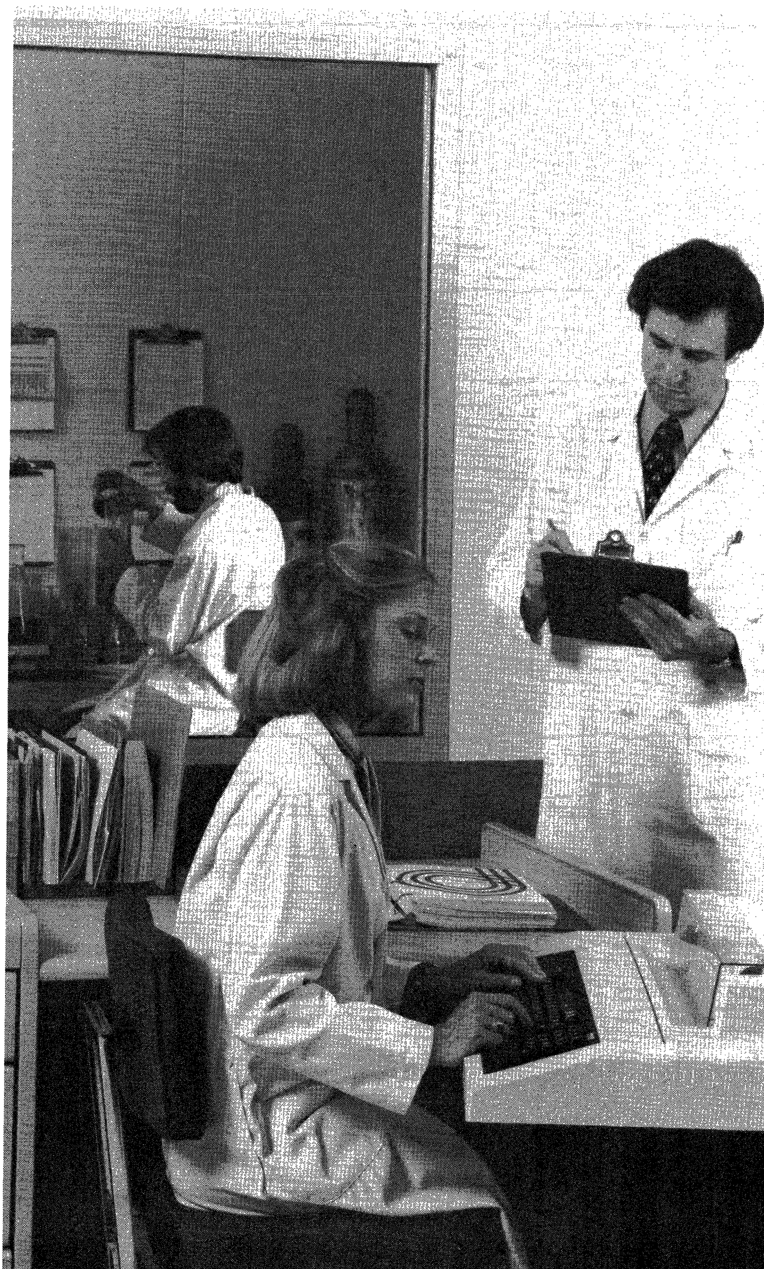
QUILL is a query/report writer program for business applications running on CTS-300. By locating the specific information you need, this program helps you create many types of reports and terminal queries.

QUILL is friendly and easy to use—you communicate with QUILL by using simple English-like commands. QUILL uses Dictionaries to describe the data files. Using the field names in the Dictionary, the operator can use arithmetic, relational, and Boolean expressions to locate desired records. QUILL locates the records in the data file which satisfies the operator's request, and establishes a collection.

The collection is a much smaller file which is comprised of pointers to the physical locations of the desired records. QUILL uses the pointers in the collection to process the selected records. This is especially important for smaller systems with limited disk space.

Once the collection has been established, the operator is ready to create the output: either a query list on the terminal, a simple to complex report for a printer or disk, or a List Document for DECtype-300. All of the commands which create any of the forms of output can be retained in a log file. To create the output again, a command can simply be typed in, and QUILL will automatically go to work. The logged commands will generate the output against the current, up-to-date data.

QUILL interfaces with DECtype-300, a full-featured word processing application. As easy as it is to create a simple query—QUILL "selects" the appropriate data from an established data file and creates a List Document for DECtype's List Processing facility and Editor. Users will no longer have to maintain duplicate sets of data; one for data processing and the other for word processing. With QUILL, the List Documents will be as current and up-to-date as the actual data file. No conversion is necessary. As soon as QUILL has created the List Document, DECtype can then access it immediately via the list processing routine or the editor.



CHAPTER 7
DIGITAL STANDARD MUMPS

Digital Standard MUMPS (DSM) is a multiuser data management system that consists of an interactive, high-level programming language, a data management facility, and a time-sharing executive.

The language is an extension of the ANSI Standard Specification (X11.1-1977) for Massachusetts General Hospital Utility Multi-Programming System (MUMPS). MUMPS was originally developed at the Laboratory of Computer Science at Massachusetts General Hospital and was supported by Grant HS00240 from the National Center for Health Services Research and Development. System capabilities are heavily oriented toward string manipulation and relieve the user of any concern for programming peripheral devices or for structuring databases in the traditional sense.

Language processing by the system is interpretive. This greatly facilitates program development by eliminating the need to load editors, assemblers, linkers, etc. The DSM application programmer need only be concerned with developing the proper logical hierarchy for a database and efficient logic for the application requirements.

The DSM language is provided with its own standalone operating system. In addition to supporting the Standard MUMPS language and providing all operating system capabilities, the system affords a unique database structure. Data, referred to symbolically, is automatically stored and linked in sparse, hierarchical structures called M-trees. The physical and logical allocation of mass storage for the tree-structured database is handled completely by the operating system so the programmer can concentrate on application data relationships. The database can be made available to all system users or be restricted to a class of users.

The DSM-11 operating system runs on any of the PDP-11/23, 11/24, 11/34, 11/44 and 11/70 central processors. The system permits up to 63 simultaneous users, or partitions, operating on any of up to 128 terminals.

A partition holds one active user's program, local data, and system overhead data. There is no fixed correspondence between terminals and user partitions. Indeed, jobs can run without having terminals associated with them, and multiple terminals can be attached to one partition.

Partition assignment is performed dynamically either at log-in time or during execution. The recommended size for a partition is approximately 4K bytes. Partitions do not all have to be the same size; the maximum partition size is 16K bytes.

Additional features include:

- Dynamic file storage with variable length string subscripts allows the user to modify or expand data elements in the existing database easily.
- A programmer can rapidly write, test, debug, or modify a program so that a working application is quickly established. A user can enter, inspect, or change data interactively and efficiently.
- A high-performance database handler uses an in-memory disk cache (with write-through) to allow efficient sharing of the data among all users.
- A system level, transparent journal of database modifications can be maintained on either disk or magnetic tape.
- Distributed database management is implemented using DMC11 or DMR11 high-speed data communication links.
- Output to devices can be spooled.
- DSM-11 has automatic power-fail restart capability for processors with battery back-up.
- DSM-11 provides bad-block management for all disk media.
- On-line, high-speed database backup, disk media preparation, and tape-to-tape copying are standard DSM-11 features.
- Hardware device error reporting, system patching utility, and an executive debugger facilitate system maintenance.
- Streamlined, system installation and system generation procedures allow the DSM-11 system to quickly adapt to any supported hardware configuration.

The following summarizes supported hardware of the DSM-11 operating system:

MINIMUM HARDWARE REQUIRED

- One of the following processor systems:
  - PDP-11/23
  - PDP-11/24
  - PDP-11/34
  - PDP-11/44
  - PDP-11/70

- At least 96 KB of memory required to build a minimum system with up to three terminals
- One of the following mass storage packages:
  - Dual drive RL11/RL211 or RLV11/RLV21 cartridge disk system
  - Dual drive RK11 cartridge disk system (unit 0 must be an RK05J)
  - Dual drive RK611/RK711 cartridge disk system
  - A single drive disk system that consists of: One RK05J, RL01, RL02, RK06, RP04, RP05, RP06, RM02, RM03, or RM05 disk drive and one TS03, TE10, TE16, TU45, or TS11 tape drive
- One KW11-L or KW11-P line frequency clock (The line frequency clock included with a DL11-W serial line interface is acceptable)
- One LA34, LA36, LA38, LA120, or LA180 hardcopy terminal console device

OPTIONAL HARDWARE

- Additional memory up to a system total of 248 KB on PDP-11/23, or PDP-11/34 and up to 1 MB on the PDP-11/24, PDP-11/44, or PDP-11/70
- Up to eight RK05 disk drives (an RK05F disk drive represents two units)
- Up to four RL01/RL02 disk drives
- Up to eight RK06/RK07 disk drives
- Up to eight RP04/RP05/RP06/RM03/RM05 disk drives
- Up to four TS03, TE10, TE16, TU45, TS11 tape transports
- Terminal and communication devices as follows:
  - VT50, VT52, VT55 (no graphics support), VT100 (in VT52 compatibility mode), LA34, LA36, LA38, LA120, or LA180 terminals on DZ11, DH11, DL11, DLV11 and DLV11-J interfaces; modem support provided for DL11-E, DH11-AD, and DZ11-A (with BC05D cable)
  - Up to a total of 128 terminals using DZ11 or DL11 interfaces
  - Up to a total of 17 terminals using single line DL11 interfaces
  - Up to a total of 16 terminal and communication interfaces, where each DMC11, DMR11, DZ11, DH11, or DL11 counts as one interface
- Up to a total of 17 LP11 or LA11-P lineprinters, single line interfaces, and/or high-speed data links

USER INTERFACE

DSM-11 users gain access to the system's programs by using a special log-in sequence that involves one or two access codes (depending on the user's privileges). These codes, provided by the system manager, are the User Class Identifier Code (UCI) and the Programmer Access Code (PAC).

The DSM-11 system can have up to 50 UCIs (classes of users). A UCI allows access to the programs and globals listed in the program and to global directories for that UCI. A user who is permitted simply to run programs needs to know only the UCI and the name of the programs for that UCI.

Users who are allowed to create or modify programs and global files must know the system's PAC, which permits system operation in direct mode. A programmer can issue DSM commands at the keyboard, as well as create, modify, and delete data and programs associated with the user's UCI.

DSM-11 also employs a concept known as "tied terminals." An attempt to log-in at a tied terminal activates the task to which the terminal is tied and limits the user to the resources associated with that task. This capability gives the system manager an effective control mechanism for system access.

INTERPRETER

DSM-11 is implemented as an interpreter. This minimizes the programmer's time in solving a problem, the computer time needed to check it, and the elapsed time required to obtain a final running program. The interpreter is that part of the operating system responsible for these services.

The interpreter examines and analyzes all Standard MUMPS language statements and executes the desired operations. Each Standard MUMPS language statement undergoes identical processing each time it is executed by the interpreter. Intermediate code is not generated. Comprehensive error checking is also performed to ensure proper language syntax.

In addition, the interpreter stores and loads programs through the disk storage system. During program execution, the interpreter can overlay external program segments invoked by an active program. Proper linkages are set up to return to the invoking program when execution of the segments terminates.

A number of major advantages are obtained from the interpreter. Programs written in an interpretive language do not require any compilation or assembly. Error comments during execution are printed at the programmer's terminal and allow quick recovery, program modification, and re-execution. All program debugging and modification operations are performed directly at the terminal in the DSM language.

Almost any DSM command or function can be executed from the keyboard in direct mode. When a command is entered, the DSM language interpreter immediately executes it and gives the appropriate response to the programmer. A command line can consist of several Standard MUMPS commands and arguments, comments and data. For example, the programmer can enter the command line:

```
> WRITE "7+5=",7+5
```

This command tells DSM to print the characters "7+5 =" on the terminal, evaluate the arithmetic expression 7+5 and print the result on the terminal. DSM responds by typing:

```
7+5=12
>
```

The DO command tells DSM to begin executing at a specified label of the stored program. It will continue until it encounters a control command such as GOTO or QUIT, or arrives at a point where there is nothing else to interpret.

To create a program, the programmer enters one or more lines of MUMPS commands. Once a program has been created, the programmer can store the contents of the partition's program buffer on disk or on a secondary storage device such as magnetic tape. The program can then be reloaded into the program buffer from the disk or secondary storage. A program can be modified when it is loaded in the program buffer by adding new lines or by replacing, deleting, or modifying existing lines of code.

TERMINALS AND ANCILLARY I/O DEVICES

In addition to the disk space reserved by the DSM database supervisor, DSM allows access to terminals and ancillary I/O devices such as the lineprinter and magnetic tape. Each I/O device has a unique identification number in the system.

The OPEN command establishes ownership of terminals and ancillary I/O devices. Then I/O may proceed, using available I/O commands. In general, the programmer need not be concerned with specific characteristics of I/O devices, since data transfers consist of ASCII strings not greater than 255 characters. There are, however, certain physical operating characteristics that may be of interest to the programmer, such as rewinding a magtape or a form feed on the lineprinter.

The commands affecting input/output operations to the terminals and ancillary devices are: READ, WRITE, WRITE *, ZLOAD and ZPRINT. The WRITE command is used to output both local and global data, as well as literals, constants, and format control characters. The WRITE * command is used primarily to take advantage of I/O device special features, which are specified, generally, by non-printing ASCII codes. The WRITE * command accepts numeric arguments, of which the low-order seven bits are taken as the decimal representation of the ASCII code. For example, the command W *10 is used to output a line feed character.

DSM also has three special "devices." They are the Sequential Disk Processor, the CPU-CPU device, and the Job Communication device.

The Sequential Disk Processor (SDP) allows the user to physically access the disk as an assignable sequential I/O device. The SDP can access only the disk space that is explicitly set aside for its use. Other disk space, including the global database structure, cannot be accessed. Sequential disk processing allows the user to impose any file structure on the SDP space.

The CPU-CPU device is a DMC11 synchronous interface, full- or half-duplex, that connects one DSM-11 CPU to another CPU. The other CPU does not necessarily have to be a DSM-11 system, but does have to recognize DDCMP protocol. This device allows a DSM program to communicate with a program running on another central processor.

In-memory job communication (Job Comm) permits jobs to send information to other jobs without using the disk. Communication occurs through a series of pseudo-devices that are used in pairs; even-numbered devices are "receivers" and odd-numbered devices are "transmitters."

SPOOLING

DSM-11 also includes the ability to spool output to line printers. The spooling device is a file-structured mechanism used for temporary storage of information. Typically, a user directs the output of several programs to separate files on this device. The files are then processed one at a time by a de-spooling program that writes them to an output device.

To aid in classifying spool files, each has a destination code and its own unique file index number. The destination code is a value, in the range of 1 to 255, recorded in the directory entry for easy access. By using this code, a file can easily aid in retrieving a particular group of files.

JOURNALING

DSM-11 also supports the technique known as journaling, which allows an additional copy of data modified on the disk to be made on another device. In the DSM system, any item that is changed on the database may also be written to a disk or magnetic tape as a journal record. Even if a disk failure occurs, it is always possible to restore the journal tape entries onto the previous backup copy and bring the system up-to-date as of the time of the failure. Journaling runs at the system level, and is transparently built into the operating system so that DSM-11 programs need not be modified or specially written to handle journaling. The desired database transactions are recorded automatically onto the journaling media.

DATA MANAGEMENT

Data Storage Elements

In DSM-11, all data are referenced symbolically, in the context of hierarchical global variables and arrays. The content and structure of the tree-structured global arrays are logicaly mapped into the system's physical storage medium.

All user data, numeric or string, is stored in the system as ASCII character strings. DSM-11 interprets these strings in one of two ways: as numbers, such as those used in calculations, or as strings, such as names and addresses.

Numbers in DSM are signed numbers that can be up to 32 significant decimal digits long. Examples of numbers are:

2.08
151.95
403.333
.6379465

DSM string data is any contiguous series of legal DSM characters that are to be considered a single data entity. Strings in DSM can be up to 255 characters long. Examples of strings are:

HELLO, MY NAME IS
55 SECONDS
2,564,843,485,076,193
FRIENDS, ROMANS, COUNTRYMEN ...
FROP%X10.CF

Variables

Program data values can be expressed as literals, constants, or variables. Two types of variables can be created in DSM programs: local variables and global variables, each of which may be subscripted.

Variables can be created, modified, and deleted using the SET, READ, and KILL commands.

A subscript is a value enclosed in parentheses and appended to a variable name. It uniquely identifies data elements that are to reside under that variable name. All subscripted variables residing under a common name are collectively referred to as an array. An array can consist of variables with more than one level of subscripting; when more than one level is used for global array subscripts, they are separated by commas.

DSM uses sparse arrays that contain only those elements explicitly defined. Unlike other languages that may require a declaration of the maximum size of an array to preallocate space, DSM dynamically allocates storage for all array elements only as needed.

Local variables, which are variables that reside in the same partition as the commands that created them, are used as scratch or transient data. They are accessible only to programs running in the same partition. Variables such as ABC, R45, X, %D have no subscripts and are called simple variables. Subscripted variables can have multiple levels of subscripting, with numeric or string subscripts, such as ABC(2), R49("LIST"), ABC(4+B(C*D)/X,89).

Global variables are subscripted arrays stored on disk. External to a program's partition, they provide a common database available to all programs authorized through the system protection scheme. There is no logical limit to the number of subscripts that can be used. Like subscripted local variables, global arrays also reside in sparse arrays and are created simply by reference in a program. Each global array name is similar to a local variable name, but is always preceded by the circumflex symbol"↑".

The DSM Disk Structure and Global Arrays

Disk volumes allocated for the storage of DSM globals and programs are the primary storage media used by the DSM-11 system. Each UCI defined by the system manager has two directories associated with it: the global directory (that is, the file directory) and the program directory.

The system manager, who can locate the directories on any disk unit in the system, can also limit program and global storage to specific disk units.

Globals are logically organized as multi-dimensional tree-structured arrays. An element of an array has a logical name consisting of the global name and the subscript(s) uniquely identifying the element. For example, ↑ABC(2,3.4,"JONES") is the name of the element in the global called ABC, whose first subscript is 2, whose second subscript is 3.4, and whose third subscript is "JONES." The elements of a global array are called nodes. The user's global directory contains the names of all the globals it can reference, as well as pointers to the tree structure for each of the globals.

UTILITIES

A set of DSM language utility programs provides the user with the tools to maintain and service the system efficiently. All these utilities are written as Standard MUMPS language programs and as such can be easily modified and extended to suit the needs of a particular installation.

The utility programs consist of two operationally distinct groups: system utility programs and library utility programs. The system utility programs provide functions for use by the system manager. They are under the control of the system UCI and are accessible only to those individuals possessing the system UCI code.

Library utility programs provide general services which are available to all system users, regardless of UCI. These programs also reside under the system UCI but employ a naming convention which distinguishes them from system utilities.

The DSM-11 backup utility programs allow the user to save significant data from DSM disks. Some of the other utility programs include functions to:

- Label disks and magtapes for identification purposes
- Format and test disks; initialize disks to be used in a DSM environment
- Make exact image copies of magtape and disk volumes
- Allow the direct allocation or deallocation of individual blocks on a DSM disk
- Check the integrity of the database

THE MUMPS LANGUAGE

The following paragraphs discuss some of the major elements of the Standard MUMPS language.

EXPRESSIONS

An expression is a value description that can be made in the Standard MUMPS language, including any legal combinations of operands and operators. The following are examples of expression elements:

123.34	constant

ABC	simple variable
"ABCD"	literal
MX(5)	local subscripted variable
↑XYZ(2,5)	global variable
$LENGTH(Z)	function reference
(A+B-(C/D))	subexpression

The operators in an expression serve to represent the various arithmetic and logical computations of the Standard MUMPS language. Following is a list of Standard MUMPS expression operators:

TYPE	SYMBOL FUNCTION
Arithmetic	+ Addition
	- Subtraction or Unary minus
	* Multiplication
	/ Division
	# Module
	\ Integer divide
Relational	< Less than
	> Greater than
	= Equality
Boolean	& AND
	! OR
	' NOT
String relational	[Contains
	] Follows
	? Pattern verification
	= Equality
String concatenation	- Concatenation
Indirection	@ Indirection

Indirection is denoted by the character @ followed by an atomic expression. The value of the expression is substituted for the occurrence of indirection before the rest of the line is interpreted.

Of special importance are the relational string operators. They provide facilities for determining the characteristics of string data. The operators return true or false results. They are:

- String Contains ([) — The string specified by the left operand is examined for the occurrence of the string specified by the right operand.
- String Follows (]) — The string specified by the left operand is compared character-for-character with the string specified by the right operand to establish relative position according to the ASCII collating sequence.
- Pattern Verification (?) — The string specified by the left operand is examined for the occurrence of the character patterns specified by pattern specification codes.

Commands

A command is the basic unit of expression in the Standard MUMPS language. A command is a mnemonic that symbolizes the action to be performed, such as GOTO or SET. The command name can be abbreviated to one letter. It usually takes one or more arguments that specify the objects of the action to be performed. Several Standard MUMPS commands can be present on a command line.

An optional Boolean-valued expression preceded by a colon can be used as part of an argument to specify conditional execution. For example, "GOTO LOOP:A>B" means that control is transferred to "LOOP" if A is greater than B.

The following is a list of DSM commands:

BREAK	Suspends execution of a routine and brings the terminal back to direct mode.
CLOSE	Releases one or more designated devices from ownership.
DO	Initiates execution of DSM routine at the label specified, with an implied return.
ELSE	Conditionally executes the statements following it.
FOR	Produces looping by repeating commands residing on the same line for a specific set of variable values.
GOTO	Interpreter execution is transferred either to a specified line or routine.
HALT	Ends your use of DSM-11.

HANG	Suspends program execution for a specified time interval.
IF	Permits the conditional execution of the commands or statement that follow it.
KILL	Deletes the specified local and global variables.
LOCK	Makes a particular variable or node of a variable unavailable for locking by another user.
OPEN	Obtains ownership of one or more devices.
QUIT	Terminates the current flow of execution.
READ	Receives data from the current device.
SET	Assigns the value of an expression to a variable.
USE	Designates a specific open device as the current device for input and output.
VIEW	Allows you to read and write data to disk storage or to alter locations in memory.
WRITE	Sends data and/or control information to the current device.
XECUTE	Executes DSM-11 statements that result from the evaluation of an expression.

ZCommands

The following commands, known as Z-commands, are the DSM-11 extensions to the Standard MUMPS language:

ZGO	Resumes execution of a routine after a BREAK command.
ZINSERT	Inserts a line into the routine currently in memory.
ZJOB	Starts a specified routine in a new partition.
ZLOAD	Loads a routine into memory.
ZPRINT	Writes the current routine to the current output device.
ZREMOVE	Deletes the current routine or specified lines in the current routine.

ZSAVE	Stores a routine in your routine directory.
ZUSE	Allows temporary use of a terminal device owned by another job.
ZWRITE	Writes all local variables to the current output device.

Functions

A function performs an operation and returns a value, based on the outcome of that operation. The following is a list of available functions:

$ASCII	Returns the ASCII code of a string character as a decimal integer.
$CHAR	Translates a decimal integer into a ASCII character.
$DATA	Returns an integer indicating whether a specified node contains data or has descendants.
$EXTRACT	Returns a substring of a string expression, selected by position number.
$FIND	Returns an integer specifying the end position of a specified substring.
$JUSTIFY	Returns a string, right-justified in a field of a specified length.
$LENGTH	Returns number of characters in a string.
$NEXT	Returns the subscript of the next sibling in collating sequence to the specified global or local node.
$PIECE	Returns a substring from a specified string selected by delimiter.
$RANDOM	Returns a pseudo-random integer uniformly distributed in a closed interval.
$SELECT	Returns the value of the first expression in its argument list, whose matched truth value expression is true.
$TEXT	Returns the specified line from the routine currently in memory.
$VIEW	Returns an integer between 0 and 65535, equal to the contents of the memory location specified in the argument.

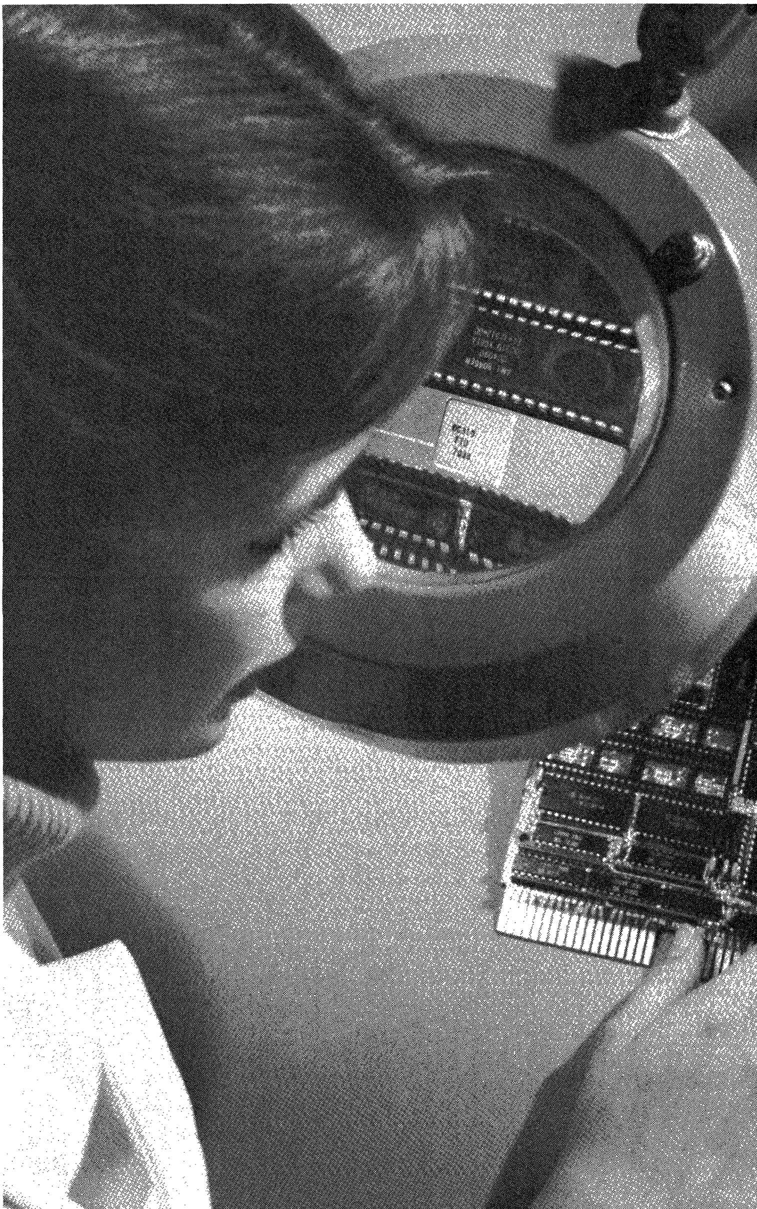
$Z-Function Descriptions
Certain functions, called $Z-functions, are DSM-11 specific. They are provided as extensions to Standard MUMPS, giving more options to the user.

$ZCALL	Provides a general-purpose function call to user-written routines.
$ZNEXT	Performs a physical scan of a global array.
$ZSORT	Returns the subscript of the next sibling in a string collating sequence of a specified array node.

Special Variables
A number of special reference-only variables are defined within the system to control the flow of information and to provide system information to Standard MUMPS programmers. These variables are maintained and updated by the system for each job partition. The following is a list of the special variables, including the $Z special variables.

$HOROLOG	Contains the current date and time.
$IO	Identifies the current I/O device.
$JOB	Contains the job number.
$STORAGE	Contains the amount of free space available within the current partition.
$TEST	Contains a truth value computed from execution of the most recent IF command, containing an argument, or an OPEN, LOCK, or READ with a timeout.
$X	Contains a non-negative integer value equal to the next column position to be output.
$Y	Contains the current line number.
$ZA	Contains status or error information for the current device.
$ZB	Contains status information on the current device, in the form of a numeric value.
$ZERROR	When an error occurs, this variable contains the line segment that caused the error.
$ZNAME	Contains the name of the current routine.

$ZTRAP	Contains a reference to a line and/or routine to which you want control to pass in the event of an error.
$ZVERSION	Contains the name and version of your DSM system.



CHAPTER 8
MICROPOWER/PASCAL

INTRODUCTION

MicroPower/Pascal is an advanced software tool kit for developing microcomputer applications. It includes a high-performance, optimizing Pascal compiler, a subset of the RT-11 operating system, and all the tools you need to create concurrent, real-time application programs. You create these applications on a PDP-11 host system for execution and debugging in a separate target microcomputer that can be any DIGITAL Q-BUS processor from the FALCON SBC-11/21 to the PDP-11/23-PLUS. Each application is constructed especially for its target system, with the exact set of operating system services needed.

MicroPower/Pascal is particularly suited for dedicated, real-time microcomputer applications such as process control, instrumentation, and robotics.

Target Environment

- Pascal extensions support real-time multitasking
- Applications reside in ROM and/or RAM
- Assembly language interface allows MACRO-11 tasks
- Applications can be debugged interactively
- File system is compatible with RT-11
- Device drivers support many LSI-11 bus interfaces
- DPV11 synchronous serial line interface supports X.25 protocol
- Applications can be transported from the host to the target by: (1) Down-line loading, (2) ROM, or (3) Bootable media

Host Development Environment

- Optimizing compiler produces fast, compact object code compatible with any DIGITAL microcomputer

PRODUCT DESCRIPTION

MicroPower/Pascal is a microcomputer software architecture that extends standard Pascal to incorporate system implementation language capabilities and support concurrent programming (multitasking). MicroPower/Pascal lets you code microcomputer applications that have direct access to device registers, and can perform interrupt handling. Built-in procedures allow easy access to the file system, clock process, device drivers, and the operating system services of the kernel.

When you team MicroPower/Pascal with your PDP-11 system, you will have a complete hardware/software package with everything you need to build quality microcomputer applications. MicroPower/Pascal builds a complete and powerful real-time software application so compact that it could reside in as little as 8 Kbytes of memory. For your most complex applications, you can address up to 4 Mbytes of memory on the LSI-11/23.

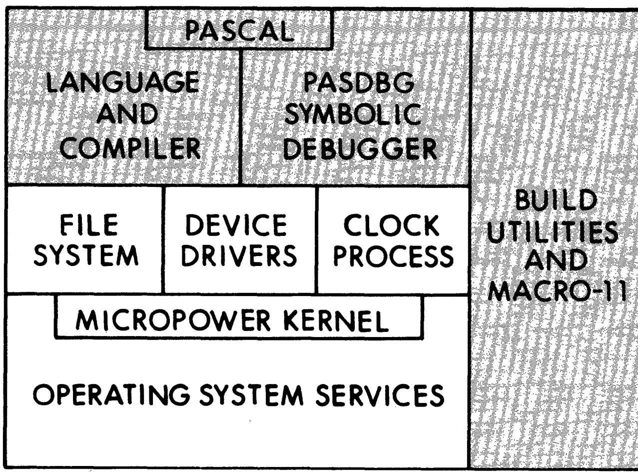


Figure 8-1 MicroPower/Pascal Components

Those components that reside in the host are shown by background shading. Those components not shaded reside in the target system (only those components and services that your application requires are included).

Host and Target Processors

MicroPower/Pascal uses a two processor development environment: a host PDP-11 running the RT-11 extended memory (XM) operating system, where the Pascal compiler and development utilities reside and execute, and a target Q-bus PDP-11, where the application program resides and executes. This provides the most effective work environment for developing target system programs. You can transport your final application program to the target microcomputer by one of three methods: writing it into read-only memory (ROM), downline loading it over a serial line, or recording it on magnetic storage media such as a floppy disk or tape cartridge which you can bootstrap on the target.

Concurrent Programming Capability
Concurrent programming means your Pascal source code is structured into independent parts called processes, that appear to execute simultaneously. Each process competes with all other processes for control of the target processor, but cooperates with all other processes in manipulating shared resources such as memory and peripheral devices.

Target System Kernel
MicroPower/Pascal processes have no need for a conventional operating system. Instead, every application contains its own customized set of routines, called the kernel, that supports them. MicroPower/Pascal automatically selects those operating system services your application requires from a library in the PDP-11 host computer, and places them in a kernel. By including only required system services, the kernel and the application it supports make the most efficient use of memory.

The target system kernel lets applications access device registers, the file system, the clock process, and device drivers. The kernel also performs interrupt handling and lets concurrent tasks share the target processor.

Synchronizing Processes
Key to this concurrent application design is the mechanism for sharing control of the CPU and other common resources, such as data areas and peripheral devices. In the MicroPower/Pascal target system, executing processes are synchronized by *semaphores*.

Semaphores are global data structures that are manipulated by two or more processes. They act like flags that are raised and lowered by processes to signal their progress to other processes. You create semaphores in a source program to guide the response of the entire application to external, real-time events. Semaphores can halt a process until another process sends it a signal to proceed. This lets two processes share access to common data, without corrupting the data.

Application Development Tools
MicroPower/Pascal utility programs construct your application and load it into the target system memory. They accept as input object modules of compiled or assembled source code contained in files. The utilities also accept object modules from various module libraries. They link these object modules with a customized kernel to create the application.

Modular architecture makes it easy to test, debug, update, and expand your applications. It also reduces memory requirements for applications without sacrificing the ability to build large, versatile, 4 Mbyte configurations.

The MicroPower/Pascal utilities include:

- MERGE
- RELOC
- MIB
- DLLOAD
- COPYB

MERGE accepts multiple object modules containing compiled or assembled source code and data as input. It automatically combines program sections (p-sects) with identical names from all input object modules. MERGE also uses the symbol tables created in each object module during compilation to resolve intermodule references. For every reference to a declared EXTERNAL name, MERGE looks for a declared GLOBAL definition in the other object modules. Undefined symbols are flagged.

The first component of the merged object module which MERGE outputs is the kernel of basic services required to support your processes. To make a relocatable kernel, MERGE must have configuration information (which you supply in a separate object module) and the system libraries of object modules.

RELOC is the utility program that assigns addresses to the entities within a merged object module. It produces a process image module with one base address. This base address is later assigned to be the module's correct location within the application's memory range. With RELOC, you can directly specify the virtual base addresses of different parts of the application. RELOC also separates p-sects according to their Read-Only or Read/Write attributes, and modifies the code sections to execute properly at their assigned addresses.

The *Memory Image Builder (MIB)* utility creates the executable application by placing all its components into one structure, called the memory image. This memory image includes each merged, relocated piece of the application with intermodule references resolved. The MIB utility lets you control the placement of pieces of the application in memory.

DLLOAD lets you load your application into target system RAM over a communication link (DLV11 serial line interface) from the development system. When you run DLLOAD at the host, the bootstrap program in the target LSI-11's ROM begins running as soon as you power up the target. The target system boots the application from the host into its memory and begins to run it.

COPYB generates a bootable media volume for either TU58 tape cartridge or RX02 floppy diskette. You can then use this volume to load your application into the target system.

There is another way to load an application into the target system: you can burn the application program into a ROM chip and install the chip into the target. (However, ROM programming hardware and software are not included with this product.)

MicroPower/Pascal Compiler

The MicroPower/Pascal compiler runs on any PDP-11 with the RT-11 XM operating system and at least 128 Kbytes of memory. This compiler contains the most sophisticated global optimization available. It inspects all program modules for redundancy and produces code that executes almost as quickly as MACRO for a ROM and/or RAM environment. It significantly reduces the size and improves the speed of application programs by efficiently using the LSI-11'S general purpose registers and hardware stack capabilities. The compiler provides for separate module compilation and efficient interfacing to MACRO-11 assembly language routines. High-level language access to the modular run-time routines (kernel) means more efficient, and less expensive, system level software development with little need for MACRO coding. You need not get involved in intricate machine instructions, nor must you learn separate operating system functions.

Compliance with International Standards Organization (ISO) specifications allows using the source code from other ISO compilers with full compatibility.

An extensive library of Object Time System (OTS) routines provides the compiler with run-time support for Pascal functions including utility and I/O routines and arithmetic routines such as floating-point support.

Symbolic Debugger

The Symbolic Debugger program, PASDBG, residing in the host PDP-11, down-line loads and remotely controls the execution of applications in the target processor. This is accomplished without expensive in-circuit emulation hardware. Not only does it allow full program debugging in the original Pascal language terms, but it also enables the programmer to view the target's kernel and concurrently executing processes. Debugging the application in the actual target system assures a more reliable final product.

Although PASDBG resides in the host, debugging an application program requires some additional code in the target. Building an application for debugging adds about 800 words to the size of the application. Setting the debug switch also increases the size of the code generated when compiling a module. However, you only set the debug switch on modules you are debugging. You add undebugged modules to the application a few at a time, debugging each, then rebuilding without debugger support. In this manner, the entire application is built from small, debugged pieces.

RT-11 Operating System

The MicroPower/Pascal software package includes a subset of the RT-11 operating system for use on the host development system. The following RT-11 components are included:

- Extended memory (XM) monitor
- SYSMAC
- HELP
- KED, EDIT, and K52
- MACRO-11
- LINKER (LINK)
- Peripheral Interchange Programs (PIP)
- Resource (RESOURC)
- Librarian (LIBR)
- Device Utility Program (DUP)
- Directory (DIR)
- Queue Packages
- DUMP
- SRCCOM and BINCOM
- FILEX
- FORMAT
- RT-11 documentation subset

MACRO-11 Source Libraries

The MACRO-11 interface to the run-time system is included in the form of a macro library, which is useful in developing MACRO-11 programs. Using MACRO-11 modules lets you handle the most time-critical applications.

Device and File Support

MicroPower/Pascal provides precompiled driver processes that act as interfaces between your application and various DIGITAL devices (such as the RX02 floppy disk drive). You can also include a file system process and modules that allow you to create, access and maintain data on target mass storage devices in a format compatible with RT-11. Because driver processes and the file system are both fully accessible from your Pascal source code, I/O operations are much easier.

OPERATING ENVIRONMENT

Host Development System

The RT-11 XM operating system comes with the MicroPower/Pascal software package. This package will run on any of the following PDP-11 or LSI-11 systems:

- 11/23, 11/23-PLUS, 11/24, 11/34, 11/35, 11/40, 11/44, 11/45, 11/50, 11/55, or 11/60
- EIS, KT-11 memory management unit and line frequency clock
- Minimum of 128 Kbytes of memory
- 18-bit memory management
- Two serial-line interfaces of the DL11 or DLV11 family (with cables) for the console terminal and the host/target communication line
- Console terminal: VT52, VT100, LA34, LA36, LA120
- Two random-access, mass-storage device drives (RK06, RK07, RL01, RL02, or RX02), at least one of which must be either RL02 or RX02

Note: MicroPower/Pascal is shipped as files on one of two media—RL02 disk or RX02 floppy diskette.

Target Environment

MicroPower/Pascal applications will run on any of the following Q-bus processors:

- LSI-11, 11/2, 11/23
- PDP-11/03, 11/23, 11/23-PLUS
- FALCON SBC-11/21 (KXT11-A2 chips required during debugging)

A serial line interface is required to use PASDBG.

Maximum memory on a PDP-11/23 or LSI-11/23 with 22-bit addressing is 4 Mbytes. Minimum memory on the FALCON, PDP-11/03, or LSI-11/2 is 8 Kbytes.

The following devices are supported in the target environment:

- MRV11-C PROM board
- MSV11-D, L (parity and 22-bit address support), and P RAMs
- MXV11-A RAM with ROM option

- DLV11-E, F, and J asynchronous communications interfaces
- DPV11 synchronous communications interface
- DRV11, DRV11-J, and FALCON SBC11/21 parallel I/O devices
- TU58 DECtape II, RX02 floppy disks
- Line clocks for the LSI-11, LSI-11/2, LSI-11/23, and FALCON SBC 11/21

CHAPTER 9
PROGRAMMING LANGUAGES

INTRODUCTION TO PROGRAMMING LANGUAGES

Doing useful work on a computer depends upon the ease with which you can communicate your information and requests to it. Different circumstances determine different methods of programming, and broad categories of problems are often treated in different ways. This accounts for the growth of many different programming languages.

Some languages, such as FORTRAN, were originally intended for processing enormous amounts of numerical data through complicated formulas at high speeds. Others, such as COBOL, were developed for commercial applications in which there wasn't so much computing, but there was more data management. And still others, like BASIC, were invented to provide easy, non-threatening access to students, so that they could quickly use the computer for problem solving, rather than worry about the intricacies of programming.

While some of these distinctions have become blurred over time, it is still true that certain kinds of problems are best attacked through certain kinds of languages, and the chapters that follow attempt to show the special strengths of each DIGITAL-supplied language in satisfying specific application needs.

The American National Standards Institute (ANSI) defines standards for the various computer languages typically found in the United States. Such a standard is designated with a year suffix—e.g., FORTRAN-77 is the most recent FORTRAN standard—and a programmer familiar with that language can tell immediately what general functionalities will be available in the language. Of course, computer languages are not frozen, and over time new standards develop, based upon need, either in industry or government, and pressure from users of the language. Consequently, most vendors offer standard languages with enhancements, so that they meet both government requirements and the needs of the programmers. Subsequent chapters explain DIGITAL's enhancements to ANSI standards.

One of the great benefits of standardization is that each operating system takes care of the implementation of any particular language. For example, the actual realization of FORTRAN in the RSTS/E system might operate much differently from that in the RSX-11M system, but the programmer need not really know how those differences are managed. He or she need only spend a day or two learning system-specific characteristics, and then can program with complete ease.

There are three types of language processors in programming. Essentially what they all do is to take the words and symbols typed by the programmer at a terminal and translate them into a series of binary codes that the computer can actually understand. When the computer is to output information, the processors take the binary codes and return them to a format that can be read and understood by people.

The first type of processor is called an **assembler**. It is a one-for-one translator: one coded instruction becomes one instruction to the computer. The assembler-level language on PDP-11 computers is called MACRO-11. It is slower to code and compile MACRO-11 programs than just about any other language, but in return the programmer gets considerably more control over the actual operation of a program than is possible under other languages.

Compilers and **interpreters** are the other two types of language processors. As opposed to the assembler-level language, these process what are always called the higher level languages, the languages with such familiar names as FORTRAN, BASIC, and COBOL. In addition to such industry-wide languages, DIGITAL-specific languages such as DATATRIEVE-11 and DIBOL are also higher level languages.

A fundamental difference between compilers and assemblers is the number of machine instructions that may be represented by a single language instruction. It may be, for example, that a single FORTRAN command is compiled into twenty or more machine instructions. Of course, this speeds up the coding process immensely, but it also means that the programmer must relinquish some of the control over program execution and environment that would be available to the MACRO-11 program.

Most compilers do not translate the **source code** which the programmer has written until they read the program all the way through at least once. Several passes over the source code are used to produce what is called **object code**, the form of binary formats that the machine can actually execute. Such multipass compilation allows the compiler to eliminate unnecessary code—called code optimization—and to perform many levels of error checking. A virtue of error checking at compilation time is that far fewer errors are actually encountered in the execution (running) of the program. Thus, programmer time is more efficiently spent and the computer resources are better used.

Interpreters translate source statements immediately into a format that the machine can interpret. The option for code optimization is lost, but this is balanced by the ability to execute programs on a statement-by-statement basis. Program development is enhanced in an interpreter, since there is an immediate response from the computer to the programmer in the case of detected errors. An entire program need not be read to find one level of error. In many situations, this is preferable to waiting until the entire program is compiled.

Most operating systems offered by DIGITAL can support a variety of language processors. It is unlikely that a particular installation would require all the compilers and interpreters available from DIGITAL, but it might have several, such as FORTRAN, DATATRIEVE, and BASIC. Language processors are usually layered products, purchased in addition to the operating system. For example, COBOL is a layered product for IAS, but BASIC is bundled with RSTS/E.

In many cases, application programs need not be written exclusively in a single language. For example, it may happen that a specific operation, such as the management of I/O devices (by I/O drivers) is best accomplished by programs written in assembler-level language, while the rest of the program is coded in COBOL. The driver may be coded in its most efficient format and later incorporated into the compiled COBOL object code. The complex details of this type of operation are handled by the operating system and the language processors, and are transparent to the programmer.

Many of the actual routines required by an application program are not written into the program. When the BASIC programmer asks the machine to extract a square root, for example, he might simply use the SQRT instruction in his program. Within the **Object Time System** (OTS) of the BASIC compiler is a mathematical functions library, which holds a square root algorithm. The SQRT instruction causes the algorithm to be called up into the program and to run on the appropriate variable. Since there are many cases in which it is simpler to include commonly used routines in programs than to rewrite them from scratch, each compiler is equipped with an Object Time System, filled with frequently required routines and functions. As the compilation process occurs, the locations of needed OTS routines are flagged. At the end of compilation, when the object code is ready, the appropriate routines from the OTS are inserted in the program at the flags. An interpreted language may also have an OTS, but it is more likely to be called at runtime, rather than at compile-time.

You may insert your own common routines into the OTS, so that your efficiency in coding is improved. Drivers for your specific devices, or algorithms for often-run procedures, can be programmed once, and then just called as necessary.

Program development refers to the operation of writing and checking workable computer programs. Obviously, there is more to it than merely writing the language code, but the more sophisticated the operating system, the easier will be the use of the facilities available for program development. In computer jargon, the more features the operating system provides to simplify the programmer's task, the "friendlier" the program development environment. PDP-11 computers provide a very friendly environment under most operating systems. The history of software improvement is often the history of making the full functionality of the computer more and more readily available to users.

Some of the facilities of the program development environment are listed and described below. Not every operating system provides all such facilities; the chart (Table 1-2, Chapter 1) provides a comparison across the operating systems provided for use with the PDP-11 family.

First among the program development utilities are the **editors.** An editor allows the addition, deletion, movement, and concatenation of text. It also provides capabilities for searching a text for specific character strings, for replacement of one string by another, and for most of the other text manipulation operations one might want to perform in any writing. In developing a program, the editors provide an easy way to create a file and to correct and alter programs, either for experimenting with new ideas or for changing programs as required by new application circumstances or by the discovery of errors.

The **debugger** is another utility of extreme usefulness to programmers. It vastly simplifies the task of checking a program for logical errors by letting the programmer "step through" the program and follow what is happening to the values of chosen variables at each step of the way. Both the debugger and the editor are usually used by the programmer right at a video or hardcopy terminal, in an interactive session.

The **linker** is the crucial utility that takes object files written (created) by the language processors and prepares them for execution. It does this in various ways for various machines, operating systems, and languages. Basically, the linker adjusts addresses of the modules that make up the program—both those modules in the source code and those drawn from the OTS and its libraries; the linker "resolves" addresses—that is, it arranges the modules in such a way that there is no inconsistency in the references among modules and within the segments of the program. The linker also organizes, defines, and resolves certain kinds of symbols used internally in the compilation and execution of computer programs.

The **librarian** is, just as the name implies, the utility that manages the creation, modification, and maintenance of libraries in the operating system.

Modularity is the term used to describe the division of a program into blocks of logically related material. Very large programs might be modularized in order to compile efficiently, or to run efficiently. Complex programs might be broken into modules for program development: code optimization, debugging. An advantage of modularized programs in this latter situation is that modules can be computed individually before linking, so that an error requires only the recompilation of one module rather than the whole program.

CHAPTER 10
PDP-11 MACRO

ASSEMBLY LANGUAGE FEATURES

The assembly level language for PDP-11 operating systems is called PDP-11 MACRO (or sometimes, MACRO-11). It is a fast, compact assembly language that gives the programmer complete control over the environment in which a program is developed and executes.

PDP-11 MACRO processes source programs written in the MACRO assembly language and produces a relocatable object module and optional assembly listing. MACRO is included with the RT-11, RSX-11M, RSX-11M-PLUS, IAS, RSTS/E, and VAX/VMS operating systems.

In addition, it provides for:

- Global symbols for linking separately assembled object programs. (This promotes modular program design.)
- Device and file name specifications for input and output files.
- User-defined macros.
- Comprehensive system macro library.
- Program sectioning directives.
- Conditional assembly directives.
- Assembly and listing control functions at program and command string levels.
- Alphabetized, formatted symbol table listing.
- Default error listing on command output device.

The MACRO assembler for all operating systems also features:

- Global arithmetic, global assignment operator, global label operator, and default global declarations.
- Multiple macro libraries with fast access structure.
- Predefined (default) register definitions.

PROGRAM STRUCTURE

A MACRO source program is composed of a sequence of source coding lines, each of which contains a single assembly language statement followed by a statement terminator, such as a carriage return. The assembler processes source statements sequentially, generating binary machine instructions and data words or performing assembly-time operations (such as macro expansions) for each statement.

A statement can contain up to four fields, identified by order of appearance and by specified terminating characters. The general statement is:

```
label:  operator  operand(s)  ;comments
```

of which the label and comment fields are optional. Operator and operand fields are interdependent: either can be be omitted depending on the contents of the other.

A label is a unique user-defined symbol which is assigned the value of the current location counter and entered into the user-defined symbol table. It provides a symbolic means of referring to a specific location within a program. The value of the label can be either absolute (fixed in memory independent of the position of the program) or relocatable (not fixed in memory), depending on whether the location counter value is currently absolute or relocatable.

Comments do not affect assembly processing or program execution, but are useful in source listings for later analysis, documentation, or debugging purposes.

An operator field can contain a macro call, a PDP-11 instruction mnemonic, or an assembler directive. When the operator is a macro call, the assembler inserts the appropriate code during assembly to expand the macro; for an instruction mnemonic, it specifies the instruction to be generated and the action to be performed on any operands which follow; and when the operator is an assembler directive, it specifies a certain function or action to be performed during assembly. Operands can be expressions, numbers, symbolic arguments, or macro arguments.

Some statements have no operands:

```
BPT
```

Some statements have one operand:

```
CLR  R0
```

while others have two:

```
MOV  #344,R2
```

Symbols and Symbol Definitions

Three types of symbols can be defined for use within MACRO source programs: permanent symbols, user-defined symbols, and macro symbols. Correspondingly, MACRO maintains three types of symbol tables: the Permanent Symbol Table (PST), the User Symbol Table (UST), and the Macro Symbol Table (MST).

Permanent symbols consist of the PDP-11 instruction mnemonics and assembler directives. Also, the assembler has REGISTER names predefined for R0 to R5, SP (stack pointer), and PC (program counter). The PST contains all the permanent symbols automatically recognized by MACRO; it is part of the assembler itself. Since these symbols are permanent, they do not have to be defined by the user in the source program.

User-defined symbols are those given as labels or defined by direct assignment, while macro symbols are those symbols used as macro names. The UST and MST are constructed during assembly by adding the symbols to the UST or MST as they are encountered. To determine the value of the symbol, the assembler searches the three symbol tables; for opcodes, the search order is MST, PST, UST; for operands, the search order is UST, PST.

The search orders allow redefinition of Permanent Symbol Table entries as user-defined or macro symbols, so that the same name can be assigned to both a macro and a label.

User-defined symbols are either **internal** or **external** (global) to a source program module. An internal symbol definition is limited to the module in which it appears. A global symbol can be defined in one source program module and referenced within another.

Internal symbols are temporary definitions, resolved by the assembler. Global symbols are preserved in the object module and are not resolved until the object modules are linked into an executable program. With some exceptions, all user-defined symbols are internal unless explicitly defined as global.

A direct assignment statement with the general format **symbol** = **expression** associates a symbol with a value.

By using two equal signs instead of one, the symbol is declared a global symbol. **Expressions** are combinations of terms that are joined together by binary operators—+, −, *, ÷, & (logical AND), ! (logical OR)—and that reduce to a 16-bit value.

Local symbols are specially formatted internal symbols used as labels within a given range of source code, called a local symbol block. They have the form n$, where n is a decimal integer between 1 and 65,535, inclusive, for example, 1$, 27$, 59$, 104$.

Local symbols provide a convenient means of generating labels to be referenced only within a local symbol block. Their use reduces the possibility of entry point symbols with multiple definitions. Because a local symbol may not be referenced from other source program modules or even from outside its local symbol block, local symbols of the same name can appear in other local symbol blocks without conflict.

Directives

A program statement can contain one of three different operators: a macro call, a PDP-11 instruction mnemonic, or an assembler directive. MACRO includes directives for:

- Listing control
- Function specification
- Data storage
- Radix and numeric usage declarations
- Location counter control
- Program termination
- Program boundaries information
- Program sectioning
- Global symbol definition
- Conditional assembly
- Macro definition
- Macro attributes
- Macro message control
- Repeat block definition
- Macro libraries

The six numbered sections that follow illustrate some of the capabilities of the various classes of directives.

1. Listing Control Directives

Several directives are provided to control the content, format, and pagination of all listing output generated during assembly. Facilities also exist for creating object module names and other identification information in the listing output.

The listing control options can also be specified at assembly time through options included in the listing file specification in the command string issued to the MACRO assembler. The use of these options overrides all corresponding listing control directives in the source program.

When no listing file is specified, any errors encountered in the source program are printed on the terminal from which MACRO was initiated.

2. Function Directives

Function control options are available through the .ENABL and .DSABL directives. These directives are included in a source program to invoke or inhibit certain MACRO functions and operations incidental to the assembly process. They include:

- Produce absolute binary output.
- Assemble all relative addresses as absolute addresses. This function is useful during the debugging phase of program development.
- Cause source columns 73 and greater (to the end of the line) to be treated as comment. The most common use of this feature is to permit sequence numbers in card columns 73-80.
- Truncate or round floating point literals.
- Accept lower case ASCII input instead of converting it to upper case.
- Enable a local symbol block to cross program section boundaries.
- Inhibit binary output.
- Inhibit the normal default register definitions.
- Treat all undefined symbol references as default global references.

3. Conditional Assembly Directives

Conditional assembly directives enable the programmer to include or exclude blocks of source code during the assembly process, based on the evaluation of stated condition tests within the body of the program. This allows a programmer to generate several variations of a program from the same source.

The programmer can define a conditional assembly block of code, and within that block, issue subconditional directives. Subconditional directives indicate:

- The assembly of an alternate body of code when the condition of the block tests false.
- The assembly of a non-contiguous body of code within the conditional assembly block, depending on the result of the conditional test on entering the block.
- The unconditional assembly of a body of code within a conditional assembly block.

Conditional assembly directives *can* be nested to 16 levels.

4. Macro Definitions and Repeat Blocks

In assembly language programming, it is often convenient and desirable to generate a recurring coding sequence by invoking a single statement within the program. In order to do this, the desired coding sequence is first established with dummy arguments as a macro definition. Once a macro has been defined, a single statement calling the macro by name with a list of real arguments (replacing the corresponding dummy arguments in the macro definition) generates the desired coding sequence or macro expansion.

MACRO can automatically create unique local symbols. This automatic facility is invoked on each call of a macro whose definition contains a dummy argument preceded by the question mark (?) character, if a real argument of the macro call is either null or missing.

An indefinite repeat block is a structure that is very similar to a macro definition. Such a structure is essentially a macro definition that has only one dummy argument. At each expansion of the indefinite repeat range, this dummy argument is replaced with successive elements of a specified real argument list. An indefinite repeat block directive and its associated repeat range are coded inline within the source program. This type of macro definition does not require calling the macro by name.

An indefinite repeat block can appear within or outside of another macro definition, indefinite repeat block, or repeat block.

5. Macro Calls and Structured Macro Libraries

All macro definitions must occur prior to their references within the user program. MACRO provides a selection mechanism for the programmer to indicate in advance those system macro definitions required in the program. (System macros include the monitor programmed requests or executive directives available with each operating system.)

The .MCALL directive is used to specify the names of all the macro definitions not defined in the current program but used in the program. When this directive is encountered, MACRO searches the system macro library file to find the requested definition.

MACRO extends this macro call facility by enabling the programmer to retrieve macros from libraries of user-defined macros. The .MCALL directive provides the means to access both user-defined and system macro libraries during assembly.

The MACRO assembler assumes that the system macro library and user-defined macro libraries are constructed in a special direct access format to retrieve macro definitions quickly. These structured macro libraries are created by the Librarian utility program.

Each library file contains an index of the macro definitions it contains.

When an .MCALL directive is encountered in the source program, MACRO searches the user macro library(s) for the named macro definitions, and, if necessary, continues the search with the system macro library. Because each macro library contains an index of all of its entries, MACRO searches only the index in each library to find where the macro definition is stored.

6. Program Sectioning Directives

The .PSECT directive is used to declare names for program sections and to establish certain program section attributes. These program section attributes are used when the program is linked into an executable load module or task.

A program can consist of an absolute program section, an unnamed relocatable program section, and up to 254 named relocatable or absolute program sections. Absolute program sections serve to link the program with fixed memory locations such as interrupt vectors and the peripheral device register addresses, as well as to define values of constants.

The relocatable program sections are not fixed at an absolute address. Instead, symbols within a relocatable section are defined relative to the start of that section. The programmer specifies the overall ordering of relocatable .PSECTS, but the task builder (or linker) resolves the final addresses of the .PSECTS according to their attributes.

By maintaining separate location counters for each program section, MACRO allows the user to create data structures which are not physically contiguous within the program, but which can be linked contiguously following assembly.

The programmer can save the current .PSECT context with a .SAVE directive, and later restore that context with a .RESTORE directive.

The .PSECT directive allows the user to exercise absolute control over the memory allocation of a program at taskbuild time, since any program attributes established through this directive are passed to the Taskbuilder. For example, if a programmer is writing programs for a multiuser environment, a program section containing pure code (instructions only) or a program section containing impure code (data only) can be explicitly declared through the .PSECT directive. Furthermore, these program sections can be explicitly declared as read-only code, qualifying them for use as protected, reentrant programs. In addition, program sections exhibiting the global attribute can be explicitly allocated in a task's overlay structure by the user at taskbuild time. The advantages gained through sectioning programs in this manner therefore relate primarily to control of memory allocation, program modularity, and more effective partitioning of memory.

The .PSECT directive allows the user to define the following program section attributes:

- **Access** — Two types of access can be permitted to the program section: read-only or read/write. RSX-11M-PLUS and IAS support read-only access by setting hardware protection for the program section.
- **Contents** — A program section can contain either instructions or data. This attribute allows the Taskbuilder to differentiate global symbols that are program entry-point instructions from those that are data values.
- **Scope** — The scope of the program section can be global or local. In building single-segment programs, the scope of the program has no meaning, because the total memory allocation for the program will go into the root segment of the task. The global or local attribute is significant only in the case of overlays. If an object module contains a local program section, then the storage allocation for that module will occur within the segment in which the module resides. Many modules can reference this same program section, and the memory allocation for each module is either concatenated or overlaid within the segment, depending on the argument of the program section defining its allocation requirements (see below). If an object module contains a global program section, the memory area allocations to this program section are collected across segment boundaries, and the allocation of memory for that section will go into the segment nearest the root in which the first memory allocation to this program section appeared.
- **Relocatability** — A program section can be absolute or relocatable. When a program section is declared to be absolute, the program section requires no relocation. The program section is assembled and loaded, starting at absolute virtual address 0. When the program section is declared to be relocatable, the Taskbuilder calculates a relocation bias and adds to it all references within the program section.
- **Allocation Requirements** — The program section can be concatenated or overlaid. When concatenated, all memory allocations to the program section are to be concatenated with other references to this same program section in order to determine the total memory allocation requirements for this program section. When overlaid, all memory allocations to the program section are to be overlaid. Thus,

the total allocation requirement for the program section is equal to the largest individual allocation request for this program section.

ASSEMBLER OPERATION

The MACRO assembler can accept source data from any input device. The sources to be included in a single assembly are listed in the command string from left to right in the order of assembly. The last statement in the last source specified is normally the .END statement, but if the .END statement is not provided, it is assumed.

Assembler output consists of the binary object file and an optional assembly listing followed by the symbol table listing and a cross reference listing.

MACRO is a two-pass assembler. During pass one, MACRO locates and reads all required macros from libraries, builds symbol tables and program section tables for the program, and performs a rudimentary assembly of each source statement. During pass two, MACRO completes the assembly, writes out an object file, and generates an assembly and symbol table listing for the program.

The object module MACRO produces must be processed by the operating system's linker utility program (called Linker or Taskbuilder) to create an executable program. The linker joins separately assembled object modules into a single load module (or task image). The linker fixes (makes absolute) the values of the external or relocatable symbols in the object module.

To enable the linker to fix the value of an expression, MACRO passes it certain directives and parameters. In the case of the relocatable expressions in the object module, the linker adds the base of the associated relocatable program section to the value of the relocatable expression provided by MACRO. In the case of external expression values, the linker determines the value of the external term in the expression (since the external expression must be defined in at least one of the other object modules being linked together) and then adds it to the absolute portion of the external expression, as provided by MACRO.

In summary, an executable program image can be constructed from one or more source modules, which can be assembled either separately or together. The resultant object module(s) must be linked together using the linker utility. Figure 9-1 illustrates the processing steps required to produce an executable program from several sources stored as files.

ASSEMBLER ENVIRONMENTS

MACRO is the assembler included in the RT-11, RSX-11M, RSX-11M-PLUS, IAS, and VAX/VMS operating systems. IAS MACRO is identical to the MACRO assembler used in the RSX-11 systems. In addition, MACRO is included in the FORTRAN IV package option available for the RSTS/E system. MACRO is included with the VAX/VMS operating systems to assemble compatibility mode programs.

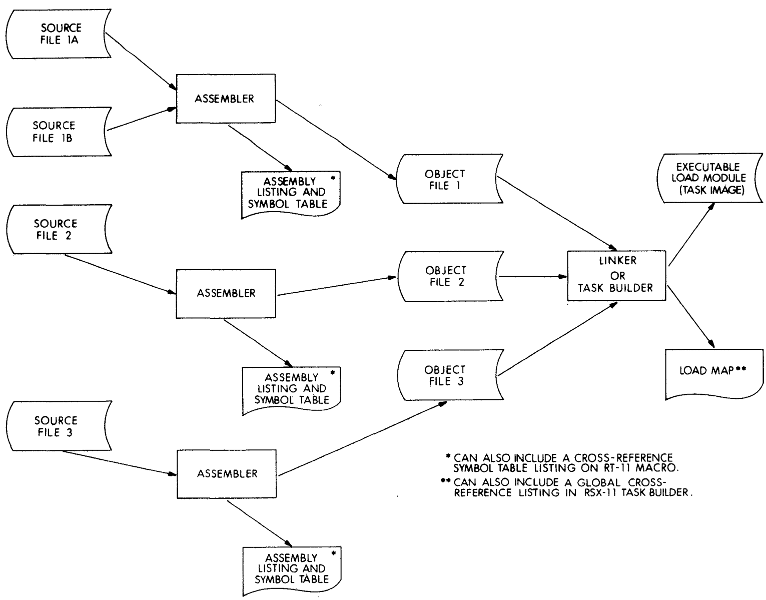
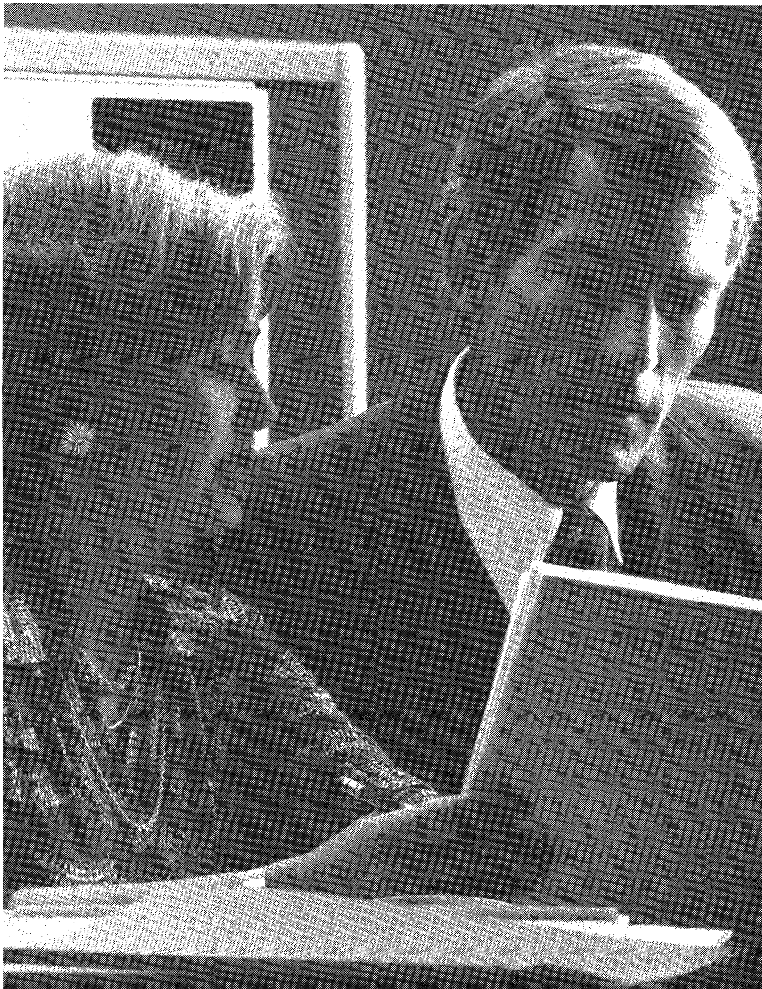


Figure 10-1 MACRO Assembly Procedure



CHAPTER 11
FORTRAN

INTRODUCTION

FORTRAN was developed in the mid-1950s specifically to handle scientific applications in which large amounts of computation were to be done. Since then, it has evolved into one of the most widely used languages, with applications in realtime control (scientific experiments, industrial processes, data collection and reduction), computation (structural analysis, simulation and modeling, electronic design, heavy computing data reduction), and general data processing (maintenance of data bases and report generation). Because of its traditional predominance in certain markets and its long, stable history, FORTRAN continues to be taught to most people specializing in computer and information science in college.

DIGITAL offers two versions of FORTRAN for use on its PDP-11 computers. The first, FORTRAN IV, is based on the ANSI (X3.9-1966) FORTRAN standard. This FORTRAN language works on all PDP-11 operating systems and is characterized by high compilation speed and efficiency in small memory environments.

The second FORTRAN offering, PDP-11 FORTRAN-77 conforms to the most recent ANSI FORTRAN standard, X3.9-1978, (commonly referred to as FORTRAN-77) at the subset language level. Earlier versions of PDP-11 FORTRAN-77 were called PDP-11 FORTRAN-IV-PLUS and were based on the 1966 ANSI standard. PDP-11 FORTRAN-77 runs under the RSX-11M, RSX-11M-PLUS, IAS, and RSTS/E operating systems. It produces machine code highly optimized for execution on a PDP-11 with a floating point processor. PDP-11 FORTRAN-77 features optimization techniques, which improve memory efficiency and increase program execution speed.

ELEMENTS COMMON TO PDP-11 FORTRAN IV AND PDP-11 FORTRAN-77

Specifications and Standards

PDP-11 FORTRAN IV is based on the previous specification for ANSI FORTRAN, X3.9-1966. The following are enhancements to this standard:

- Array Subscripts — Any arithmetic expression can be used as an array subscript. If the value of the expression is not an integer, it is converted to integer type.
- Array Dimensions — Arrays can have up to seven dimensions.

- Alphanumeric Literals — Strings of characters bounded by apostrophes can be used in place of Hollerith constants.
- Mixed-Mode Expressions — Mixed-mode expressions can contain any data type, including complex and byte.
- End of Line Comments — Any FORTRAN statement can be followed, in the same line, by a comment that begins with an exclamation point.
- Debugging Statements — Statements that are included in a program for debugging purposes can be so designated by the letter D in column 1. Those statements are compiled only when the associated compiler command string option switch is set. They are treated as comments otherwise.
- Read/Write End-of-File or Error Condition Transfer — The specifications END=n and ERR=n (where n is a statement number) can be included in any READ or WRITE statement to transfer control to the specified statement upon detection of an end-of-file or error condition. The ERR=n option is also permitted in the ENCODE and DECODE statements, allowing program control of data format errors.
- General Expressions in I/O Lists — General expressions are permitted in I/O lists of WRITE, TYPE, and PRINT statements.
- General Expression DO and GO TO Parameters — General expressions are permitted for the initial value, increment, and limit parameters in the DO statement, and as the control parameter in the computed GO TO statement.
- DO Increment Parameter — The value of the DO statement increment parameter can be negative.
- Optional Statement Label List — The statement label list in an assigned GO TO is optional.
- Override Field Width Specifications — Undersized input data fields can contain external field separators to override the FORMAT field width specifications for those fields (called "short field termination"), permitting free-format input from terminals.
- Default FORMAT Widths — The FORTRAN IV programmer may specify input or output formatting by type and default width and precision values will be supplied.
- Additional I/O Statements:

  File Control and Attribute Definition
  - OPEN
  - CLOSE

  List-Directed (Free Format) u = Logical Unit Number
  - READ (u,*)

WRITE (u,*)
TYPE*
ACCEPT*
PRINT*

Device-Oriented I/O
ACCEPT
TYPE
PRINT

Memory-to-Memory Formatting
ENCODE
DECODE

Unformatted Direct Access I/O
DEFINE FILE

READ (u'r)	u = logical unit number
WRITE (u'r)	r = record number
FIND (u'r)	

The unformatted direct access I/O facility allows the FORTRAN programmer to read and write files written in any format.

- Logical Operations on INTEGER Data — The logical operators .AND., .OR., .NOT., .XOR., and .EQV. may be applied to integer data to perform bit masking and manipulation.
- Additional Data Type — The byte data type (keyword LOGICAL*1 or BYTE) is useful for storing small integer values as well as for storing and manipulating character information.
- IMPLICIT Declaration — IMPLICIT redefines the implied data type of symbolic names.

PDP-11 FORTRAN IV FUNCTIONS AND FEATURES

Any FORTRAN program consists of two kinds of FORTRAN statements (executable and nonexecutable) and optional comments. Executable statements describe the action of the program. Nonexecutable statements describe the data arrangement and characteristics, and provide editing and data conversion information.

FORTRAN comprises assignment statements, control statements, I/O statements, FORMAT statements, and specification statements. Of these, FORMAT and specification statements are nonexecutable. Table 10-1 summarizes the FORTRAN language components common to both PDP-11 FORTRAN IV and PDP-11 FORTRAN-77.

The PDP-11 FORTRAN IV compiler and Object Time System are available as an optional language processing system for the RT-11, RSTS, IAS, RSX, and VMS operating systems. The compiler accepts source programs written in the FORTRAN IV language and produces an object file which must be linked prior to execution.

Table 11-1 PDP-11 FORTRAN IV and PDP-11 FORTRAN-77 Common Language Components

Expression Operators

Type	Operator	Operates On
Arithmetic	** exponentiation * multiplication / division +, −addition, subtraction, unary plus and minus	arithmetic or logical constants, variables and expressions
Relational	.GT. greater than .GE. greater than or equal to .LT. less than .LE. less than or equal to .EQ. equal to .NQ. not equal to (FORTRAN IV) .NE. not equal to (FORTRAN-77)	arithmetic or logical constants, variables and expressions (all relational operators have equal priority)
Logical	.NOT. .NOT.A is true if and only if A is false .AND. A.AND.B is true if and only if A and B are both true .OR. A.OR.B is true if and only if A or B or both are true .EQV. A.EQV.B is true if and only if either A and B are both true or A and B are both false .XOR. A.XOR.B is true if and only if A is true and B is false or B is true and A is false	logical or integer constants, variables and expressions

Assignment Statements

variable= expression	Arithmetic/Logical Assignment: The value of the arithmetic or logical expression is assigned to the variable.
ASSIGN-TO	The ASSIGN statement is used to associate a statement label with an integer variable. The variable can then be used as a transfer destination in a subsequent assigned GO TO statement in the same program unit.

Control Statements

GO TO	Unconditional	Transfers control to the same statement every time it is executed.
	Computed	Permits a choice of transfer destinations, based on a value of an expression within the statement.
	Assigned	Transfers control to a statement label that is represented by a variable. Because the relationship between the variable and a specific statement label must be established by an ASSIGN statement, the transfer destination can be changed, depending upon which ASSIGN statement was most recently executed.
IF	Arithmetic	Transfers control to a statement depending on the value of an arithmetic expression. Used for conditional control transfers.
	Logical	Executes a statement if the test of a logical expression is true.
	Block	Conditionally executes blocks (or groups) of statements (FORTRAN-77 only).
DO		Causes the statements in its range to be repeat-

	edly executed a specified number of times. The range of the DO begins with the statement following the DO and ends with a specified terminal statement. The number of iterations is determined by the values for the initial, terminal, and increment parameters.
CONTINUE	Passes control to the next executable statement. Used primarily as the terminal statement of a DO loop when that loop would otherwise end with a GO TO, arithmetic IF, or other prohibited control statement.
CALL	Executes a SUBROUTINE subprogram or other external procedure and passes it actual arguments to replace the dummy arguments in the subprogram.
RETURN	Returns control from a subprogram to the calling program unit.
PAUSE	Temporarily suspends execution and displays a message on the terminal.
STOP	Terminates program execution and returns control to the operating system. Prints an optional message on the terminal.
END	Marks the end of a program unit. In a main program, if control reaches the END statement, a CALL EXIT is implicitly executed. In a subprogram, a RETURN statement is implicitly executed.
OPEN	Associates an existing file with a logical unit, or creates a new file and associates it with a logical unit. In addition, the statement can contain specifications for file attributes that direct the creation or subsequent processing. The attributes include specifying: the file name, the method of access (direct, sequential or append), protection (read-only or read/write), form (formatted, unformatted), record size, block allocation or extension, whether the file can be shared, and disposition (whether the file is to be deleted or saved when closed). In addition, the OPEN statement can be modified by an ERR keyword which specifies the statement to which control is transferred if an error is detected.

CLOSE	Disassociates a file from a logical unit. Disposition attributes specified in the OPEN statement can be modified. For example, a file opened as a file to be deleted can be saved, or a file opened to be saved can be deleted.	

Input/Output Statements

READ	Formatted	Reads at least one logical record from the specified unit according to the given format specifications, and assigns values to the elements in a list.
	Unformatted	Reads one logical record from the specified unit, assigning the input values to the variables in a list.
	Direct Access	Reads the specified logical record from the specified unit and assigns the input values to the variables in a list.
	List-directed	Reads data from the specified unit, converts it into internal format, and assigns the input values to the elements of the I/O list, converting the value to the data type of the element if necessary.
	Error Control	Optional elements in the READ statement allow control transfer on error conditions. If an end-of-file condition is detected and the END option is specified, execution continues at a given statement. If a recoverable I/O error occurs and the ERR option is specified, execution continues at a given statement.
WRITE	Formatted	Writes one or more logical records containing the values of the variables in a list onto the

		specified unit in the given format.
	Unformatted	Writes one logical record containing the values of the variables in the list onto the specified unit.
	Direct Access	Writes one logical record containing the values of the variables in the list into the specified record of the given unit.
	List-directed	Writes the elements of the I/O list to the specified unit, translating and editing each value according to the data type of the value.
	Error Control	Optional elements in the WRITE statement allow control transfer on error conditions. If an I/O error occurs and the ERR option is specified, execution continues at the given statement.
ACCEPT	Identical to a formatted or list-directed READ statement, except that input comes from a logical unit normally connected to the terminal keyboard.	
TYPE	Identical to a formatted or list-directed WRITE except that output is directed to a logical unit normally connected to the terminal printer.	
PRINT	Same as a TYPE statement, except that output is directed to a logical unit normally connected to the lineprinter.	
DEFINE FILE	Defines the record structure of a direct access file: the logical unit number, the number of fixed-length records in the file, the length of a single record, and the pointer to the next record.	
REWIND	The given logical unit is repositioned to the beginning of the currently open file.	
BACKSPACE	The currently open file on the given logical unit is backspaced one record.	
END FILE	An end-of-file record is written on the file open on	

	the given logical unit.
FIND	Positions the direct access file on the given logical unit to the specified record and sets the associated variable.
ENCODE	Writes the elements in the I/O list into a memory buffer, translating the data into ASCII format. The ERR option allows control transfer to a given statement if an error condition is detected.
DECODE	Reads the elements in the I/O list from a memory buffer, translating the data from ASCII format into internal binary format. The ERR option allows control transfer to a given statement if an error is detected.

Format Statements

FORMAT	Describes the format in which one or more records are to be transmitted. The format descriptors include integer and octal, logical, real, double precision, complex, literal and editing. Real, double precision and complex formats can be scaled.

Specification Statements

IMPLICIT	Overrides the implied data type of symbolic names, in which all names that begin with the letters I, J, K, L, M, or N are presumed to be INTEGER values, and all names beginning with any another letter are assumed to be REAL values, unless otherwise specified. IMPLICIT allows the programmer to define the initial letters for implied data types. If a variable is not given an explicit type, and its name begins with a letter defined in an IMPLICIT statement, its default type is that defined by the IMPLICIT statement.
type var1, var2,...,varn	Type Declaration: The given variable names are assigned the specified data type in the program unit. Type is one of INTEGER*2, INTEGER*4, REAL*4, REAL*8, DOUBLE PRECISION, COMPLEX*8, LOGICAL*4, LOGICAL*1, or BYTE.
DIMENSION	Specifies the number of dimensions in an array and the number of elements in each dimension.

COMMON	Reserves one or more contiguous blocks of storage space under the specified name to contain the variables associated with the block name.
EQUIVALENCE	Declares two or more variable names in the same program unit to be associated with the same storage location.
EXTERNAL	Permits the use of external procedures (functions, subroutines and FORTRAN library functions) as arguments to other subprograms.
DATA	Assigns initial values to variables, arrays, and array elements prior to program execution.
PROGRAM	Assigns a symbolic name to a main program unit. If present, it is the first statement in the main program.
BLOCK DATA	Begins a special type of program unit that declares common blocks and defines data in common blocks.

User-Written Subprograms

name (var1, var2, ...) = expression	Arithmetic Statement Function: Creates a user-defined function having the variables as dummy arguments. When referenced, the expression is evaluated using the actual arguments in the function call.
FUNCTION	Begins a FUNCTION subprogram, indicating the program name and any dummy variable names. An optional type specification can be included.
SUBROUTINE	Begins a SUBROUTINE subprogram, indicating the program name and any dummy variable names.

FORTRAN Library Functions

ABS(X)	Real absolute value
IABS(X)	Integer absolute value
DABS(X)	Double Precision absolute value
CABS(Z)	Complex to Real, absolute value
FLOAT(I)	Integer to Real conversion

IFIX(X)	Real to Integer conversion
SNGL(X)	Double to Real conversion
DBLE(X)	Real to Double conversion
REAL(Z)	Complex to Real conversion
AIMAG(Z)	Complex to Real conversion
CMPLX(X,Y)	Real to Complex conversion
AINT(X)	Real to Real truncation
INT(X)	Real to Integer conversion
IDINT(X)	Double to Integer conversion
AMOD(X,Y)	Real remainder
MOD(I,J)	Integer remainder
DMOD(I,J)	Double Precision remainder
AMAX0(I,J,...)	Real maximum from Integer list
AMAX1(X,Y,...)	Real maximum from Real list
MAX0(I,J,...)	Integer maximum from Integer list
MAX1(X,Y,...)	Integer maximum from Real list
DMAX1(X,Y,...)	Double maximum from Double list
AMIN0(I,J,...)	Real minimum of Integer list
AMIN1(X,Y,...)	Real minimum of Real list
MIN0(I,J,...)	Integer minimum of Integer list
MIN1(X,Y,...)	Integer minimum of Real list
DMIN1(X,Y,...)	Double minimum from Double list
SIGN(X,Y)	Real transfer of sign
ISIGN(I,J)	Integer transfer of sign
DSIGN(X,Y)	Double Precision transfer of sign
DIM(X,Y)	Real positive difference
IDIM(I,J)	Integer positive difference
EXP(X)	e raised to the X power (X is Real)
DEXP(X)	e raised to the X power (X is Double)
CEXP(Z)	e raised to the Z power (Z is Complex)

ALOG(X)	Returns the natural log of X (X is Real)
ALOG10(X)	Returns the log base 10 of X (X is Real)
DLOG(X)	Returns the natural log of X (X is Double)
DLOG10(X)	Returns the log base 10 of X (X is Double)
CLOG(Z)	Returns the natural log of Z (Z is Complex)
SQRT(X)	Square root of Real argument
DSQRT(X)	Square root of Double Precision argument
CSQRT(Z)	Square root of Complex argument
SIN(X)	Real sine
DSIN(X)	Double Precision sine
CSIN(Z)	Complex sine
COS(X)	Real cosine
DCOS(X)	Double Precision cosine
CCOS(Z)	Complex cosine
TANH(X)	Hyperbolic tangent
ATAN(X)	Real arctangent
DATAN(X)	Double Precision arctangent
ATAN2(X,Y)	Real arctangent of (X/Y)
DATAN2(X,Y)	Double Precision arctangent of (X/Y)
CONJG(Z)	Complex conjugate
RAN(I,J)	Returns a random number between 0 and 1

The PDP-11 FORTRAN IV compiler is characterized by extremely rapid compilation rates, yet it also performs well in small environments. For example, on an RT-11 system with as little as 16 Kbytes of memory, FORTRAN IV can compile programs of up to 450 lines. On an RT-11 system with 56 Kbytes, FORTRAN IV can compile programs containing as many as 2200 lines.

Despite its small size requirements and high compilation rate, FORTRAN IV provides a high level of automatic object program optimization. The compiler performs redundant expression elimination, constant expression folding, branch structure optimization, and several types of subscripting optimizations.

FORTRAN IV has no statement-ordering requirements; therefore, declarations can appear anywhere within the source program. Terminal format input (using the tab character to delimit field) makes program preparation easier.

In order to allow larger FORTRAN programs, FORTRAN IV can allocate array storage outside a program's logical address space. Such arrays are called virtual arrays and can contain any data type, but they may also require operating system support of memory management directives.

PDP-11 FORTRAN IV COMPILER OPERATION

The PDP-11 FORTRAN IV compiler accepts a source written in the FORTRAN language as input and produces an object file and a listing file as output. The object file must subsequently be processed by the operating system's linker program (for example, Linker or Taskbuilder) to produce an executable program.

PDP-11 COMMAND STRING SPECIFICATION OPTIONS

In the input/output file specification command string issued to the FORTRAN IV compiler to request program compilation, a programmer can specify switch parameter options, some of which are:

Specify Listing Options

The user can request a number of listing options. By default, the user is supplied with diagnostics (if any), a source program listing, and the storage map. In addition, the user can request a generated code listing, or can combine any of the listing options in a single listing. The generated code listing contains a symbolic representation of the object code generated by the compiler, including a location offset from the base of the program unit, the symbolic Object Time System (OTS) routine names, and routine arguments. The code generated for each statement is labeled with the same internal sequence number that appears in the source program listing, for easy cross reference.

Selectively Compile Debugging Statement Lines

The user can request the compiler to include in the compilation those lines with a D in column one. These statements allow the inclusion of programmer-selected debugging aids (see below).

Code Generation Options

The compiler can generate in-line code which directly supports FIS, EIS, EAE or threaded code for machines without the additional arithmetic hardware.

Include or Suppress Internal Sequence Numbers
Suppressing internal sequence number accounting reduces program storage requirements for generated code and slightly increases execution time, but disables line number information during traceback.

Allocate Two Words for Default Length of Integer Variables
Normally, single storage words will be the default allocation for integer variables not given an explicit length specification (i.e., INTEGER*2 or INTEGER*4). Only one word is used for computation. You can request that the default allocation be two storage words.

Enable/Disable Vectoring of Arrays
Array vectoring is a process which decreases the time necessary to reference elements of a multidimensional array by using some additional memory to store array accessing information. Where size is a more critical factor than speed, you can disable the vectoring of all arrays. If arrays are vectored, it is so noted in the storage map listing.

Enable/Disable Compiler Warning Diagnostics
Warning diagnostics report conditions which are not fatal error conditions, but which can be potentially dangerous at execution time, or which may present compatibility problems with other FORTRAN compilers running on the operating systems. For example, a warning message is generated if a variable name exceeds six characters in length. This is potentially dangerous because another variable name may have the same first six characters. Warning diagnostics are normally enabled, but the user can suppress their inclusion in the diagnostics listing.

PDP-11 FORTRAN IV INTERNAL OPERATION AND STRUCTURE

Instead of using temporary files to process source programs, the FORTRAN IV compiler performs all its activities in main memory. It reads the entire source program once, stores it in memory in a compacted format, and processes the compacted code in memory. Since a disk device is not used for temporary file operations, compilation speed is significantly increased.

To reduce the memory requirements of such a compilation system, the FORTRAN IV compiler employs a multiphase overlaid structure. The compiler consists of a large number of overlays. Most of the space allocated to the compiler is occupied by the compressed source code.

The compiler begins by reading in as much of the source program as can fit in memory. It then compresses the source code in memory by removing blanks and other unnecessary data. It continues to read in more source code, compressing it as it goes, until the entire program segment fits in memory.

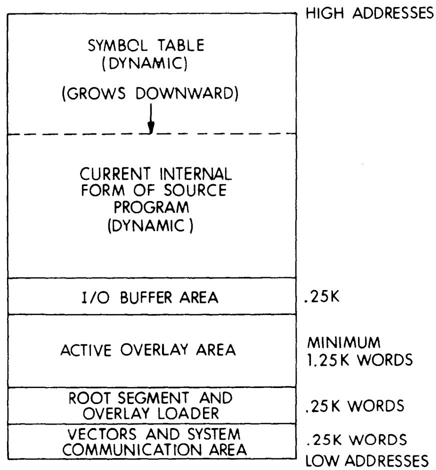


Figure 11-1 Compile-Time Memory Map

Once the source code is compacted into memory, the compiler begins processing the internal form of the source code as a whole. Because the entire program segment is available to the compiler, FORTRAN IV does not require statement ordering restrictions.

Object Code Generation

A few executable FORTRAN statements can be translated directly into machine instructions. Typical FORTRAN operations, however, require long sequences of PDP-11 machine instructions. For example, standard sequences are needed to locate an element of a multidimensional array, initialize an I/O operation, or simulate a floating point operation not supported by the hardware configuration.

The common sequences of PDP-11 machine instructions are contained in a library known as the FORTRAN Object Time System (OTS). The FORTRAN IV compiler does not always generate pure machine instructions for the FORTRAN source code statements. It simply determines which combination of appropriate OTS routines is needed to implement a FORTRAN program. During the linking process for an object program, the linker utility includes the needed OTS routines into the load module. During program execution, these routines are chained together to effect the desired result. However, in-line code is used for improved execution speed for some operations where appropriate.

During compilation, FORTRAN IV performs ten categories of program optimization.

Briefly, they are:

- Compiled FORMAT Statements — FORMAT statements are translated into internal form at compile time, increasing execution speed and decreasing program size.
- Array Vectoring — Provides for faster location of array elements in multidimensional arrays.
- Constant Folding — Integer constant expressions are evaluated at compile time.
- Constant Subscript Evaluation — Constant subscript expressions in array calculations are evaluated at compile time.
- Unreachable Code Elimination — Unreachable statements are eliminated from the object code.
- Common Subexpression Elimination — Redundant subexpressions whose operands do not change between computations are replaced by temporary values calculated only once.
- Peephole Optimizations — Sequences of operations are replaced with shorter and faster equivalent operations.
- Branch Optimization for Arithmetic and Logical IF — Branch structures can be sped up and decreased in size.
- Register Allocation — Register allocation is improved to minimize direct memory references for variables.
- Loop Optimization — Expressions dependent on loop index variables are replaced with less complex arithmetic operations.

Libraries

The FORTRAN programmer can create a library of commonly used assembly language and FORTRAN functions and subroutines. The operating system's librarian utility provides a library creation and modification capability. Library files may be included in the command string to the linker utility. The linker recognizes the file as a library file and links only those routines in the library that are required in the executable program. By default, the linker also automatically searches the FORTRAN system library for any other required routines.

Debugging a FORTRAN Program

Two debugging facilities are available to the FORTRAN programmer. The FORTRAN Object Time System provides a traceback feature for fatal runtime errors. This feature locates the actual program unit and line number of a runtime error. Immediately following the error message, the error handler will list the line number and program unit name in which the error occurred. If the program unit is a subroutine or function subprogram, the error handler will trace back to the calling program unit and display the name of that program unit and the line number where the call occurred. This process will continue until the calling sequence has been traced back to a specific line number in the main program. This allows the exact determination of the location of an error even if the error occurs in a deeply nested subroutine.

In addition to the FORTRAN OTS error diagnostics which include the traceback feature, there is another debugging tool available. A "D" in column one of a FORTRAN statement allows that statement to be conditionally compiled. These statements are considered comment lines by the compiler unless the appropriate debugging lines switch is issued in the compiler command string. In this case, the lines are compiled as regular FORTRAN statements. Liberal use of the PAUSE statement and selective variable printing can provide the programmer with a method of monitoring program execution. This feature allows the inclusion of debugging aids that can be compiled in the early program testing stages and later eliminated without source program modification.

PDP-11 FORTRAN IV OPERATING ENVIRONMENTS

Though the compiler operation and facilities under all operating systems are essentially identical, each operating system provides additional features particular to the environment. For example, the monitor programmed requests or executive directives are usually available as a library of FORTRAN-callable routines.

Under RT-11

The entire PDP-11 FORTRAN IV language processing system is operational in 16 Kbytes under the RT-11 SJ, FB, or XM monitors. The RT-11 System Subroutine Library (SYSLIB) is a collection of FORTRAN-callable routines that allow a FORTRAN user to utilize various features of the RT-11 Foreground/Background (FB) and Single-Job (SJ) monitors. SYSLIB also provides various utility functions, a complete character string manipulation package, and 2-word integer support. SYSLIB is provided as a library of object modules to be combined with FORTRAN programs at link-time. SYSLIB allows the RT-11 FORTRAN user to write almost all application programs in FORTRAN with no assembly language coding.

Also available under RT-11 are:

- A library of FORTRAN-callable graphics routines supporting the VT11, GT40, GT42, and GT44 graphics hardware systems.
- Plotting support for the LV11 electrostatic printer/plotter.
- Laboratory data acquisition and manipulation routines used in conjunction with the LPS-11 and AR11 laboratory peripheral hardware.

- The Scientific Subroutine Library, providing FORTRAN-language routines for mathematical and statistical applications.
- Stand-alone program execution.

Under RSTS/E

PDP-11 FORTRAN IV operates in interactive or batch mode under the RSTS/E monitor. The FORTRAN IV language processing system includes the FORTRAN IV compiler, the Object Time System (OTS), and several utility programs.

The entire system (including compiler and optimization components) is completely functional in an 16 Kbyte user area. A system interface occupying 8 Kbytes of memory is shareable among all FORTRAN IV users on the system. In addition, the FORTRAN IV system provides overlay support for programs and data, allowing extremely large programs to be run in a small region of memory.

RSTS/E FORTRAN IV provides assembly language subprogram support, using the MACRO assembler. Although the assembly language subprogram cannot issue any monitor calls, MACRO provides the experienced user with a tool to further enhance computational performance.

Under RSX-11 and IAS

In RSX-11M and RSX-11M-PLUS, the FORTRAN IV compiler runs in a minimum partition of 14 Kbytes. If run in a larger partition, it uses the extra space for program and symbol table storage. In IAS, the compiler task requires 16 Kbytes minimally and can be extended when it is installed. As with RSX-11 systems, the additional space allows the processing of larger FORTRAN programs.

An RSX-11/IAS library consists of object modules. Two types of libraries exist, shared and relocatable.

Relocatable libraries are stored in files. Object modules from relocatable libraries are built into the task image of each task referencing the module. The Taskbuilder is used to include modules from relocatable libraries in a task image. When a library specification is encountered in the command string, those modules in the library which contain definitions of any currently undefined global symbols are included in the task image. The user can construct relocatable libraries of assembly language and FORTRAN routines using the Librarian utility.

Shared libraries are located in main memory and a single copy of each library is used by all referencing tasks. Access to a shared library is gained by specifying the name of the library in an option at taskbuild time. Shared libraries are built using the taskbuilder. They must contain shareable (re-entrant) code.

Each RSX-11/IAS system has a system relocatable library. The system relocatable library is automatically searched by the Taskbuilder if any undefined global references are left after processing all user-specified input files. The FORTRAN OTS may be included in the system library and hence is loaded automatically with FORTRAN programs.

The RSX-11/IAS system library provides FORTRAN-callable forms of most executive directives. The FORTRAN programmer can schedule the execution of tasks, communicate with concurrently executing tasks, and manipulate system resources through these calls.

Industrial Society of America (ISA) extensions for process I/O control are available in FORTRAN-callable format under RSX-11M. Support for laboratory and process control peripherals is also included.

PDP-11 FORTRAN-77 FUNCTIONS AND FEATURES

The PDP-11 FORTRAN-77 compiler accepts a source program and produces a relocatable object module and optionally a listing file as output. PDP-11 FORTRAN-77 is designed to minimize the size and increase the speed of executable programs. It accomplishes this through extensive optimizations such as subexpression elimination, peephole optimizations, removal of invariant expressions from DO loops, and allocation of processor registers across block IF constructs and DO loops.

The PDP-11 FORTRAN-77 language processor is a high-performance, optimizing compiler whose language specifications conform to the American National Standard Institute (ANSI) FORTRAN standard X3.9-1978 at the subset language level. The FORTRAN-77 compiler provides optional, switch-selectable support for programs conforming to the previous ANSI FORTRAN standard X3.9-1966. Programs which successfully compile using the PDP-11 FORTRAN-77 compiler can be compiled using VAX-11 FORTRAN without modification to the source code. Programs which successfully compile using PDP-11 FORTRAN-IV can be compiled using either FORTRAN-77 or VAX FORTRAN by setting the /NOF77 switch.

Full-language FORTRAN-77 Features

PDP-11 FORTRAN-77 includes the following features of full-language FORTRAN as defined by the ANSI FORTRAN standard X3.9-1978:

- Double precision and complex data types.
- Function subprograms, including LEN, ICHAR, and INDEX.
- Exponentiation forms, including double precision.
- Format edit descriptors, including S, SP, SS, T, TL, and TR.

- Generic function selection based on argument data type for FORTRAN-defined functions.
- Use of any arithmetic expression as the initial value, increment, or final value in a DO statement.
- Use of a real or double-precision variable as a DO statement control variable.
- CLOSE and OPEN statements.
- Use of the specification ERR=s in READ or WRITE statements to transfer control when an error occurs to the statement specified by s.
- Use of list-directed I/O to perform formatted I/O without a format specification.
- Use of constants and expressions in the I/O lists of WRITE, REWRITE, TYPE, and PRINT statements.
- Specification of lower bounds for array dimensions in array declarators.
- Use of ENTRY statements in SUBROUTINE and FUNCTION subprograms to define multiple entry points.
- Use of PARAMETER statements to assign symbolic names to constant values.

LANGUAGE EXTENSIONS

DIGITAL-Supplied Enhancements to the FORTRAN-77 Subset Standard

The following language extensions beyond the ANSI FORTRAN standard X3.9-1978 are included in PDP-11 FORTRAN-77:

- You can use any arithmetic expression as an array subscript. If the expression is not an integer type, it is converted to integer type.
- Mixed-mode expressions can contain elements of any data type except character.
- The LOGICAL*1 and LOGICAL*2 data types have been added.
- The IMPLICIT statement redefines the implied data type of symbolic names.
- The following input/output statements have been added:

ACCEPT TYPE PRINT	Device-oriented I/O
READ (u'r) WRITE (u'r) FIND (u'r)	Unformatted direct-access I/O

READ (u'r,fmt) WRITE (u'r,fmt)	Formatted direct-access I/O
DEFINE FILE	File control and attribute specification
ENCODE DECODE	Formatted data conversion in memory
READ (u,f,key) READ (u,key)	Indexed I/O
REWRITE DELETE UNLOCK	Record control and update

- You can include any explanatory comment on the same line as any statement. These comments begin with an exclamation point (!).
- You can include debugging statements in a program by placing the letter D in column 1. These statements are compiled only when you specify a compiler command qualifier; otherwise, they are treated as comments.
- You can use any arithmetic expression as the control parameter in the computed GO TO statement.
- Virtual arrays provide large data areas outside of normal program address space.
- You can include the specification ERR=s in any OPEN, CLOSE, FIND, DELETE, UNLOCK, BACKSPACE, REWIND, or ENDFILE statement to transfer control to the statement specified by s when an error condition occurs.
- The INCLUDE statement incorporates FORTRAN statements from a separate file into a FORTRAN program during compilation.
- ENCODE, DECODE statements. The ENCODE and DECODE statements transfer data between variables or arrays in internal storage, and translate that data from internal to character form, or from character to internal form, according to format specifiers.
- The INTEGER*4 data type provides a sign bit and 31 data bits.
- You can use hexadecimal and octal constants in place of any numeric constants.
- O and Z format edit descriptors.
- You can use character substrings and all the character intrinsic functions defined in the full language except CHAR.

PDP-11 FORTRAN-77 Object Time System (OTS)

The compiler's Object Time System (OTS) is a library of routines that are selectively linked with compiler-produced object modules by the operating system's taskbuilder, to produce a task ready for execution. The PDP-11 FORTRAN-77 OTS contains routines for I/O processing, task control, error processing, mathematical computation and system subroutine access. By selective linking, if a program performs only sequential formatted I/O, none of the direct-access I/O routines is included in the task. The OTS is composed of the following routines:

- Math routines, including the FORTRAN-77 library functions and other arithmetic routines (e.g., exponentiation routines).
- Miscellaneous utility routines (e.g. ASSIGN, DATE, ERRSET).
- Routines that handle FORTRAN-77 input/output.
- Error-handling routines that process arithmetic errors, I/O errors, and system errors.
- Miscellaneous routines required by the compiled code.

PDP-11 FORTRAN-77 can create either or both of the following object time systems:

- The OTS based on File Control Services (FCS), is a package of routines that can handle many file operations transparently to the user, and allows sequential and random access to sequentially organized files.
- The OTS based on Record Management Services (RMS), uses RMS to provide access to sequential, relative, and indexed files.

PDP-11 FORTRAN-77 Optimizations

Optimizations are techniques used to increase the execution efficiency of an object program. PDP-11 FORTRAN-77 optimizations include:

- Peephole optimizations: The initial machine instructions generated by a FORTRAN program are examined to find operations which can be replaced by shorter, faster code sequences. The final code generated by the compiler contains these improved code sequences.
- Common subexpression elimination: Often the same subexpression appears in more than one computation. If the values of the operands of a common subexpression are not changed between computations, that value can be computed once and substituted wherever the subexpression appears.
- Removal of invariant expressions from DO loops: An algorithm executes faster if computations are moved from frequently executed program sequences to less frequently executed program sequences. In particular, computations within a loop involving only constants can be moved outside the loop.

- Allocation of processor registers across block IF constructs and DO loops: Wherever possible, frequently referenced variables are retained in registers to reduce the number of load and store instructions executed. Frequently used variables and expressions are also assigned to registers across block IF constructs and DO loops.
- Shareable Code: For the RSX-11M-PLUS and IAS operating systems, the compiler produces shared object code as a compile-time option. Shared tasks may then be created by using the multiuser-linker option. This improves memory utilization in multiuser systems because many users share one memory-resident task.

CHAPTER 12
THE BASIC LANGUAGE

INTRODUCTION
BASIC is an acronym for Beginner's All-purpose Symbolic Instruction Code. BASIC was developed at Dartmouth College to answer the need for an easy-to-learn, conversational programming language accessible to people who are not computer specialists. Characteristics of the BASIC language include simple English words, understandable abbreviations, and the familiar symbols for mathematical and logical operations.

BASIC is the most widely implemented and most widely used programming language in the world today. DIGITAL's BASICs have always been in the vanguard of the computer industry, and today, DIGITAL's BASIC implementations are acknowledged as the industry leaders.

BASIC, in its interactive versions, such as BASIC-PLUS and BASIC-11, gives the novice programmer almost immediate use of the computer, allowing him or her to get results for mathematical requests very easily. In addition, with little training the beginner can write and run meaningful programs. Interactivity encourages the new user to practice and experiment with the language, since there is a quick response from the computer telling whether the instruction worked and, if not, what went wrong. BASIC also includes powerful capabilities necessary to users who want to do file management, matrix manipulation, editing, and other more advanced computer operations.

Most of DIGITAL's versions of BASIC offer the advantages of interactive program development, including powerful statement editing features plus HELP and debugging facilities. Their friendly environments have made BASIC one of the most popular programming languages in commercial and technical applications, as well as in academia.

PDP-11 BASIC IMPLEMENTATIONS

BASIC-PLUS-2
PDP-11 BASIC-PLUS-2 is the most powerful, most advanced BASIC language implementation available on PDP-11 systems. As a true compiler, BASIC-PLUS-2 significantly improves the performance of compute-bound BASIC applications. Fast program execution and a variety of advanced programming features make BASIC-PLUS-2 a highly productive programming environment and powerful enough for

a wide variety of applications. BASIC-PLUS-2 is available on the RSTS/E, CTS-500, RSX-11M, RSX-11M-PLUS, and IAS operating systems and is generally a superset of BASIC-PLUS and a subset of VAX-11 BASIC. This makes BASIC-PLUS-2 applications highly transportable across a wide variety of DIGITAL systems. More detailed information on BASIC-PLUS-2 is included in the Product Descriptions section of this chapter.

BASIC-PLUS

BASIC-PLUS was specifically designed for and runs exclusively on RSTS/E and CTS-500 as one of many language options. It is included with both operating systems. Because of its conversational nature, BASIC-PLUS is especially suited to their timesharing environments.

Experienced programmers can use BASIC-PLUS's advanced features and facilities to produce complex and efficient programs. In general, BASIC-PLUS provides the following advantages:

- Programs can be written to conserve memory space and reduce execution time.
- Programs can handle a wide range of data by manipulating character strings.
- Programmers can obtain greater precision than is possible with floating-point and integer operands by using arithmetic and numeric string data manipulation.

It is not surprising that BASIC-PLUS is widely used for sophisticated scientific and business applications. Beginning programmers find BASIC-PLUS convenient and easy to use. BASIC-PLUS is also widely used as an educational tool in installations ranging from elementary schools to universities.

BASIC-11

BASIC-11 is an easy-to-learn programming language similar to Dartmouth standard BASIC. Like Dartmouth BASIC, it is a conversational language that uses simple English statements and familiar mathematical notation. Its immediate response and interactive features allow users to develop and debug programs in a minimum of time. It can be used for executing large data processing tasks and for performing quick, one-time calculations. It also provides advanced techniques for intricate data manipulation and efficient problem solution. BASIC-11 is available on the RT-11, RT^2, RT^2/PDT, RSX-11M, RSX-11M-PLUS, and IAS operating systems.

FEATURES COMMON TO THE BASIC LANGUAGE

GENERAL SYNTAX

A BASIC program is composed of groups of statements containing instructions to the computer. Each group begins with a number that identifies it as a statement and indicates the order of statement execution relative to other lines in the program. Each statement starts with an English word specifying the type of operation to be performed.

More than one statement can be written on a single line when each statement after the first is preceded by a backslash. For example:

```
10 INPUT A,B,C
```

is a single statement line, while

```
20 LET X=11 \ PRINT X,Y,Z \ IF X=A THEN 10
```

is a multiple statement line containing three statements: LET, PRINT, and IF.

BASIC Language Elements

In addition to real and integer formats, BASIC accepts exponential notation. Numeric data can be input in any one or all of these formats. BASIC automatically uses the most efficient format for printing a number, according to its size. It automatically suppresses leading and trailing zeros in integer and decimal numbers and formats all exponential numbers.

It can also process information in the form of strings. A **string** is a sequence of alphabetic, numeric, or special characters treated as a unit, either a constant or a variable.

A string constant is a list of characters enclosed in quotes that can be used in such diverse BASIC statements as PRINT, CALL, and CHAIN. String constants can also be used to assign a value to a string variable, for example, in the LET and INPUT statements, as with:

```
30 LET A$ = "HELLO"
```

Subscripted variables provide additional computing capabilities for dealing with lists, tables, matrices, or any set of related variables. In BASIC, variables are allowed either one or two subscripts. For example, a list of floating point values might be stored in an array A(I) where I goes from 0 to 5:

A(0), A(1), A(2), A(3), A(4), A(5)

This allows reference to each of the six elements in the list, and can be considered a one-dimensional algebraic matrix. Analogously, you can construct two-dimensional arrays by using two subscripts. For example:

B(I,J)

where I goes from 0 to 3 and J goes from 0 to 5, defines a 24-element matrix.

Any variable name followed by a percent sign (%) indicates an integer variable. For example: A%, C7%, C%(5).

Any variable name followed by a dollar sign ($) character indicates a string variable (for example: A$, C7$), while a matrix variable name followed by the dollar sign character denotes the string form of that variable (for example: V$(n), M2$(n), C$(m,n), G1$(m,n)).

Variables without % or $ suffixes are considered floating point variables; e.g., A, B7, C(I), D(J,K).

The user can assign values to variables by using a LET statement, by entering the value as data in an INPUT statement, or by using a READ statement with associated data statements. Values assigned to a variable do not change until the next time a statement that contains a new value for that variable is encountered.

Operators — BASIC performs addition, subtraction, multiplication, division and exponentiation. IF-THEN statements have access to a variety of relational operators (less than, not equal, greater than or equal to, for example). Most operators of both kinds work with strings as well as with numerical arguments; for strings, the relational operators do alphabetic comparisons.

Statements — The following summary of BASIC statements gives a brief explanation of each statement's use.

CALL	Transfers control to a subprogram, optionally passes parameters to it, and stores the location of the calling program for an eventual return.
CHAIN	Terminates execution of the program, loads the program specified, and begins execution of the lowest line number or, when a line number is present in the statement, at the specified line number.
CLOSE	Closes the file(s) associated with the logical unit number(s) and virtual file logical unit number(s).
DATA	Creates a data block for the READ statement. Can contain any combination of strings and numbers.
DEF FN	Defines a user function.
DIM	Reserves space in memory for arrays according to the subscripts specified.
END	Placed at the physical end of the program to terminate execution (optional).

FOR	Sets up a loop to be executed the specified number of times.
GOSUB	Unconditionally transfers control to specified line of subroutine.
GO TO	Unconditionally transfers control to specified line number.
IF	Conditionally executes the specified statements or transfers control to the specified line number. If the condition is not satisfied, execution continues at the next sequential line. The expressions and the relational operator must all be string or all be numeric.
INPUT	Inputs data from a file or from the user's terminal. Variables can be arithmetic or string.
KILL	Deletes the specified file.
LET	Assigns the value of an expression to the specified variable(s).
NAME AS	Renames the specified file.
NEXT	Placed at the end of the FOR loop to return control to the FOR statement.
ON GOSUB	Conditionally transfers control to the subroutine at one line number specified in the list. The value of the expression determines the line number to which control is transferred.
ON GO TO	Conditionally transfers control to one line number in the specified list. The value of the expression determines the line number to which control is transferred.
OPEN FOR INPUT [OUTPUT] AS FILE #n	Opens a file for input [or output] and associates the file with the specified logical unit number or channel number.
OVERLAY	Merges the current program with a program segment stored in a file (BASIC-11 only).
PRINT	Prints the values of the specified expressions on the terminal or, when specified, to the file associated with the logical unit expression. The TAB function can also be included.

PRINT USING	Generates output formatted according to a format string (either numeric or string).
RANDOMIZE	Causes the random number generator (RND function) to produce different random numbers every time the program is run.
READ	Assigns values listed in DATA statements to the specified variables. These variables can be numeric or string.
REM	Contains explanatory comments in a BASIC program.
RETURN	Terminates a subroutine and returns control to the statement following the last executed GOSUB statement.
RESTORE	Resets to the beginning the data pointer.
STOP	Suspends execution of the program.

FUNCTIONS

BASIC provides a variety of functions to perform mathematical and string operations.

Arithmetic Functions

ABS	Returns the absolute value of an expression
ATN	Returns the arc tangent as an angle in radians
COS	Returns the cosine of an expression in radians
EXP	Returns the value of the constant e (approximately 2.71828) raised to a given power, which can be an expression
INT	Returns the greatest integer less than or equal to a given expression
LOG	Returns the natural logarithm of an expression
LOG10	Returns the base 10 logarithm of an expression
PI	Returns the value of pi (approximately 3.14159)
RND	Returns a random number between 0 and 1
SGN	Returns value indicating the sign of an expression
SIN	Returns the sine of an expression in radians
SQR	Returns the square root of an expression

TAB	Causes the terminal print head to tab to column number given by an expression (valid only in PRINT)
SYS	Special system function calls; controls terminal I/O and performs special functions

String Functions

CHR$	Generates a one-character string whose ASCII value is the low-order eight bits of the integer value of the given expression
TIME$	Returns the time as a string
DATE$	Returns the date as a string
LEN	Returns the number of characters in the given string
POS	Searches for and returns the position of the first occurrence of a substring in a string
SEG$/MID	Returns the string of characters in the given positions in the string
STR$	Returns the string which represents the numeric value of the given expression
TRM$	Returns the given string without trailing blanks
VAL	Returns the value of the decimal number contained in the given string expression

User-Defined Functions

In some programs you may find it necessary to execute the same sequence of statements in several different places. BASIC allows you to define unique operations or expressions and to call these functions in the same way as, for example, the square root or trigonometric functions. Each function can be defined once and can appear anywhere in the program. User-defined functions simplify program entry, contribute to modular coding, and help to streamline programs.

BASIC Files

Data are stored either in sequential files or in random access, virtual array files. Data are read by an INPUT statement and written by a PRINT statement. Virtual arrays are random-access, disk-resident files that are similar to arrays stored in memory. A program can create and access virtual arrays just as it accesses memory-resident arrays: using array names and subscript values. Because the arrays are stored on disk, programmers can manipulate large amounts of data without affecting program size.

BASIC-PLUS-2 also provides the RMS-11 Record Management System. Through RMS-11, BASIC-PLUS-2 provides virtual array, block I/O, terminal-format, sequential, relative, and indexed files.

Creating, Modifying and Executing BASIC Programs

A BASIC program is entered in the system using the editing commands. Once the program has been entered, it can be retrieved, listed, modified, or executed using the editing commands. These commands are:

APPEND	Merges the program currently in memory with a program stored in a file. All lines in the program in memory that have duplicate line numbers with the program in the file are replaced by the lines from the program in the file.
BYE	Terminates the session at the terminal.
CLEAR	This command is used when a program has been executed and then edited. Before rerunning the program, the array and string buffers are cleared to provide more memory space. (interpreters only)
LENGTH	Displays on the terminal the amount of storage required by the BASIC-11 program currently in memory. This information is useful in determining the minimum user area in which a specific program can run.
LIST LISTNH	Types on the terminal the program currently in memory. A range of line numbers can be specified. The "NH" suffix suppresses header printing.
NEW	Clears the user area in memory and assigns a specified name to the current program. Used to create a new program.
OLD	Clears the user area and reads a program from a specified file into the user area in memory.
RENAME	Changes the current program name to a specified name.
REPLACE	Replaces the specified file with the program currently in memory.
RESEQ	Allows a user to resequence the line numbers in a

	program. (BASIC-11 only)
RUN RUNNH	If issued with no file specification, executes the program currently in memory. If a file specification is issued, clears the user area, reads a program in from the file, and executes the program. The "NH" suffix suppress header printing. (not BASIC-PLUS-2/RSX)
SAVE	Copies the contents of the user area to a file, lists the contents on the lineprinter, or punches the contents on paper tape.
UNSAVE	Deletes the specified file.

In addition to the editing commands, the BASIC system recognizes the following special control characters:

CTRL/C	Interrupts program execution and prints the READY message
CTRL/O	Enables/disables console output
CTRL/U	Deletes the current line being typed
RUBOUT	Deletes the last character typed

PRODUCT DESCRIPTIONS

BASIC-PLUS-2

Functions and Features

BASIC-PLUS-2 is the most powerful and advanced BASIC available on PDP-11 systems. It combines a powerful implementation language compiler with an integrated set of program development utilities. Fast program execution is one way BASIC-PLUS-2 helps improve programmer productivity. A language-integrated I/O syntax conveniently accesses the RMS-11 record/file handling facilities. CALL statements allow modular structuring of programs. MAP statements permit variable-oriented data record access.

BASIC-PLUS-2 generates "threaded code." Threaded code executes at high-speed and produces smaller object programs than conventional inline instruction generation. Smaller programs mean fewer overlays are needed, fewer trips to disk are necessary, and throughput is higher.

Language Features

BASIC-PLUS-2's language features provide greater programmer flexibility, more language statements, more sophisticated data typing and manipulation, and, through RMS, easier file access than most other BASIC implementations—including DIGITAL's BASIC-PLUS.

Data Typing and Declarations

The type of variable or numeric value in BASIC-PLUS-2 is identified by the last character of the variable name or constant. A variable ending in a dollar sign indicates a string variable; a variable or numeric constant ending in a percent sign indicates an integer; and a variable or numeric constant ending in any other character specifies a floating-point quantity.

Variables may be used in BASIC-PLUS-2 programs without being "declared" to the compiler. Scalar (i.e., single-value) variables that are not declared are assigned storage from a general dynamic storage area, which is available to the current program (or subprogram) only. Undeclared arrays have a dimension size of 10, if one-dimensional, or 10X10, if two-dimensional. The DIMENSION statement is used to declare arrays with a size other than the default.

COMMON and MAP Statements — The COMMON and MAP declarations are used to declare variables or arrays in a static, naed storage area, accessible to other subroutines in the program image.

The COMMON statement defines a named, shared area of memory called a COMMON block, occupied by specified variable values. These values can be read or changed by any BASIC-PLUS-2 subprogram with a COMMON block of the same name. The COMMON statement enables a subprogram to pass data to another program or subprogram. Strings passed in COMMON are fixed length, thus reducing string handling overhead.

COMMON and MAP are similar in function. The MAP statement allocates record buffer space. With MAP, users create a storage area that will serve as an I/O buffer associated with one or more open I/O channels. The MAP feature is unique to PDP-11 BASIC-PLUS-2 and VAX-11 BASIC—no other BASIC implementation provides it. MAP's save program space and perform better than other methods of declaring variables. Because a MAP statement defines fixed-length character strings, it provides maximum control over storage allocation and reduces overhead. And, because MAP statements define data types at compile time, execution time is faster.

Functions

A function performs one or more operations on a specified set of arguments and returns a result, either numeric or string, to the calling program. BASIC-PLUS-2 provides both library and user-defined functions.

String Handling Functions — With BASIC-PLUS-2, programmers can concatenate and compare strings; convert string and numeric representations, and analyze the composition of strings. BASIC-PLUS-2 includes string functions that:

- Create a string containing a specified number of identical characters
- Locate a substring within a longer string
- Edit a string: change lowercase to uppercase; change square brackets to parentheses; trim trailing blanks/tabs from a string; delete form feeds, rubouts, line feeds, carriage returns, and nulls; trim parity, etc.
- Determine the length of a string

BASIC-PLUS-2 also supports string functions to perform string-to-numeric and numeric-to-string conversions. Unlike many BASIC languages, BASIC-PLUS-2 imposes no limit on the size of string values or string elements of arrays manipulated in memory, other than the amount of available memory.

Mathematical and Numeric String Functions
BASIC-PLUS-2 provides algebraic, exponential, trigonometric, and random number functions. In addition, its string arithmetic functions permit greater precision—up to 56 digits—than floating-point calculations. BASIC-PLUS-2 also includes matric functions for transposing and inverting matrices.

Program Control Constructs
In a BASIC program, control ordinarily moves from one line to another in consecutive line order. Within a line, control moves from statement to statement. However, execution can be diverted from the normal sequence to another portion of a program or to a subprogram, continue execution at that point, and then return control to the original program. BASIC-PLUS-2 provides a variety of methods to control program execution sequence. These include:

- Subroutine constructs
- CALL statement for subprograms
- Statement modifiers

Programmers can use BASIC-PLUS-2 to write structured programs much as they would use structured programming languages such as PASCAL. Structured programs are easier to write and maintain than conventional programs.

Subroutines — A subroutine is a block of statements within a program that performs an operation and returns program control to the statement following the subroutine reference. The BASIC-PLUS-2 subroutine constructs use GOSUB, ON GOSUB, and RETURN statements.

Subroutines differ from functions and subprograms. A subroutine is a sequence of instructions to be executed several times in the course of a program. User-defined functions define a mathematical expression to be evaluated once, which then can be used repeatedly throughout a program. Subprograms are program units that can be separately compiled and then invoked from an external program.

Subprograms — Separately compiled subprograms can be invoked using the CALL statement. Subprograms:

- Divide large programs into more manageable units
- Provide a convenient means for executing frequently used programs
- Permit control to transfer from one program to another
- Permit program overlays to conserve memory

Statement Modifiers — Programmers can use statement modifiers for conditional or repetitive execution of a statement. Modifiers save program text space and increase readability. Any nondeclarative statement in BASIC-PLUS-2 can have one of the five supported statement modifiers: FOR, IF, UNLESS, UNTIL, and WHILE.

Modifiers cannot stand alone; they *must* be appended to a statement, and all executable BASIC-PLUS-2 statements can be modified.

When using statement modifiers with the various forms of the IF statement, the following rules apply:

1. Append statement modifiers to either the THEN clause or the ELSE clause of an IF statement.
2. The statement modifier applies only to the clause it is appended to and not to the statement as a whole.

If there is more than one statement on a line, the modifier applies only to the statement immediately preceding it. More than one statement modifier can be appended to a single statement. In this case, BASIC-PLUS-2 processes the modifiers from right to left.

Matrix Operations

With the MAT statement, the following operations can be performed on arrays:

1. Assignment
2. Addition
3. Subtraction

4. Multiplication
5. Transposition
6. Inversion

Each MAT operation statement begins with the keyword MAT followed by an expression to be evaluated. The value of one array can be assigned to another, for example, as in:

```
10 MAT A=B
```

This statement sets each entry to array A equal to the corresponding entry of array B. A is redimensioned to the size of array B.

Files and Records

A major distinction between BASIC-PLUS-2 and BASIC-PLUS is access to the Record Management Services (RMS) with BASIC-PLUS-2. RMS greatly increases the ease with which programmers can develop and run complex programs.

There are four types of files in BASIC-PLUS-2:

1. RMS record files
2. Terminal format files
3. Virtual array files
4. RSTS native (block I/O)

RMS-11

RMS-11 is a record and file management system that provides a variety of file organizations and access modes. Through RMS, BASIC-PLUS-2 provides virtual array, block I/O, terminal format, sequential, relative, and indexed files. This variety means users can choose file organizations and access methods best suited to individual applications.

BASIC-PLUS-2 has specific language elements for creating a file, describing the attributes of a file, opening a file, associating a record buffer with the file, describing the contents of the record buffer, performing input/output operations on a file, and allowing multiuser access to a file. With specific language elements for each of these operations, a CALL statement is not necessary for performing file handling functions. Because programmers can deal with logical records rather than with physical disk blocks, record and file handling is much easier than with other BASIC systems.

Terminal Format Files

A terminal format file is a stream of ASCII characters stored in lines of various lengths. The end of a line is determined by a line terminator, e.g., line feed. BASIC-PLUS-2 stores these ASCII characters, including spaces and line terminators, exactly as they would appear on the terminal; hence the name terminal format file.

Terminal format files are sequential access files (i.e., they contain records that must be read or written one after another from the beginning of the file). This means that a record cannot be retrieved without first retrieving each of the items preceding it in turn.

BASIC-PLUS-2 maintains a file pointer that keeps track of the user's location in the file. To add new items to an existing file without overwriting current information, the entire file must be read. This action places the file pointer at the end of the file where data can be added.

Virtual Array Files

A virtual array file, like a terminal format file, is information stored on a disk. Once a virtual array file is opened, however, the similarity with terminal format files ends. Elements in a virtual array can be accessed exactly as elements in an array in memory.

Virtual array files are random access files. The last element in a virtual array can be accessed as quickly as the first.

When BASIC-PLUS-2 stores data in a virtual array file, it does not convert them to ASCII characters but rather stores them in the internal binary representation. Consequently, there is no loss of precision caused by data conversion.

Transportability Package

The BASIC Transportability Package provides both documentation and software aids for users of DIGITAL BASIC. The software utilities and the BASIC Transportability Manual assist users wishing to move programs from DIGITAL BASIC implementations to the mainstream Digital offerings (i.e., VAX-11 BASIC and PDP-11 BASIC-PLUS-2). The documentation also covers both moving existing programs and data between operating systems and also writing new applications in BASIC that are transportable across systems.

BASIC-PLUS

Functions and Features

The BASIC-PLUS language interpreter enables you to write programs in BASIC-PLUS and to interact with the RSTS/E operating system. BASIC-PLUS runs exclusively on RSTS/E.

BASIC-PLUS incorporates the following features:

Immediate Mode: Commands can be executed immediately by BASIC-PLUS instead of being stored for later execution.

Program Editing: An existing program can be edited by adding or deleting lines, or renaming the program. The user can combine two programs into a single program and request the listing of a program, either in whole or in part, on a terminal or lineprinter.

Program Control and Storage: Facilities are included for storing both programs and data on any mass storage device and for retrieving them later for use during program execution.

Documentation and Debugging: The insertion of remarks and comments within a program is easy in this version of BASIC. Program debugging is aided by the printing of meaningful diagnostic messages that pinpoint errors detected during the program's execution.

Access to System Peripheral Equipment: The user program is able to perform input and output with various equipment, such as disk, industry-compatible magnetic tape, lineprinter, and floppy disks.

Record I/O: Language extensions provide a means of handling records composed of fixed-length fields in a highly efficient manner.

Matrix Computations: A set of commands is available for performing matrix I/O, addition, subtraction, multiplication, inversion, and transposition.

Alphanumeric Strings: Alphanumeric strings can be manipulated with the same ease as numeric data. Individual characters within these strings are accessible to the user.

Output Formatting: The PRINT and PRINT-USING statements include facilities for tabs and spaces as well as precise specifications of the output line formatting and floating dollar sign, asterisk fill, and comma insertion in numeric output.

String Arithmetic: A set of functions performs arithmetic on operands that are numeric strings instead of integer or floating point numbers. This provides a means of calculating values of higher than normal precision, or values that must not be affected by round-off error (at the expense of slower execution time).

Immediate Mode Operations

Most BASIC-PLUS statements can either be included in a program for later execution or be issued online at the terminal as commands that are immediately executed by the BASIC language processor. Immediate mode operation is especially useful in two ways: 1) to perform simple calculations that do not justify writing a complete program; 2) to debug a program.

To make program debugging easier, you can insert several STOP statements in the program. When the program is run, each STOP statement causes the program to halt and identify the line in the program at which the program was interrupted. You can then examine the current contents of variables and change them if necessary, and then continue.

Data Formats and Operations

BASIC-PLUS allows you to manipulate string, integer numeric, or floating point numeric data. BASIC-PLUS permits a user program to combine integer variables or integer-valued expressions using a logical operator to give a bitwise integer result. The logical operators AND, OR, NOT, XOR, IMP, and EQV operate on integer data in a bitwise manner.

BASIC-PLUS users working with floating point numbers can increase accuracy of operations involving fractional numbers by using the scaled arithmetic feature or the string arithmetic functions. Furthermore, users can perform arithmetic operations using a mix of integer and floating point numbers. If both operands of an arithmetic operation are either explicitly integer or explicitly floating point, the system automatically generates integer or floating point results. If one operand is an integer and another is floating point, the system converts the integer to a floating point representation and generates a floating point result. If one operand is an integer and the other operand is a constant that can be interpreted either as a floating point number or an integer, the system generates an integer result.

Matrix Manipulation

Variables of any type are legal in matrices, though any particular matrix must be composed of a single type of data. Explicitly dimensioning a matrix establishes the number of elements in each row and column and the number of elements in the matrix. (Implicitly dimensioned matrices are assumed to have ten elements in each dimension referenced.) Explicit dimensioning is done using the DIM statement.

By using the matrix I/O (MAT) statements, you can alter the number of elements in each row and the number of columns in the matrix, as long as the total number of elements does not exceed the number defined when the matrix was dimensioned. The MAT operations do not set row zero or column zero, nor do they initialize values in the space allocated to the matrix unless specific MAT functions are executed.

The operations of addition, subtraction, and multiplication (including scalar multiplication) can be performed on matrices using the common BASIC mathematical operators; functions also exist for performing transposition and inversion of matrices.

Advanced Statement and Function Features
BASIC-PLUS extends the BASIC language by including several additional statements for easier logic flow control, function definitions, and faster response in a timesharing environment. The ON-GOTO, ON-GOSUB, IF-THEN-ELSE, FOR-WHILE, and FOR-UNTIL statements provide a variety of conditional controls over looping and subroutine execution. The ON ERROR GOTO statement allows the programmer to write subroutines that handle error conditions normally considered fatal. The program can test a system variable named ERR to determine which error occurred, and can examine a system variable named ERL to determine the line number at which the error occurred. SLEEP and WAIT allow program suspension, either for a specified time interval or until input from a terminal is received. The PRINT-USING statement provides special output formatting, including exponential representation, dollar signs, commas, trailing minus sign, and asterisk fill. The DEF statement allows multiple-line function definitions. Multiple-line function definitions can be nested, can be written in any data type and can contain any variety of argument types.

Five statement modifiers are available within BASIC-PLUS; IF, UNLESS, FOR (including FOR-WHILE and FOR-UNTIL), WHILE and UNTIL. These modifiers are appended to program statements to indicate conditional execution of the statement or the creation of implied FOR loops.

RSTS/E also includes several system functions and statements that allow program access to system information and conversion routines. The program can obtain the current date and time, the CPU time, connect time, kilocore ticks, and device time used for the job. It can convert a numeric value to a string date or time or vice versa, can swap bytes, or convert an integer in RADIX-50 format to a character string.

Table 12-1 Basic Language Features

	B-11/RT-11 MU B-11/ RT-11	BASIC-PLUS RSTS/E	BASIC-PLUS-2
Data and Variables			
Integer constants and variables	X	X	X
Floating point constants and variables	X	X	X
Character string constants and variables	X[1]	X	X

[1] Not in 8K.

Table 12-1 (Cont.) Basic Language Features

	B-11/RT-11 MU B-11 RT-11	BASIC-PLUS RSTS/E	BASIC-PLUS-2
Integer arrays, one or two dimensions	X	X	X
Floating point arrays, one or two dimensions	X	X	X
Character string arrays, one or two dimensions	X[1]	X	X
Long variable and array names (up to 30 characters)	—	X[2]	X
Expressions			
+ − * / ^	X	X	X
** equivalent to	—	X	X
< > = < = > = < > for numeric data	X	X	X
= = (approximately equal) for numeric data	—	X	X
relations for strings re collating sequence	X[3]	X	X
AND, OR, NOT, XOR, IMP, EQV, logic operations on integers	—	X	X
string concatenation	X[3]	X	X
string arithmetic	—	X	X
Matrix operations + − *	—	X	X
Matrix inversion and transpose	—	X	X
= (Matrix assignment scale, matrix scalar multiplication)	—	X	X
Matrix determinant ZER, CON, IND, NUL$	—	X	X
Matrix initialization	—	X	X
string = =	—	X	X
LSET/RSET	—	X	X
Functions			
Mathematical (ABS, SIN, COS, TAN, COT, SGN, LOG, EXP, ATN, INT, RND, SQR)	X	X	X
Mathematical (ATN2, FIX, MOD, MOD%, PI)	—	X[10]	X[10]
String LEFT, RIGHT, MIDdle, LENgth	X[4,5]	X	X
String search for substring	X[6,5]	X	X

2 In EXTEND mode.
3 Not in 8K.
4 LEN, SEG functions.
5 Not in 8K.
6 POS function.
7 TIME supported in V2.
8 STR$ is NUM$ in BASIC-PLUS.
10 PI and FIX only.

Table 12-1 (Cont.) Basic Language Features

	B-11/RT-11 MU B-11/ RT-11	BASIC-PLUS RSTS/E	BASIC-PLUS-2
SPACE$	—	X	X
TRM$ (delete trailing spaces)	X[6]	X[8]	X
ASCII code of character	X[6]	X	X
Character equivalent to ASCII code (CHR$)	X[6]	X	X
Date and time	X[7]	X	X
Numeric String Conversion (VAL and STR$)	X[5]	X[8]	X
FORMAT$	—	—	X
Octal and Binary Functions (OCT and BIN)	X	—	—
Common log (LOG10)	X	X	X
TAB for print positioning	X	X	X
Assembly language routines	X	—	X[11]
TRC	—	—	—
POS, CCPOS, COMP$, DIF$, NUM$, PLACE$, PROD$, QUO$, RAD$, SUM$, XLATE)	X[11]	X	X
Program Lines			
Maximum line number	32767	32767	32767
Multiple statement lines	X	X	X
Multiple line statements	—	X	X
Assignment			
LET	X	X	X
Word LET optional	X	X	X
Multiple assignments	—	X	X
MOVE with (MAP)	—	—	X
Control			
GOTO	X	X	X
IF-THEN	X	X	X
IF-GOTO	X	X	X
IF-THEN-ELSE	—	X	X
FOR, NEXT	X	X	X
FOR-WHILE, FOR-UNTIL	—	X	X
WHILE, UNTIL	—	X	X
ON-GOTO	X	X	X
CHAIN	X	X	X
OVERLAY	X	—	—
Subroutines and Functions			
GOSUB	X	X	X
RETURN	X	X	X
ON-GOSUB	X	X	X

[11] Octal only.
[12] DEF in BASIC-PLUS is DEF*.
[13] DEF in BASIC-PLUS is DEF*.
[14] For machine language subroutines only.

Table 12-1 (Cont.) Basic Language Features

	B-11/RT-11 MU B-11 RT-11	BASIC-PLUS RSTS/E	BASIC-PLUS-2
locals in DEF	—	—	—
DEF, single line	X	X[12]	X[12]
DEF, multiple line	—	X[13]	X[13]
DEF*, multi-line (global arguments)	—	—	X
SUB	—	—	X
CALL	X[14]	—	X
FNEXIT	—	—	X
SUBEXIT	—	—	X
Program overlay	—	—	X
Error Trapping			
ON ERROR GOTO	X[16]	X	X
RESUME	X[16]	X	X
ON ERROR GO BACK	X[16,15]	—	X
MATRIX I/O			
MAT READ	—	X	X
MAT INPUT	—	X	X
MAT PRINT	—	X	X
MAT LET	—	X	X
MAT LINPUT	—	—	X
Statement Modifiers			
IF, UNLESS, FOR, WHILE, UNTIL	—	X	X
Input/Output			
GET	—	X	X
PUT	—	X	X
FIELD	—	X	X
UNLOCK	—	X	X
DELETE, FIND, RESTORE, SCRATCH, UPDATE	—	—	X
record/bucket locking	—	X	X
INPUT	X	X	X
INPUT LINE	—	X	X
LINPUT	X	—	X
PRINT	X	X	X
PRINT USING	X[17]	X	X
Files			
OPEN	X	X	X
CLOSE	X	X	X
NAME-AS	X[18]	X	X
KILL	X	X	X

15 RESUME 0 has same function.
16 MU BASIC-11 V02 only.
17 Not in 8K.
18 NAME TO.
19 Utility program for BASIC-PLUS-2.

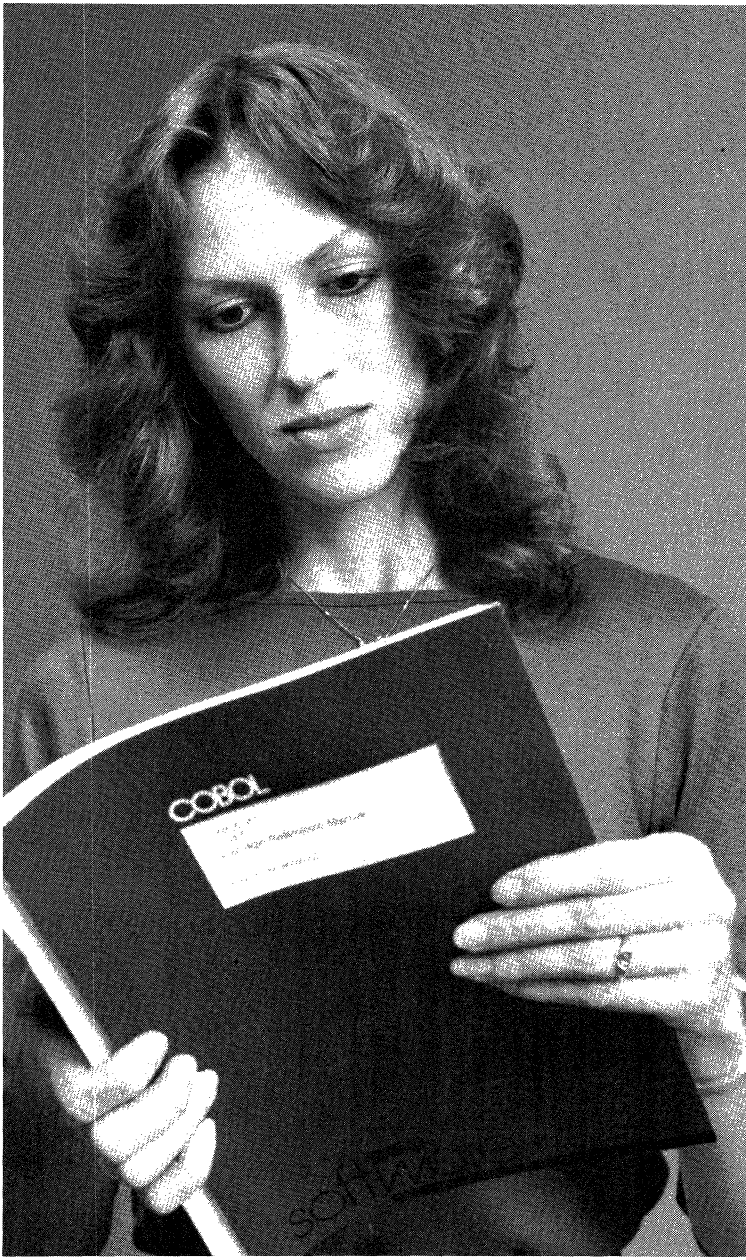
Table 12-1 (Cont.) Basic Language Features

	B-11/RT-11 MU B-11 RT-11	BASIC-PLUS RSTS/E	BASIC-PLUS-2
IF END	X	—	—
Virtual Files	X	X	X
Record Files	—	X	X
READ	X	X	X
DATA	X	X	X
NODATA	—	—	—
RESTORE	X	X	X
Specifications			
REM	X	X	X
DIM	X	X	X
RANDOMIZE	X	X	X
COMMON	X[19]	—	X
MAP	—	—	X
CHANGE string to/from array	X	X	X
STOP	X	X	X
END	X	X	X
END statement optional	X	X	X
SLEEP	X	X	X
WAIT	X	—	—
Editing			
DELETE	X	X	X
RENAME	X	X	X
LIST	X	X	X
LENGTH	X	X	—
RESEQ	X	—	X
SUB	X	—	—
Debugging aid (BREAK, STEP, PRINT, LET, TRACE, etc.)	—	—	X
Intra-line character editing	—	—	—
SEQUENCE	—	—	X
CROSS REFERENCE	—	—	X
Program storage/retrieval			
NEW	X	X	X
OLD	X	X	X
SAVE	X	X	X
REPLACE	X	X	X
UNSAVE	X	X	X
APPEND	X	X	X
COMPILE	X	X	X
CATALOG	X[20]	X	—
COMPILE with switches	—	—	X

[20] Utility program for MU BASIC-11 V01.
[21] RSTS/E only.
[22] MU BASIC-11 V2 only.
[23] Several functions available.
[24] BASIC-11/RT-11 only.

Table 12-1 (Cont.) Basic Language Features

	B-11/RT-11 MU B-11 RT-11	BASIC-PLUS RSTS/E	BASIC-PLUS-2
BUILD	—	—	X
INQUIRE	—	—	X
Miscellaneous			
KEY	—	X	—
TAPE	—	X	X
RUN	X	X	X[21]
HELLO	X[22]	X	—
BYE	X[23]	X	—
SCALE	—	X	X
MON	—	—	—
SYS	X[23]	X[21]	X[21]
Immediate Mode	X	X	—
CALL Interface to FMS-11 (Forms Management System)	X[24]	—	X


COBOL

CHAPTER 13
COBOL

INTRODUCTION

COBOL, the COmmon Business Oriented Language is an industry-wide data processing language that has been designed specifically for business applications such as payroll, inventory control, and accounts receivable.

DIGITAL offers PDP-11 COBOL and COBOL-81, both of which conform to the ANSI-74 COBOL standard (X3.23-1974) and run on systems ranging in size from the PDP-11/23 and PDP-11/24 through the PDP-11/70.

COBOL-81 provides an efficient, entry-level COBOL for small RSTS/E, RSX-11M, and RSX-11M-PLUS business systems where small size, high performance, ease of use, and low cost are prime considerations. By fully utilizing the Commercial Instruction Set (CIS), COBOL-81 produces compact, high-performance programs.

COBOL-81 is a subset of VAX-11 COBOL. Programs written for COBOL-81 can be compiled and executed using VAX-11 COBOL without source changes, giving customers a migration path from the smallest PDP-11 systems to the largest VAX/VMS systems. This compatibility is important to the increasing number of customers who combine VAX and PDP-11 systems to meet their business needs.

PDP-11 COBOL is designed for sophisticated applications requiring rich functionality. A typical PDP-11 COBOL customer will meet one of the following criteria:

- Have a large library of PDP-11 COBOL programs
- Or, have applications based on other vendors' high-level ANSI-74 COBOL

COBOL-81

COBOL-81 is one member of DIGITAL's commercial language offerings. It is a high-performance compiler that produces compact object code. COBOL-81 not only follows very closely Level 1 of the ANSI-74 standard, but also implements many items planned for the next release of the ANSI standard, anticipated in 1982.

COBOL-81 provides features that are aimed at making the COBOL programmer and the COBOL programs highly productive on small business systems.

COBOL-81 is designed and implemented to run under the RSTS/E, RSX-11M, and RSX-11M-PLUS operating systems and on the PDP-11/23-PLUS, PDP-11/24's and PDP-11/44's, on which compactness, speed, and ease-of-use are prime considerations.

COBOL-81, a subset of VAX-11 COBOL, has been designed for upward compatibility to VAX-11 COBOL. COBOL-81 is intended for entry-level users; it will enable them to begin with a small PDP-11 system and grow upward to all PDP-11 and VAX systems. Programs written for COBOL-81 can compile and execute using VAX-11 COBOL without source changes.

The hardware configuration supporting COBOL-81 is any valid RSTS/E, RSX-11M, or RSX-11M-PLUS operating system configuration with a user area of at least 48 Kbytes of memory, if one is using an RMS resident library (otherwise 52 Kbytes and at least 3500 free blocks of on-line storage on the public disk structure, plus additional space for user programs and data files). The RSX-11M and RSX-11M-PLUS configurations must include the Extended Instruction Set. Optional hardware supported includes any mass storage, unit record, or terminal device supported by the prequisite software (except TU56 DECtape and TU58 DECtape II). Also supported are the KEF-11BB Commercial Instruction Set for 11/24, the KEF11-B Commercial Instruction Set for 11/23-PLUS, and the KE44-A Commercial Instruction Set for 11/44.

General Characteristics

COBOL-81 has been designed so that customers can install the software without requiring the aid of a DIGITAL software specialist. The installation procedure determines a default compiler for the user's hardware configuration. If the compiler is acceptable to the user (indicated by a yes response to questions from the system), the default compiler is then built. If, however, the compiler is not acceptable, the system prompts the user with several more questions in order to build a customized compiler.

The compiler performance is impressive; it averages up to 500 lines per minute on a PDP-11/44. Because the compiler is designed for the Commercial Instruction Set (CIS), it generates compact high-performance object code, resulting in highly productive applications. This design also requires less use of time-consuming overlays.

COBOL-81 is defined as an implementation of ANSI COBOL with support of the following:

Language Features

- Level 1+ Nucleus Module
- Level 1 Table-Handling Module

- Level 1+ Sequential I/O Module
- Level 2 Indexed I/O Module
- Level 2- Segmentation Module
- Level 1 Library Module
- Level 1 Interprogram Communication Module

The COBOL-81 processing Modules are:

Nucleus	This Module contains all the essential language elements required for internal processing.
Table Handling Module	This Module provides the ability to define and manipulate tabular data.
Sequential I/O Module	This Module provides the ability to define and access sequentially organized files.
Indexed I/O Module	This Module provides the ability to define and access indexed sequential files including dynamic access.
Segmentation Module	This Module allows for specifying overlay of the Procedure Division at object time.
Library Module	The Library Module provides the facility for copying predefined COBOL text into the source program.
Interprogram Communication Module	This Module provides the functionality of communicating with one or more other programs at runtime.

Data Types

COBOL-81 provides the following data types to the COBOL programmer:

- Numeric DISPLAY Data

- Trailing overpunch sign
- Leading overpunch sign
- Trailing separate sign
- Leading separate sign
- Unsigned
- Numeric-edited

• Numeric COMPUTATIONAL Data
  - Word fixed binary
  - Longword fixed binary
  - Quadword fixed binary

• Packed-Decimal Data (COMPUTATIONAL-3)
  - Unsigned packed decimal
  - Signed packed decimal

• Alphanumeric DISPLAY Data
  - Alphanumeric
  - Alphabetic
  - Alphanumeric-edited

As indicated previously, COBOL-81 supports the COMP-3 (packed-decimal) data type (two decimal digits per byte). This data type offers the following advantages:

• faster arithmetic operations than standard numeric display data type (on a CIS machine)
• storage (disk and memory) savings
• compatibility with and migration from other COBOL vendors

These data types are required over a spectrum of application systems; they provide for flexibility in system specification and design and for compatibility with both IBM and other COBOL implementations.

File Organization
The Sequential I/O Module meets full Level 1 ANSI-74 standards with several Level 2 features. The Indexed I/O Module meets full Level 2 ANSI-74 standards. The Indexed I/O Module statements enable COBOL-81 programs to use RMS multikey record management services to process files. These files can be accessed sequentially, randomly, and dynamically, using one or more indexed keys to select records.

Because COBOL-81 uses RMS for I/O handling, it is capable of handling files created under other PDP-11 languages, given data type compatibility. This multikey facility offers flexibility and power in the development of application systems and is a valuable language feature.

Additional I/O features include variable-length records through extensions to the RECORD VARYING clause, the ability to designate sequential input files as OPTIONAL, additional FILE STATUS values, and an APPLY clause from which to specify file characteristics that are not ordinarily available through COBOL language syntax.

COBOL-81 also supports file sharing, an important feature required for interactive applicaton programs.

Character String Facilities

COBOL-81 provides INSPECT, STRING, and UNSTRING verbs for character-string handling. Using these verbs, programmers can count and/or replace embedded character strings and can join together or break out separate strings with various delimiters.

CALL Facility

The CALL statement enables a COBOL programmer to execute routines that are external to the source module in which the CALL statement appears. The COBOL-81 compiler produces an object module from a single source module. The object module file can be taskbuilt with other object modules to produce an executable image. Thus, COBOL programs can call external routines written in MACRO-11 in addition to other COBOL-81 programs.

The CALL statement facility has been extended by allowing the user to pass arguments BY REFERENCE (the default in COBOL) and BY DESCRIPTOR.

Library Facility

COBOL-81 supports a full Level 1 ANSI-74 library facility. All frequently used data descriptions and program text sections can be stored in library files that are available to all programs. The library files can be copied at compile time to reduce program preparation time and to eliminate a common source of error during program development.

Symbolic Interactive Debugger

COBOL-81 provides an easy-to-learn, easy-to-use interactive debugger. The COBOL Symbolic Interactive Debugger allows for faster, error-free program development. Programmers can debug COBOL programs by including the debugger when taskbuilding the program, rather than having to alter the source program during testing. Programmers can follow the program flow during the execution of a job.

The debugger offers the programmer the capability to:

- Reference data items by their user-defined names
- Reference section names and paragraph names
- Examine and modify the value of variables during program execution
- Optionally stop and restart programs at the line numbers, section name or paragraph name specified by the programmer
- Gain control at program commencement and at abnormal termination

Other Debugging Features

To make program debugging even easier, the COBOL-81 compiler produces source listings with embedded English-language diagnostics. Fully descriptive diagnostic messages are listed at the point of error. Many error conditions, varying from simple warnings to fatal error detections, are checked at compile time.

When an error occurs during execution, the type of error, program name, and line number of the source statement that caused the error are displayed on the user's terminal. If the program is executing with an active PERFORM, the line numbers of the active PERFORM statements will be produced on the user's terminal. When the error is detected during execution of a subprogram, a backwards trace of the calling programs that were active at the time of the error is produced on the user's terminal.

The issuance of specific English-like error messages, coupled with the traceback facility, offers the user a powerful debugging tool in identifying programming errors.

Debugging large source programs is further simplified with the optional Data Division and Procedure Division allocation maps and with modular programming techniques offered by the segmentation and interprogram communication facilities.

Another useful debugging aid is the optional cross-reference listing produced by the compiler. This is a listing of all data names, procedure names, and the source-line numbers of those program lines containing the definitions and references. For each name, a list of ordered source-line numbers is displayed. Source-line numbers for defined items are distinguished from source-line numbers for referenced items.

Interactive COBOL Execution
Programmers have the flexibility to design their own screen format. COBOL-81 ACCEPT and DISPLAY statements (in the Procedure Division) allow for easy terminal-oriented interaction between a COBOL-81 program and the programmer.

The ACCEPT statement lets the programmer enter input lines to the COBOL program.

The DISPLAY statement transfers data from a specified literal or data item to a programmer's terminal. The statement can be modified by a special WITH NO ADVANCING phrase (without automatic appending of carriage return and linefeed) that allows the COBOL program to control the format of the message sent. The WITH NO ADVANCING phrase causes the device to remain positioned on the same line and the same character position following the last character displayed. This is especially useful when prompting messages are typed on the terminal, or when the programmer wishes to control the linefeeds within the program.

COBOL-81 also has the capability to call FMS, the Forms Management System.

Source Program Formats
The COBOL-81 compiler accepts source programs that are coded using either the ANSI-standard or a shorter, easy-to-enter DIGITAL terminal format. Terminal format is designed for use with interactive text editors. It eliminates the line numbers and identification fields and allows the user to enter horizontal tab characters and short text lines.

Utility Programs
COBOL-81 provides the REFORMAT and BLDODL utilities to aid the user in data processing.

The REFORMAT utility reads COBOL source programs that are coded using DIGITAL terminal format and converts the source statements to the ANSI standard format accepted by other COBOL compilers throughout the industry. It also has the inverse option to accept programs written in ANSI standard format and to convert the source statements to DIGITAL terminal format. This offers the advantage of saving disk space and compile-time processing when a user is initially migrating from a non-DIGITAL COBOL system to COBOL-81.

The BLDODL utility combines skeleton overlay description files generated by COBOL compilations into a single ODL file for use by the taskbuilder. This utility allows the user a simplified way of structuring segmented programs or subprograms into an efficient task image.

Commercial Instruction Set (CIS)
COBOL-81 takes full advantage of the CIS to enhance performance in data movement and packed-decimal arithmetic. The utilization of CIS also provides the added benefit of compact object code, reducing the requirement for time-consuming overlays.

Resident Library Support
COBOL-81 provides for resident library support that decreases disk storage requirements for task images, increases Taskbuilder performance, and increases memory availability in a multi-user environment.

PDP-11 COBOL
PDP-11 COBOL is a high-level language specifically designed to provide fast direct access data processing for commercial applications. Its high computational capabilities complement the performance capabilities of the RSTS, IAS, RSX-11M, and RSX-11M-PLUS operating systems. PDP-11 COBOL can be used to create online terminal applications or to write batch applications. It is based on the ANSI-74, X3.23-1974 standard and includes interactive symbolic debugging facilities and packed-decimal data support. On systems with the CIS, PDP-11 COBOL takes advantage of the Commercial Instruction Set to enhance performance in data movement and packed-decimal arithmetic.

The hardware configuration supporting PDP-11 COBOL is any valid RSTS/E, RSX-11M, RSX-11M-PLUS, or IAS operating system configuration with a user area of at least 60 Kbytes of memory and at least 4000 free blocks of on-line disk storage in the public disk structure. The RSX-11M and RSX-11M-PLUS configurations must include the Extended Instruction Set. Optional hardware supported includes any storage, unit record, or terminal device supported by the prequisite software, except TU56 DECtape and TU58 DECtape II. Also supported are the KEF-11BB Commercial Instruction Set for 11/24, the KEF-11B Commercial Instruction Set for 11/23-PLUS, and the KE44-A Commercial Instruction Set for 11/44.

PDP-11 COBOL is a compiler conforming in language element, representation, symbology, and coding format to ANSI-74 COBOL. It includes:

Language Features
- Full Level 2 Nucleus Module
- Full Level 2 Table-Handling Module
- Full Level 2 Sequential I/O Module

- Full Level 2 Relative I/O Module
- Full Level 2 Indexed I/O Module
- Level 2- Segmentation Module
- Level 1+ Library Module (with partial high-level replacing facility)
- Full Level 1 Interprogram Communication Module

The PDP-11 COBOL processing modules are:

Nucleus	This Module contains all the essential language elements required for internal processing.
Table Handling Module	This Module provides the ability to define and manipulate tabular data.
Sequential I/O Module	This Module provides the ability to define and access sequentially organized files.
Relative I/O Module	This Module provides the capability for defining and accessing external files in which records are identified by relative record numbers.
Indexed I/O Module	This Module provides the ability to define and access indexed sequential files including dynamic access.
Segmentation Module	This Module allows for specifying overlay of the Procedure Division at object time.
Library Module	The Library Module has partial high-level REPLACING facility for copying predefined COBOL text into the source program, changing text while copying.

Interprogram Communication Module	This Module provides the functionality of communicating with one or more other programs at runtime.

Because PDP-11 COBOL uses RMS for I/O handling, it is capable of handling files created under other PDP-11 languages, given data-type compatibility.

The nucleus, table handling, sequential I/O, relative I/O, and indexed I/O modules of PDP-11 COBOL meet full ANSI-74 high-level standards. PDP-11 COBOL offers high-level extensions in the Segmentation and Library modules.

Data Types

PDP-11 COBOL supports the standard data types plus most of the other common COBOL data types. They include:

- Numeric DISPLAY Data
  - Trailing overpunch sign
  - Leading overpunch sign
  - Trailing separate sign
  - Leading separate sign
  - Unsigned
  - Numeric-edited
- Numeric COMPUTATIONAL Data
  - Packed decimal
  - 1-word fixed binary
  - 2-word fixed binary
  - 4-word fixed binary
- Alphanumeric DISPLAY Data
  - Alphanumeric
  - Alphabetic
  - Alphanumeric-edited

These are data types which are required over a spectrum of application systems and are provided for flexibility in the specification and design of such systems.

File Organization
The Sequential I/O, Relative I/O, and multikey Indexed I/O modules meet the full ANSI-74 high-level standards and include all the COBOL verbs. The Indexed I/O Module statements enable COBOL programs to use RMS multikey record management services to process files. These files can be accessed sequentially, randomly, and dynamically, using one or more indexed keys to select records. This multikey facility offers flexibility and power in the development of application systems and is a valuable language feature.

Character String Facilities
PDP-11 COBOL provides INSPECT, STRING, and UNSTRING verbs for character-string handling. Using these verbs, programmers can count and/or replace embedded character strings, and can join together or break out separate strings with various delimiters.

CALL Facility
The CALL statement enables a COBOL programmer to execute routines that are external to the source module in which the CALL statement appears. The COBOL-81 compiler produces an object module from a single source module. The object module file can be task built with other object modules to produce an executable image. Thus, COBOL programs can call external routines written in MACRO-11 in addition to other COBOL-81 programs.

The CALL statement facility has been extended by allowing the user to pass arguments BY REFERENCE (the default in COBOL) and BY DESCRIPTOR.

Library Facility
With PDP-11 COBOL, programmers have a full Level 1 ANSI-74 library facility that includes high-level extensions (COPY...REPLACING). Frequently used data descriptions and program text sections can be held in library files that are available to all programs. These files can then be copied at compile time to reduce program preparation time and to eliminate a common source of errors.

Symbolic Interactive Debugger
PDP-11 COBOL provides an easy-to-learn, easy-to-use interactive debugger. The Symbolic COBOL Interactive Debugger reduces the time required to test programs. Altering source programs during testing is often unnecessary because the programmer can debug COBOL programs by including the debugger when linking the program. The symbolic debugger allows programmers to follow program flow during the execution of a job and offers:

- The ability to reference data items by their user-defined names, including qualification and subscripting.
- The ability to reference section names and paragraph names.
- The ability to examine and modify the value of variables during program execution.
- The option to stop and restart programs at locations specified by the programmer at the beginning or during the execution of the program.
- The ability to alter program flow during the debugging session.
- The ability to gain control before normal or abnormal termination.

Other Debugging Features

To make program debugging even easier, the PDP-11 COBOL compiler produces source-language listings with embedded diagnostics. Fully descriptive diagnostic messages are listed at the point of error. Over 400 different error conditions are checked—varying from simple warnings to fatal error detections.

Debugging large source programs is further simplified with the optional Data Division allocation map and with modular programming techniques offered by the segmentation and interprogram communication facilities.

Another useful debugging aid is the optional cross-reference listing produced by the compiler. This is a listing of all data names, procedure names, and the source-line numbers of those program lines containing the definitions and references. For each item, a list of ordered source-line numbers is displayed. Source-line numbers for defined items are distinguished from source-line referenced items.

Interactive COBOL Execution

The ACCEPT and DISPLAY statements of the PROCEDURE DIVISION allow for easy terminal-oriented interaction between a PDP-11 COBOL program and a programmer.

The ACCEPT statement enables the programmer to enter input lines to the COBOL program.

The DISPLAY statement transfers data from a specified literal or data item to a programmer's terminal. The statement can be modified by a special WITH NO ADVANCING phrase (without automatic appending of carriage return and linefeed) that allows the COBOL program to control the format of the message sent. The WITH NO ADVANCING phrase causes the device to remain positioned on the same line and the same character position following the last character displayed.

This is especially useful when typing prompting messages on the terminal, or when the programmer wishes to control the linefeeds within the program.

The ACCEPT and DISPLAY statements are intended primarily for use with keyboard devices. However, PDP-11 COBOL also allows the ACCEPT statement to accept cards from a cardreader and the DISPLAY statement to display data on a lineprinter.

In addition, more advanced screen facilities can be invoked by PDP-11 COBOL by calling FMS, the Forms Management System.

Source Program Formats

PDP-11 COBOL compiler accepts source programs that are coded using the ANSI (conventional) format or the shorter, easy-to-enter DIGITAL terminal format. Terminal format is designed for use with interactive text editors. It eliminates the line number and identification fields and allows horizontal tab characters and short lines. These capabilities offer potential savings in disk space and allow for easier interactive input of source programs.

Utility Programs

PDP-11 COBOL provides the RFRMT and MERGE utilities to aid the user with data processing. The RFRMT (reformat) utility reads COBOL source programs that are coded using DIGITAL terminal format and converts the source statements to the ANSI standard format accepted by other COBOL compilers throughout the industry. The MERGE utility program merges skeleton overlay description files generated by COBOL compilations into a single ODL file.

Table 13–1 Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
CHARACTER SET					
Words					
0,1,...9 A,B,...Z -	1	NUC	X	X	X
Punctuation					
.'() space or blank	1	NUC	X	X	X
=	1	NUC	X	X	—
, ;	2	NUC	X	X	X
'		EXT	—	X	—
Arithmetic + - * / **	2	NUC	X	X	X
Relational < > =	2	NUC	X	X	X
Editing					
B 0 + - CR DB Z * $. ,	1	NUC	X	X	X
/	1	NUC	X	X	X
Separators					
: and , not permitted	1	NUC	X	—	—
; and , are permitted	1	NUC	X	X	X
COBOL WORDS (max 30 chars)	1	NUC	X	X	X
User-defined Words	1	NUC	X	X	X
cd-name	1	COM	X	—	—
condition name	2	NUC	X	X	—
data-name (1st char alpha)	1	NUC	X	—	—
data-name	2	NUC	X	X	X
file-name	1	SEQ	X	X	X
index-name	1	TBL	X	X	X
level-number	1	NUC	X	X	X
library-name	2	LIB	X	X	—
mnemonic-name	1	NUC	X	X	—
paragraph-name	1	NUC	X	X	X
program-name	1	NUC	X	X	X
record-name	1	SEQ	X	X	X
report-name	1	RPW	X	—	—
routine-name (optional)	1	NUC	X	—	—
section-name	1	NUC	X	X	X
segment-number	1	SEG	X	X	X
text-name	1	LIB	X	X	X
System Names	1	NUC	X	X	X
computer-name			X	X	X
implementor-name			X	X	X
language-name (optional)			X	—	—
Reserved Words	1	NUC	X	X	X
key words	1	NUC	X	X	X
optional words	1	NUC	X	X	X
qualifier connectives: OF IN	2	NUC	X	X	—
series connectives: , ;	2	NUC	X	X	X

Table 13–1 (cont.) Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
logical connectives:					
AND, OR, AND NOT, OR NOT	2	NUC	X	X	X
LINE-, PAGE-COUNTER registers	1	RPW	X	—	—
LINAGE-COUNTER register	2	SEQ	X	X	—
DEBUG-ITEM register	1	DEB	X	—	—
ZERO constant	1	NUC	X	X	X
ZEROS, ZEROES constants	2	NUC	X	X	X
SPACE constants	1	NUC	X	X	X
SPACES constant	2	NUC	X	X	X
HIGH-VALUE, LOW-VALUE	1	NUC	X	X	X
HIGH-VALUES, LOW-VALUES	2	NUC	X	X	X
QUOTE constant	1	NUC	X	X	X
QUOTES constant	2	NUC	X	X	X
ALL literal	2	NUC	X	X	X
arithmetic special chars	2	NUC	X	X	X
relational special chars	2	NUC	X	X	X
non-numeric literals (1–120 chars)	1	NUC	X	X	X
quote within non-numeric literals			X	X	X
numeric literals (1–18 chars)			X	X	X
PICTURE strings	1	NUC	X	X	X
comment entries	1	NUC	X	X	X
No Qualification Permitted	1	NUC	X	X	X
Qualification Permitted	2	NUC	X	X	—
Subscripting to 3 Levels	1	TBL	X	X	X
Indexing to 3 Levels	1	TBL	X	X	X
IDENTIFICATION DIVISION					
PROGRAM-ID	1	NUC	X	X	X
AUTHOR	1	NUC	X	X	X
INSTALLATION	1	NUC	X	X	X
DATE-WRITTEN	1	NUC	X	X	X
DATE-COMPILED	2	NUC	X	X	X
SECURITY	1	NUC	X	X	X
ENVIRONMENT DIVISION					
Configuration Section					
Can be omitted		EXT	—	X	X
SOURCE-COMPUTER	1	NUC	X	X	X
WITH DEBUGGING MODE	1	DEB	X	—	—
OBJECT-COMPUTER	1	NUC	X	X	X
MEMORY SIZE	1	NUC	X	X	X
COLLATING SEQUENCE	1	NUC	X	X	X
SEGMENT-LIMIT	2	SEG	X	X	X
SPECIAL-NAMES	1	NUC	X	X	X
ON STATUS	1	NUC	X	X	—

Table 13–1 (cont.) Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
OFF STATUS	1	NUC	X	X	—
SPECIAL-NAMES series	1	NUC	X	X	—
STANDARD-1 alphabet-name	1	NUC	X	X	X
NATIVE alphabet-name	1	NUC	X	X	X
Implementor-name					
alphabet-name	1	NUC	X	—	—
literal alphabet-name	2	NUC	X	—	—
CURRENCY SIGN	1	NUC	X	X	X
DECIMAL-POINT	1	NUC	X	X	X
Input-Output Section					
FILE-CONTROL SELECT	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
	1	SRT	X	—	—
OPTIONAL	2	SEQ	X	X	X
ASSIGN TO implementor-name	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
	1	SRT	X	—	—
RESERVE integer AREA(S)	2	SEQ	X	X	X
	2	REL	X	X	—
	2	INX	X	X	X
SEQUENTIAL ORGANIZATION	1	SEQ	X	X	X
RELATIVE ORGANIZATION	1	REL	X	X	—
INDEXED ORGANIZATION	1	INX	X	X	X
SEQUENTIAL ACCESS MODE	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
RANDOM ACCESS MODE	1	REL	X	X	—
	1	INX	X	X	X
DYNAMIC ACCESS MODE	2	REL	X	X	—
	2	INX	X	X	X
RELATIVE KEY	1	REL	X	X	—
RECORD KEY	1	INX	X	X	X
ALTERNATE RECORD KEY	2	INX	X	X	X
FILE STATUS	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
I-O CONTROL: RERUN	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
SAME AREA	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X

Table 13–1 (cont.) Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
SAME RECORD AREA	2	SEQ	X	X	X
	2	REL	X	X	—
	2	INX	X	X	X
	2	SRT	X	—	—
SAME SORT-MERGE AREA	2	SRT	X	—	—
SAME series	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
MULTIPLE FILE TAPES	2	SEQ	X	X	—
APPLY		EXT	—	X	X
DATA DIVISION					
Communication Section	1	COM	X	—	—
File Section	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
	1	SRT	X	—	—
	1	RPW	X	—	—
linkage section	1	IPC	X	X	X
working storage section	1	NUC	X	X	X
report section	1	RPW	X	—	—
communications description entry	1	COM	X	—	—
data description entry	1	NUC	X	X	X
file description entry	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
	1	RPW	X	—	—
record description entry	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
Sort-merge description entry	1	SRT	X	—	—
Report description	1	RPW	X	—	—
Report group description entry	1	RPW	X	—	—
Clauses					
BLANK WHEN ZERO clause	1	NUC	X	X	X
BLOCK CONTAINS clause integer CHARACTERS/RECORDS	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
	1	RPW	X	—	—
integer-1 TO integer-2	2	SEQ	X	1	1
	2	REL	X	1	—
	2	INX	X	1	1
	1	RPW	X	—	—

Table 13–1 (cont.) Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
CODE clause	1	RPW	X	—	—
CODE-SET clause	1	SEQ	X	X	X
	1	RPW	X	—	—
COLUMN NUMBER clause	1	RPW	X	—	—
CONTROL clause	1	RPW	X	—	—
data-name clause	1	NUC	X	X	X
	1	RPW	X	—	—
DATA-RECORD clause	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
	1	SRT	X	—	—
FILLER	1	NUC	X	X	X
GROUP INDICATE clause	1	RPW	X	—	—
JUSTIFIED clause (JUST)	1	NUC	X	X	X
LABEL RECORDS clause					
STANDARD/OMITTED	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
	1	RPW	X	—	—
LEVEL-NUMBER					
01 thru 10 (must be 2 digits)	1	NUC	X	—	—
1 thru 49 (may be one digit)	2	NUC	X	X	X
66	2	NUC	X	X	—
77	1	NUC	X	X	X
88	2	NUC	X	X	—
LINAGE clause	2	SEQ	X	X	—
LINE NUMBER clause	1	RPW	X	—	—
NEXT GROUP clause	1	RPW	X	—	—
OCCURS clause					
integer times	1	TBL	X	X	X
ASCENDING/DESCENDING	2	TBL	X	X	—
data-name series	2	TBL	X	X	—
INDEXED BY index-name	1	TBL	X	X	X
Integer-1 TO integer-2					
DEPENDING ON	2	TBL	X	X	—
PAGE clause	1	RPW	X	—	—
PICTURE clause					
Character string max 30 chars	1	NUC	X	X	X
Data characters: A X 9	1	NUC	X	X	X
Operational symbols: S V P	1	NUC	X	X	X
Fixed insertion characters:					
0 B , . $ + - CR DB	1	NUC	X	X	X
Fixed insertion character: /	1	NUC	X	X	X

Table 13-1 (cont.) Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
Replacement chars: $ + - Z *	1	NUC	X	X	X
Currency sign substitution	1	NUC	X	X	X
Decimal point substitution	1	NUC	X	X	X
RECORD CONTAINS clause	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
	1	SRT	X	—	—
	1	RPW	X	—	—
REDEFINES clause					
(must not be nested)	1	NUC	X	—	—
REDEFINES clause (nesting)	2	NUC	X	X	X
RENAMES clause	2	NUC	X	X	—
REPORT clause	1	RPW	X	—	—
SIGN clause	1	NUC	X	X	X
SOURCE clause	1	RPW	X	—	—
SUM clause	1	RPW	X	—	—
SYNCHRONIZED clause	1	NUC	X	X	X
TYPE clause	1	RPW	X	—	—
USAGE clause					
COMPUTATIONAL (means binary)	1	NUC	X	X	X
DISPLAY	1	NUC	X	X	X
INDEX	1	TBL	X	X	X
VALUE clause					
literal	1	NUC	X	X	X
literal series	2	NUC	X	X	—
literal THRU literal	2	NUC	X	X	—
literal range series	2	NUC	X	X	—
VALUE OF clause					
implementor-name IS literal	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
	1	RPW	X	—	—
implementor-name IS data-name	2	SEQ	X	X	X
	2	REL	X	X	—
	2	INX	X	X	X
	2	RPW	X	—	—
PROCEDURE DIVISION					
USING phrase	1	IPC	X	X	X
Declaratives	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
	1	RPW	X	—	—
	1	DEB	X	—	—
Arithmetic expressions	2	NUC	X	X	X

Table 13–1 (cont.) Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
Conditional expressions	1	NUC	X	X	X
Simple conditions	1	NUC	X	X	X
Relation conditions	1	NUC	X	X	X
[NOT] GREATER THAN	1	NUC	X	X	X
[NOT] >	2	NUC	X	X	X
[NOT] LESS THAN	1	NUC	X	X	X
[NOT] <	2	NUC	X	X	X
[NOT] EQUAL TO	1	NUC	X	X	X
[NOT] =	2	NUC	X	X	X
numeric operands	1	NUC	X	X	X
nonnumeric operands (must be equal size)	1	NUC	X	—	—
nonnumeric (may be unequal)	2	NUC	X	X	X
Class conditions	1	NUC	X	X	X
NOT option	1	NUC	X	X	X
Switch-status condition	1	NUC	X	X	—
NOT option		EXT	—	X	—
Condition-name condition	2	NUC	X	X	—
NOT option		EXT	—	X	—
Sign condition	2	NUC	X	X	X
NOT option	2	NUC	X	X	X
Logical AND OR and NOT	2	NUC	X	X	X
Negated simple conditions	2	NUC	X	X	X
Combined and negated combined	2	NUC	X	X	X
Abbreviated combined relation	2	NUC	X	X	—
Arithmetic operands	1	NUC	X	X	X
Overlapping operands	1	NUC	X	X	X
	1	TBL	X	X	X
Multiple arithmetic results	2	NUC	X	X	—
ACCEPT statement					
Only one transfer of data	1	NUC	X	X	X
No restrictions on transfers	2	NUC	X	—	—
FROM	2	NUC	X	X	X
FROM DATE	2	NUC	X	X	X
FROM DAY	2	NUC	X	X	X
FROM TIME	2	NUC	X	X	X
MESSAGE COUNT	1	COM	X	—	—
ADD statement					
identifier literal series	1	NUC	X	X	X
TO identifier	1	NUC	X	X	X
TO identifier series	2	NUC	X	X	—
GIVING identifier	1	NUC	X	X	X
GIVING identifier series	2	NUC	X	X	—
ROUNDED	1	NUC	X	X	X

Table 13-1 (cont.) Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
SIZE ERROR	1	NUC	X	X	X
CORRESPONDING	2	NUC	X	X	—
ALTER procedure-name	1	NUC	X	X	—
ALTER procedure-name series	2	NUC	X	X	—
CALL literal	1	IPC	X	X	X
CALL identifier	2	IPC	X	—	—
CALL USING data-name	1	IPC	X	X	X
CALL ON OVERFLOW	2	IPC	X	—	—
CANCEL statement	2	IPC	X	—	—
CLOSE single file-name	1	SEQ	X	X	X
CLOSE file-name series	2	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
REEL	1	SEQ	X	X	—
UNIT	1	SEQ	X	X	—
NO REWIND	2	SEQ	X	X	X
LOCK	2	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
FOR REMOVAL	2	SEQ	X	X	—
COMPUTE identifier series	2	NUC	X	X	X
DELETE statement	1	REL	X	X	—
	1	INX	X	X	X
DISABLE statement					
INPUT	1	COM	X	—	—
TERMINAL INPUT	2	COM	X	—	—
OUTPUT	1	COM	X	—	—
KEY identifier/literal	1	COM	X	—	—
DISPLAY statement					
only one transfer of data	1	NUC	X	—	—
no restriction	2	NUC	X	X	X
UPON	2	NUC	X	X	—
WITH NO ADVANCING		EXT	—	X	X
DIVIDE statement					
INTO identifier	1	NUC	X	X	X
INTO identifier series	2	NUC	X	X	—
BY identifier	1	NUC	X	X	X
GIVING identifier	1	NUC	X	X	X
GIVING identifier series	2	NUC	X	X	—
ROUNDED	1	NUC	X	X	X
REMAINDER	2	NUC	X	X	X
SIZE ERROR	1	NUC	X	X	X
ENABLE statement					
INPUT	1	COM	X	—	—

Table 13-1 (cont.) Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
TERMINAL INPUT	2	COM	X	—	—
OUTPUT	1	COM	X	—	—
KEY identifier/literal	1	COM	X	—	—
ENTER statement (optional)	1	NUC	X	—	—
EXIT statement	1	NUC	X	X	X
EXIT PROGRAM statement	1	IPC	X	X	X
GENERATE statement	1	RPW	X	—	—
GO TO statement					
procedure-name required	1	NUC	X	X	X
procedure-name optional	2	NUC	X	X	—
DEPENDING ON phrase	1	NUC	X	X	X
IF statement					
statements must be imperative	1	NUC	X	—	—
nested statements	2	NUC	X	X	X
ELSE	1	NUC	X	X	X
INITIATE statement	1	RPW	X	—	—
INSPECT statement					
single character data item	1	NUC	X	X	X
multi-character data item	2	NUC	X	X	X
MERGE statement	2	SRT	X	—	—
MOVE statement					
TO identifier	1	NUC	X	X	X
TO identifier series	1	NUC	X	X	X
CORRESPONDING	2	NUC	X	X	—
MULTIPLY statement					
BY identifier	1	NUC	X	X	X
BY identifier series	2	NUC	X	X	—
GIVING identifier	1	NUC	X	X	X
GIVING identifier series	2	NUC	X	X	—
ROUNDED	1	NUC	X	X	X
SIZE ERROR	1	NUC	X	X	X
OPEN statement					
INPUT single file-name	1	SEQ	X	X	X
INPUT file-name series	2	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
INPUT REVERSED	2	SEQ	X	—	—
INPUT NO REWIND	2	NUC	X	X	X
OUTPUT single file-name	1	SEQ	X	X	X
OUTPUT file-name series	2	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
OUTPUT NO REWIND	2	SEQ	X	X	X
I-O single file-name	1	SEQ	X	X	X

Table 13-1 (cont.) Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
I-O file-name series	2	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
EXTEND	2	SEQ	X	X	X
INPUT, OUTPUT, I-O, EXTEND	2	SEQ	X	X	X
INPUT, OUTPUT and I-O series					
	1	REL	X	X	—
	1	INX	X	X	X
PERFORM statement					
procedure name	1	NUC	X	X	X
THRU	1	NUC	X	X	X
TIMES	1	NUC	X	X	X
UNTIL	2	NUC	X	X	X
VARYING	2	NUC	X	X	—
READ statement					
file-name	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
INVALID KEY	1	REL	X	X	—
	1	INX	X	X	X
INTO identifier	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
NEXT	2	REL	X	X	—
	2	INX	X	X	X
AT END	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
KEY IS	2	INX	X	X	X
RECEIVE statement					
MESSAGE	1	COM	X	—	—
SEGMENT	2	COM	X	—	—
INTO identifier	1	COM	X	—	—
NO DATA phrase	1	COM	X	—	—
RELEASE statement					
record name	1	SRT	X	—	—
FROM	1	SRT	X	—	—
RETURN statement					
file-name	1	SRT	X	—	—
INTO	1	SRT	X	—	—
AT END	1	SRT	X	—	—
REWRITE statement					
FROM identifier	1	SEQ	X	X	X
	1	REL	X	X	—

Table 13–1 (cont.) Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
USE FOR DEBUGGING statement					
procedure-name	1	DEB	X	—	—
procedure-name series	1	DEB	X	—	—
ALL PROCEDURES	1	DEB	X	—	—
ALL REFERENCES OF identifier	2	DEB	X	—	—
file-name series	2	DEB	X	—	—
cd-name series	2	DEB	X	—	—
WRITE statement					
record-name	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
SEGMENTATION					
segment-number	1	SEG	X	X	X
Fixed Memory Range 0–49	1	SEG	X	X	X
Non-fixed Memory Range 50–99	1	SEG	X	—	—
SEGMENT-LIMIT	2	SEG	X	X	X
LIBRARY					
COPY	1	LIB	X	X	X
OF/IN LIBRARY	2	LIB	X	—	—
REPLACING	2	LIB	X	X	—
Pseudo-text may be replaced	2	LIB	X	—	—
REFERENCE FORMAT					
Sequence Numbers	1	NUC	X	X	X
may be omitted		EXT	—	X	X
Area A	1	NUC	X	X	X
Division header	1	NUC	X	X	X
Section header	1	NUC	X	X	X
Paragraph header	1	NUC	X	X	X
Data Division entries	1	NUC	X	X	X
Area B	1	NUC	X	X	X
Paragraphs	1	NUC	X	X	X
Data Division entries	1	NUC	X	X	X
Continuation of Lines					
Nonnumeric Literals	1	NUC	X	X	X
Words and Numeric Literals	2	NUC	X	X	X
Comments					
With *	1	NUC	X	X	X
With /	1	NUC	X	X	X
With D	1	DEB	X	X	—
FIPS INFORMATION					
FIPS Flagging at					
Low		FIP	—	X	—
Low-Intermediate		FIP	—	X	—
and I-O procedures					

Table 13-1 (cont.) Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
	1	INX	X	X	X
INVALID KEY phrase	1	REL	X	X	—
	1	INX	X	X	X
SEARCH statement	2	TBL	X	X	—
SEND statement					
FROM identifier	2	COM	X	—	—
FROM identifier WITH	1	COM	X	—	—
WITH identifier	2	COM	X	—	—
WITH EGI	1	COM	X	—	—
WITH EMI	1	COM	X	—	—
BEFORE/AFTER ADVANCING	1	COM	X	—	—
SET statement	1	TBL	X	X	X
SORT statement					
Limited to one SORT, STOP and I-O procedures	1	SRT	X	—	—
Program not limited to one SORT	2	SRT	X	—	—
COLLATING SEQUENCE phrase	2	SRT	X	—	—
START statement	2	REL	X	X	—
	2	INX	X	X	X
STOP statement	1	NUC	X	X	X
STRING statement	2	NUC	X	X	X
SUBTRACT statement					
identifier/literal series	1	NUC	X	X	X
FROM	1	NUC	X	X	X
FROM series	2	NUC	X	X	—
GIVING identifier	1	NUC	X	X	X
GIVING identifier series	2	NUC	X	X	—
ROUNDED	1	NUC	X	X	X
SIZE ERROR	1	NUC	X	X	X
CORRESPONDING	2	NUC	X	X	—
SUPPRESS statement	1	RPW	X	—	—
TERMINATE statement	1	RPW	X	—	—
UNSTRING statement	2	NUC	X	X	X
USE statement					
EXCEPTION/ERROR PROCEDURE ON file-name/ INPUT/OUTPUT/I-O	1	SEQ	X	X	X
	1	REL	X	X	—
	1	INX	X	X	X
ON file-name series	2	SEQ	X	X	X
	2	REL	X	X	—
	2	INX	X	X	X
ON EXTEND	2	SEQ	X	X	X
BEFORE REPORTING	1	RPW	X	—	—

Table 13-1 (cont.) Comparison of COBOL Language Elements

Language Elements	Level	Module	ANS-74	PDP-11 COBOL V4.4	COBOL-81 V1.1
High-Intermediate		FIP	—	—	—
High		FIP	—	—	—
Certified at					
Low Level		FIP	—	X	—
Low-Intermediate		FIP	—	X	—
High-Intermediate		FIP	—	—	—
High		FIP	—	—	—

Abbreviations:
X = feature implemented according to standard
— = feature not implemented

NUC = Nucleus
TBL = Table Handling
SEQ = Sequential I/O
REL = Relative I/O
INX = Indexed I/O
SRT = Sort/Merge
RPW = Report Writer
SEG = Segmentation
LIB = Library
DEB = Debugging
IPC = Inter-program comm
COM = Communications
EXT = Additions to COBOL language

CHAPTER 14
DIBOL-11

INTRODUCTION

DIGITAL's business-oriented DIBOL-11 programming language is similar in some ways to COBOL, but is more concise and easier to use. DIBOL-11 programs can do data manipulation, evaluation of arithmetic expressions, subscripting, record redefinition, calls to subroutines, and sequential, indexed, and random access to files. In addition, the interactive on-line debugging utility simplifies the programmer's job of isolating and correcting program errors.

Because of its high interactivity, DIBOL-11 is a good program development language, and its simple syntax and free-form coding make the language easy to learn while providing for simpler program documentation.

DIBOL-11 can be used in multijob timesharing environments to permit several application programs to run simultaneously. Of course, programs written for timesharing can also run on a single-user system. Another language feature is the availability of external subroutine libraries. Because subroutines can be held in libraries, programmers may create more compact programs, increasing efficiency and productivity. Such subroutines can be either DIGITAL-supplied or user-developed.

The DIBOL-11 programming language is provided as part of the CTS-300 commercial operating system, which itself is based on the RT-11 operating system. DIBOL-11 is an option for CTS-500, a commercial operating system based on RSTS/E.

Program Structure

A DIBOL-11 program is separated into two major parts: a Data Division and a Procedure Division. The Data Division contains the nonexecutable data specification statements that define the characteristics and identity of the data used by the program. The Procedure Division contains all the program statements that implement the actions or tasks to be performed. PROC and END statements are used to define the program structure. The PROC statement separates the Data Division statements from the Procedure Division statements, and the END statement specifies the logical end of the program.

Data Division statements from the Procedure Division statements, and the END statement specifies the logical end of the program.

DIGITAL BUSINESS-ORIENTED LANGUAGE IMPLEMENTATION
SOURCE LANGUAGE INPUT MEDIA

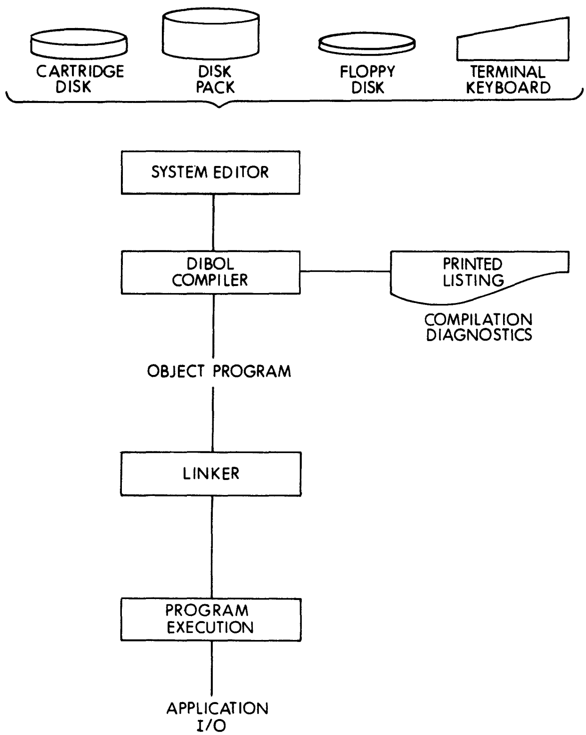


Figure 14-1 DIBOL Implementation

STATEMENT TYPES

DIBOL-11 statements fall into five functional groups: compiler directives, data specifications, data manipulation, control, and input/output. They include both arithmetic and logical expressions. The operators in an expression represent various arithmetic and manipulative functions of the DIBOL-11 language. Operators are classified either as unary or binary operators and include most of the usual arithmetic, relational, and boolean operations. In addition, there is a simple mechanism for formatting converted decimal data.

Compiler Directive Statements

As the name suggests, these are instructions to the compiler; they are not executable at runtime and do not affect program operation. Among the compiler directives are statements that identify programs as external subroutines, that separate Data Division statements from Procedure Division statements, that cause the program listing to skip to a new page, that end the program, and that perform other, similar chores.

Data Specification Statements
Data specification statements (also referred to as field definition statements) define and identify the characteristics of the data processed by a DIBOL-11 program. For example, data can be either numeric or alphanumeric, and can have certain size requirements and initial values. Fields of data that are grouped together are preceded by a RECORD or COMMON statement, and may be redefined at that level. The data specification statements are:

RECORD	Defines and identifies the beginning of one or more grouped fields
COMMON	Defines and identifies the beginning of one or more grouped fields and allows external subroutines directly to use/share a field defined in the main program Data Division section

Data Manipulation Statements
These statements are used to perform calculations as well as data modification, conversion, and movement as stated below:

INCR	Increments a variable by one
LOCASE	Converts uppercase characters to lowercase
UPCASE	Converts lowercase characters to uppercase

Data Movement

=	Moves the results of the expression on the right of the equal sign to the variable specified on the left of the equal sign

The operators in an expression represent various arithmetic and manipulative functions of the DIBOL-11 language. Operators are classified either as unary or binary operators and include most of the usual arithmetic, relational, and boolean operations. In addition, there is a simple mechanism for formatting converted decimal data.

Control Statements
Control statements govern the order of a program's instruction by modifying the normal sequence of statement execution. Some control statements call either internal or external subroutines (CALL, XCALL),

some transfer control to other statements (GOTO), some execute a statement based on the results of a logical condition (IF). In addition, there are controls for disabling and enabling trapping of runtime errors (OFFERROR, ONERROR), for returning from subroutines (RETURN), for suspending program operation for specified intervals (SLEEP), and for terminating execution, and (optionally) chaining to another program (STOP).

Input/Output Statements
Input/output statements control the transmission and reception of data between memory and PDP-11 input/output devices such as the disk, the lineprinter, and the terminal. The input/output statements are:

ACCEPT	Reads a character from a device
CLOSE	Terminates use of an input/output channel and closes the associated file
DELETE	Deletes a record from an ISAM file
DISPLAY	Writes a character string to a device
FORMS	Sends special form control characters used by lineprinters
LPQUE	Requests printing of a file by a spooling program
OPEN	Initializes a file in preparation for input/output operations
READ	Reads a record from a file (direct access)
READS	Reads the next record in sequence from a file
UNLOCK	Releases a file record for access by another program when operating in a time-sharing environment
WRITE	Writes a record to a file (direct access)
WRITES	Writes the next record in sequence to a file

Debugging Tools
The DIBOL Debugging Technique (DDT) allows you to interact with your DIBOL program while it is executing. Using DDT, you can set predetermined stopping points (called breakpoints) where you wish to temporarily suspend execution of the program. You can examine or alter the contents of variables using their symbolic names, trace through complicated sequences of subroutine nestings, and single

step through lines of a DIBOL program. These features allow you to locate problems, correct data values, and identify programming errors directly, before re-editing, recompiling, and relinking your program.

CHAPTER 15
INTRODUCTION TO FILE MANAGEMENT

PDP-11 operating systems provide a number of utilities and programs that are designed to make file management easy, both in the structuring and in the accessing of files.

A file is any designated collection of related information. FORTRAN programs can be files; lists of employees and their Social Security numbers are files; accounts receivable for July comprise a file; even a roster of comments from operators to the system manager could constitute a file. The elements that make up a file, namely, records and fields, were described in Chapter 2, but it might be useful to review them here.

Fields are specified groups of bits (or more typically, bytes). An employee's name is a field in his record, as is the part code in an inventory record. But fields need not have content-specific definitions. For example, bytes 19 through 45 of an accounts receivable record may be a field of interest to a programmer even though they cannot be interpreted as a name, amount, or number.

Records are combinations of fields. Together, a person's name, Social Security number, address, identification number, and salary code could constitute a record in the personnel file. Accounts receivable for a particular customer could be a record in the accounts receivable file.

The way programs get at records is called the **access mode**. Sometimes records are accessed sequentially, from the beginning of the file right through to the end. Sometimes they are accessed randomly: that is, the address of the record is known and the computer goes directly to it. Sometimes they are accessed according to information in the records themselves; for example, all employees with the number 01754 in their zip code field could be retrieved by the computer. Since the way in which records are accessed depends upon the way in which the information was put into the file in the first place, an important consideration for any programmer is the structure—or **organization**—of the file. And while a programmer may want to determine all the complex details of file and record organization himself, it is important to note that most DIGITAL operating systems supply ample facilities for making this chore fast and easy.

Most important among such facilities are the Record Management Services (RMS). This powerful software is, in varying versions, part of all the operating systems that support it (i.e., packaged together). RMS makes many of the details of file structure and access transparent to the programmer, and thus helps boost programmer productivity.

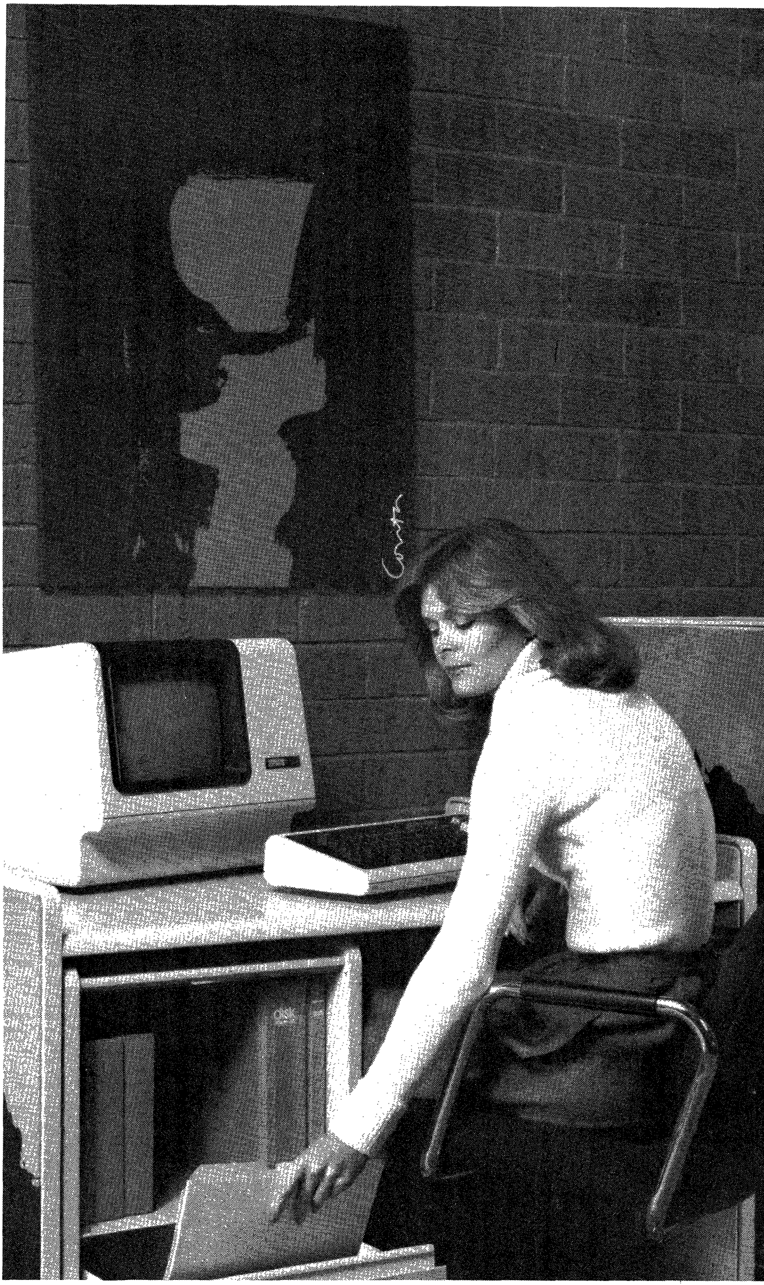
RSX-11 systems also include the File Control Services (FCS), a package of routines that can handle many file operations transparently to the user.

Some of the other programs or utilities that make file and record manipulation easy in PDP-11 systems are SORT, PIP, FILEX, VERIFY, and DUMP. SORT provides four different sorting techniques, among which a user can choose to best accommodate job needs and decisions about speed, record format, and storage devices. Like RMS, SORT handles almost all the sorting details once it is invoked by the program, cutting program development time and improving work speed.

The Peripheral Interchange Program (PIP) moves files from one device (e.g., a disk) to another (e.g., lineprinter). Invoking the PIP program is a simple matter: once called up, it manages all the details of the transfer. Another file copy routine, FILEX, can copy files from one format into another format. VERIFY validates data in files; DUMP lets a programmer examine the contents of files at a terminal or lineprinter. Such utilities sometimes have slightly different names or capabilities under the various operating systems, but they generally conform to the characteristics outlined in the next chapter.

In some ways, the distinction between file management and database management is arbitrary. In all cases, DIGITAL is committed to providing you with speed, power, and ease of use in the handling of records and files. But because we want to emphasize the distinction between databases and simple groups of data, we have gathered DATATRIEVE and DBMS into a section of their own. Naturally, many of the capabilities of database managers overlap, or even exploit, those of the file managers. Thus, DATATRIEVE is combined with RMS to give end users excellent access to information in databases without requiring that they know anything about the programmer's procedures in designing and creating the information.

It is true of file and record management software, as with all DIGITAL products, that continual development and improvement may enhance the capabilities described in the chapters that follow. As always, your DIGITAL software specialist is a good source of information on the most recent versions of software products.



CHAPTER 16
FILE MANAGEMENT UTILITIES

While the descriptions that follow do not exhaust the list of DIGITAL's file management programs or utilities, they do suggest the breadth of products available.

FILE CONTROL SERVICES (FCS)

RSX-11 File Control Services enable you to perform record-oriented and block-oriented I/O operations, and to perform additional functions required for file control, such as open, close, wait, and delete operations. To invoke FCS functions, the user issues macro calls to specify desired file control operations. The FCS macros are then called at assembly time to generate code for specified functions and operations. Figure 16-1 illustrates the file access operation.

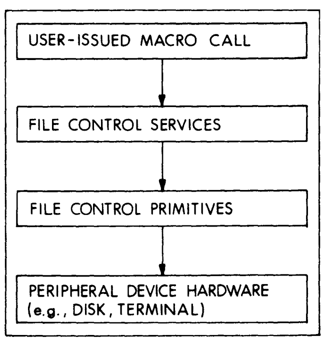


Figure 16-1 File Access Operation

FCS is a set of routines linked with the user program at taskbuild time from a resident system library or a system object module library. These routines, consisting of pure, position-independent code, provide a user interface to the file system, enabling the user to read and write files on file-structured devices and to process files in terms of logical records.

FCS allows you to write a collection of data (consisting of distinct logical records) to a file in a way that enables you to retrieve the data at will. Data can be gotten from the file without having to know the exact form in which it was written to the file. FCS thus provides a sense of transparency to the user so that records can be read or written in logical units that are consistent with an applications requirement.

File Access Method
Under FCS, RSX-11 supports both sequential and direct access to files. The sequential access method is device-independent, that is, it can be used for both record-oriented and file-structured devices (for example, card reader and disk, respectively). The direct access method can be used only for file-structured devices.

Data Formats for File-Structured Devices
Data are transferred between peripheral devices and memory in blocks. A data file consists of virtual blocks, each of which may contain one or more logical records. Records in a virtual block can be either fixed or variable in length.

Virtual blocks and logical records within a file are numbered sequentially, starting with one. A virtual block number is a file-relative value, while a physical block number is a volume-relative value. For example, the first virtual block in a file is always virtual block number 1, but at the same time it could also be physical block number 156.

Block I/O Operations
The READ and WRITE macro calls allow the user to read and write virtual blocks of data from and to a file without regard to logical records in a file. Block I/O operations provide a very efficient means of processing file data, since such operations do not involve the blocking and deblocking of records within the file. Also, in block I/O operations, the user can read or write files in an asynchronous manner; control can be returned to the user program before the request I/O operation is completed.

When block I/O is used, the number of the virtual block to be processed is specified as a parameter in the appropriate READ and WRITE macro call. The virtual block so specified is processed directly in a buffer reserved by the program in its own memory space.

As implied above, the user is responsible for synchronizing all block I/O operations. Such asynchronous operations can be coordinated through an event flag specified in the READ and WRITE call. The event flag is used by the system to signal the completion of the I/O transfer, enabling the user to coordinate those block I/O operations which depend on each other.

Record I/O Operations
The GET and PUT macro calls are provided for processing record-oriented files. GET and PUT operations perform the necessary blocking and deblocking of the records within the virtual blocks of the file, allowing the user to read or write individual records.

In preparing for record I/O operations, the user program must specify the format of the records. For example, it must specify whether the records are fixed or variable in length, or whether records that are to be output to a carriage-control device are to contain carriage-control information, which can be either at the beginning of the record or embedded within the records.

For sequential access files, I/O operations can be performed for both fixed and variable length records. For direct access files, I/O operations can be performed only for fixed length records.

In contrast to block I/O operations, all record I/O operations are synchronous; control is returned to the user program only after the requested I/O operation is performed.

Because GET and PUT operations process logical records within a virtual block, only a limited number of GET or PUT operations result in an actual I/O transfer, that is, when the end of a data block is encountered. Therefore, all GET and PUT I/O requests will not necessarily involve a physical transfer of data.

The File Storage Region

The file storage region (FSR) is an area allocated in the user program as the working storage area for record I/O operations. The FSR consists of two program sections which are always contiguous to each other. The first program section of the FSR contains the block buffers and the block buffer headers for record I/O processing. The user determines the size of the area at assembly time. The number of block buffers and associated headers is based on the number of files that the user intends to open simultaneously for record I/O operations.

The second program section of the FSR contains input data that are used and maintained by FCS in performing record I/O operations. Portions of this area are initialized at task-build time, and other portions are maintained by FCS. This program section is intentionally isolated from the user to preserve its integrity.

Blocking and deblocking of records during input is accomplished in the FSR block buffer during output. Note also that FCS serves as the user interface to the FSR block buffer pool. All record I/O operations initiated through GET and PUT calls are totally synchronized by FCS.

Data Transfer Modes

When record I/O is used, a program can gain access to a record in either of two ways after the virtual block has been transferred into the FSR from a file:

MOVE MODE Individual records are moved from the FSR

	buffer. Move mode simulates the reading of a record directly into a user record buffer, thereby making the blocking and deblocking of records transparent to the user.
LOCATE MODE	The user program accesses records directly in the FSR block buffer. Program overhead is reduced in locate mode, since records can be processed directly within the FSR block buffer.

Shared Access to Files

FCS permits shared access to files according to established conventions. Two macro calls, among several available in FCS for opening files, can be issued to invoke these functions. The OPNS macro call is used specifically to open a file for shared access. The OPEN call, on the other hand, invokes generalized open functions which have shared access implications only in relation to other I/O requests then issued.

OPNS allows several active read-access requests and one write-access request for the same file. OPEN allows multiple read-access requests for the same file, but does not permit concurrent write access. Note that shared access during reading does not necessarily imply the presence of read requests from several separate tasks. The same task can open the same file using different logical unit numbers.

Spooling Operations

FCS provides facilities at both the macro and subroutine level to queue files for subsequent printing. A task issues the PRINT macro call to queue a file for printing on the system lineprinter.

FCS Macros and Macro Use

FCS includes four basic kinds of macro that simplify the user's interface to the system's file control primitives. The four kinds are:

- Initialization macros
- File-process macros
- Command line processing macros
- The CALL macro

The initialization and file-processing macros are used to establish the database description and the necessary temporary storage areas needed to perform I/O operations. The command line processing macros are used to dynamically process I/O commands entered from a terminal. The CALL macro is used to invoke file control routines.

The initialization and file-processing macros set up the following structures to define the database:

- A file data block (FDB) that contains execution-time information necessary for file processing. It defines the basic characteristics of a file, i.e., record type, record size, access privileges, etc.
- A data set descriptor that is accessed by FCS to obtain the file name, type, version number, and location necessary to open a specified file. The data set descriptor is used when a program accesses a given set of known or predefined files.
- A default file name block that is accessed by FCS to obtain default file information required to open a file. This is accessed when complete file information is not specified in the data set descriptor. It is used by programs written to access a general set of files.

There are two types of initialization macros: assembly time macros and runtime macros. Data supplied during assembly of the source program establish the initial values in the FDB. Data supplied at run time can either initialize additional portions of the FDB or change values established at assembly time. Furthermore, the data supplied through the file-processing macros can either initialize portions of the FDB or change previously initialized values. The user not only has a broad range of control over defining the data base characteristics, but also has control over when the definitions are made.

File processing macros also determine the way in which files are processed. These macro calls are invoked and expanded at assembly time. The resulting code is then executed at runtime to perform the following operations:

OPEN	Opens and prepares a file for processing
OPNS	Opens and prepares a file for processing; allows shared access to the file (depending on the mode of access)
OPNT	Creates and opens a temporary file for processing
OFID	Opens an existing file using the file identification provided in the filename block
GET	Reads logical records from a file
GETR	Reads fixed-length records from a file in random access mode
GETS	Reads records from a file in sequential access mode
PUT	Writes logical records to a file

PUTR	Writes fixed-length records to a file in random mode
PUTS	Writes records to a file in sequential mode
READ	Reads virtual blocks from a file
WRITE	Writes virtual blocks to a file
DELETE	Removes a named file from the associated volume directory and deallocates the space occupied by the file
WAIT	Suspends program execution until a requested block I/O is performed
PRINT	Queues a file for printing on a special terminal or lineprinter

In summary, the file-processing macros allow the user to specify random access or sequential access to files, and perform block oriented or record oriented file processing. In addition, the PRINT macro allows the user to spool files to a lineprinter or terminal device.

The command line processing macros allow the user to access special routines available in the system object library. The Get Command Line (GCML) routine accomplishes all the logical functions associated with the entry of a command line from a terminal, an indirect command file, or an on-line storage medium. The Command String Interpreter (CSI) routine takes command lines from the GCML input buffer and parses them into appropriate data set descriptors required by FCS for opening files.

The CALL macro allows the user to access a special set of file control routines. These routines allow a MACRO program to perform the following operations: find, insert, or delete a directory entry, rename a file, extend a file, mark a temporary file for deletion, and delete a file, among other operations.

SORT

The SORT utility program allows you to reorder data from any input file into a new file in either ascending or descending sequence based upon control or key fields within the input data records themselves. SORT runs under any operating system that includes RMS (Record Management Services).

If you do not wish to sort the actual data, SORT can still be used to extract key information, sort that information, and store the sorted information on a permanent file. Later that file can be used to access the data in the order of the key information on the sorted file. The contents of the sorted file may be entire records, key fields, or record indexes relative to the position of each record within the file (the first record on the data base is record 1, the second, 2, etc.). SORT provides four sorting techniques which are outlined later in this chapter.

The SORT utility program may be controlled by a command string and an optional specification file. There is a simple format for each. If your SORT application does not require that records be restructured or that only a subset of the input file be sorted, then only a command string is needed to control SORT.

DATA FILES

SORT may accept a file from any one of the peripheral devices available in the system configuration: disk units, magtape units, or terminals.

A record is usually divided into several logical areas called data fields. The data in each field may or may not be relevant to SORT. SORT uses record identifiers to distinguish the various types of records in a file, while it uses the key fields in each record to reorder an input file. The key fields may be any one of a number of different data types including character, zoned decimal, two's-complement binary, and 2- or 4-word floating point. Any other data field in a record may be retained in the output file or ignored.

Table 16-1 Selecting the Sorting Process and Devices That Best Suit the Processing Environment

Sorting Technique	Input File	Output File	Work File
SORTR (Record Sort)	Disk Magtape* Paper Tape Cards Console	Disk Magtape* Paper Tape Printer Console	Disk (3-8 files)
SORTT (Tag Sort)	Disk	Disk Magtape* Printer Console Paper Tape	Disk (3-8 files)
SORTA (Address routing Sort)	Disk	Disk	Disk (3-8 files)

Sorting Technique	Input File	Output File	Work File
SORTI (Index Sort)	Disk	Disk	Disk (3-8 files)

* Provided records are at least 18 bytes long. Magtape must be in ANSI format.

COMMAND STRING AND SPECIFICATION FILE

The user can direct the SORT program by entering a command string, which serves three functions:

1. References devices in the system for each file in the current sort.
2. Specifies switches that define file parameters used in the sorting process.
3. References a specification file or specifies other switches to control the sort.

Several command string switches define the sorting process parameters. One switch describes record formats and the maximum record size. Another delimits the internal work files. Others provide detailed file information to RMS.

Normally, the sort must be directed with a specification file, but two additional switches may be used instead of a specification file. The first specifies the sorting process option; the second identifies the key fields. The use of these switches is limited to sorting an input file of uniform format:

1. The key fields must reside in the same location in every record of the input file.
2. The file must contain only the records to be included in the sort. Figure 16-2 illustrates a general sort that would require only a command string and switches.

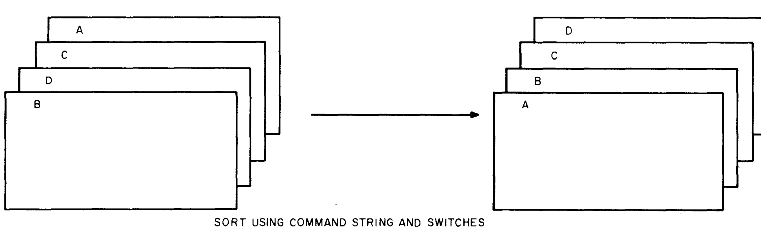


Figure 16-2 Sort Using Command String and Switches

The specification file is the supplement to the command string, which provides the basis for controlling and directing the sorting process.

The specification file provides a variety of controlling features. They are listed below:

1. Record Selection

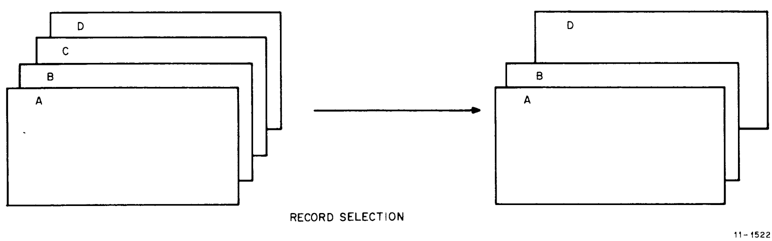


Figure 16-3 Record Selection

You can include or omit any records from the sorting process. The output file will contain only the specified records.

2. Alternate Collating Sequence

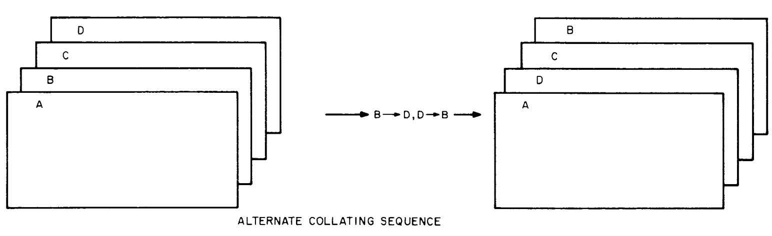


Figure 16-4 Alternate Collating Sequence

If necessary, you can specify an alternate collating sequence. The normal sequence is that implied in ASCII code. One alternate chòice is EBCDIC values. The other is an individual alternate collating sequence (ALTSEQ). An ALTSEQ can be used to change the ASCII values of the normal sequence. It applies to all the alphanumeric key data in the records, but only during the actual sorting process. The output record remains unchanged.

3. Forced Keys

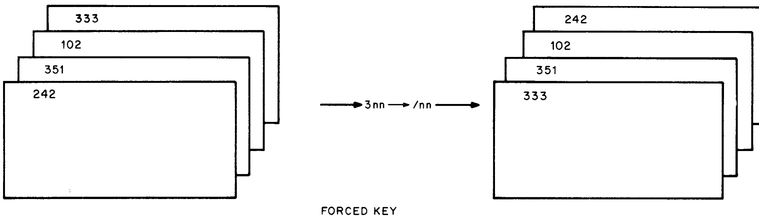


Figure 16-5 Forced Key

An ALTSEQ applies to all positions of the key. Forced keys allow the user to specify an alternate sequence for particular positions within the key. An alternate can be specified by substituting a lower-valued character, such as the slash (/) in the example above. Since the slash comes before 0, the 300-series records in the example are brought to the front of the file. Notice that the records so treated are in sequence and in front of the rest of the sorted file. The net effect is that of two sorted files, one behind the other.

4. Input Format Variation

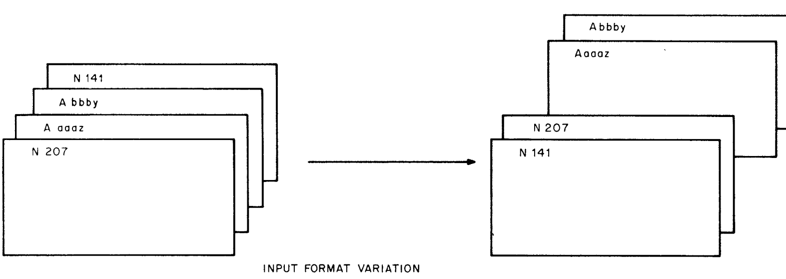


Figure 16-6 Input Format Variation

If the input file contains records with several different formats, the user can identify those records by type so that they may be properly handled. Note that only one type may be selected and sorted per run.

In the example above, A and N are record identifiers.

5. Output Format Variation

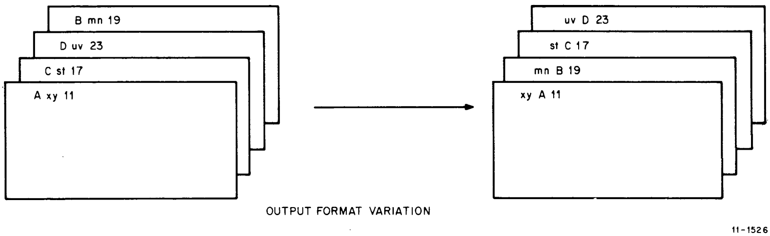


Figure 16-7 Output Format Variation

You can change the format of the data file during the sort, but you cannot change the contents of any given data item.

SORT OPERATION

The SORT program consists of two basic parts: a control program and a subroutine package called SORTS. The control program directs the overall processing, while SORTS serves as a collection of subroutines available to the control program during its processing. The subroutine package can be invoked from a user-written program. This is supported in most PDP-11 programming languages.

There are three phases of operation in the SORT control program. In the first phase, SORT reads the command string, decodes it, and stores the switch values and the specification file, if present. Any errors in the command string or specification file are reported at this point.

Phase two begins the presort operation. The control program is called to open and read the input file and establish the keys. The SORTS subroutine begins the initial sorting process. At this point, the amount of available internal storage space becomes important to the efficiency of the sort. If that space is not sufficient to hold all the records, SORT builds strings of sorted records and transfers them to scratch files on bulk storage devices. In order to merge these files and complete the sort, space for at least three scratch files must be available. The SORT program normally provides for a maximum of eight scratch files. Either a switch in the command string or the amount of available internal work space can reduce the number of scratch files used.

The final merge phase rebuilds the intermediate scratch files into a merged file. Another subroutine reads the records in the proper sequence. The records are then written into the output file. If there are no scratch files to merge because main memory was sufficient to hold all the records, the sorted records are written directly into the output file. After the last record is written, the control program cleans up the scratch files and returns to the first phase; SORT is then ready to accept another job.

SORT PROCESSING OPTIONS

Table 16-2 Sorting Process Options

Type of SORT	Type of File	Record Size and Format	Speed	Device
SORTR (Record Sort)	Input and Output	Any	Slowest	Any
SORTT (Tag Sort)	Input	Any	Slow for large file	Disk
	Output	Any		Any
SORTA (Address routing Sort)	Input	Any	Fastest	Disk
	Output	Fixed, six bytes		Any
SORTI (Index Sort)	Input	Any	Fast	Disk
	Output	Fixed, 6-byte pointer + original key		Any

Record Sort (SORTR)

The Record Sort (SORTR) outputs all specified record data in a sorted sequence. Each record is kept intact throughout the entire sorting process. Since it moves the whole record, SORTR is relatively slow and may require considerable main memory or external storage work space for large files.

Tag Sort (SORTT)

The Tag Sort (SORTT) produces the same kind of output file as SORTR, but it handles only record pointers and key fields. Since SORTT moves a smaller amount of data than SORTR, SORTT usually performs a faster sort than SORTR. The input file must be randomly reaccessed to create the entire output file, which may be lengthy process for large files.

Address Routing Sort (SORTA)
SORTA produces address routing files, which consist of relative record pointers, beginning at 1, in binary words. These files can be used as a special index file to access randomly the data in the original file. It is possible to maintain only one data file, but several different index files as needed. Like SORTT, SORTA uses the minimum amount of data necessary in the sorting process. Once the input phase is completed, the input file is not read again. The output data are in a restricted mode. This means that SORTA is the fastest sorting method in the sort package.

Index Sort (SORTI)
SORTI produces an index file consisting of relative record pointers, as in SORTA, and index keys. This makes it slightly slower than SORTA. During processing, SORTI handles only the relative record pointers and two forms of the key fields. One form is used for sorting and the other is left as it was in the original data.

OTHER UTILITIES

Running across most systems is a group of file management utilities that help make the various operations you need easier and quicker. The major features of these utilities are listed below.

PIP	The Peripheral Interchange Program (PIP) is a general-purpose file utility package for both the general user and programmer and the system manager. PIP normally handles all files with the operating systems standard data formats. In general, the program transfers data files from any device in the system to any other device in the system. PIP can also delete or rename any existing file. Some operating systems include special file management operations in the PIP utility, such as directory listings, device initialization and formatting, and account creation.
FILEX	A File Exchange program, this is a special-purpose file transfer utility similar in operation to PIP. It provides the ability to copy files stored in one kind of format to another format. This enables a user to create data on one system in a special format and then transfer the data to a device in a

format that another system can read. (FILEX is called FLX on RSX-11 systems.)

DUMP — DUMP displays all or selected portions of a file on a terminal or lineprinter. In general, DUMP enables the user to inspect the file in any of three modes: ASCII, byte, and octal. In ASCII mode, the content of each byte is printed as an ASCII character. In byte mode, the content of each byte is printed as an octal value. In octal mode, the content of each word is printed as an octal value. (DUMP is DMP for RSX-11 systems.)

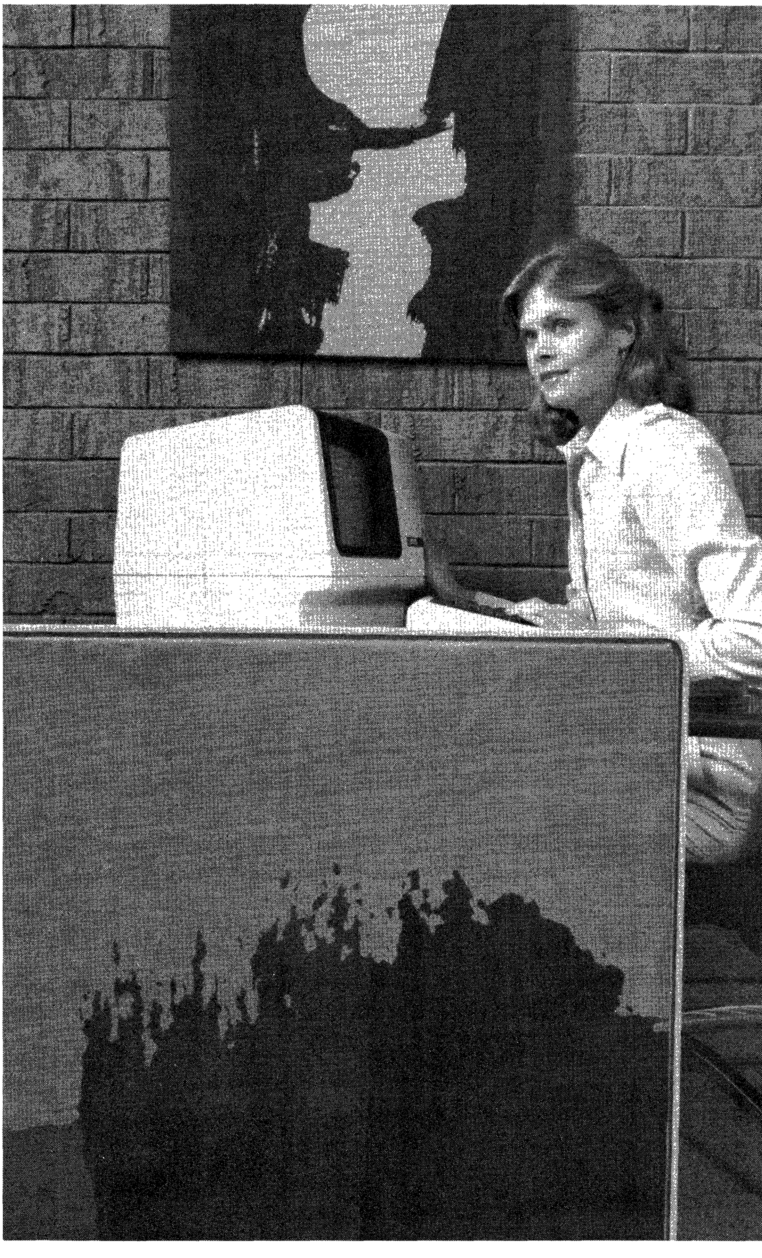
VERIFY — In general, a VERIFY program checks the readability and validity of data on a file-structured device. (VERIFY is VFY for RSX-11 systems.)

DUP — The device utility program (DUP) is a Device Maintenance Utility Program. DUP creates files on file-structured RT-11 devices. It can also extend files on certain file-structured devices such as disks, and it can compress, image copy, initialize, or boot RT-11 file structured devices. DUP does not operate on non-file-structured devices such as lineprinters or terminals.

DSC — DSC enables the user to backup/restore disk volumes to magnetic tape or other disks and to combine unused blocks on disks to create contiguous blocks. DSC comes both as a stand-alone and an online program.

CMP — CMP is a utility that will compare, line by line, two ASCII files. Its output can be either a new file with all the differences encountered, a listing of one with change bars marking the differences, or an output suitable for input to the SLP utility.

BRU — BRU backs up an RP06 disk to TU45 tape in less than an hour, which is approximately a 4-to-1 improvement over the current DSC program. BRU also supports incremental backups (such as backing up only the files that have been modified since the previous backup), greatly reducing the amount of time required for proper disk backup.



CHAPTER 17
RECORD MANAGEMENT SERVICES (RMS)

RMS OVERVIEW

Record Management Services, a set of general-purpose file-handling capabilities, combines with a host operating system to provide efficient and flexible data storage, retrieval, and modification. When writing programs, you can select processing methods suitable to your application from among several RMS file structuring and accessing techniques.

Not only does RMS handle such functions as file organization and access methods, but it also manages the other file attributes (e.g., storage medium and record format) and the runtime environment. By accomplishing most of its work transparently, RMS relieves programmers of many of the complexities associated with file and record manipulation.

The pages that follow describe in some detail the Record Management Services available on PDP-11 computers. All operating systems available from DIGITAL for the PDP-11 family have RMS bundled, that is, included as part of the operating system.

FILE ORGANIZATION

A **file** is a collection of related information whose requirements are established by the nature of application programs needing the information. For example, a company might maintain personnel information (employee names, addresses, job titles) in one file and product information (part numbers, prices, specifications) in a second, separate, file. Within each of these files, the information is divided into **records**. In the personnel file, it would be logical for all the information on a single employee to constitute a single record and for the number of records in the file to equal the number of employees. Similarly, each record in the product information file would represent a description of a single product. The number of records in the file reflects the requirements of a particular application, in this case, a central registry of products sold by a company.

Each record in the personnel and product files would be subdivided into discrete pieces of information known as **data fields** whose number, location within the record, and logical interpretation are defined by the programmer. Program applications then interpret a particular data field in records of the personnel file as the name of an employee. They would interpret another data field in records of the product file as a part number. Figure 17-1 illustrates records that might occur in a personnel file and in a product file.

DATA FIELDS:	NAME	ADDRESS	BADGE NO.	DEPARTMENT	TITLE
	JONES	MAIN ST, USA	1452	PAYROLL	CLERK

PERSONNEL RECORD

DATA FIELDS:	PART NO.	DESCRIPTION	PRICE	IN STOCK	SPECIFICATION
	219	WIDGET	$1.86	1430	3"×2"×1"

PRODUCT RECORD

Figure 17-1 Personnel and Product Records

Thus, the relationships among data fields and records are known and are embedded in the logic of the programs. RMS does not require an awareness of such logical relationships; rather, RMS processes records as single units of data. *Programs either build records and pass them to RMS for storage in a file or issue requests for records while RMS performs the necessary operations to retrieve the records from a file.*

The purpose of RMS, then, is to ensure that every record written into a file can subsequently be retrieved and passed to a requesting program as a single logical unit of data. The structure, or **organization**, of a file establishes the manner in which RMS stores and retrieves records. The way a program requests the storage or retrieval of records is known as the **access mode**. Legal access modes depend on the organization of a file.

RMS FILE ORGANIZATIONS

When creating a file, you have a choice of three file organizations:

- Sequential
- Relative
- Indexed

Sequential File Organization

In sequential file organization (see Figure 17-2), records appear in a physical sequence that is always identical to the order in which the records were originally written to the file by an application program.

Relative File Organization

When relative organization is selected, RMS structures a file as a

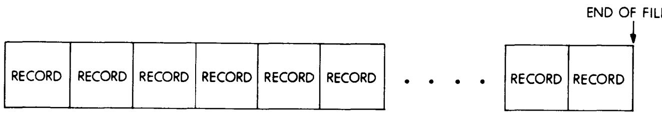


Figure 17-2 Sequential File Organization

series of fixed-size record cells. Cell size is based on the size specified as the maximum permitted length for a record in the file. RMS considers these cells as successively numbered from 1 (the first) to n (the last), and the cell's number represents its location **relative** to the beginning of the file.

Each cell in a relative file can contain a single record. There is no requirement, however, that every cell contain a record. Empty cells can be interspersed among cells containing records.

Since cell numbers in a relative file are unique, they can be used to identify both a cell and the record (if any) occupying that cell. Thus, record number 1 occupies the first cell in the file, record number 17 occupies the seventeenth cell, and so forth. When a cell number is used to identify a record, it is also known as a **relative record number**. Figure 17-3 depicts the structure of a relatively organized file.

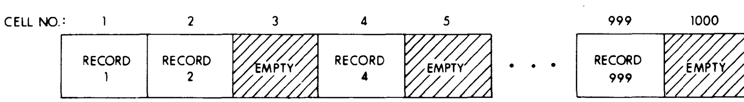


Figure 17-3 Relative File Organization

Indexed File Organization

Unlike the physical ordering of records in a sequential file or the relative positioning of records in a relative file, the location of records in indexed file organization is transparent to the program. RMS completely controls the placement of records in an indexed file. The presence of **keys** in the records of the file governs this placement.

The key, chosen by the programmer, is a data type present in every record of a particular indexed file. The location and length of this data type are attributes of the file, and therefore are identical for all records in the given file. Legal key data types are: string (1-255 bytes), integer (2 and 4 bytes), unsigned binary (2 and 4 bytes), and packed decimal (1-16 bytes). Selecting a data type indicates to RMS that the content (i.e., key value) of that key in any particular record written to the file can be used by a program to identify that record for subsequent retrieval. Since the key is the arbitrary choice of the programmer, it can, of course, be equal to a field. Therefore, in the inventory file, the part number field could be a key; in the personnel file, the last name field could be a key.

At least one key, the **primary key**, must be defined for every indexed file. Optionally, additional **alternate keys** can be defined. Each alternate key represents an additional character string in records of the file. The key value in any one of these additional strings can also be used as a means of identifying the record for retrieval.

As programs write records into an indexed file, RMS locates the values contained in the primary and alternate keys. From the values in keys within records, RMS builds a tree-structured table known as an index, consisting of a series of entries, each of which contains a key value copied from a record that a program wrote into the file. With each key value is a pointer to the location in the file of the record from which the value was copied. RMS builds and maintains separate indexes for the primary and alternate keys defined for the file. Each index is stored in the file. Figure 17-4 shows the general structure of an indexed file that has been defined with only a single key. Figure 17-5 depicts an indexed file defined with two keys: a primary key and one alternate key.

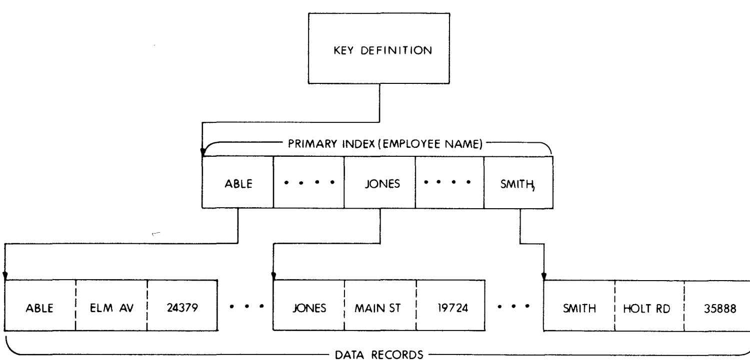


Figure 17-4 Single Key Indexed File Organization

RMS ACCESS MODES

The various methods of retrieving and storing records in a file are called access modes. A different access mode can be used to process records within the file each time it is opened. Additionally, a program

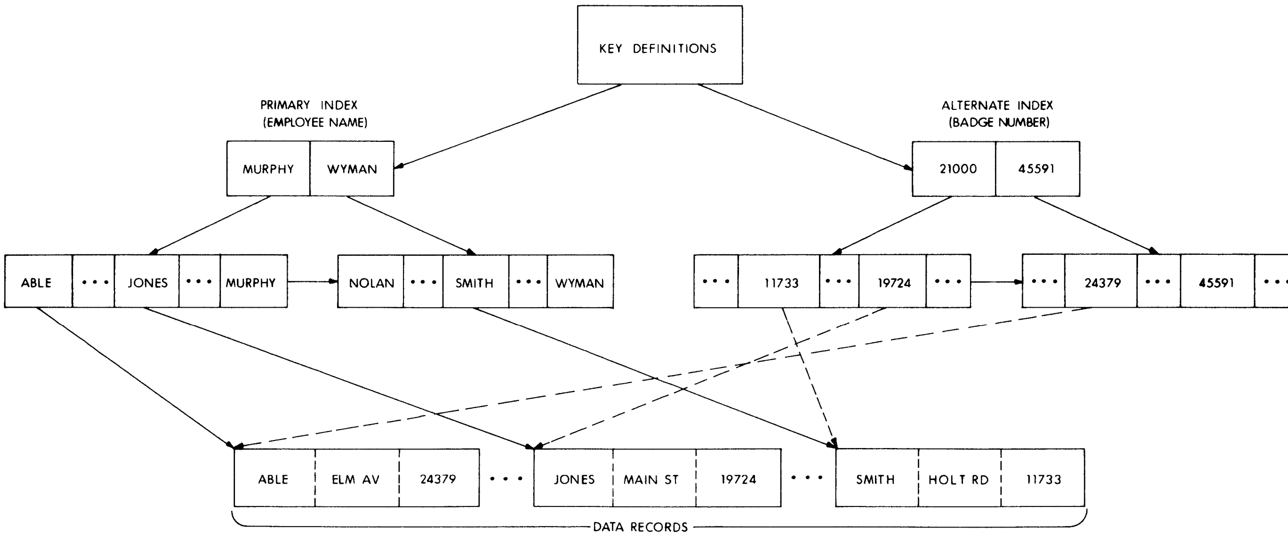


Figure 17-5 Multikey Indexed File Organization

can change access mode during the processing of a file, by a procedure known as dynamic access.

RMS provides three record access modes:

- Sequential
- Random
- Record's file address (RFA)

For logical reasons, RMS permits only certain combinations of file organization and access mode. Table 17-1 lists these combinations.

Table 17-1 Permissable Combinations of Access Modes and File Organizations

File Organization	Access Mode			
	Sequential	Random		RFA
		Record #	Key Value	
Sequential	Yes	No	No	Yes*
Relative	Yes	Yes	No	Yes
Indexed	Yes	No	Yes	Yes

*Disk files only.

The following subsections describe RMS access modes and the capability of changing access mode during program execution.

Sequential Access Mode

Sequential access mode can be used with any RMS file. Sequential access means that records are retrieved or written in a particular sequence. The organization of the file establishes this sequence.

Sequential Access to Sequential Files In a sequentially organized file, physical arrangement establishes the order in which records are retrieved when using sequential access mode. To read a particular record in a file—say one is the fifteenth record—a program must open the file and access the first fourteen records before accessing the desired record. Thus each record in a sequential file can be retrieved only by first accessing all records that physically precede it. Similarly, once a program has retrieved the fifteenth record, it can read all the remaining records (from the sixteenth on) in physical sequence. It cannot, however, read any preceding record without beginning again with the first record.

When writing new records to a sequential file in sequential access mode, a program must first request that RMS position the file immediately following the last record. Then each sequential write operation the program issues causes a record to be written following the previous record.

Sequential Access to Relative Files During the sequential access of records in the relative file organization, the contents of the record cells in the file establish the order in which a program processes records. RMS recognizes whether successively numbered record cells are empty or contain records.

When a program issues read requests in sequential access mode for a relative file, RMS ignores empty record cells and searches successive cells for the first one containing a record. If, for example, a relative file contains records only in cells 3, 13, and 47, successive sequential read requests cause RMS to return relative record number 3, then relative record number 13, and finally relative record number 47.

When a program adds new records in sequential access mode to a relative file, the order in which RMS writes the records depends on ascending relative cell numbers. Each write request causes RMS to place a record in the cell whose relative number is one higher than the relative number of the previous request, as long as that cell does not already contain a record. If the cell already contains a record, RMS rejects the write operation. Thus, RMS allows a program to write new records only into empty cells in the file.

Sequential Access to Indexed Files In an indexed file, the presence of one or more indexes permits RMS to determine the order in which to process records in sequential access mode. The entries in an index are arranged in ascending order by key values. Thus, an index represents a logical (rather than physical) ordering of the records in the file. If more than one key is defined for the file, each separate index associated with a key represents a different logical ordering of the records in the file. A program, then, can use the sequential access mode to retrieve records in the order represented by any index.

When reading records in sequential access mode from an indexed file, a program initially specifies a key (e.g., primary key, first alternate key, second alternate key, etc.) to RMS. Thereafter, RMS uses the index associated with that specified key to retrieve records in the sequence represented by the entries in the index. Each successive record RMS returns in response to a programmed read request contains a value in the specified key field that is equal to or greater than that of the previous record returned.

In contrast to a sequential read request, sequential write requests to an indexed file do not require the initial key specification. Rather, RMS uses the stored definition of the primary key field to locate the primary key value in each record to be written to the file. When a program issues a series of sequential write requests, RMS verifies that each successive record contains a key value in the primary key field that is equal to or greater than that of the preceding record.

Random Access Mode

In random access mode, the program, rather than the organization of the file, establishes the order in which records are processed. Each program request for access to a record operates independently of the previous record accessed. Associated with each request in random mode is an identification of the particular record of interest. Successive requests in random mode can identify and access records anywhere in the file.

Random access mode cannot be used with sequentially organized files. Both the relative and indexed file organizations, however, permit random access to records. The subsections that follow describe the use of random access with these organizations. Each organization provides a distinct way programs can identify records for access.

Random Access to Relative Files Programs can read or write records in a relative file by specifying relative record number. RMS interprets each number as the corresponding cell in the file. A program can read records at random by successively requesting, for example, record number 47, record number 11, record number 31, and so forth. If no record exists in a specified cell, RMS returns a nonexistence indicator to the requesting program. Similarly, a program can store records in a relative file by identifying the cell in the file that a record is to occupy. If a program attempts to write a new record in a cell already containing a record, RMS returns a record-already-exists indicator to the program.

Random Access to Indexed Files The indexed file organization also permits random access of records. However, for indexed files, a key value rather than a relative record number identifies the record.

Each program read request in random access mode specifies a key value and the index (e.g., primary index, first alternate index, second alternate index, etc.) that RMS must search. When RMS finds the key value in the specified index, it reads the record that the index entry points to and passes the record to the user program. Under random access the programmer could, for example, instruct RMS to return all records with SMITH in the key equal to last name field.

In contrast to read requests, which require a program-specified key value, program requests to write records randomly in an indexed file do not require the separate specification of a key value. All key values (primary and, if any, alternate key values) are in the record itself. When an indexed file is opened, RMS retrieves all definitions stored in the file. Thus, RMS knows the location and length of each key field in a record. Before writing a record into the file, RMS examines the values contained in the key fields and creates new entries in the indexes. In this way RMS ensures that the record can be retrieved by any of its key values. Thus, the process by which RMS adds new records to the file is precisely the process it uses to construct the original index or indexes.

Record's File Address (RFA) Access Mode

Record's file address (RFA) access mode can be used with any file organization as long as the file resides on a disk device. This access mode is further limited to retrieval operations only. Like random access mode, however, RFA access allows a specific record to be identified for retrieval.

As the name suggests, every record within a file has a unique address. The actual format of this address depends on the organization of the file. In all instances, however, only RMS can interpret this format.

The most important feature of RFA access is that the address (RFA) of any record remains constant while the record exists in the file. After every successful read or write operation, RMS returns the RFA of the subject record to the program. The program can then save this RFA to use again to retrieve the same record. It is not required that this RFA be used only during the current execution of the program. RFAs can be saved and used at any subsequent time.

Dynamic Access

Dynamic access is not strictly an access mode. Rather, it is the capability to switch from one access mode to another while processing a file. There is no limitation on the number of times such switching can occur. The only limitation is that the file organization (or, in the case of RFA access, the device containing the file) must support the access mode selected.

As an example, dynamic access can be used effectively immediately following a random or RFA access mode operation. When a program accesses a record in one of these modes, RMS establishes a new current position in the file. Programs can then switch to sequential access mode. By using the randomly accessed record (rather than the beginning of the file) as the starting point, programs can retrieve succeeding records in the sequence established by the file's organization.

FILE ATTRIBUTES

The logical and physical characteristics of a RMS file are known as its attributes. These characteristics are defined by the source language statements of an application program or by the RMS utility program DEFINE. RMS uses this information about the attributes to structure a file on the storage medium.

The most important attribute of any RMS file is its organization. A file for use in a particular application can be tailored by making the proper selection of this and other attributes. In addition to file organization, the user can choose from among the following attributes:

- Storage medium on which the file resides
- File and protection specification of the file
- Format and size of records
- Size of the file
- Size of a particular storage structure, known as the bucket, within relative and indexed files
- Definition of keys for indexed files

Storage Media

Selection of a storage medium on which RMS builds a file is related to the organization of the file. Permanent sequential files can be created on disk devices or ANSI magnetic tape volumes. Transient files can be written on devices such as lineprinters and terminals. Unlike sequential files, relative and indexed files can reside only on disk devices.

File Specifications

The name assigned to a new file enables RMS to find the file on the storage medium. RMS allows for the assignment of a protection specification to a file at the time it is created.

When a file is created, the user must provide the format and maximum size specifications for the records the file will contain. The specified format establishes how each record appears physically in the file on a storage medium. The size specification allows RMS to verify that records written into the file do not exceed the length specified when the file was created.

RMS Record Formats

- Fixed

- Variable
- Variable-with-fixed-control (VFC)
- Stream

Like the selection of a storage medium, the choice of a format for the records of a file depends on a file's organization. Table 17-1 shows the allowed combinations of record format and file organization.

Table 17-2 Record Formats and File Organizations

File Organization	Record Format			
	Fixed	Variable	VFC	Stream
Sequential	Yes	Yes	Yes	disk only
Relative	Yes	Yes	Yes	No
Indexed	Yes	Yes	No	No

Fixed Length Record Format The term fixed length record format refers to records of a file that must all be one specified size. Each record occupies an identical amount of space in the file.

Variable Length Record Format In variable length record format, records in a file can be either equal or unequal in length. To allow retrieval of variable length records from a file, RMS prefixes a count field to each record it writes. The count field describes the length (in bytes) of the record. RMS removes this count field before it passes a record to the program.

Variable-with-Fixed-Control Record Format Variable-with-fixed-control (VFC) records consist of two distinct parts: the fixed control area and the user data record. The size of the fixed control area is identical for all records of the file. The contents of each fixed control area are completely under the control of the program and can be used for any purpose. As an example, fixed control areas can be used to store the identifier (e.g., relative record number or RFA) of related records.

The second part of a VFC record is similar to a variable length record. It is a user data record, variable in length and composed of individual data fields.

Stream Format Records Records in stream format can vary in size. However, no count field precedes each record. Instead, RMS considers the entire file a stream of contiguous ASCII characters. Each record in the file is delimited by one of the following:

- Form feed (FF)
- Vertical tab (VT)
- Line feed (LF)
- Carriage return immediately followed by line feed (CR-LF)

Stream format records are supported for file interchange with non-RMS-application programs. Since this format is not very efficient, it should be used only when such interchange is a concern.

Size of Records

The programmer provides RMS with record size information along with the selected record format. RMS use of this information depends on the record format chosen.

When fixed format records are chosen, the actual size of each record in the file must be indicated. This size specification becomes part of the information stored and maintained by RMS for the file. Thereafter, if a program attempts to write a record whose length differs from this specified size, RMS will reject the operation.

When creating a file with variable length format records, you can specify a maximum record size greater than zero or, for sequential and indexed files, a maximum record size equal to zero. If the specified size is greater than zero, RMS interprets the value as the size of the largest record that can be written into the file.

VFC format records require two size specifications. The first size identifies the length of the fixed control area of all records in the file; the second size specification represents the maximum length of the data portion of the VFC records. RMS handles this second size specification in a manner similar to its handling of the size specification for variable format records.

For stream format records, RMS permits the user to specify the same record size information as for variable format records. That is, a non-zero value represents the maximum permitted size of any record written in the file while a zero value suppresses RMS size checking.

Size of RMS Files

The size of an RMS file is expressed as a number of **virtual blocks**. Virtual blocks are physical storage structures. That is, each virtual block in a file is a unit of data whose size depends on the physical medium on which the file resides. For example, the size of virtual blocks in files on disk devices is 512 bytes.

The operating system assigns ascending numbers to a file's virtual blocks. This numbering scheme allows a file to appear as a series of adjacent virtual blocks. In reality, though, the successive numbering of virtual blocks and the physical placement of these blocks on a storage medium need not correspond.

The virtual blocks of a file contain the records that programs write into the file. Depending on the size of records, a virtual block can contain one record, more than one record, or a portion of a record.

When creating an RMS file, you can specify an initial allocation size. If no file size information is given, RMS allocates the minimum amount of storage needed to contain the defined attributes of the file.

Buckets in Relative and Indexed Files

RMS uses a storage structure known as a **bucket** for building and maintaining relative and indexed files. Unlike a virtual block, a bucket can never contain a portion of a record. That is, RMS does not permit records to span bucket boundaries.

The size of buckets in a file is defined at the time the files are created. A large bucket size will serve to increase sequential mode processing speed of a file, since fewer actual I/O transfers are required to access records. Minimizing bucket size, on the other hand, means that less I/O buffer space is required to support file processing.

Key Definitions for Indexed Files

To define a key for an indexed file, the position and length of character data in the records of the file must be specified. At least one key, the primary key, must be defined for an indexed file. Additionally, up to 254 alternate keys can be defined. Each primary and alternate key represents from 1 to 255 characters in each record of the file.

When identifying the position and the length of keys to RMS, you can define either simple or segmented keys. A simple key is a single, contiguous string of characters in the record; in other words, a single data field. A segmented key, however, can consist of from two to eight data fields within records. These data fields need not be contiguous, and RMS treats the separate data fields (segments) as a logically contiguous character string.

At file creation time, two characteristics for each key can be specified:

- Duplicate key values are allowed
- Key value can change

If duplicate key values are allowed, the programmer indicates that more than one record in the file can have the same value in a given key.

The personnel file can serve as an example of the use of duplicate keys. At file creation time, the department name field could be defined as an alternate key. As programs wrote records into the file, the alternate index for the department name key field would contain multiple entries for each key value (e.g., PAYROLL, SALES, ADMINISTRATION) since departments are composed of more than one employee. When such duplication occurs, RMS stores the records so that they can be retrieved in first-in/first-out (FIFO) order.

An application could be written to list the names of employees in any particular department. A single execution of the application could list the names of all employees working, for example, in the department called SALES. By randomly accessing the file by alternate key and the key value SALES, the application would obtain the first record written into the file containing this value. Then, the application could switch to sequential access and successively obtain records with the same value, SALES, in the alternate key field. Part of the logic of the application would be to determine the point at which a sequentially accessed record no longer contained the value SALES in the alternate key field. The program could then switch back to random access mode and access the first record containing a different value (e.g., PAYROLL) in the department name key field.

The second key characteristic (key value can change) indicates that records can be read and then written back into the file with a modified value in the key. When such modification occurs, the appropriate index is automatically updated to reflect the new key value. This characteristic can be specified only for alternate keys. Further, when specifying this characteristic, the user must also specify that the duplicate key values are allowed.

If the sample personnel file were created with the department name field as an alternate key, the creator of the file would need to specify that key values can change. This allows a program to access a record in the file and change the contents of a department name data field to reflect the transfer of an employee from one department to another.

The user can also declare the converse of either of these two key characteristics. That is, the user can specify for a given key that duplicate key values are not allowed or that key values cannot change. When duplicate key values are not allowed, RMS rejects any program request to write a record containing a value in the key that is already present in another record. Similarly, when the key value cannot change, RMS does not allow a program to write a record back into the file with a modified value in the key.

PROGRAM OPERATIONS ON RMS FILES

After RMS has created a file according to the user's description of file characteristics, a program can access the file and store and retrieve data. The organization of the file determines the types of record operations permitted.

If the record accessing capabilities of RMS are not utilized, programs can access the file as a physical structure, in which case RMS considers the file simply as an array of virtual blocks. To process a file at the physical level, programs use a type of access known as **block I/O**.

Record Operations on RMS Files

The organization of a file, defined when the file is created, determines the types of operations that the program can perform on records. Depending on file organization, RMS permits a program to perform the following record operations:

- Read a record—RMS returns an existing record within the file to the program.
- Write a record—RMS adds a new record that the program constructs to the file. The new record cannot replace an already existing record.
- Find a record—RMS locates an existing record in the file. It does not return the record to the program, but establishes a new current position in the file.
- Update a record—The program modifies the contents of a record read from the file. RMS writes the modified record into the file, replacing the old record.

Sequential File Organization Record Operations

In sequential file organization, a program can read existing records from the file using sequential or RFA access modes. New records can be added only to the end of the file and only through the use of sequential access mode. The find operation is supported in both sequential and RFA access mode. In sequential access mode, the program can use a find operation to skip records. In RFA access mode, the program can use the find operation to establish a random starting point in the file for sequential read operations. The sequential file organization does not support the delete operation, since the structure of the file requires that records be adjacent in and across virtual blocks. A program can, however, update existing records in disk files as long as the modification of a record does not alter its size.

Relative File Organization Record Operations
Relative file organization permits programs greater flexibility in performing record operations than does sequential organization. A program can read existing records from the file using sequential, random, or RFA access mode. New records can be sequentially or randomly written as long as the intended record cell does not already contain a record. Similarly, any access mode can be used to perform a find operation. After a record has been found or read, RMS permits the delete operation. Once a record has been deleted, the record cell is available for a new record. A program can also update records in the file. If the format of the records is variable, update operations can modify record length up to the maximum size specified when the file was created.

Indexed File Organization Record Operations
Indexed file organization provides the greatest flexibility in performing record operations. A program can read existing records from the file in sequential, RFA, or random access mode. When reading records in random access mode, the program can choose one of four types of matches that RMS must perform using the program-provided key value. The four types of matches are:

- Exact key match
- Approximate key match
- Generic key match
- Approximate and generic key match

Exact key match requires that the contents of the key in the record retrieved precisely match the key value specified in the program read operation.

The approximate match facility allows the program to select either of the following relationships between the key of the record retrieved and the key value specified by the program:

- Equal to or greater than
- Greater than

The advantage of this kind of match is that if the requested key value does not exist in any record of the file, RMS returns the record that contains the next higher key value. This allows the program to retrieve records without knowing an exact key value.

Generic key match means that the program need specify only an initial portion of the key value, thereby forming a logical truncation upon the key. RMS returns to the program the first occurrence of a record whose key contains a value beginning with those characters. This capability is useful in applications where a series of records must be retrieved according to the contents of only a part of the key field. In an indexed inventory file, for example, a company might designate its part numbers in such a way that the first three digits represent the vendor from whom the part is purchased. In order to retrieve the record associated with a particular part, the program would normally supply the entire part number. Generic selection permits the retrieval of the first record representing parts purchased from a specific vendor.

The final type of key match combines both generic and approximate facilities. The program specifies only an initial portion of the key value, as with generic match. Additionally, a program specifies that the key data field of the record retrieved must be either:

- Equal to or greater than the program-supplied value
- Greater than the program-supplied value

In addition to versatile read operations, RMS allows any number of new records to be written into an indexed file. It rejects a write operation only if the value contained in a key of the record violated a user-defined key characteristic (e.g., duplicate key values not permitted).

The find operation, similar to the read operation, can be performed in sequential, RFA, or random access mode. When finding records in random access mode, the program can specify any one of the four types of key matches provided for read operations.

In addition to read, write, and find operations, the program can delete any record in an indexed file and update any record. The only restriction RMS applies during an update operation is that the contents of the modified record must not violate any user-defined key characteristic (e.g., key values cannot change and duplicate key values are not permitted).

Block I/O

Block I/O allows a program to bypass the record processing capabilities of RMS entirely. Rather than performing record operations through the use of supported access modes, a program can process a file as a physical structure consisting solely of virtual blocks.

Using block I/O, a program reads or writes multiple virtual blocks by identifying a starting virtual block number in the file. Regardless of the organization of the file, RMS accesses the identified block or blocks on behalf of the program.

Since RMS files, particularly relative and indexed files, contain internal information meaningful only to RMS itself, DIGITAL does not recommend that a file be modified by using block I/O. The presence of the block I/O facility, however, does permit user-created file structures. The resultant structures must be user-maintained using specialized programs. The structures cannot be accessed using RMS record access mode and record operations.

RMS RUN TIME ENVIRONMENT

The environment within which a program processes RMS files at run time consists of two levels, the file processing level and the record processing level.

At the file processing level, RMS and the host operating system provide an environment that permits concurrently executing programs to share access to the same file. RMS ascertains the amount of sharing permissible from information provided by the programs themselves. Additionally, at the file processing level, RMS provides facilities that allow programs to minimize buffer space requirements for file processing.

At the record processing level, RMS allows programs to access records in a file through one or more record access streams. Each record access stream represents an independent and simultaneously active series of record operations directed toward the file. Within each stream, programs can perform record operations synchronously or asynchronously on operating systems which support this facility. That is, RMS allows programs to choose between receiving control only after a record operation request has been satisfied (synchronous operation) or receiving control before the request has been satisfied (asynchronous operation).

For both synchronous and asynchronous record operations, RMS provides two record transfer modes: move mode and locate mode. Move mode causes RMS to copy a record from an I/O buffer into a program-provided location. Locate mode allows programs to address records directly in an I/O buffer.

FILE PROCESSING ENVIRONMENT

RMS provides two major facilities at the file processing level: file sharing and buffer handling.

File Sharing

Timely access to critical files requires that more than one concurrently executing program be allowed to process the same file at the same time. Therefore, RMS allows executing programs to share files rather than process files serially. The manner in which a file can be shared depends on the organization of the file. Program-provided information further establishes the degree of sharing of a particular file.

File Organization and Sharing With the exception of magnetic tape files, which cannot be shared, every RMS file can be shared by any number of programs that are reading, but not writing, the file. Sequential files on disk can be accessed by a single writer or shared by multiple readers. Relative and indexed files, however, can be shared by multiple readers and multiple writers.

Program Sharing A file's organization establishes whether it can be shared for reading with a single writer or for multiple readers and writers. A program specifies whether such sharing actually occurs at runtime. The user controls the sharing of a file through information the program provides RMS when it opens the file. First, a program must declare what operations it intends to perform on the file. Second, a program must specify whether other programs can read the file or both read and write the file concurrently with that program.

The combination of these two types of information allows RMS to determine if multiple user programs can access a file at the same time. Whenever a program's sharing information is compatible with the corresponding information another program provides, concurrent access is allowed.

Bucket Locking RMS uses a bucket locking facility to control operations to a relative or indexed file that is being accessed by one or more writers. The purpose of this facility is to ensure that a program can add, delete, or modify a record in a file without another program's simultaneously accessing the same record.

When a program opens an indexed or relative file with the declared intention of writing or updating records, RMS locks any bucket accessed by the program. This locking prevents another program from accessing any record in the bucket until the program releases it, and remains in effect until the program accesses another bucket. RMS then unlocks the first bucket and locks the second.

Buffer Handling

To a program, record processing under RMS appears as the movement of records directly between a file and the program itself. Transparently to the program, however, RMS reads or writes virtual blocks or buckets of a file into or from internal memory areas known as I/O buffers. Records within these buffers are then made available to the program.

In addition to buffers that contain virtual blocks or buckets, RMS requires a set of internal control structures to support file processing. The combination of these buffers and control structures is known as the space pool.

RECORD PROCESSING ENVIRONMENT

After opening a file, a program can access records in the file through the RMS record processing environment. This environment provides three facilities:

- Record access streams
- Synchronous or asynchronous record operations
- Record transfer modes

Record Access Streams In the record processing environment, a program accesses records in a file through a record access stream, a serial sequence of record operation requests. For example, a program can issue a read request for a particular record, receive the record from RMS, modify the contents of the record, and then issue an update request that causes RMS to write the record back into the file. The sequence of read and update record operation requests can then be performed for a different record, or other record operations can be performed, again in a serial fashion. Thus, within a record access stream, there is at most one record being processed at any time. However, for relative and indexed files, RMS permits a program to establish multiple record access streams for record operations to the same file. The presence of such multiple record access streams allows programs to process in parallel more than one record of a file. Each stream represents an independent and concurrently active sequence of record operations. Further, when such streams update records in the file, RMS employs the same bucket locking mechanism among streams that it uses to control the sharing of a file among separate programs.

Synchronous and Asynchronous Record Operations Within each record access stream, a program can perform any record operation either synchronously or asynchronously. (The RSTS/E operating system supports synchronous record operations only.) When a record operation is performed synchronously, RMS returns control to a program only after the record operation request has been satisfied (e.g., a record has been read and passed to one program). When a record operation is performed asynchronously, RMS can return control to one program before the record operation request has been satisfied. A program, then, can utilize the time required for the physical transfer between the file and memory of the block or bucket containing the record to perform other computations. However, a program cannot issue a second record operation through the same stream until the first record operation has completed. To ascertain when a record operation has actually been performed, a program can issue a wait request and regain control when the record operation is complete.

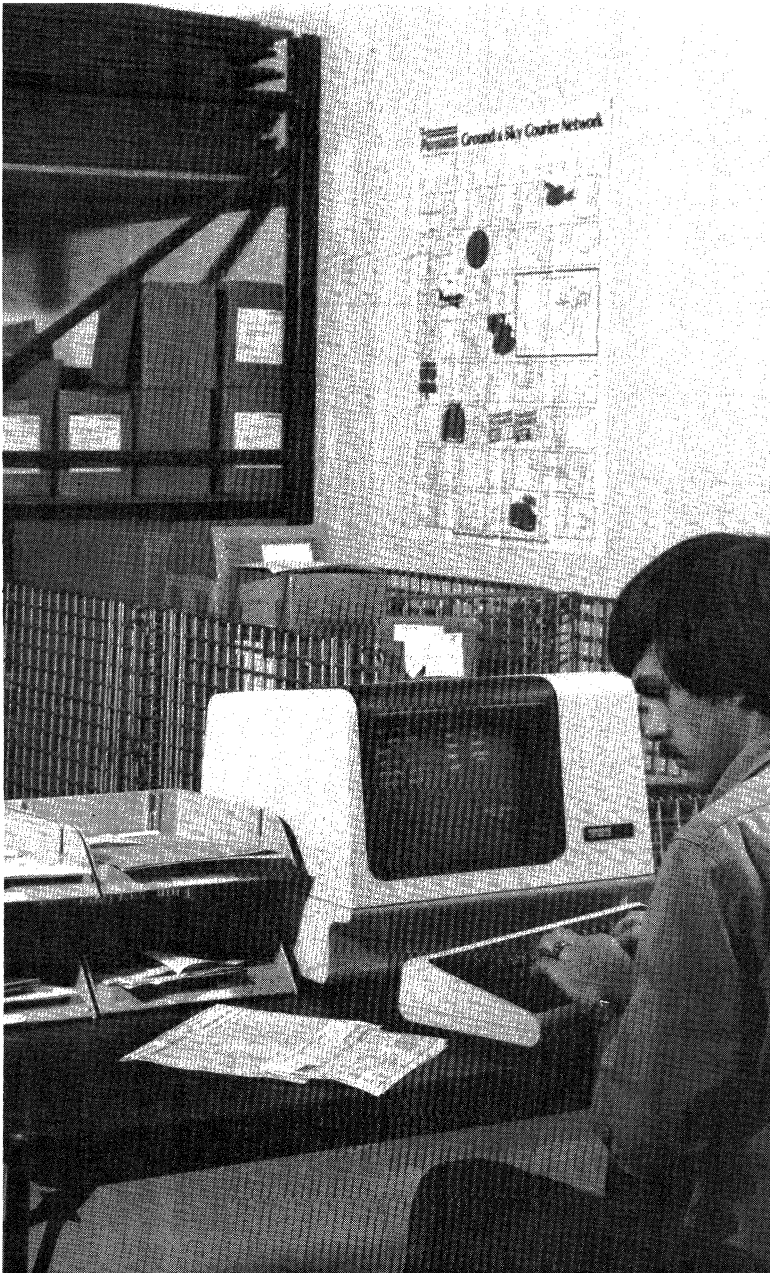
Record Transfer Modes In addition to specifying synchronous or asynchronous operations for each request in a record access stream, a program can utilize either of two record transfer modes to gain access to each record in memory:

- Move Mode Record Transfers—RMS permits move mode record operations for all file organizations and record operations. Move mode requires that an individual record be copied between the I/O buffer and a program. For read operations, RMS reads a block or bucket into an I/O buffer, finds the desired record within the buffer, and moves the record to a program-specified location.

  Before a write or update operation in move mode, the program builds or modifies a record in its own work space. Then the program issues a write or update record operation request, and RMS moves the record to an I/O buffer.

- Locate Mode Record Transfers—RMS supports locate mode record transfers for read operations to all file organizations. However, it permits locate mode on write operations for sequential files only.

  Locate mode reduces the amount of data movement, thereby saving processing time. This mode enables programs to access records directly in an I/O buffer. Therefore, there is normally no need for RMS to copy records from the I/O buffer to a program. To allow the program to access a record in the I/O buffer, RMS provides the program with the address and size of the record in the I/O buffer.


Ground & Sky Courier Network

CHAPTER 18

INTRODUCTION TO DATABASE MANAGEMENT

Computers have helped both to promote and to manage the data explosion of the last two decades. Whether to satisfy government requirements, to manage inventory more efficiently, to speed up order processing and billing, or to serve in one of thousands of other data operations, computer-produced information is now an integral part of organizational life. And increasingly, organizations must view the data that they generate or collect as a valuable resource. Such a resource is costly, both in its production and its maintenance: many operations would be hampered or halted if it were disrupted. Therefore, just as an organization's physical plant and personnel are resources that must be protected and managed effectively, so, too, must the data resource be protected and managed. Just as raw materials and equipment for manufacturing processes need to be maintained and kept up to date, information needs to be kept current.

It would probably be inefficient for a company to have three or four groups charged with the responsibility of purchasing and warehousing identical parts for a manufacturing operation. Wasted time and space, redundancy of labor allocation, and loss of useful space could all result.

What is really needed is a central acquisition and storage facility, with excellent distribution, to get parts quickly and efficiently to locations that require them.

Naturally enough, there may be parts specific to a location and necessary only to the local operation. These **should** be purchased and stored locally.

Similarly, a savings in time and cost, and an increase in accuracy can be obtained through the establishment of a central database to handle data common to several operations (application programs) within a company.

If people store the same information, then there is waste in the generation cost and in the storage overhead; if programmers must spend their time finding and reformatting information that others have created and stored, instead of writing application programs, then there is inefficiency and waste; if unauthorized people have access to data they don't need for their jobs, there is the chance of error or violation of confidentiality. Local data, of course, can still be created and stored as required by local programs.

Database management is a step toward reducing the problems that arise when management confronts the data explosion and the ever-increasing cost and complexity of the data it needs.

Once a consistent plan of database design is adopted, daily operations can call for some central data and some local data. Redundant data generation is reduced because everyone knows and can get at necessary data. Installation growth is simplified since alterations of the database need be done just once, instead of once for each form in which the information is stored.

Though database establishment is a centralizing act, it is not contrary to the philosophy of distributed processing. In fact, the centralized database actually can increase the efficiency of distributed processing by making information developed at one node available to users at all nodes who have a legitimate need for it. If, for example, inventory and accounting data are generated by half a dozen different departments and locations within the company, the central data base can act as a filter to let regional personnel learn quickly what is happening at other locations and to let management at the corporate level get uniformly formatted reports from everywhere.

How a Database Works

Consider a series of application programs, A_1, A_2, ..., A_n, and a series of files, F_1, F_2, ..., F_n as illustrated in Figure 18-1. As long as A_1 wishes to access and use data in F_1, the corresponding file, and as long as there is no need for programs to access other files, then there would be no need for a comprehensive database.

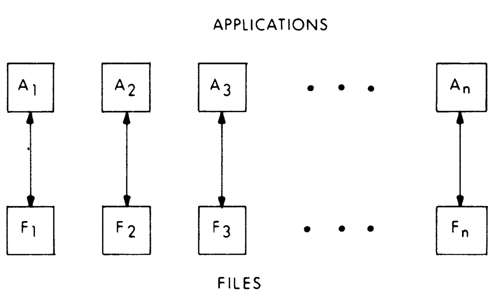


Figure 18-1 Pre-Database Configuration

But now consider the case of some of the applications wanting to access, use, or update information in a variety of files, sometimes several at a time, in order to accomplish their tasks. Naturally, each application could redevelop all the data it needs, but the cost would be high overhead and reduced programmer productivity. Or, as illustrated in Figure 18-2, the application programmer could try to get into each of the files built by other applications and to use their data.

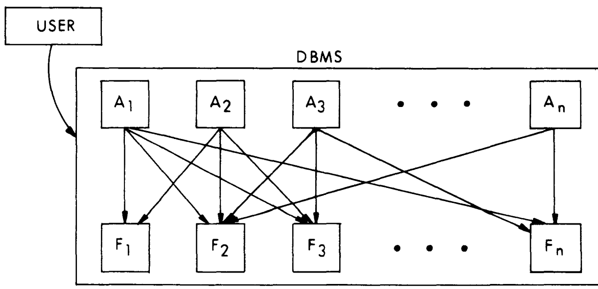


Figure 18-2 Complex File Sharing

Some of the problems that arise here are incompatibility of data formats and complexity of the interrelationships that the programmer has to manage. Data integrity is threatened because of access by numerous users with different interests and needs. Program maintenance becomes very complicated: if any one of the files is changed in format, all the programs that access it have to be changed, too. Data security is weakened when the data are available to a variety of users with several privilege options and degrees of skill. And finally, the end user finds himself confronting really difficult data management programming—the system becomes increasingly forbidding to nonspecialists who only want to get some information quickly in order to do their jobs, and who cannot write the sophisticated programs necessary to dig data out of entangled files.

As time goes on, the program-file problem grows more and more complex, unless a database properly structured and managed is introduced to solve some data processing difficulties. Temporarily we may think of a database as a pool of data. Through a structure of "schema" and "subschema," any program that needs it can access the database and, according to the job and privilege, read, write, and update the material in it, or use the information for computations. Thus, the database would now be both functionally simpler and operationally easier than the same amount of data without a database system. Figure 18-3 is a schematic of the database with its defining schema and subschema.

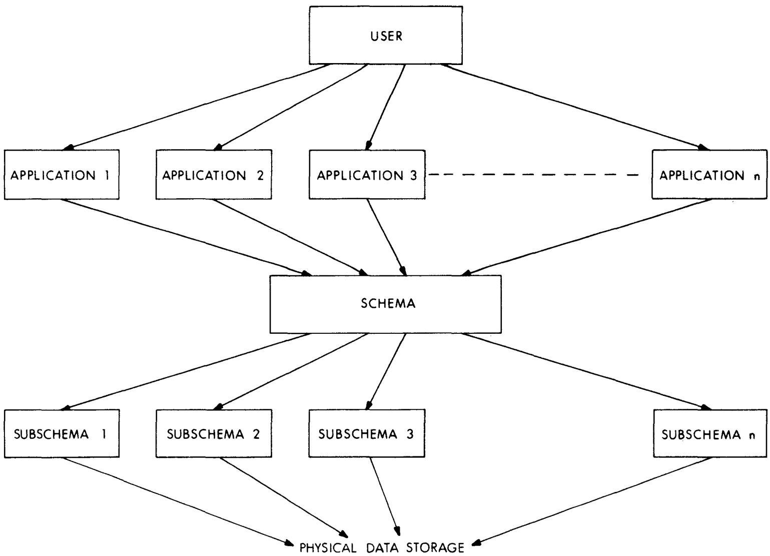


Figure 18-3 A Database System

Numerous benefits accrue to the organization that develops such a database. First, development resources are now used for development. That is, programmer time is spent in program development rather than in program maintenance—those activities required to update all programs when files change, and to make programs agree with the data formats developed prior to the program. It has been estimated that a maintenance-free database could save 50% on programmer costs.

Both data security and data integrity are better served. Fewer complex accesses to the data means less likelihood of erroneous updating or deletion; better organization means easier determination of who should and should not get to certain kinds of information. As a corollary, data redundancy is reduced because fewer persons have to have exclusive access to it, and also because everyone now knows what is available in the central database.

Finally, and most importantly, a level of data/program independence is achieved. The benefit is that it is no longer necessary to update programs each time the data files are changed, nor to alter the data formats each time a new program is written that wants to get at some information.

To gain the maximum benefit from a database management system, the company or organization must commit to a comprehensive database analysis. Through such an analysis the company determines the proper data relations and structures, and other details that must be considered before implementation.

Knowledgeable people are required to design and continually maintain the database. As a payoff, once the company has committed the necessary resources—a small group of people to organize and orchestrate database activities—then the majority of programmers can spend their time more productively than before, doing development rather than maintenance, helping users with queries, and so on.

Naturally, there is a genuine need to incorporate security measures into any database structure, just as they are built into less sophisticated file and record systems. The use of "subschemas" provides levels of security that give users only information that they require. With proper privilege and special kinds of prior recognition, users can access increasingly sensitive levels of data. Of course, the masking of data also provides for increased simplicity apart from the whole security side of the database. One receives only the information that is useful to a particular application, and no other.

The Conference on Data Systems Languages—CODASYL—produced the so-called CODASYL specifications, which define the standard database. DIGITAL's Database Management System (DBMS-11) described in Chapter 20 is a CODASYL-based product. Figure 18-4 illustrates schematically how an inquiry language such as DATATRIEVE, DBMS-11, and DIGITAL's Record Management Services (RMS), see Chapter 17, work to give users access to databases.

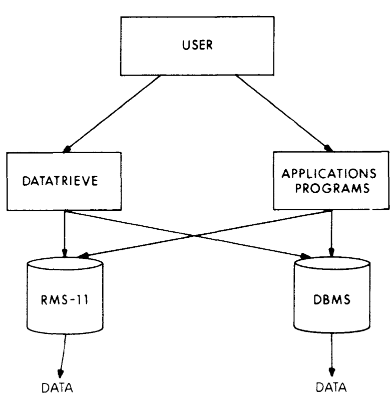


Figure 18-4 The End User in DBMS

Database design and implementation are complex operations that are usually accomplished incrementally in organizations, especially those that already have some database capacity, or have many subgroups generating and using data. The two chapters that follow explain some aspects of database design and implementation. (Chapter 19 describes DATATRIEVE, the inquiry, update and report generating language. Chapter 20 describes DIGITAL's Database Management System.) But in every case, you should consult your DIGITAL software specialist to get the most recent word both on feasibility for your application, and on the power of DIGITAL database software products.

CHAPTER 19
DATATRIEVE-11

INTRODUCTION

DATATRIEVE-11 is a data maintenance, inquiry and report writing system. It is available on IAS, RSTS/E, RSX-11M, and RSX-11M-PLUS operating systems for PDP-11 computers. It provides users with direct, fast, easy access to the data in sequential, indexed, and relative RMS-11 files. DATATRIEVE-11 accepts simple words and phrases to extract, modify, or update RMS-11 data. With fewer than ten commands, users can find, print, update, and sort records.

By eliminating the need for many specialized application programs and their time-consuming compilations, DATATRIEVE-11 helps to maximize programmer and system productivity. And because it is so easy to learn and simple to use, all users can access data without the services of a programmer. DATATRIEVE-11 can be learned quite easily, thanks to its familiar syntax. In addition, it immediately notifies you of any errors, so that you may correct them immediately. DATATRIEVE-11 makes file access simple, while maintaining the file security provided by the operating system.

Additional facilities are provided by the system for selective data retrieval, sorting, formatting, updating, and report generation.

DESCRIPTION

There are many advantages of using DATATRIEVE-11 over application programs to generate ad hoc queries and reports. The three major categories of DATATRIEVE-11 capabilities are:

- Data Access and Update Facilities
- Report Generation Facilities
- Data Dictionary Facility

Data Access and Update Facilities

The inquiry and update commands provided by DATATRIEVE-11 enable the user to perform record and file manipulation. DATATRIEVE-11 offers simple and advanced commands. Simple commands enable the novice to find, update, and sort records. Advanced commands can be used to perform more complex functions such as combining commands to form procedures.

DATATRIEVE-11 provides the first time user with flexible "value-based" data access/update capabilities that can eliminate the need for programming overhead in many situations. Information is returned to the user in the form of collections of records that can be manipulated and/or displayed on the terminal or printer using the DATATRIEVE-11 report writing facility. Several specific features bring this power to users.

- GUIDE MODE is a tutorial aid with automatic prompting. This feature permits the novice to retrieve and display data by stepping through a subset of commands.
- The documentation set for DATATRIEVE-11 includes a Primer designed to introduce the novice to the use of DATATRIEVE-11, and a User's Guide that uses examples to present the various DATATRIEVE-11 functions.
- The commands are simple words and phrases instead of confusing acronyms.
- DATATRIEVE-11 supports simple arrays.
- A data type is provided that recognizes data formats and facilities, entering and displaying dates in any one of several formats.
- DATATRIEVE-11 provides a full set of arithmetic operators (addition, subtraction, multiplication, division, and negation), statistical operators (total, average, maximum, minimum, and count), and conversion between data types used in DIGITAL's FORTRAN, COBOL, DIBOL, and BASIC-PLUS-2 languages.

Report Generation

In addition to its inquiry and update commands, DATATRIEVE-11 provides a report writing facility to generate reports from RMS-11 files and DBMS-11 databases. The data can come directly from the files or can be preselected and manipulated through a series of DATATRIEVE-11 commands. Users can specify such parameters as spacing, titles, headings, and totals on their reports. As in the inquiry and update facility, errors in commands are discovered immediately to avoid printing wrong or incomplete reports.

Data Dictionary Facility

The Data Dictionary maintains definitions of record structures and domain names. A record structure describes the format of the records in the file. A domain is a named group of data containing records of a single type. Record structures and domain names must be defined before DATATRIEVE-11 can be used to access data.

The definitions provide a substantial level of data and program independence because the definitions (or views) can cross file boundaries. Thus, by providing a single value-based DATATRIEVE-11 query, users can access information from multiple files and records. DATATRIEVE-11 also provides commands to list the contents of the Data

Dictionary, to delete entries, and to control access to individual entries.

DATATRIEVE-11 COMMANDS

DATATRIEVE-11 is a multifaceted data management facility that can store, update, and retrieve information and generate reports. The major commands include:

- HELP — which provides a summary of each DATATRIEVE-11 command
- READY — which identifies a domain for processing and controls the access mode to the appropriate file
- FIND — which establishes a collection (subset) of records contained in either a domain or a previously established collection based on a Boolean expression
- SORT — which reorders a collection of records in either the ascending or descending sequence of the contents of one or more fields in the records
- PRINT — which prints one or more fields of one or more records. Output can optionally be directed to a lineprinter or disk file. Format control can be specified. A column header is generated automatically
- SELECT — which identifies a single record in a collection for subsequent individual processing
- MODIFY — which alters the values of one or more fields for either the select record or all records in collection. Replacement values are prompted for by name
- STORE — which creates a new record. The value for each field contained in the record is prompted for by name, or indicated on a predefined form
- ERASE — which deletes one or more records from the RMS-11 file corresponding to the appropriate domain
- FOR — which executes a subsequent command once for each record in record collection, providing a simple looping facility
- DECLARE — which defines global and local variables to be used within a DATATRIEVE-11 query
- DEFINE — which provides a consistent mechanism for creating domain, record, table, procedure, and view definitions in the DATATRIEVE-11 Data Dictionary
- EDIT — which invokes an editor that inserts, modifies, or deletes text from the DATATRIEVE-11 Data Dictionary

In addition to the simple data manipulation commands, a number of more complex commands are available for the advanced user. These commands, such as REPEAT, BEGIN-END, and IF-THEN-ELSE, may be used to combine two or more DATATRIEVE-11 commands into a single compound command. These, in turn, may be stored in the Data Dictionary as procedures for invocation by less experienced users.

DATATRIEVE-11 can be used interactively from a terminal or in batch. Data can be accessed in RMS-11 files and DBMS-11 database structures.

Designed to be used by both novices and computer professionals, DATATRIEVE-11 operates effectively in commercial, technical, scientific, industrial, or educational environments. Typical applications range all the way from producing a complex report to answering a casual question. For example, using DATATRIEVE-11, a personnel file could be queried to determine how many employees held bachelor's degrees, or the same file could be used to produce a report with a complete statistical analysis of the employee education versus compensation.

Another typical environment where DATATRIEVE-11 would be useful is a distributorship with an order processing system. In this setting, sales data could be extracted by territory. Order backlogs might be retrieved, sorted by supplier, and printed on a report.

Data Definition
The data definition process involves establishing special DATATRIEVE-11 constructs called **domains**.

Domains — The main concept is central to DATATRIEVE-11. Domains represent relationships between actual physical data and descriptions of data. DATATRIEVE-11 performs all data management in terms of domains. Domains must be defined before DATATRIEVE-11 can manage the data associated with them.

In the simplest form, a DATATRIEVE-11 domain definition consists of a domain name, the name of the RMS-11 file, and the name of a record format description. A record format description defines the fields within a record, assigning each field a name and specifying its length, data type, and other vital parameters. All DATATRIEVE-11 domain definitions and record format descriptions are contained in the DATATRIEVE-11 Data Dictionary.

Record format descriptions can specify data validation criteria on a per-field basis. DATATRIEVE-11 automatically uses the validation parameters to screen data at the time of input so that only data defined as valid is accepted. Supported validation parameters include range checks, or must-match tables.

Domains can span multiple RMS-11 files or DBMS-11 record types and can also include the name of an associated DATATRIEVE-11 table.

Data Management

Data management involves creating and maintaining data in a current and correct state by adding, eliminating, and modifying records. The STORE, ERASE, and MODIFY statements are used to perform these relatively straightforward functions.

Populating Files — When an application requires the creation of new files, the files must be filled with data. This process is called "populating" the file. A series of successive STORE statements is used for this purpose. With the STORE statement, DATATRIEVE-11 prompts the user for each field value and, before accepting input, performs any validation checks specified by the record format description.

Data Retrieval

Maintaining an accurate database, however, is not an end in itself. Data is used to make decisions, generate reports, initiate transactions, and generally facilitate the operational processes of an enterprise. DATATRIEVE-11 allows stored data to be retrieved in an easily understood form regardless of underlying data structure (RMS-11 or DBMS-11).

The data retrieval statements of DATATRIEVE-11 are simple and particularly powerful statements. They consist of verbs modified by a Record Selection Expression (RSE). The RSE defines a subset of the records in the domain. These records are then selected by DATATRIEVE-11 for retrieval. One statement can get the answer to a casual query or produce a long, detailed report.

"EMPLOYEES WITH SALARY GREATER THAN $20,000," "ACCOUNTS WITH UNPAID-BALANCE GREATER THAN $600," or "DONORS WITH BLOOD TYPE EQUAL O-NEG" are examples of typical RSE's. Multiple conditions can be combined in a single RSE—for example, "DONORS WITH BLOOD TYPE EQUAL O-NEG AND LAST DONATION DATE LESS THAN JANUARY 1982." The DATATRIEVE-11 SORT operator can be appended to the RSE to order the records being retrieved.

Ad hoc information retrieval with DATATRIEVE-11 is normally performed as an iterative process using a series of statements to progressively narrow down the group of records to be retrieved. This works by using a FIND request with a specified domain as its object to establish what is called the current collection. Subsequent FIND requests progressively narrow down the current collection until the user is satisfied with the results. For example, the statement "FIND DONORS WITH BLOOD TYPE EQUAL O-NEG AND LAST DONATION DATE LESS THAN JANUARY 1981" might yield the DATATRIEVE-11 response "200 RECORDS FOUND." In this case, the user could narrow down the current collection with the statement "FIND CURRENT WITH ZIP-CODE EQUAL 77451." DATATRIEVE-11 might then respond with "14 RECORDS FOUND" and the user could PRINT these records to get telephone numbers for soliciting blood donations to help an accident victim.

Report Generation

In addition to its inquiry and update commands, DATATRIEVE-11 provides a report writer facility to generate reports directly from the RMS-11 files, DBMS-11 data, or the current collection. Although the report facility allows application programmers to specify spacing, titles, headings, and totals, the default settings are suitable for many applications, further simplifying its use. As in the inquiry and update facility, errors in commands are discovered immediately so that you can correct the commands before printing wrong or incomplete reports.

When reporting requirements change, you need not rewrite or modify an entire reporting program. All you do is issue modified statements to the report facility. The DATATRIEVE-11 report writer provides easy-to-use commands to control the following report functions:

- Report name, date, and page numbering
- Page width and length specification
- Detail line specification
- Multiple control break specification with automatic totaling at any level
- Multiple report sections
- Statistical lines—such as total, average, count, etc.

A DATATRIEVE-11 report command can be freely intermixed with other DATATRIEVE commands.

Reports

The PRINT statement is used to output information to a display terminal, a printer, or a RMS-11 file. Though there are some formatting options possible with the PRINT statement, they are limited. The REPORT command provides a more comprehensive set of formatting options for producing standard printed reports with page and column headings, page numbers, totals, and subtotals.

Stored Procedures
With the DEFINE PROCEDURE command, users can define sequences of DATATRIEVE-11 commands and statements and store them for later use. PROCEDURES can be invoked to run by themselves or can be embedded in other sequences of commands and statements.

Ease of Use Features
Guide Mode — DATATRIEVE-11 provides a self-teaching facility for use with VT52 and VT100 family terminals called guide mode. In this mode of operation, users are guided through their DATATRIEVE-11 sessions with a series of prompts.

To invoke guide mode, the user issues a SET GUIDE command. DATATRIEVE-11 immediately responds with "ENTER COMMAND, TYPE ? FOR HELP." If "?" is typed at this point, DATATRIEVE-11 will present the user with the possible responses—in this case, READY, SHOW, or LEAVE. If one of the alternatives is selected, DATATRIEVE-11 then proceeds to guide the user through the syntax of the selected statement. In the case of READY, DATATRIEVE-11 prompts with "DOMAIN NAME, END WITH SPACE."

DATATRIEVE-11 Editor — The DATATRIEVE-11 editor is a subset of the Digital standard editor, EDT. It may be used only in line mode and may edit only definitions stored in the DATATRIEVE Data Dictionary.

Application Design Tool — The Application Design Tool (ADT) is a DATATRIEVE-11 utility that simplifies the process of defining domains, record formats, and creating RMS-11 data files. Operating in an interactive mode, ADT presents the user with a series of simple questions. The user's responses provide ADT with information to generate the proper definitions. For RMS-11 files, ADT will prompt the user to get a full set of parameters pertaining to organization, index keys, etc. ADT will then create an indirect command file that the user can execute immediately or at some later time to create the desired file.

Advanced Features
View Domains — DATATRIEVE-11 allows domains to be defined that can subset the fields of a record and can span multiple RMS-11 files or DBMS-11 record types. These are called view domains because they provide a user's logical view of the data. Once view domains have been established, they can be used in much the same way as simple domains.

This facility is basic to high-level data access. It makes it possible for a single statement to retrieve a set of related records. For example, in an employee records application there might be an employee master file with company confidential information pertaining to salary that could be masked out during a view domain. Other information in the master file such as addresses and telephone numbers could then be combined in another view domain with a special file of records used in a car-pooling application.

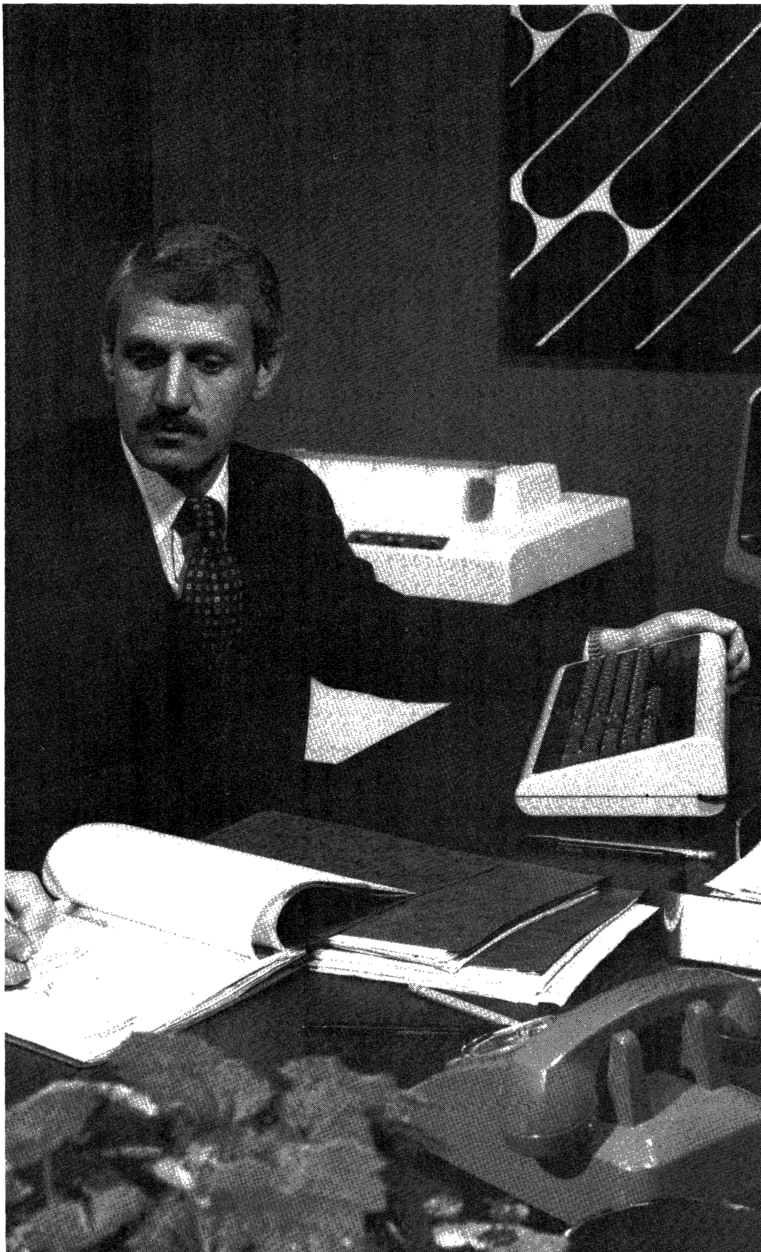
View domains can also be used with RMS-11 files for domains containing records related in a hierarchical fashion. For example, in an order processing application there might be an account master file and an order file. These files could be combined in a view domain to produce billing statements with data drawn from both files. A single record in this view domain could be defined to contain one account master record and all the orders applying to that account.

DBMS Domains — DBMS domains are a DATATRIEVE-11 feature to take advantage of the record format descriptions and interrecord relationships defined in DBMS-11 subschemas. When DBMS-11 domains are used, a schema, subschema, and a record type are simply identified. DATATRIEVE-11 uses the record format description and relationships defined for the record type in the DBMS-11 Data Dictionary.

Tables — DATATRIEVE-11 tables can be defined to reside in the DATATRIEVE-11 Data Dictionary. Tables can be used as a must-match list for field validation or for argument function type conversions. For instance, a must-match list of valid U.S. Mail state abbreviations could be used to check an address field, or an argument function table could be used to convert from state abbreviation codes to the spelled-out state name.

Data Protection

Data protection is accomplished through two independent mechanisms: the protection systems of the host operating system and those within DATATRIEVE-11. The DATATRIEVE-11 protection system uses passwords and User Identification Codes (UIC's or PPN's) to allow a user to regulate access to domains, records, procedures, and tables through access requirements recorded in the Data Dictionary. Thus, each resource has its own security system to assure access is not granted to unauthorized users.



CHAPTER 20

DATABASE MANAGEMENT SYSTEM (DBMS-11)

INTRODUCTION

DBMS-11 is a CODASYL-compliant database management system that runs under the RSX-11M, RSX-11M-PLUS, and IAS operating systems. By allowing the creation of a common data resource for any number of application programs, DBMS-11 reduces redundant data, provides data consistency, and allows the database to be maintained more easily and securely. In addition to the data modeling capabilities of a network database, DBMS-11 offers security and data protection features like journaling, automatic recovery, and subschemas which define the users view of the database.

DBMS-11 permits each application program to access an appropriate subdivision of the database through a simple set of commands that act as extensions to COBOL and FORTRAN programs or through calls from BASIC and MACRO programs.

Two sets of language facilities control DBMS-11 for database administration and application programming. The Data Description Languages (DDL) allows the central database to be defined and created; the Data Manipulation Language (DML) allows individual application programmers to access portions of the database by using simple commands embedded within application programs.

The description of each database is called the **schema** and is implemented with the Schema Data Description Language (Schema DDL). The Schema DDL performs these three functions:

- Defines all data elements (records, groups, items) in the database
- Describes all logical relationships (sets) that are to exist between elements
- Defines the physical mapping of the schema to files

Record definition—Records are defined in DBMS-11 with a definition language similar to PDP-11 COBOL. Most data types used in PDP-11 COBOL and FORTRAN-77 are supported by DBMS-11. In addition, such structures as groups, repeating groups, and variable length repeating groups can be defined.

Set Definition—DBMS-11 allows logical relationships among records to be defined in any combination of sequential, hierarchical, or network data structures. This flexibility optimizes record access, reduces or eliminates duplication of stored data, and provides direct access to associated records in the database.

Physical Mapping—Physical mapping of areas into files is accomplished using the Schema DDL. In the Schema DDL, the size of an area is described as a number of pages. A page is a fixed-length block of information transferred to and from physical storage. The actual size of a page is set in the DMCL. The DMCL can exclude some areas defined in the schema, making them unavailable for general processing.

Once a central database is defined, any number of logical subdivisions can be defined using the Subschema DDL. Each subschema defines a specific combination of records and structures which apply to a given application program. Central control and controlled allocation of each database not only provide for maintainability and security of data, but also permit markedly improved application programmer efficiency. For example, the data description function is removed from the scope of the application programmer. Individual application programs are easier to write and debug, and have superior portability and better maintainability.

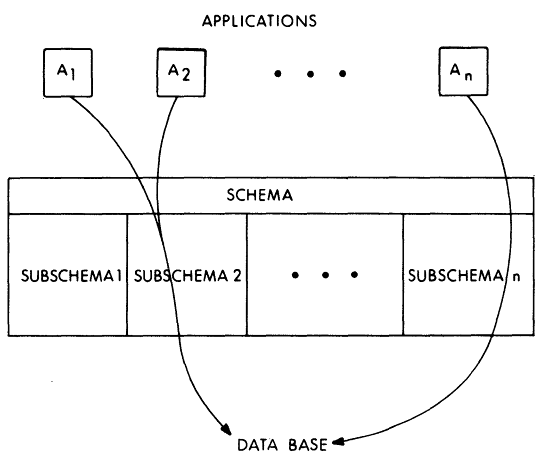


Figure 20-1 Schema and Subschemas

RECORD CHARACTERISTICS

The basic unit within the DBMS-11 database is the **record**. Individual records are differentiated from one another by their format—defined using the Schema DDL. For example, one record type might be named CUSTOMER and could include all record occurrences that have the following three data items:

- 8 characters for customer number

- 32 characters for customer name
- 32 characters for customer address

Any number of record types can be defined to meet the needs of the user community. Further, each record type can be included in any number of subschemas; identical record types need not be duplicated for different application programs. For example, the record type EMPLOYEE can be in the subschema for both the personnel and medical benefits application programs.

Since large databases are generally stored on disk systems where the time between successive accesses is the key to optimum performance, database performance can be improved by locating and retrieving these related records with a single access. DBMS-11 offers three modes of record storage that provide flexible record placement control.

These record location modes are:

- DIRECT — gives the user control over logical storage location. In this mode, a suggested database key (desired location) is supplied before the record is stored. If the suggested database key is available, it will be assigned to that record. If unavailable, the next available database key will be assigned.
- CALCULATED (CALC) — stores the record based on the value of one or more data items within the record. This option can be used to spread records evenly over an area. Every CALC record provides a "keyed" entry point into the database.
- VIA — used for record occurrences that will be referenced primarily in conjunction with another record type. For example, if record type EMPLOYEE is usually accessed in conjunction with record type COMPANY, the VIA option would store record occurrences of EMPLOYEE as close to occurrences of the specific COMPANY as is possible. This clusters member records around owners, minimizing the number of physical accesses necessary.

SET CHARACTERISTICS

While the ability to control the physical placement of records is important to optimize system speed, the most important aspect of any database management system's usability is the number and kind of data relationships that can be supported.

Logical relationships are established by defining named collections of record types—each called a **set**. Each set must have one record type declared as the owner record and one or more record types declared as its member records. Seven characteristics of sets in DBMS-11 are illustrated in Table 20-1.

Set Ordering

DBMS-11 includes a series of options to establish and maintain set relationships. Since each set is described independently from any other set, the record order of each set can be defined for most efficient access. Record order within a set may be defined to be:

- FIRST (New records are positioned first in a series of records.)
- LAST (New records are positioned last in the series of records.)
- PRIOR (New records go immediately before a record occurrence established by the user program.)
- NEXT (New records go immediately after a record occurrence established by the user program.)
- SORTED (Records will be logically positioned in ascending or descending order based on the value of one or more data items within the record.)

The logical ordering of member record occurrences in a set is independent of the physical placement of the records. Additionally, the same record type can participate (be a member) in any number of different sets, each with a different ordering criterion.

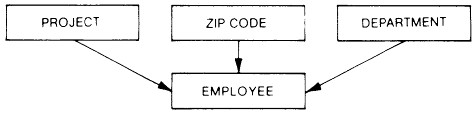
Set Membership

Not only can a record type participate as a member of different sets with a different relationship in each set, but the type of membership may be different in each set. Set membership can be *optional* or *mandatory*, and *manual* or *automatic*, depending on whether the user application program is permitted to CONNECT or DISCONNECT an occurrence of this record type from the set.

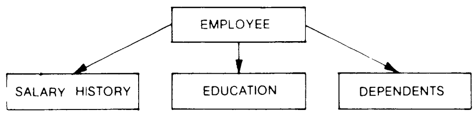
- **Optional** set membership allows a record to be removed from a set (DISCONNECT) without the record's being deleted from the database.
- **Mandatory** set membership defines a record as a permanent member of a set as long as the record is present in the database.
- **Automatic** set membership defines the record to be specified as a member of a set as an automatic function performed by the database management system when the record occurrence is stored in the database.
- **Manual** set membership allows the connection to a set of a record occurrence to be performed by the user program (CONNECT).

Table 20-1 Set Relationships

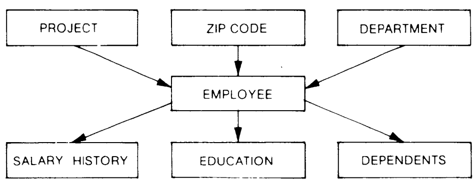
1. Any record may participate as a member in one or more SETs.



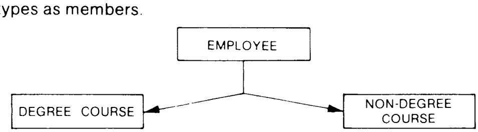
2. Any record may be specified as the owner of one or more SETs.



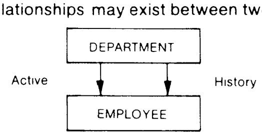
3. Any record may participate as a member of any number of SETs, and also be an owner of one or more SETs.



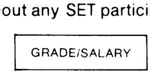
4. A SET may have only one record type as its owner but may have one or more record types as members.



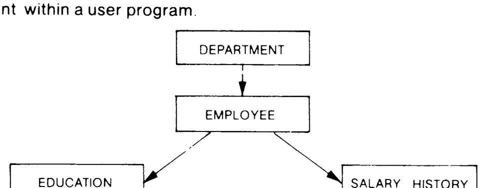
5. Any number of SET relationships may exist between two record types.



6. A record type may exist without any SET participation—as neither a member nor an owner of a SET.



7. Any record type may be defined as an optional member of a SET. Participation of each record occurrence is established or deleted based on execution of a statement within a user program.



Set Linkage

The relationship between record types within a set is maintained by the existence of pointers **(linkage)** to related records. Members of sets are always linked in the forward direction (**next** pointer). Sets may also be defined to be linked in the reverse direction (**prior** pointer) or linked to the owner (**owner** pointer). Owner pointers allow the owner record to be accessed directly from a member record without following the next or prior pointer chain to the end.

Thus, options for set linkage are: next pointers, next and prior pointers, next and owner pointers, or next, prior, and owner pointers.

PHYSICAL SPACE MANAGEMENT

The basic unit of physical space management under DBMS-11 is the **page**. A page is a fixed-length block transferred to and from storage (size defined by the user) which will be maintained by the DBMS-11 input/output routines.

The physical extent of the database is described in pages using the Schema DDL. The database is divided by the Schema DDL into **areas**. For example, area 1 might be pages 1-1000; area 2, pages 1001-3000, and so on.

Within a page, any number of records of different types may be stored, each with its own length. Space management is employed within each page so that when a record is deleted, the associated space is made available for reuse. This eliminates efficiency-robbing gaps in the database.

The database may be mapped to any combination of system **files**:

- The entire database may be assigned to a single file
- Files may be assigned to areas on a one-to-one basis
- Several files may be associated with one area

The applications programmer is never aware of which files are connected to the portion of the database.

Note that each database has its own buffer pool, whose size is defined through the DMCL. Database pages are read and maintained according to a "least-recently-used" algorithm. This technique reduces overall I/O overhead.

Multiple Databases

DBMS-11 supports up to five simultaneously active databases per system. Although the centralization of data is a goal of database management, some database applications are essentially disjointed. If the Engineering Department needs a database for design information and shares a computer with the Medical Records Department which also uses DBMS-11, they are not required to pool their information. Similarly, one database can be used to debug new programs while production work continues.

Table 20-2 Physical Storage Allocation Under DBMS-11

	PAGES 1–N (Entire Physical Database)		
DBMS-11 AREAS	AREA 1 PAGES 1–1000 (1st Physical Area)	AREA 2 PAGES 1001–3000 (2nd Physical Area)	AREA "X" PAGES "b"–"N" Xth Physical Area)
POSSIBLE "FILES" MAPPINGS	FILE A	FILES B & C B C	FILES D–Z

DATABASE UTILITIES

DBMS-11 includes a comprehensive set of utilities that allows the database administrator to monitor and audit the activity of the system, measure the performance of the system, and recover the database after a hardware or software failure.

Data Dictionary Utilities — The Data Dictionary contains information about the definitions, structures, and use of data. Information in the dictionary is used by the DML processors so that each program gets an accurate picture of the database. Programmers do not code data declarations for DBMS records and sets. The data dictionary report program produces reports on the dictionary contents tailored to the needs of programmers and database administrators. A second utility, DBCLUC, allows language specific information to be stored in the data dictionary.

Database Recovery and Journaling — Database recovery and journaling automatically maintain a journal of all changes made to the database. This journal includes both "before" and "after" images of modified portions of the database. Checkpoint statistics are also included.

- *Online Recovery*—immediately recovers a database without affecting other programs operating at the same time. This runtime facility performs as a rollback operation replacing "before" images for the program that terminated abnormally.
- *Journal File Fix*—creates a usable journal file if no ending labels were placed on that file because of operating system failure, hard-

ware crash, etc. It writes the appropriate end-label information on the output journal file.

- *Journal Rollforward*—recovers the database forward to a specified point in time by reapplying "after" images from the journal tape to the database in chronological order. It provides information about each end-of-job checkpoint reached and determines if the data base is in a logical quiescent condition at this checkpoint. The roll-forward utility also takes into account a multitasking environment, and at each checkpoint will display all other programs that were active, which areas the programs had open, and their declared usage mode in each area.
- *Journal Rollback*—recovers the DBMS-11 database to a user-specified point backward in time by reapplying "before" page images from the journal tape.

Runtime Modules — Runtime modules are created by the schema, subschema, and DMCL compilers. The result of the subschema compilation is the subschema object module that describes the logical database. Similarly, the DMCL compiler creates an object module which describes the physical database. This module contains the physical control blocks for mapping areas to files used by the DBCS at run time. The schema, subschema, and DMCL definitions are placed in the Data Dictionary.

The information processed by the schema, subschema, and DMCL compilers is used by the DBCS and the applications at runtime. The DBCS is the portion of DBMS-11 that, together with the host operating system, accesses the database. DBCS receives requests from application programs and sends them to the host operating system. This relieves the application program from the burden of physical I/O processing and keeps the physical database under central control.

Page Find/Fix — This utility is used to fix corrupted internal data structures. It can locate and display a page based on a page number or key value of a CALC record. If the key value is submitted, the utility performs the CALC transform on the value and displays the page that contains the record occurrence with that value.

CALC Routine — This is a callable unit which transforms a CALC key value into a page number using the algorithm used by the database system. It may be used to test a key value set for even distribution in an area or as a mechanism to permit presenting records so that a database can be efficiently loaded.

Database Query — This utility allows the user to use interactive DML commands to access a database without writing programs.

Database Verify — This verifies that the internal structure of a database is consistent and that all set linkages are complete.

Database Operator Utility(DBO) — used to control and monitor database operation. Using DBO, the database administrator can define databases, start or stop individual databases or the entire system, initialize database files, set journaling characteristics, and display the status of some or all of the users of a database. DBO also includes backup and restore functions that provide a high-speed copy of a database or portions of it. DBO also produces a description of space utilization in the database.

DATA MANIPULATION LANGUAGES

Application programs access data under the direction of a predefined subschema. The Data Manipulation Language (DML) contains sets of high-level language statements that form syntactical and logical extensions to the FORTRAN and COBOL programming languages. The programmer writes all data manipulation requests using the appropriate DML statements. DBMS-11 allows DML statements and host language statements to be intermixed within the application program.

Applications can also make use of the CALL statement interface, which consists of a set of subroutine calls to the DBCS interface. These calls can be used with any language that supports a CALL external-subroutine statement.

The simple command structure of the data manipulation language means:

- Programmer learning time is minimized.
- Programs written by one programmer are easily understood by others.
- Application programs are portable and maintainable.
- Programming productivity is increased.

Control statements establish access to a portion of a database. The READY statement announces the user's intention to start processing within the specified area. The corresponding FINISH statement announces the end of processing.

Locating or accessing records is done with the following statements:

- FIND locates a record occurrence in the database that satisfies the record-selection-expression portion of the statement.
- GET causes a retrieval from the most recently located record.
- ACCEPT CURRENCY causes movement of the database key of the most recently located record to a named location in the program.

Modification statements result in a change to the contents of the database. Changes include the addition of new data, modifications to existing data item values, or deletion of data in the database.

- STORE uses data established by the user in working storage to create a new record occurrence in the database.
- MODIFY changes the data content of an existing record in the database.
- CONNECT and DISCONNECT cause a change in the set relationship of an existing record occurrence in the database.
- ERASE causes an existing record occurrence to be removed from the database.

The application programmer can access the database only through a subschema which is predefined by the database administrator. A subschema is made available to a program via a declarative statement. Records defined in the subschema specify the only database data that can be manipulated by the application program. This furnishes data privacy independence at the application program level. Data manipulation statements are referred to as the data manipulation language (DML). The DML processors supply record type descriptions from the subschema into the working area of the user's program.

COBOL DML

The programmer must identify a subschema in the subschema section of the Data Division. DML statements may appear anywhere in the Procedure Division and may be considered by the programmer as an extension to the COBOL language. This means that, surrounded by other COBOL statements, they may be placed at the appropriate point in any procedure. The COBOL DML processor (CDML) reads the COBOL DML source statements and searches within the Data Division for the subschema section to obtain the name of the subschema specified. Once the subschema name has been verified, the DML processor obtains the names of all valid records, sets, and areas. These are used to validate DML statements in the Procedure Division.

CDML will establish an 01 level record entry followed by selected data items in working storage for each record type included in the subschema. System control and communication data items are included automatically.

Each DML command is validated for correct syntax and usage of record-set-area relationships. At compile time, these DML validations guard against the programmer's using the database improperly; hence resources are not wasted later during system/program debugging. All DML errors detected by CDML will be displayed with the source statement in error.

Table 20-3 DBMS-11 COBOL Data Manipulation Language

CONTROL STATEMENTS:

DB *sub-schema-name* **WITHIN** *schema-name.*

READY *[realm-name]* [**USAGE MODE** IS [**PROTECTED** | **EXCLUSIVE**] {**RETRIEVAL** | **UPDATE**}] .

FINISH.

FIND [*record-name*] **DB-KEY** IS *identifier.*

FIND CURRENT [**WITHIN** {*set-name* | *realm-name*}] .

FIND {**NEXT** | **PRIOR** | **FIRST** | **LAST** | *integer* | *identifier*} [*record-name*] **WITHIN** {*set-name* | *realm-name*} .

FIND OWNER WITHIN *set-name.*

FIND {**ANY** | **DUPLICATE**} *record-name.*

FIND *record-name* **WITHIN** *set-name* [**CURRENT**] **USING** *identifier.*

IF *set-name* IS [**NOT**] **EMPTY** *imperative-statement.*

IF [**NOT**] *set-name* {**MEMBER** | **OWNER**} *imperative-statement.*

MODIFICATION STATEMENTS:

ERASE [*record-name*] [{**PERMANENT** | **SELECTIVE** | **ALL**} **MEMBERS**] .

CONNECT [*record-name*] **TO** *set-name*

MODIFY *[record-name].*

DISCONNECT *[record-name]* **FROM** *set-name.*

STORE *record-name.*

RETRIEVAL STATEMENTS:

GET [record-name].

ACCEPT *identifier* **FROM** {*record-name* | *set-name* | *realm-name*} **CURRENCY.**

Table 20-4 DBMS-11 FORTRAN Data Manipulation Language

CONTROL STATEMENTS:

INVOKE ([SUBSCHEMA = *subschema* **,SCHEMA** = *schema* **])**

$$\textbf{READY}\ \left\{\begin{array}{l}\textbf{ALL}\\ \textbf{REALM} = \textit{realm1}\end{array}\right\}\left[,\left\{\begin{array}{l}\textbf{PROTECTED}\\ \textbf{EXCLUSIVE}\\ \textbf{CONCURRENT}\end{array}\right\}\right]\left[,\left\{\begin{array}{l}\textbf{RETRIEVAL}\\ \textbf{UPDATE}\end{array}\right\}\right][,\textit{error}]\textbf{)}$$

FINISH (ALL [,*error*]**)**

FIND (*rse* [,*end*][,*error*]**)**

where rse is in one of the following six formats:

Format 1

KEY = *dbkey* [**,RECORD** = *record1*]

Format 2

$$\left\{\begin{array}{l}\textbf{DUPLICATE}\\ \textbf{ANY}\end{array}\right\}\textbf{,RECORD} = \textit{record1}$$

Format 3

$$\left\{\begin{array}{l}\textbf{OFFSET} = \textit{integer-exp}\\ \textbf{FIRST}\\ \textbf{LAST}\\ \textbf{NEXT}\\ \textbf{PRIOR}\end{array}\right\}[\textbf{,RECORD} = \textit{record1}],\left\{\begin{array}{l}\textbf{REALM} = \textit{realm1}\\ \textbf{SET} = \textit{set1}\end{array}\right\}$$

Format 4

$$\textbf{CURRENT}\left[,\left\{\begin{array}{l}\textbf{RECORD} = \textit{record1}\\ \textbf{REALM} = \textit{realm1}\\ \textbf{SET} = \textit{set1}\end{array}\right\}\right]$$

Format 5

OWNER, SET = *set1*

Format 6

RECORD = *record1*, [**CURRENT,**] **SET** = *set1*, **USING** = *id-item*

USE

Format 1

$$\textbf{USE (PROCEDURE} = \textit{identifier},\left\{\begin{array}{l}\textbf{ALL}\\ \textbf{OTHER}\\ \textbf{STATUS} = \textit{status-list}\end{array}\right\}[,\textit{error}]\textbf{)}$$

Format 2

$$\textbf{USE (}\left\{\begin{array}{l}\textbf{CLEAR}\\ \textbf{SAVE}\\ \textbf{RESTORE}\end{array}\right\}\textbf{,ALL}\ [,\textit{error}]\textbf{)}$$

Table 20-4 (cont.) DBMS-11 FORTRAN DML

MODIFICATION STATEMENTS

```
                                    ┌ ( PERMANENT ) ┐
ERASE ([RECORD = record1]           │ , { SELECTIVE } │ [,error])
                                    └ ( ALL       ) ┘
```

CONNECT ([**RECORD** = *record1,*] **SET** = *set1* [,*error*])

DISCONNECT ([**RECORD** = *record1,*] **SET** = *set1* [,*error*])

MODIFY ([**RECORD** = *record1*] [,*error*])

STORE (**RECORD** = *record1* [,*error*])

RETRIEVAL STATEMENTS

GET ([**RECORD** = *record1*] [,*error*])

```
                                  ┌ ( RECORD = record1 ) ┐
ACCEPT (CURRENCY = dbkey          │ { SET = set1       } │ [,error])
                                  │ { REALM = realm1   } │
                                  └ ( RUNUNIT          ) ┘
```

FETCH (*rse* [,*end*] [,*error*])

where rse is in one of the six formats presented for the **FIND** *statement.*

FORTRAN DML Compilation

The user identifies a predefined subschema using a DML INVOKE statement at the beginning of each main or subprogram module that contains DML statements. FORTRAN DML statements may be considered by the programmer as an extension to the FORTRAN language, and, as such, DML statements may appear anywhere in a FORTRAN program that executable statements are allowed. The FORTRAN DML preprocessor (FDML) reads the FORTRAN DML source program and converts all DML statements to standard FORTRAN statements.

FDML includes all the functionality of the COBOL DML, plus dynamic (runtime) naming, end error phrases, USE procedures, dynamic buffer binding, and selective record copies from the subschema division.

CALL Statement Interface

DBMS-11 can be used with any language, such as BASIC and MACRO-11, that supports a CALL statement. The user communicates with DBMS-11 from these languages by passing arguments through the CALL statement. The CALL statement procedure is straightforward and easy to use.

PROGRAMMING REQUIREMENTS

The DBMS-11 input/output area for the database resides in a region of memory called the User Work Area (UWA), a loading and unloading zone for data. Each record included in the subschema is automatically included in working storage by the DML processor followed by the statements that describe the name and data type of each data item. Only those data items of the record defined in the subschema are transferred to the user program. Input of a record from the database always appears in its like named area in working storage.

Storage (or output) of a record to the database requires the movement of data from various locations in the user's program to each of the data items described for the specific record in working storage. Once this is completed by user procedure statements, the record is moved physically from working storage into the database using the STORE statement.

The user is responsible for initializing all data items required to execute a DML statement successfully and must ensure that the data are correct. DBMS-11 has extensive runtime error diagnostic facilities and will update error status after every DML statement. To determine the action taken by the system in response to the request, the user must examine the error status following each DML command.

In summary, three operations are required for each access to the database:

- Initialization of data items as required by the DML statement to be executed
- Initiation of the database operation by the DML statement
- Error checking to determine the outcome of the preceding DML command

EXECUTION OF OBJECT DML PROGRAMS

The operations that take place when a DML statement is executed are discussed in this section. Numbers in parentheses refer to Figure 20-2.

- A DML statement appears in the object program as a request to the DBMS-11 interface routine (1). The request identifies the type of database service desired and any additional information, such as record name, set name, and area name, required to interpret the request properly.
- The DBMS-11 interface routine sends the request to the database control system (DBCS).
- The DBCS performs the requested database service using information supplied by the object subschema. The operation performed depends upon the type of DML statement executed. In the event of a

request to locate a record (FIND statement), the DBCS will look in the system page buffers to see if the requested record is present. If the record is not in the system page buffers, a request will be made to the operating system (4) to input a database page from the direct access file to the system page buffers (5,6). No input is initiated if the record is already present in the system page buffers.

- Changes to the database are recorded on the database journal file (7).
- The DBCS performs the requested service using additional information contained in the object subschema. The object subschema contains a representation of the data structure, record placement control, record characteristics, currency status, database operation, statistics, and constraints on DML operations. In general, the object subschema controls the operations and access of the database for each program that invokes it.
- Whenever a specified record occurrence is located by the DBCS, the database key and other system information related to the record are moved from the system page buffer to locations within the object subschema (8). This information represents the currency status of the area, sets, and record type of the record occurrence which has been located.
- The DBCS returns to the interface routine with an indication of the success or failure of the database service (9).
- If the request to the DBCS specifies movement of the contents of a record to the user working area (GET statement), data will be moved from a system page buffer to a specified record area in the user working area (10). Only the data portion of the requested record is delivered to the user; system-controlled structure data are retained by the DBCS to ensure database integrity. Data movement from the user working area to the system page buffers will occur in response to a STORE or MODIFY statement.
- The subschema interface routine moves status information regarding the outcome of the DML statement executed to locations within the user working area of the program (11).
- Control is returned to the user's program at the statement following the DML statement just executed (12).
- The user must determine the status of the previous DML statement by examining the contents of the system status information (13). For example, if a FIND statement was just executed, the contents of system status information would indicate whether the specified record occurrence was located or not. If the system status information

condition indicates that the service requested was completed successfully, the user would access the user working area as needed (14).

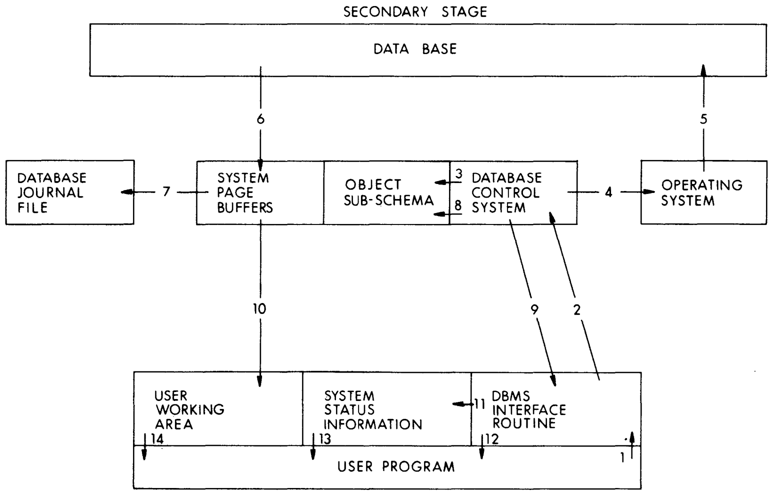


Figure 20-2

CHAPTER 21
INTRODUCTION TO OTHER UTILITIES

EDITORS

Editors are among the most important utilities in an operating system. Editors let you manipulate text in computer files that contain anything from programs to personal letters.

Because of the computer's excellent memory capabilities and its ability to work with enormous files, computer editors provide services that would be tedious or impossible to perform by pen and paper or typewriter. With an editor you can insert, delete, and relocate text, whether by single characters or by large blocks of text. If you are editing programs, you can insert, delete, or reorder program lines, correct erroneous instructions, and append programs that should logically go together.

When you edit text, you can scan the file and correct it quickly and easily. If you use a video terminal to work on a file, you can work through pass after pass without needing an intermediate hard copy. Therefore, you can save considerable time and materials.

Editors have several impressive features. They can search huge files for every occurrence of a string of characters (such as a word or phrase) and tell you where each occurrence is found. Editors can delete strings or replace them with other strings. For example, you could replace each use of the phrase "capital distribution" with "dividend" in an annual report. One or two editor commands accomplish this. Many editors can also perform search-and-delete, search-and-replace, and other such operations on designated sections of text.

Editors can be either "character-oriented" or "line-oriented." The choice of a character or line editor is often a matter of personal preference. Operating systems may have more than one editor available, thus allowing you to choose the best editor for your application.

Editors are generally used interactively, which means that you can actually carry on a dialog with the computer. However, editors can also be used in batch mode. With batch jobs, you submit editing instructions as a command file, so that the instructions take effect when the job is run.

SCREEN FORMATTERS

Video terminals are growing increasingly important in both scientific and commercial computer applications. It is essential, therefore, to make sure that information displayed on terminals is clear to people who may not be computer specialists, just as it is important to assure that nonprogrammers can insert information properly into the terminal programs. A good screen formatter helps here, by presenting the user with a formatted screen that shows data in easy-to-understand style, draws his or her attention to crucial information, and offers explanations and help for any complicated fields. Similarly, video formatters can help those who input data by showing them exactly where and in what format to type it, by verifying that the data conform to program requirements, and by highlighting important fields. People inputting information at terminals can also get help from the system when there is a complicated field to fill in, or where several options exist that might need explanations.

Chapter 23 describes three different DIGITAL screen formatters, the Forms Management System (FMS), DECFORM, and INDENT. FMS is intended specifically to take advantage of the extensive capabilities of the VT100 terminal. DECFORM works on VT50, VT52, or VT100 terminals and is meant to be used specifically with the CTS-300 and CTS-500 operating systems. INDENT supports DIGITAL's VT52 and VT100 terminals and uses the following VT100 features—reverse video, bold, underline, blink, 132 column lines, scroll, split-screen, reverse screen, and the line drawing character set—to produce highly functional, aesthetically pleasing formats.

FMS is a software "front end" that accepts user input and gets it ready for the program, or receives program output and styles it in ways easy for people to understand. Through this flexibility, the formatter can be used with a variety of programs, with only minor modification. DECFORM usually is used for stand-alone file maintenance; that is, data collection, validation, and editing without the use of a host program written in another language. INDENT is a forms management and data entry system which greatly simplifies and expedites application program development of programs written in DIBOL, COBOL, or BASIC-PLUS-2 running under the RSTS/E operating system. INDENT was designed to enable you to create forms, enter data through these forms, and validate data. Because the INDENT command language is so easy to use, an entry level programmer can quickly learn to create and modify forms definitions.

CHAPTER 22
THE EDT EDITOR

INTRODUCTION

EDT is a powerful text editor available on many DIGITAL operating systems. Though you can use EDT at a variety of terminals, it is especially powerful in conjunction with VT52 and VT100 video terminals, because it can take advantage of the editing keypad that such terminals offer. With keypad mode, a single keystroke performs an entire editing function—for example, deleting, reinserting or replacing a word. You can even redefine the functions of keypad keys (through key macros) to produce commonly needed operations. EDT provides a wide range of benefits to anyone who has to do editing work—including file creation—on a computer.

First, EDT is very easy to learn. Editing instructions are English words or their shortest unique abbreviations. The order of operands is logical for English syntax; parameters can be either line numbers in the text file or character strings that you choose. Extensive HELP facilities remind you quickly of the possible options for a particular command and of the format for that editing instruction. You can get help on general EDT operations by typing HELP. If you need help while in keypad mode, pressing the help key displays information that is specific to keypad editing.

Second, the editor protects your editing session with a journaling capability. EDT makes a record of everything you type so that your work will not be lost if your editing session is terminated by equipment failure. In addition, the editing session does not alter the original file until you are sure that you have done what you want. Instead, all editing activity takes place upon a copy of the original file in a temporary workspace called a buffer. A buffer is a part of EDT's memory that can hold an essentially unlimited amount of text. Only when you have ended the session do you have to determine whether or not to incorporate your editing activities into the file.

EDT is capable of working with many files at once. If you want to concatenate several files, create several files from one, or distribute part of a file among many others, you can do so with EDT.

In change mode on a VT100 or VT52 terminal you edit one 22-line window (screenful) at a time so that you can observe immediately the effects of any editing operations you perform. Instead of being restricted to the most recently altered line, you can see a whole screenful of text, and visualize the relationship of new and old lines. Of course, if the text is longer than 22 lines, you can easily scroll through it to get to any point you want to edit.

EDT MODES OF OPERATION

Keypad and Line Editing

With EDT you have a choice of keypad or line mode editing. These modes of editing allow you to:

- Display a range of lines
- Find, substitute, insert, and delete text
- Move, copy, and renumber lines
- Copy text into a buffer and write it on files
- Define the functions of keys

Keypad editing is available on VT100 and VT52 terminals. You use the group of keys at the right of the keyboard to enter keypad functions. Keypad editing is powerful and versatile, yet it is easy to learn and use. In keypad editing, the active buffer is displayed on the screen as you edit. You can see the changes you make to a buffer as they take place. There are a wide variety of keypad editing functions, each of which requires you to press only one or two keypad keys to perform the function. You enter commands, insert text, and perform control functions from the keyboard.

Line editing is useful for those who have hardcopy terminals or who prefer editing by numbered lines. In line editing, you make all entries from the keyboard. As you make changes to the contents of the buffer, EDT displays one or more lines at a time.

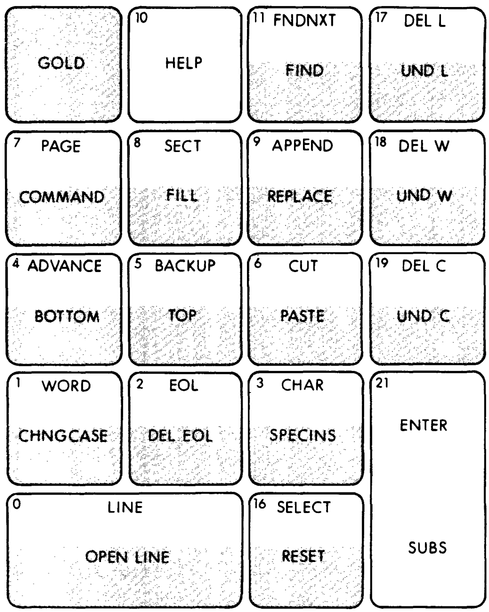
Keypad Layout

Keypad functions allow you to perform a variety of operations with a single keystroke. You can change the function of any keypad key to meet your needs with the DEFINE KEY command. The following diagrams show the keypad for the VT100 and the VT52.

Editing Operations

EDT provides facilities for positioning the cursor, inserting and deleting text, repositioning blocks of text within a file, creating auxiliary files, and more. The combination of a clear and readable video display screen, coupled with the extensive keypad functions supported by the VT100 and VT52 terminals, makes editing quick and easy.

Cursor Positioning — You move the cursor around on the screen to position it properly for inserting or modifying text. The cursor can go in any direction. For example, the arrows at the top of the VT100 keyboard can move the cursor to the right or left by any number of characters. It can be moved up or down by any number of lines. In addition, special function keys on the keypad can move the cursor to the right or left by one word or one character, to the beginning or end of a line, or to the beginning or end of the buffer.



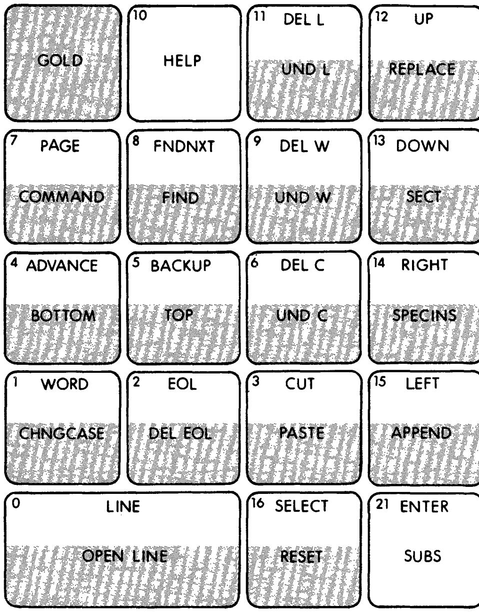
NOTE: THE NUMBERS IN THE UPPER LEFT CORNER OF THE KEYS ARE WHAT ACTUALLY APPEAR ON THE KEYS.

Common Keyboard Functions

Backspace	Go to beginning of line	CTRL/E	Increase tab level
Delete	Delete character	CTRL/K	Define key
Linefeed	Delete to start of word	CTRL/T	Adjust tabs
CTRL/A	Compute tab level	CTRL/U	Delete to start of line
CTRL/D	Decrease tab level	CTRL/W	Refresh screen
		CTRL/Z	Return to line mode

Figure 22-1 EDT VT100 Keypad

You can also move the cursor through a buffer by specifying a character string that will serve as the object of a search and then moving the cursor backward or forward directly to that point. The entire buffer is always available for editing; you may scroll forward or backward through the buffer at will.



NOTE: THE NUMBERS IN THE UPPER LEFT CORNER OF THE KEYS ARE WHAT ACTUALLY APPEAR ON THE KEYS.

Common Keyboard Functions

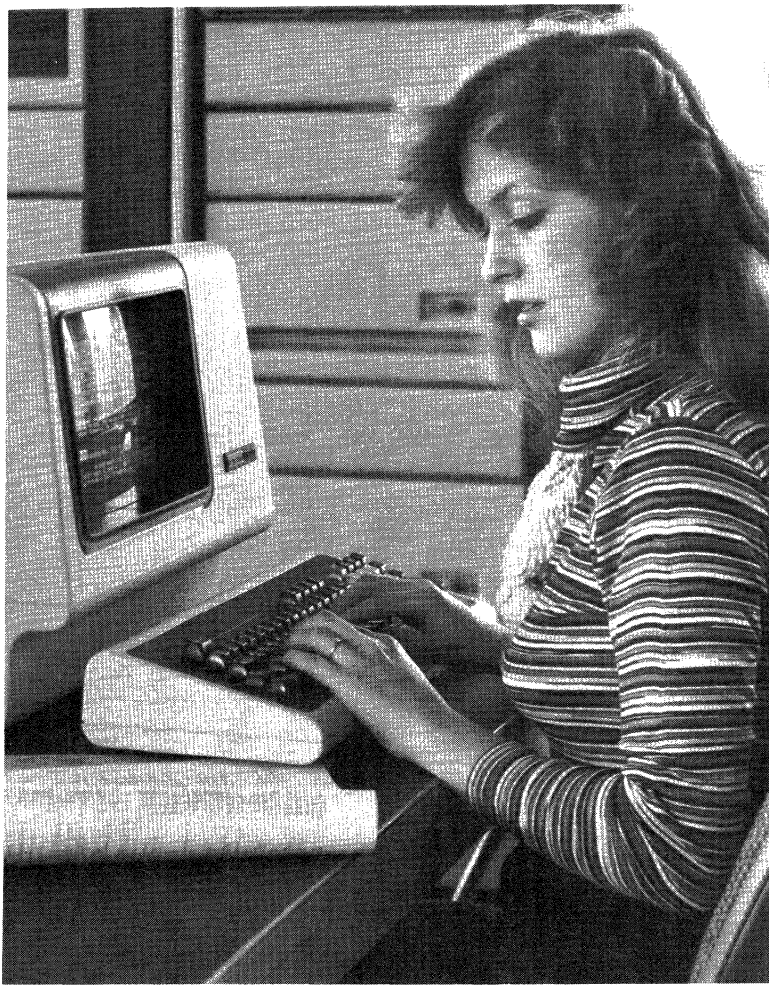
Backspace	Go to beginning of line	CTRL/F	Fill text
Delete	Delete character	CTRL/K	Define key
Linefeed	Delete to start of word	CTRL/T	Adjust tabs
CTRL/A	Compute tab level	CTRL/U	Delete to start of line
CTRL/D	Decrease tab level	CTRL/W	Refresh screen
CTRL/E	Increase tab level	CTRL/Z	Return to line mode

Figure 22-2 EDT VT52 Keypad

Inserting and Deleting Text — There are several ways to insert and delete text in a buffer. You enter text by typing alphanumeric and special characters at the keyboard. You can delete a single character, a word, or a line, and multiple words and lines backward and forward relative to the cursor by using keypad functions. Furthermore, text deleted during the current editing session can be restored by using the UNDELETE keys to recall it from special buffers reserved for the purpose. This allows quick recovery from editing mistakes or mis-typed commands. You can also combine insert and delete operations by using the special keypad functions for finding and substituting text.

Moving Text — Special function keys on the keypad allow you to mark off an entire section of text and then move it to a new position in the file, or string it together with other sections similarly marked off.

Creating Auxiliary Files — From EDT's change mode you have access to EDT's line mode commands, including the **WRITE** and **INCLUDE** commands, which allow you to read and write files during an editing session.



CHAPTER 23
SCREEN FORMATTERS

FMS-11 FORMS MANAGEMENT SYSTEM

There are numerous instances of commercial, scientific, and industrial applications in which a formatted video screen provides excellent ease-of-use benefits. For example, clerks updating inventory lists use a well-designed form to guarantee that the proper part codes, quantities, prices, suppliers, and other pertinent data are all entered exactly as required by the program that is to manipulate them. Rather than presenting the clerk with a blank screen and a complicated menu of instructions for entering the data, a form-managed video terminal supplies pictures that automatically tell where each field goes, instantly checks to see that it is filled with the right number and types of characters, and aids the clerk with concise HELP messages appropriate to the field or to the form as a whole.

Such forms can be extremely simple, or they can be quite complex, depending upon the necessities of the program that is to use the information being formatted. A chain of related forms might be required in some applications.

FMS-11 Forms Management System is a software package that provides sophisticated screen formatting for application programs. FMS-11 makes it easy to create, use, and update video forms with the VT100 family of terminals. It allows non-programmers to design forms interactively, right on the video screen, without first drafting the form on paper. FMS-11 eliminates tedious editing and recompiling of a forms program to see whether the form is satisfactory. Programmers and users will appreciate the easy-to-learn keypad-operated editor and the HELP facility. Users will like the extensive field protection and validation features that help prevent typing errors.

FMS-11 software supports a variety of standard programming languages under the major PDP-11 operating systems. Forms developed for PDP-11 systems can be run without any conversion on VAX/VMS systems using VAX-11 FMS software. FMS-11 Forms Management System is a software package that provides sophisticated screen formatting for application programs. It allows non-programmers to design forms interactively, right on the video screen, without first drafting the form on paper. FMS-11 eliminates tedious editing and recompiling of a forms program to see whether the form is satisfactory.

FMS-11 makes it easy to use the distinctive video attributes of the VT100: reverse video, bold, blink, underline, 132-column lines, jump or smooth scrolling, split or reverse screen. In addition, character data types within fields (pictures) are checked on a character-by-character basis. Furthermore, special symbols used for formatting can be imbedded within a field without breaking the field into smaller fields.

FMS-11 allows programmers to develop application programs in most higher level languages on all DIGITAL PDP-11 and VAX operating systems. Programs can be coded to be completely independent of the forms layout, since form and field names are not bound to the program until execution time.

FEATURES

Programmer Benefits

- Easy, interactive design and maintenance of video forms and application programs
- Field and record-level I/O calls
- Reduced memory usage
- Increased application flexibility
- Supported languages: BASIC-11, BASIC-PLUS-2, PDP-11 COBOL, COBOL-81, FORTRAN-IV, FORTRAN-77, DIBOL-11, and MACRO-11
- Supported PDP-11 operating systems: RT-11, RSX-11M, RSX-11M-PLUS, RSTS/E, and IAS

User Benefits

- Keypad-operated editor speeds training and use
- Field access by name allows complete rearrangement of a form without changing the application program
- Extensive field protection and validation help prevent errors
- On-line HELP for every field and every form reduces documentation and training

Description

FMS-11 is a set of utilities and subroutines that provide flexible screen formatting for applications written in assembler or high-level languages. A special-purpose interactive editor is used to create FMS-11 form definitions for display on the VT100 family of terminals (VT100, VT101, VT102, and VT125). The Form Utility provides a means for maintaining disk-resident form libraries, creating listings or object modules of forms descriptions, and listing directories. Application programs control the operator's interaction with the form by subroutine calls to the FMS-11 Form Driver subroutine library.

FMS-11 Forms

An FMS-11 form is a video screen image composed of data fields with protection and validation information, and constant background text. The data fields and background text can be highlighted using the VT100 video attributes such as reverse video and underline, blinking, and bold characters. Split screen and scrolling capabilities permit users to view more data than can be displayed on the screen at one time.

Figure 23-1 shows sample of a screen form generated by the Form Editor and demonstrates the use of different display attributes, such as reverse, bold, and underline:

```
Sample of FMS Video Attributes that use the VT100's Video Capabilities


Normal :  This line has only the assigned form-wide attribute.

          (single attribute)        & Reverse         & Bold

Under- :
line      SPRING upward          FLY away          DRIVE like mad

Reverse:
          FLOAT gently           DRIFT slowly      SLIDE smoothly

Bold   :
          STAND tall             BE strong         LIVE dangerously


Underline  FMS uses the video features of the VT100 to create on any part
& Reverse  of the screen areas of immediate noticeability.  FMS video
& Bold  :  attributes are easy to use and help distinguish different
           sections of a form.
COMMAND:
```

Figure 23-1 Sample Screen Form

Individual data fields can be display-only, enter-only (no echo), or can be restricted to modification by privileged users. Data fields can be formatted with fill characters, default values, and formatting characters (such as the dash in a phone number), which assist the user, but are not visible to the application program. Fields may be right- or left-justified or may use a special fixed-decimal field type to align data properly.

Field validation includes checking each keystroke in a field for the proper data type (e.g., alphabetic, numeric, etc.). Fields may also be defined as "must enter" or "must complete."

A line of HELP information may be associated with each field, and a chain of HELP screens may be associated with each form. If users need help while using a form, they should press the HELP key to see a line of useful information about the current field. Pressing the key a second time will display the first HELP screen associated with the current form. Continuing to press HELP will chain through any additional HELP forms chained to the first one until the operator chooses to return to the original application context.

FMS-11 Programs

A number of components are used to create FMS-11 applications. These are: the Form Editor (FED), the Form Utility (FUT), the Form Driver (FDV), and, for RT-11 only, the Application Runtime Supervisor.

Figure 23-2 illustrates the relationship of FMS-11 components to each other and to an application program.

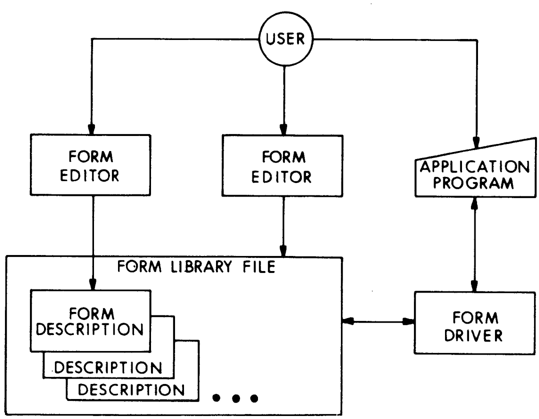


Figure 23-2 FMS-11 Components

The Form Editor

The Form Editor is a system program that provides a simple means of entering, modifying, and storing FMS-11 form descriptions. The FED allows non-programmers to customize existing, general application programs by creating or modifying form descriptions. (This is possible because the form descriptions are independent of the applications that use them.) The FED is an interactive program that uses many of the special capabilities of VT100 family video terminals.

When using the FED, a user's screen always shows the current state of the form that is being edited. Keypad and keyboard functions allow users to specify video display characteristics for either constant text or field characters. Fields are defined on the screen with picture characters similar to those used in COBOL. Short, helpful explanations about individual fields and about each form as a whole may be included as part of the form description.

Fields and forms are accessed by name, rather than by less flexible structures such as row-column coordinates and sizes. Because the relationship between programs and fields is made at execution time, a form can be completely restructured without changing the applications that use the form.

Another feature that enhances program flexibility is named data. The named data feature provides a mechanism for storing constant data (such as file names and range check parameters) in the form description, rather than with the application program. With named data, a non-programmer can easily customize program parameters with the Form Editor. Named data allows the same application program to communicate with a form that can display information and accept input in multiple human languages. By using named data, the programmer can write a more general, more maintainable application.

Form Utility

The Form Utility is a system program that performs a variety of form library maintenance functions, including creation of new libraries and the insertion, deletion, replacement, and extraction of individual forms. It also creates hard-copy listings of form descriptions, lists the directory of a form library, and produces object modules from form descriptions. These object modules can be linked with the application program to produce forms that are entirely memory-resident. In addition, on systems that support COBOL the Form Utility can write out Data Division code that corresponds to a form definition and is suitable for copying into a COBOL source program.

Form Driver

The Form Driver, a re-entrant system subroutine, uses the forms created with FED. Under the direction of the calling program, FDV displays forms, performs all screen management a form requires, handles all terminal I/O for application programs, and validates user responses by checking each response against the field and form description. Depending on the needs of the application, programs and forms may interact on either a field-by-field or a whole record basis.

The FDV may be called from applications written in any of the following languages supported by the operating system: BASIC-11, BASIC-PLUS-2, PDP-11 COBOL, COBOL-81, FORTRAN-77, FORTRAN-IV, DIBOL-11, or MACRO-11. Because the Form Driver calls are virtually identical in all languages, proficiency in using FMS-11 is easily transferable across languages and operating systems, and programs themselves become much more portable.

Application Runtime Supervisor
Available only with FMS-11/RT-11, the Application Runtime Supervisor (ARTS) controls the interface between form applications and the RT-11 operating system. The ARTS runs in the background area of the RT-11 foreground/background monitor, along with the individual application programs, which are called tasks. When an application is running, each terminal has its own copy of a task. The ARTS includes a demand scheduler that handles resources and processing activities so that each terminal may run its task independently.

The ARTS allows multiterminal applications to be written in FORTRAN IV or MACRO-11. In multiterminal applications, concurrent tasks can share public files and resident code libraries. Applications can include global system tasks not attached to any terminal. Terminal tasks can use a system task by sending messages to it and receiving messages from it.

Form applications using ARTS may be either dynamic or static. Dynamic systems allow each terminal to change tasks without affecting the tasks executing at other terminals. Static systems, on the other hand, provide fixed relationships between tasks and terminals, locking each terminal into its own individual task. Static systems are most suitable when users do the same work for long periods of time and when that work can be implemented as a small, fixed number of tasks.

Form application systems that use FDV but do not include any of the special ARTS multitask or multiterminal capabilities are also available. The most common use for such a system is debugging and testing tasks as they are being written.

The FMS-11 system generation procedure uses a clear interactive dialogue to select the ARTS features required for a particular application. The hardware on which the application executes may be predefined at ARTS generation time, or it may be specified when ARTS begins to run.

FMS-11 Example
The following code fragment (Figure 23-3) is a sample of FORTRAN application code. FMS Form Driver calls FGET and FPFT are used to

emulate a call to get all fields, but to allow the calling program to validate responses immediately on entry, before proceeding to the next field in the form.

```
        CALL FCLRSH (FORM)                  ! Display the form

        CALL FGET (RESP, TERM, "*")         ! Get first field in form
        CALL FGCF (FIELD)                   ! Get the name of the field
        GOTO 2                              ! Validate response if
                                            ! necessary

1       CALL FGET (RESP, TERM, FIELD) ! Get a field

2       .
        . Validate the user's response.
        . Following validation, the variable "ERRVAL' is zero
        . if the response is valid, non-zero if invalid.
        .

        IF (ERRVAL .NE. 0) GOTO 1           ! Get field again on error
        IF (TERM .EQ. 0) GOTO 10            ! Branch if terminator was
                                            ! "ENTER'
        CALL FPFT                           ! Else process field terminator
        CALL FGCF (FIELD)                   ! Get name of field to get
        GOTO 1                              ! Get next field

10      CALL FRETAL (DATA)                  ! Return responses for all
                                            ! fields
        .
        .
        .
```

Figure 23-3 Sample Code

DECFORM—SCREEN FORMATTING UTILITY

A second video formatter option is offered especially for the CTS-300 and CTS-500 Datasystems. DECFORM is a program generator which produces stand-alone modules for screen formatting, data entry, verification and validation, file creation and maintenance. Using an easy-to-learn descriptor language, the form designer defines the form layout, data fields, prompts, and validation options. DECFORM then produces a program which can stand alone for file creation and maintenance, or can work in conjunction with a second data processing application.

Designing interactive data entry screens and several file review functions are made easy for the programmer and end-user by the DECFORM utility, and by the special keypad to the right of the keyboard on VT52 and VT100 terminals. Cursor-control keys in the keypad allow you to advance or back up a field, and to go to the top of the screen to correct data, terminate data input, change file maintenance modes, and so forth.

Screens formatting under DECFORM is accomplished through the use of a simple forms creation language. The form designer works interactively, at a high level, with the terminal and the Datasystem, so that he or she can quickly change anything that needs correction. Generally, the designer sketches out the form on a printed sheet—such as the sample shown in Figure 23-4—and then translates the design into the forms creation language.

Screen formatting is helped by the availability of multiple fields and multiple screens. Multiple fields simply means that several fields can be entered on a single video line, making the screen more nearly resemble a printed form. Thus, both name and employee identification number could be fields on the first line of the personnel file form. People not trained in computers find them easier to use when the video formats correspond fairly closely to more familiar printed ones. When there is more to the form than will fit comfortably on one screen, multiple screens may be used. They help divide the format into convenient units, so that the form designer can avoid squeezing and crowding the format awkwardly.

For statistical, comparative, or mathematical applications, the video screen can be made to resemble a large grid. Screen formatting for such applications as order entry, shipping, and credit authorization is facilitated by the use of descriptor text. Descriptor text, written into the form design file by the programmer, guides the end user through an easy fill-in-the-blanks method of data entry. The filling-in menu can be as simple or as complex as the designer wants, based upon the complexity of the application and the degree of technical expertise of end users.

Error messages are displayed at the bottom of the screen to notify the user of the invalid entries. Further data entry operations are inhibited until the error is acknowledged and corrected.

Once the form is entered into the library of forms by the designer, it is readily available to anyone authorized to use it. Stored forms are, of course, accessible by several users at once, but only one programmer at a time may alter the form.

File Creation

Most data entry sessions commence with a simple instruction or two to call up the form: the information typed in by the end user can then either be passed to a program for computation or can be held in a file. In order to assure the accuracy of such data, DECFORM provides basic and advanced editing functions. Basic checks include numeric field, free format numeric field, alphabetic fields, check digit formulas, batch totals, table look-up, and range check.

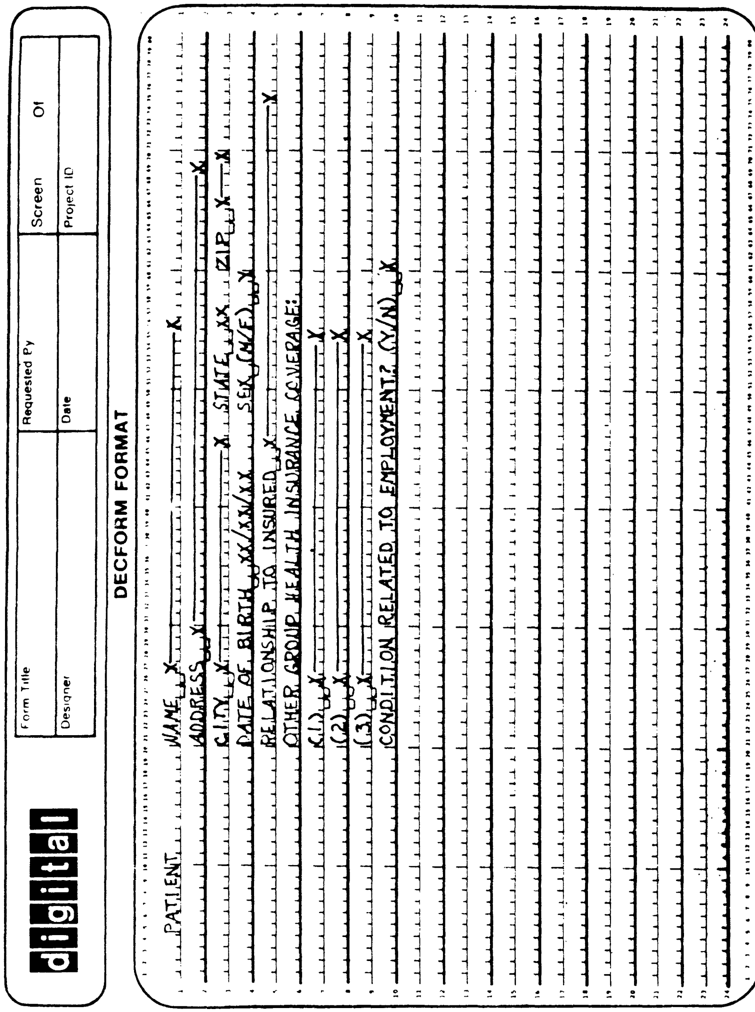


Figure 23-4 DECFORM Format Sheet

In addition, DECFORM expands the number of editing functions available to the user by offering advanced edit checks and field display options. Advanced edit checks include file validation, a math option, conditional field validation, and a programmable option. DECFORM field display options include protected field, required field, full field, no-clear, auto-halt, auto-duplicate, and override. The combination of basic and advanced edit checks and field display options provides you with additional flexibility in designing screen formats.

DECFORM also supplies efficient, easy-to-use file maintenance through such commands as CHANGE, DELETE, VERIFY, or INQUIRY. A hidden field option protects confidential or restricted information from use by unauthorized personnel. The hidden field option requires that a user give a special password before access to the protected information is permitted.

File Inquiry

Once the appropriate format and the type of maintenance is chosen, the programmer or user then selects the file to be examined. File inquiry is accomplished by initiating a file search, which is started when the user fills in fields on the screen with key information that he or she wishes to search for in a record. The program takes the key information and searches through the appropriate file until the first record with a matching key field is found. After displaying and reviewing the selected record, the user may continue the inquiry to the next record in the file, or may specify a new search key, causing the system to locate a record matching the new specification.

Searches may be either sequential or indexed. Indexed searches require that the key fields be specified when the screen format is created originally, and that the file under inquiry be set up as an ISAM file. Sequential searches may use any field as a search key.

File inquiry is a flexible operation, able to fulfill the needs of various application environments. The forms designer may request such information as a password, name of the data file where data records are to be stored, or the specific type of transaction that is to occur. This degree of flexibility enables DECFORM to be customized to suit individual requirements.

At the discretion of the forms designer, DECFORM can also maintain a question and answer dialog with the user throughout the entire data entry and file inquiry procedure. Questions such as IS SCREEN O.K.?, or IS RECORD O.K.? are flashed on the video terminal to remind the user to sight-verify any information before leaving that particular screen or record. This question and answer dialog allows the user to reposition the cursor within the screen or record field, thereby decreasing errors and increasing productivity.

File Review and Update Modes

There are four file review and update modes important to a commercial system using DECFORM.

1. Inquiry mode—inquires into a record within a file. This mode allows the operator to review data previously entered as a record within the system files.
2. Change mode—allows for both review and update of information in a record within a file. Once the record is displayed on the screen in the appropriate format, the operator may examine data and make changes where necessary. This function is one of the primary methods by which files in the system are maintained.
3. Delete mode—allows for selective deletion of records from a file. Again, the record is displayed on the screen, using the appropriate display format.
4. Verification mode—increases the reliability of the data. With the verify function, an operator reviews a record displayed on the screen and selectively re-keys data fields. If any of the re-keyed fields differ from the original contents of those fields, the operator is informed of this difference and asked which data are desired. As with the data which were originally entered, any changes must also pass any edit checks associated with fields in question.

Format Control File

The code serving as input to DECFORM is called the Format Control File, which the format developer generates to specify the exact layout of data entry and review formats. A separate Format Control File is required for each format. DECFORM takes the code composing the Format Control File and translates it into DIBOL-11 program source statements with annotated comments. It is then compiled into intermediary code, linked, and stored. Each terminal using a DECFORM format operates independently of any other terminal and therefore requires its own copy of the linked format code. The amount of memory space necessary to handle each format (and thus each terminal) varies, depending on the size and complexity of the format. Generally, the space requirements are 8-12 Kbytes of memory per format.

INDENT—INTERACTIVE DATA ENTRY

INDENT is a forms management and data entry system which greatly simplifies and expedites application program development of programs written in DIBOL, COBOL, or BASIC-PLUS-2 running under the

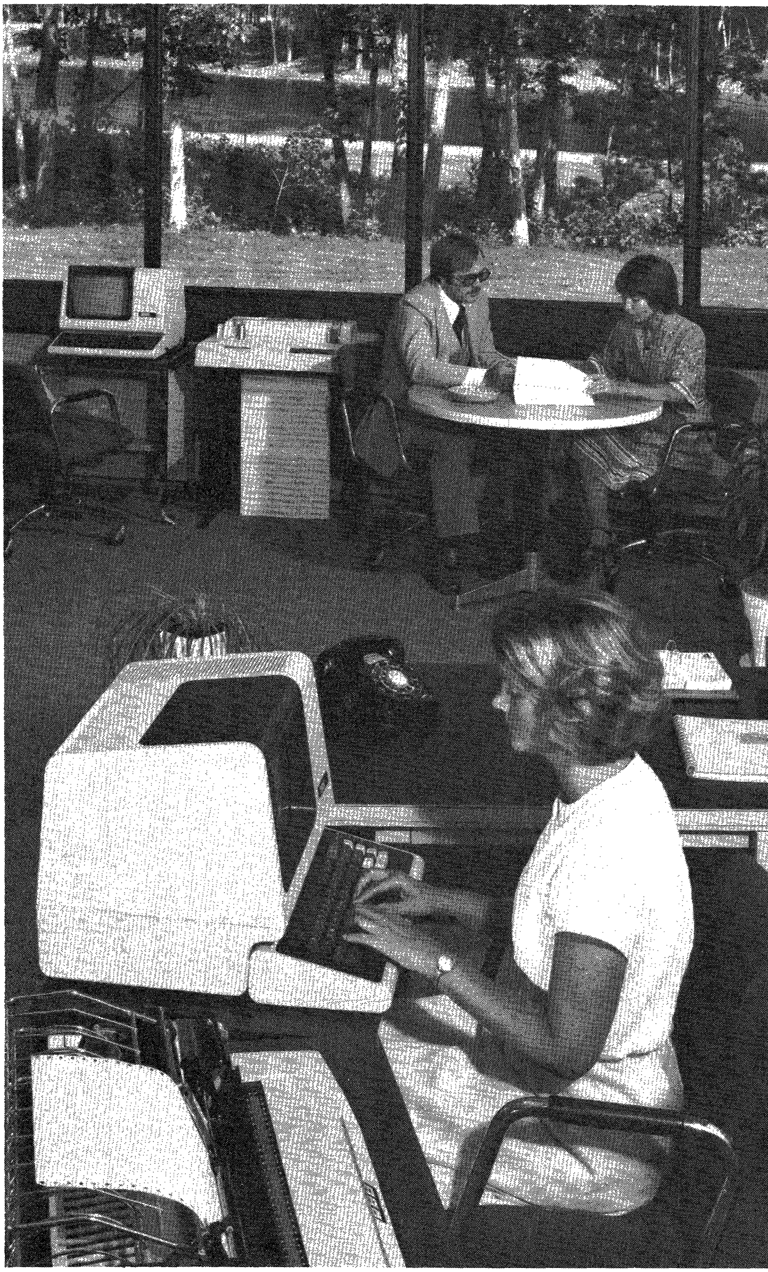
RSTS/E operating system. INDENT was designed to eliminate the many drawbacks associated with traditional forms management in commercial applications. It offers both user and developer benefits that result in more efficient program development and in more cost effective application processing.

INDENT's powerful runtime system allows a multiterminal application to simultaneously engage in many tasks with only a single host application program. INDENT supports DIGITAL's VT52 and VT100 terminals and uses the following VT100 features—reverse video, bold, underline, blink, 132 column lines, scroll, split-screen, reverse screen, and the line drawing character set—to produce highly functional, aesthetically pleasing formats.

INDENT was designed to enable you to create forms, enter data through these forms, and validate data. INDENT form definitions are created using a text editor. INDENT offers very flexible screen handling. Forms can be displayed all at once or one field at a time. Fields from different forms can be displayed one after another. Fields from a single form can be displayed in an order different from that in which they occur in the form. Forms can be chained together. Portions of a form can be scrolled on the screen. Several forms can be displayed simultaneously.

Functionality is further provided through INDENT's powerful set of forms directives and host program commands. Boxes and lines can be quickly defined; tables can include lists of literals or variables; form variables can be defined and accessed by host programs; forms can initialize host programs and host programs can initialize forms; defaults can be set and reset.

Application programming is simple and fast. Changes to host programs, data management, or forms definitions can be implemented independently of one another. Because the INDENT command language is so easy to use, an entry level programmer can quickly learn to create and modify forms definitions. The field definitions are simple so the forms designers don't have to be programmers.



CHAPTER 24
DISTRIBUTED PROCESSING AND NETWORKS

INTRODUCTION

DIGITAL produces powerful computer hardware and software products that permit the linking of computers and terminals into flexible configurations called **networks**. With networks, you can optimize the efficiency and cost-effectiveness of your data processing operation.

No matter where your processors or terminals are located—around the plant or around the world—they can, under certain circumstances, be connected in ways that allow exchange of information, files, programs, and control, as well as the sharing of peripherals. Small computers can access the powerful capabilities of mainframes when they are networked; large computers can take advantage of smaller dedicated systems that have been chosen for specific application environments.

With **distributed processing**, minicomputers are placed at the locations where they are needed, whether on the floor of a manufacturing plant, in an accounting department, in a laboratory, or in a home office. As organizations become more complex, or develop more sophisticated demands for their computer resources, the ability to network processors and share resources becomes increasingly important. DIGITAL has the distributed processing and networking products to provide customers with these essential capabilities.

DIGITAL's networking architecture offers a broad range of compatible networking options:

- DECnet—DECnet is a family of networking products which enable two or more DIGITAL computer systems to communicate.
- Internets—DIGITAL offers a family of protocol emulators called Internets. Internets provide a way for DIGITAL computers and terminals to communicate with computers and terminals built by CDC, IBM, UNIVAC, and several other companies. Users of IBM mainframes, for example, might find it efficient to distribute a number of DIGITAL minicomputers at various locations to do local computing, and then link them to the headquarters central computer to give management access to important information quickly and accurately.
- Packetnet System Interfaces (PSI)—Packetnets are computer and terminal interfaces to public packet-switched networks. These interfaces allow DIGITAL computers to communicate with those from other manufacturers through a public data network.

Each of these series of products will be outlined in detail later in this chapter. First, however, some important networking concepts will be introduced.

CONCEPTS

A **node** is a point in a network through which a user can gain access to the network or where network work may be done. In network schematics, nodes are the endpoints of the communications links that join the network. Communications links may be either dedicated or leased or dialed-up lines or satellite or microwave beams.

There are basically two types of nodes: routing and nonrouting. A routing node can receive messages from remote nodes and pass them to nodes other than those linked directly to itself. This sophisticated capability allows for more complex transfer of information around the network, but requires more software "overhead" to manage it. Nonrouting nodes can receive messages from anywhere in the network, but cannot pass them along. For this reason they are also sometimes referred to as "end nodes."

The phrase "point-to-point" describes the physical configuration of a network. In point-to-point networks, each node must have a physical link to any other node it wants to communicate with. Two point-to-point networks are shown below in Figures 24-1 and 24-2.

The routing network shown in Figure 24-2 provides the same level of communication as does a fully communicating point-to-point network, but with a reduced number of lines/modems needed by using node A as a routing node.

Multidrop connections, however, are more like party telephone lines: several nodes share a single telephone line or local line. Figure 24-3 is an illustration of a multidrop network. It is important to note that one computer is always designated as the master or control node and all other computers on that line are slaves or tributaries and respond to polling by the master node.

DECNET

DECnet expands the power of DIGITAL computers so that each system can be used to its full advantage independently, and, as part of a network, each can also provide additional computing benefits. There is a DECnet product to support each of DIGITAL's major operating systems. Capabilities vary for particular DECnet systems, but generally include the following.

DECNET CAPABILITIES

Adaptive Routing

Adaptive routing is the automatic routing of messages through a mul-

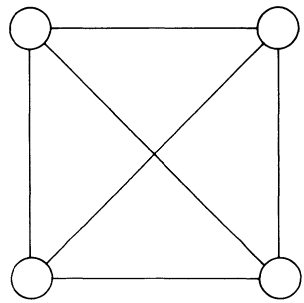


Figure 24-1 Fully Communicating Point-to-Point Network

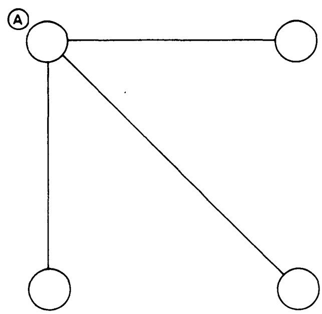


Figure 24-2 Routing Network

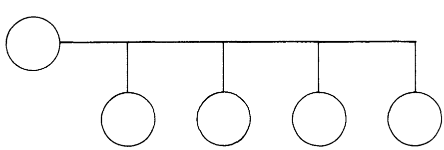


Figure 24-3 Multidrop Network

tisystem network. This is a technique in which the network chooses the least costly of all alternative routes for the transmission of network messages from one node to another, and automatically adjusts for faulty lines, interruptions, and changing line status. Nodes can be added or deleted without disrupting network operations. This feature makes larger networks feasible as well as cost-effective.

Multipoint
Multipoint permits nodes to share a common communication line. The tributary (or slave) nodes can only communicate with the control (or master) station when the master has polled them. They communicate with one another through the master node. Multipoint reduces communication costs by minimizing the number of lines and modems between nodes.

Network Command Terminal
This feature permits a terminal at one network node to have direct logical access to another node. The user's terminal appears to be physically linked to the other system and the standard network and system utilities of that other system are available for use. Consider, for example, a programmer in one city, say Seattle, who wants to use DATATRIEVE on a huge database stored in a computer in Boston. The Network Command Terminal feature lets that programmer work as if the Boston database were connected directly to the Seattle computer. There is no need to duplicate data and software on multiple systems. The only restriction is that the two communicating nodes be the same operating system and DECnet software. Intermediate nodes may be any other DECnet implementation.

Network Management
Tools for monitoring and controlling network operation are the substance of network management. For day-to-day operations, the architecture includes facilities for tuning parameters, for logging events, and for testing nodes, lines, modems, and communications interfaces.

For monitoring network operation or for testing a new network application, DECnet provides statistical and error information. Statistics relate both to nodes and to communications lines, including data on traffic and error types. The network manager can get information such as the number of connect messages sent over logical links and the number received.

Line counters are also available which record statistics like the number of data blocks sent and received successfully, the number of blocks received with errors, and the number of times tributary status has changed. Data can be logged and displayed at will.

Loopback testing is a valuable aspect of network management. A network manager can send and receive test messages over individual lines, either between nodes or through other loopback arrangements, and then compare the messages. Utilities are included for a logical series of tests that aid in isolating software and hardware problems.

Access to network performance information allows potential problems to be solved before they degrade performance. If A-to-B traffic increases, the line capacity can be increased. This network management capability, combined with the performance information available from the network coordinators and the Network Profile, provides unique data for planning for the future. It means customers who use DECnet have control and can grow with assurance.

Task-to-Task Communication

In task-to-task communication, cooperating programs exchange data. These programs can be running under different operating systems; they can be written in different languages. One important benefit of this feature is that the network manager can make specified programs secure from access.

As an example of networked task-to-task, think of a manufacturing test/material handling application. A group of PDP-11/34's is testing system components in MACRO and FORTRAN-77 under RSX-11. Once a day, the Operations Manager reviews production schedules. The number of units which have passed final test and are ready for shipment is important information for the COBOL data analysis program running under RSTS/E at headquarters. To the failure analysis program in each RSX-11 system, the running tally it keeps of the number of units which pass the test is relatively insignificant. When the COBOL programs goes to get the information for its production scheduling, though, it's there and available.

File Transfer

All DECnet systems support exchange of sequential ASCII or binary files. The DECnet software handles compatibility issues among operating systems by translating the file syntax of the sending node into a common network syntax and then retranslating at the receiving end appropriately for that node.

The transfer of file types other than sequential ASCII and binary may also be supported between particular operating systems. Check with your DIGITAL Network Specialist for details.

As an example of file transfer, think back to the task-to-task example. Since the Operations Manager in that example needed only one record in the FORTRAN program's file, a task-to-task solution made sense. If additional information in that file had also interested the Operations Manager, transferring the whole file might have been preferable.

Remote Resource Access

Sharing such resources as expensive peripheral devices or massive database files is economical as well as convenient. A person at one node can make use of a remote disk storage device or specialized peripheral equipment that makes overhead projection transparencies from word-processor files, just as if they were nearby.

This capability is sometimes also referred to as "remote file (or record) access" when programs access file-structured devices remotely. Figure 24-4 illustrates remote resource access.

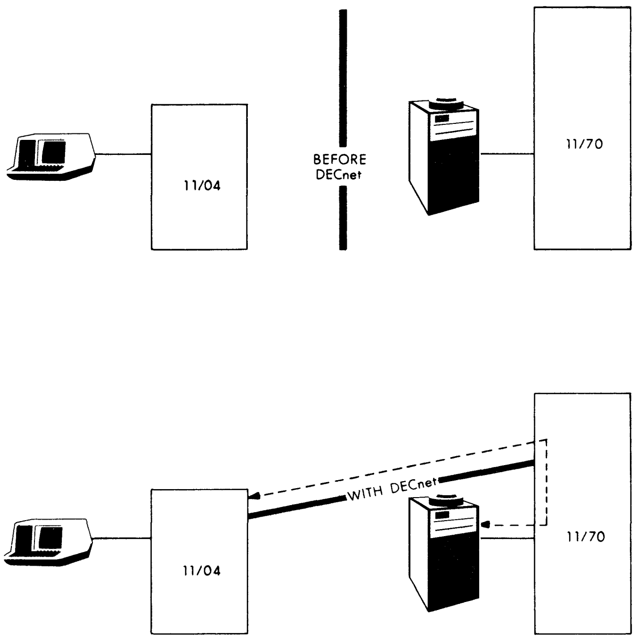


Figure 24-4 Remote Resource Access

Remote Command File Submission and Execution

A user at a source node requests a destination node to execute a command file. The command file may already be at the destination node, or the source may send it along with the request. This capability turns the user console into a remote job entry terminal for a system that supports batch or indirect command processing. In combination with the file transfer function, it's very powerful.

A small lab system, for example, might acquire data but might not be powerful enough to run the data analysis program. This could be run as a batch job on a larger processor, with the commands submitted from the lab. Later, the file containing the results could be transferred back to the lab for review.

DECnet can also support full batch capability with log file and spooling on base systems that support batch. On RSX-11M-PLUS, for example, the user can generate the node with either command file or batch capability.

Downline Loading

Tasks (programs) or whole software systems can be developed on a node with good peripheral, compiler, and memory support and then be sent to the computer where they will ultimately be used.

Downline task loading is invaluable for final check-out of applications programs which have been developed by a central, but geographically separated, applications programming group.

Downline system loading (and its converse, upline system dumping) is particularly useful for small memory-based systems or for systems in hostile environments.

Our example in Figure 24-5 shows an RSX-11S system (the only system supported for downline loading), monitoring conditions in a coal mine. It is a likely candidate for downline task or system loading. New applications, once tested, can be downline task loaded. Likewise, the whole system can be regenerated and downline system loaded. The applications or system programmer can do this from a comfortable location with good computer peripheral support. Programs already executing on the core-only RSX-11S node can be checkpointed to the disk file system of an adjacent node and later restored to main memory of the RSX-11S node. No hardhat and elevator descent are required.

Upline dump of crash information is also supported for memory-only satellite nodes. The dump yields the contents of registers and memory. These may be analyzed on RSX-11M and RSX-11M-PLUS systems by a Network Crash Dump Analyzer.

Terminal Communication

The terminal communication facility has many applications. It's a handy way to talk to a person at another terminal or system console. You can request the computer operator at headquarters to mount a magnetic tape with data you need to produce a report remotely. You can tell a remote operator that you're ready to send data and that he should be prepared.

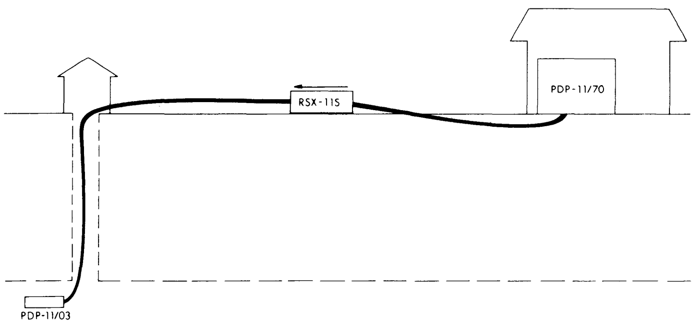


Figure 24-5 Downline Loading

Auto-Answer
Once someone dials the number of a destination node, DECnet answers the call, which establishes the communications link, and then attends to the processing requests. Auto-Answer is supported by DECnet.

In order to get an overview of the entire DECnet picture, please refer to Table 24-1. It compares the capabilities of all our different DECnet products running on PDP-11 operating systems. Note that the names of DECnet products reflect their compatible operating systems; for example, DECnet/E is the DECnet software for the RSTS/E operating system.

INTERNETS

Data Transfer Facilitators, Not Hardware Emulators
Internets are a family of protocol emulator products that connect DIGITAL computers with non-DIGITAL systems. If you need a way for DIGITAL computers to communicate and exchange data with computers from other manufacturers, DIGITAL provides mechanisms for interchanging data with IBM, UNIVAC, CDC, and other host processors. DIGITAL's goal is not to provide plug-compatible replacements for terminal subsystems, but instead, to interchange data by using common communications protocols. Emulating a protocol already recognized and supported on another vendor's system is the easiest way to speak to that system.

While our protocol emulator products appear to another vendor's computers to be supported devices, they are, in fact, parts of powerful DIGITAL systems. You get local file systems, many different languages, transaction processing—a wide selection of computing power.

Table 24-1 Network Comparisons

	DECnet-11S, V3*	DECnet-RT, V2*	DECnet-11M, V3*	DECnet/E, V2*	DECnet-IAS, V3*	DECnet-11M-PLUS, V1*	DECnet-VAX, V2*	DECnet-20, V2
NETWORK MANAGEMENT								
Loopback Testing								
Physical Link		X	X	X	X	X	X	
Logical Link	X	X	X	X	X	X	X	
Event Logging	X	X	X	X	X	X	X	
Status/Statistics								
Line	X	X	X	X	X	X	X	X
Node	X	X	X	X	X	X	X	
Node Resources								
Configuration	X	X	X	X	X	X	X	
Monitoring	X	X	X	X	X	X	X	
HOMOGENEOUS NETWORK COMMAND TERMINALS	X	X[1]	X	X	X	X	X	
FILE TRANSFER								
Copy Sequential Files		X	X	X	X	X	X	X
Copy ISAM Files (Homogeneously)				X			X	X
Directory of Files		X	X	X	X	X	X	X
File Spooling			X	X	X	X		
REMOTE JOB ENTRY								
Command File Submission		X	X	X	X	X	X	
Command File Execution			X	X	X	X	X	X
Batch				X		X	X	X
REMOTE RESOURCE ACCESS								
Local Node to Remote								
Files		X	X	X	X	X	X	
Unit Record	X	X	X	X	X	X	X	
Terminal	X	X	X	X	X	X	X	
Remote Node to Local								
Files		X	X	X	X	X	X	
Unit Record	X	X	X	X	X	X	X	
Terminal	X	X	X	X	X	X	X	
LANGUAGE								
MACRO	X	X	X	X	X	X	X	X
FORTRAN IV	X	X	X	X	X	X	X	
BASIC-PLUS				X				
BASIC-PLUS-2	X		X	X	X	X		
COBOL			X	X	X		X	
SOFTWARE INTERFACE								
Message Level	X		X		X	X	X	X
Segment Level		X		X				
HOST SUPPORT FOR RSX-11S MEMORY-ONLY SYSTEM								
Down-Line System Load			X		X	X	X	
Down-Line Task Load			X		X	X	X	
Up-Line Crash Dump			X		X	X		

* Phase III systems.

	DECnet-11S, V3*	DECnet-RT, V2*	DECnet-11M, V3*	DECnet/E, V2*	DECnet-IAS, V3*	DECnet-11M-PLUS, V1*	DECnet-VAX, V2*	DECnet-20,V2
DIRECT LINE ACCESS								
MACRO	X	X	X					
Multipoint	X	X[1]	X					
Point-to-Point	X	X	X					
Multiple Lines	X		X					
TRANSPORT								
Full-Routing	X		X	X	X	X	X	
Non-Routing	X	X	X	X	X			
Point-to-Point	X	X	X	X	X	X	X	X
PHYSICAL CONNECTIONS								
Multipoint	X	X[1]	X	X		X		
Point-to-Point	X	X	X	X	X	X	X	X
Multiple Lines	X		X	X	X	X	X	X
CONFIGURATION								
Mapped, Full-Routing or Non-Routing	X	X[2]	X			X		
Unmapped, Non-Routing	X	X	X					
COMMUNICATIONS SUPPORT								
Synchronous	X	X	X	X	X	X	X	X
Asynchronous	X	X	X		X	X		
Parallel	X		X		X	X		
Local Coaxial	X	X	X	X	X	X	X	X
Local 20 mA	X	X	X		X	X		
Remote—								
EIA RS-232/CCITT (V.24)	X	X	X	X	X	X	X	X
EIA RS-449/422	X	X	X	X	X	X	X	
CCITT (V.35)	X	X	X	X		X	X	X
Half-Duplex	X	X	X	X	X	X	X	
Full-Duplex	X	X	X	X	X	X	X	X
Autoanswer	X	X	X	X	X	X	X	

* Phase III Systems.

1 Tributaries only.

2 Mapped, non-routing.

3 Unsupported network command terminal capabilities to RSX and VMS systems.

Internet Products Summary

Over the past several years, DIGITAL has developed a large number of Internet products to meet customer communications needs. Our Internet products emulate these protocols:

- IBM System Network Architecture: SNA
- IBM Remote Batch: 2780, 3780, HASP Workstation
- IBM Interactive: 3271

- UNIVAC Remote Batch: UN1004
- CDC Interactive/Batch: MUX200

Table 24-2 below shows which members of our Internet family are supported by PDP-11 operating systems.

Table 24-2 Internet Support by Operating Systems

	2780	3780	IBM RJE/ HASP	3271	SNA	Univac UN1004	CDC MUX200
(RSX-11S)	—	—	—	—	—	—	—
RT-11 (CTS-300)	X	X		X			
RSX-11M	X	X	X	X	X	X	X
RSX-11M-PLUS	X	X	X	X			
RSTS/E (CTS-500)	X	X		X			
IAS	X		X				X

Following are brief descriptions of these major Internet products available from DIGITAL.

SNA

The RSX-11M/SNA Protocol Emulator provides a mechanism by which a DIGITAL application program can exchange data with an application program in an IBM SNA network. (SNA is IBM's Systems Network Architecture.) The SNA Protocol Emulator appears to the IBM system to be a programmable cluster controller, supported by SNA. DIGITAL realizes that many IBM users who move to SNA would like to have the flexibility of adding other vendors to the network. To meet this need, we have developed the RSX-11M/SNA Protocol Emulator.

Features — The RSX-11M/SNA Protocol Emulator (SNA P.E.) product is the link by which a DIGITAL program exchanges data with an IBM program running in an SNA network. The DIGITAL protocol emulator allows interactive access between a program in a IBM host and a program in a DIGITAL system. Its application is functionally similar to that of the 3271 Protocol Emulator, except that its interface is to an SNA communications controller and driver.

The SNA P.E. appears to SNA to be a programmable cluster controller, a supported device. It supports up to four lines and up to 32 SNA sessions. It can coexist on a multipoint line with IBM SNA devices.

A particularly important feature is that it provides the flexibility of three levels of user interface. SNA is a layered architecture—different functions occupy separate layers.

Sample Application — Let's consider an example of an SNA Internet application. An automotive company has DIGITAL equipment in five remote warehouses and a large IBM mainframe at headquarters. SNA is implemented on the IBM mainframe. Each warehouse has a PDP-11/34 running RSX-11M to maintain local inventories. The mainframe maintains the corporate database, which includes the inventories at all five warehouses.

Suppose a customer needs a part not stocked in the local warehouse. The local parts department has the opportunity to check the corporate database, by means of the SNA P. E., to see if the part is available from one of the other warehouses. The mainframe system transmits price and delivery information to the requestor. It places an order with the warehouse which has the part and updates the master and local databases. The applications themselves are handled by user-written programs. Figure 24-6 shows this SNA example.

Product Description — As stated earlier, the RSX-11M SNA/P.E. is a product designed to allow RSX-11M systems to participate within an SNA environment. Since SNA is a layered architecture, each node in the network must be able to provide the layers required for SNA.

If a user wanted to use anything other than an IBM product, he would have to perform all of the functions of each SNA layer. This would be a major programming effort, requiring an indepth knowledge of SNA protocols and a commitment to provide ongoing support.

The SNA P.E. is designed to perform the functions of the SNA layers up to and including part of presentation services, depending on the level of support the user selects.

Three levels of support are available to the user:

EC	Emulator Control
XEC	Extended Emulator Control
AC	Application Control

Regardless of the mode selected, the IBM application program and the RSX-11M application program must cooperate. This cooperation can be achieved by designing the two applications together, or by

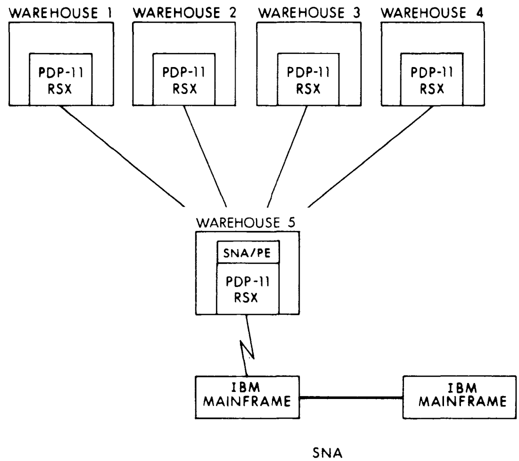


Figure 24-6 SNA Example

knowing the intricacies of one program and designing the other to cooperate. Simultaneous design is the preferred method, except for existing IBM applications, in which case it would probably be most practical to design the RSX-11M application to the IBM specification.

Emulator Control Mode (EC) requires the least involvement for the application in SNA protocols. EC session support is restricted to a subset of what IBM refers to as a "type 1 interactive session" of an IBM 3790 cluster controller. The application's responsibility is to identify the resource in the IBM SNA network with which it wishes to engage in a session, and to issue, send, and receive directives at the appropriate times. EC mode could be used to speak to a CICS application. The user is responsible for providing an application program (the end-user layer) in the IBM system and an application program covering the end-user level and some of the presentation services in the RSX-11M system.

Extended Emulator Control Mode (XEC) provides more support of SNA protocol but requires the user application to get more deeply involved with the SNA layers. XEC mode requires a greater knowledge of SNA protocol. The support provided is approximately the equivalent of the "type 2 interactive session" of an IBM 3790 cluster controller.

The user is responsible for providing an application program (end-user) in the IBM system and an application program in the RSX-11M system which must cover the end-user, presentation services, and part of the data flow control layers.

Applications Control Mode (AC) provides the application direct access to the SNA protocol (Transmission Subsystem). The AC mode is the most powerful, but it's also the most difficult to implement and requires the greatest programming effort. An application programmer making use of AC mode should be well-versed in SNA protocol.

IBM Remote Batch Protocol Emulators (2780/3780, HASP Workstation)

Three DIGITAL remote job entry (RJE) emulators are available for exchanging data with IBM systems: 2780, 3780 and HASP Workstation Protocol Emulators.

The DIGITAL products offer distinct advantages over the IBM products whose protocols they emulate. At the IBM RJE stations, storage is limited to cards for input and to printer or card-punch for output from the host. The DIGITAL Internet products, since they are integrated into base operating systems, handle all I/O through file systems. Before submitting programs, data, and commands to the host, the DIGITAL user can create and edit files on his computer facilities. Output from the mainframe to the DIGITAL system can be spooled to printer or to disk.

The 2780/3780 and HASP are the most commonly implemented communications protocols. They are excellent, low-risk, entry-level products—turnkey packages with standard IBM system software at the IBM end and a straightforward user interface at the DIGITAL end.

In addition to IBM systems, the 2780/3780 and HASP protocol emulators can be compatible with Honeywell, Data General, and other manufacturers' products. Your DIGITAL network specialist can help you determine how these Internets can fit into your communications design.

The IBM 2780/3780 is a card reader, card punch, printer, and control unit. It transmits a single data stream. The IBM operator loads a card deck with JCL (Job Control Language) headers and transmits the batch job. Our emulator makes use of our mass storage devices. We simulate a card deck with a JCL header in our file.

HASP is sometimes referred as "HASP Workstation" or "Multileaving Workstation." A real HASP Workstation is, functionally, an enhanced 2780. Besides the reader, punch, and printer, it supports a terminal with CRT and keyboard. Through the DIGITAL HASP Protocol Emulator, operators can communicate directly with the IBM mainframe from a local terminal to control and check the status of jobs on the IBM host. This capability is referred to as remote console support.

The HASP Protocol Emulator product also supports multiple I/O streams, the capability of having several devices and/or file transfers active at the same time. With this multileaving capability a short job can be interleaved while a longer job is running.

IBM Programmable Interactive Protocol Emulator (3271)
DIGITAL's 3271 Protocol Emulator provides an interactive, task-to-task link to an IBM mainframe. It provides a mechanism by which an IBM program and a DIGITAL program can communicate.

A real 3271 (3270 is the IBM series number, 3271 the controller product) is a multidrop BISYNC cluster controller with video terminals and printers. The 3271 can transmit and receive data a screenful at a time. It is often used for form-filling applications with CICS, IMS, DL1, or user-coded applications, or for general-purpose timesharing under TSO.

Our emulator appears to the IBM system as a cluster controller. To run it, you need two application programs, one for the IBM side, one for the DIGITAL side, to send and receive the data. The IBM system treats the user application program on the DIGITAL side as just another terminal connected to a control unit. The DIGITAL system can coexist with 3270 terminals in a network. IBM customers can make use of their existing terminal-support application.

The DIGITAL emulator program frames the data with appropriate characters: Start of Text, Unit Identification (Control Unit and Terminal Unit Numbers), CRCs, End Text. It segments the message into protocol-acceptable units and generally manages the line protocol as required.

The DIGITAL user application program has two responsibilities:

- To identify itself to the protocol emulator by terminal unit and control unit number. This step is also referred to as "attaching a pseudo-device."
- To send/receive data in a format acceptable to the IBM program at the other end.

Note also that, since the 3271 Protocol Emulator emulates a cluster controller, multiple DIGITAL user application programs can send/receive data simultaneously to/from the mainframe on the same physical line. The 3271 also provides multiline support.

UNIVAC Protocol Emulators(UN1004)
UN1004/RSX Capabilities — UN1004/RSX is a PDP-11 based software package that provides a means of communication with UNIVAC 1100 series mainframes. This product can be compared functionally to

the IBM 2780 protocol emulator. The 2780 protocol is symmetrical, but the UN1004 protocol allows only specific non-identical operations by each of the communicating components. In simple language, this means that while the 2780 protocol could, in principle, be used to communicate between two PDP-11s, the UN1004 could not.

The UN1004 protocol was designed by UNIVAC to provide communication between a host UNIVAC 1100 series mainframe and a remote batch terminal consisting of a keyboard, a card reader/punch, and a lineprinter. The input for UN1004/RSX can be from any valid RSX-11M-supported peripheral that will store a valid UNIVAC batch stream.

Although the UN1004/RSX emulator is a single-user product, more than one user can submit jobs to a common job queue. The resulting output from the UNIVAC host will be received in a common queue which does not contain any user identification.

Figure 24-7 illustrates a typical UN1004 configuration.

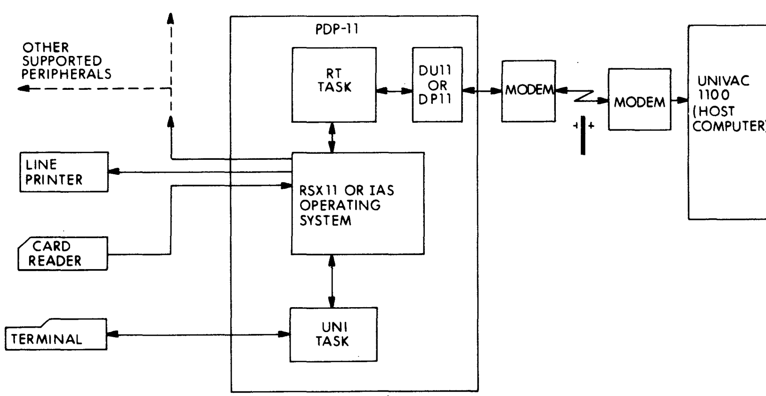


Figure 24-7 UN1004 Configuration

CDC Protocol Emulator (MUX200)

MUX200/RSX-IAS Capabilities — MUX200/RSX-IAS is a PDP-11 based software package which provides a means of communication with a CDC-6000 or CDC-CYBER series host computer. The product may be used to communicate to the host computer either interactively or in remote job entry (RJE) mode. Up to 16 terminals may be connected to the host through MUX200/RSX. However, in many cases the host software restricts this number to 12. Each of the interactive users may submit jobs to a job queue that MUX200/RSX-IAS uses to schedule transmissions to the host. Output from the host is automatically spooled to a device which has been defined by the system manager.

The protocol used is the CDC mode 4A protocol, which allows speeds up to 9600 baud. Note that the DIGITAL product is warranted for speeds up to 4800 baud.

MUX200/RSX-IAS is not a one-to-one replacement for the CDC-200UT, which uses the same protocol.

MUX200/RSX-IAS has the following features:

- Output received from the host CDC system may be spooled to a lineprinter upon detection of a text string predefined by the user.
- Up to eight RSX-IAS datasets may be specified for transmission to the host in a single command.
- RSX-IAS terminals may be detached for other use while the software package is operating. Data received from the host which are directed to the terminal are saved for printout when the terminal is reattached.
- User-written tasks can replace the RSX-IAS terminal and control the emulator as if the task were a terminal.

PUBLIC PACKET SWITCHING NETWORKS (PACKETNETS)

In the 1970's the International Telephone and Telegraph Consultative Committee—CCITT—developed a series of recommendations for standard communications protocols that could be used by the PTT's and other common carriers to provide data communications services. Known as X.25, this recommendation, developed for the public packet switching networks (PPSN's), defines the interface between the computer and the network.

The fundamental technology used in Public Packet Switched Networks (PPSN's) is called packet switching. With it, user data and control information needed to assure delivery to the correct location are formed into discrete entities—packets. The network dynamically interleaves the packets of many users over shared transmission facilities and routes packets to their destinations. Unlike conventional telephone setups, where the user is charged for both connect time and distance, regardless of the amount of data passed, charges in PPSN's are determined so that the person who uses the line the most pays the most.

DIGITAL's Implementation of the X.25 Interface

Since 1975, DIGITAL has been following the growth of packet-switched networks with great interest and has an ongoing program to provide the X.25 software on its 16-, 32-, and 36-bit computer systems.

The X.25 interface has been incorporated into DIGITAL Network Architecture so that DIGITAL-based networks can communicate over both a nationwide PPSN and a private network at the same time. No other computer manufacturer supports this type of approach to networking under multiple computer architectures and operating systems.

X.25 is rapidly becoming the standard international communications protocol, as it finds increasing adoption among users and computer manufacturers. X.25 allows computers from different manufacturers to work together: with appropriate security validation, any system on the network can send data to any other system on the network. X.25 provides dynamic routing and ensures data integrity, at the same time relieving users of any concern about input and output speeds of the various processors in the network.

Before the advent of packet-switched networks, users required leased or switched lines. These lines are generally not used very efficiently since there are long idle periods between actual data transmissions. Sending data in packets significantly improves the efficiency of the transmission lines, since, by sharing the line among many users, the amount of time the line is idle is reduced. Bandwidth is allocated allocated only when a user is actually transmitting data.

Within the near future, interfaces to PPSN's will be available in:

United States — Telenet
Canada — Datapac
France — Transpac
United Kingdom — PSS
Holland — DN1
Germany — Datex-P

As others become operational, they will be selectively supported.

APPENDIX A

DECUS

DECUS, The Digital Equipment Computer Users Society, is one of the largest and most active user groups in the computer industry. DECUS has grown into an international organization with over 60,000 members worldwide since it was founded in 1961.

DECUS membership is free—upon application—to owners of DEC computers and to their computer-interested employees. Membership carries important benefits and opportunities; among them are access to the program library; membership in local, regional, and national organizations; invitations to symposia dedicated to optimal use of DEC equipment; opportunity to present papers and workshops on your own ideas; and, finally, access to special interest groups dedicated to particular uses, languages, operating systems, and hardware configurations.

The program library maintained by DECUS contains over 1700 active software packages written and submitted by members and DIGITAL employees, and available to you for the media fee and reproduction cost only. Programs in the library range from enhanced editors and cross compilers to statistics packages and games. Of particular interest to college and university customers, for example, might be a package of programs for registration, class scheduling, dormitory management, and annual giving records. A laboratory user could take advantage of various statistical packages or programs that perform Fourier transforms or least squares fitting. There are programs for circuit analysis, resonance simulation, blood-count evaluation, and stress testing, and scores of others which medical, scientific, or engineering customers could employ. Business people can find accounting packages, case studies, and payroll programs among the library's offerings. In addition, of course, there is a wide range of data management, display graphics, and enhanced utility programs available.

Local, regional, and national DECUS organizations give members the opportunity to meet other DIGITAL customers and employees in an informal setting. From the monthly local meeting to the semi-annual national symposium, the members can discuss their ideas, can learn what others are doing, and can give DIGITAL feedback necessary in improvement and future development of important products. Often, the national meetings in the various countries also provide the stage for major new product announcements by the company, and a showplace for interesting developments in both hardware and software technology. At any meeting a member might describe ideas and programs he has implemented, or fine tuning that has been achieved for a particular application. Members give papers, participate in panel discussions, lead workshops, or conduct demonstrations for the benefit of other members.

DECUS also publishes newsletters focusing on special interests, technical books that contain the compilation of symposia presentations, and a society newsletter.

Many members derive a particular benefit from joining DECUS Special Interest Groups. Special Interest Groups often meet as subsets of regional and national meetings, or they may meet on their own, to discuss their special field. Here, for example, all RSTS/E users or everyone interested in COBOL can have a chance to get together and discuss topics of mutual importance. At present there are 22 active Special Interest Groups (SIGs) in the US alone. Many of the SIGs print newsletters and disseminate valuable technical information to members. The SIGs really are the front-line of mutual help and problem solving.

DIGITAL provides DECUS with administrative personnel and office space around the world, but the organization is run by its members, who act as speakers for conferences, planners for meeting, editorial and production talent for newsletters and minutes, and the inventors of the ideas and new programs necessary to keep the library up to date. Belonging to DECUS is a valuable adjunct to owning DIGITAL equipment on both the program exchange and the information exchange fronts.

For further information about DECUS, contact:

DECUS One Iron Way (MR2-2/E55)Marlboro, MA 01752

APPENDIX B
COMMONLY USED ABBREVIATIONS

A	Amps
A/D	Analog/Digital
ACP	Ancillary Control Processor
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
AST	Asynchronous System Trap
ATL	Active Task List
BAC	BASIC Compiled Program File
BAK	Back-up File
BAS	BASIC Source Program File
BASIC	Beginner's All-purpose Symbolic Instruction Code
BAT	Batch File
BI	Batch Input Device
BP	Batch Pseudo-Device
CAI	Computer Assisted Instruction
CBL	COBOL Source Program
CCITT	Comite Consultatif Internationale de Telegraphie et Telephonie
CIL	Core Image Library
CL	Console Log Device
CLI	Command Language Interpreter
CMD	Command File
CMI	Computer Managed Instruction
CO	Console Output Device
COB	COBOL Source Program

COBOL	Common Business Oriented Language
COMTEX	Communications Oriented Multiple Terminal Executive
CPU	Central Processing Unit
CR	Card Reader
CRC	Cyclic Redundancy Check
CREF	Cross-Reference
CRT	Cathode Ray Tube
CSECT	Control Section
CSI	Command String Interpreter
CT	Cassette Tape
CTRL	Control Key
CUSPs	Commonly-Used System Programs
DAT	Data File
DBMS	Data Base Management System
DEC	Digital Equipment Corporation
DDCMP	DIGITAL Data Communications Message Protocol
DIR	Directory File
DMP	Dump File
DMS	Data Management System
DNA	DIGITAL Network Architecture
DOS	Disk Operating System
DP	Data Processing
DPB	Directive Parameter Block
DSM	DIGITAL Standard Mumps
DSW	Directive Status Word
DT	DECtape
EAE	Extended Arithmetic Element
EDT	DIGITAL Standard Editor
EDI	Editor Utility

EDIT	Editor Utility
EIA	Electronics Industry Association
EIS	Extended Instruction Set
EMT	Emulator Trap
EOD	End of Data
EOF	End of File
EOJ	End of Job
EOL	End of Line
EOM	End of Medium
FA	Formatted ASCII
FB	Formatted Binary
F/B	Foreground/Background
FCP	File Control Primitives
FCS	File Control Services
FDB	File Data Block
FILEX	File Exchange Utility
FIS	Floating Instruction Set
FLX	File Exchange Utility
FNB	Filename Block
FOR	FORTRAN Source Program
FORTRAN	Formula Translator
FPP	Floating Point Processor
FSR	File Storage Region
FTN	FORTRAN Source Program
F4P	FORTRAN IV-PLUS Source Program
G	Giga (one billion)
GT	Graphics Terminal
HASP	Houston Automatic Spooling Program
Hz	Hertz
IAS	Interactive Application System

ID	Identification Code
I/O	Input/Output
IOT	Input/Output Trap
IOX	I/O Executive
ISR	Interrupt Service Routine
JMP	Jump
JSR	Jump to Subroutine
K	1024 decimal (from "kilo")
KB	Keyboard
KBL	Keyboard Listener
KCT	Kilo-Core Tick
LBR	Librarian
LDA	Load Module
LED	Light Emitting Diode
LIB	Library File
LIBR	Librarian
LICIL	Linked Core Image Library
LIS	Listing File
LP	Line Printer
LST	Listing File
LUN	Logical Unit Number
μ	micro (mu — one millionth)
m	milli (one thousandth), or meters
M	mega (one million)
MAC	MACRO Source Program
MAP	Load Map
MCR	Monitor Console Routine
MFD	Master File Directory
MO	Message Output Device
MST	Macro Symbol Table

MT	Magnetic Tape
MTBF	Mean Time Between Failures
n	nano (one billionth)
NCP	Network Control Processor
NPR	Nonprocessor Request
OBJ	Object Module
ODL	Overlay Description Language
ODT	On-line Debugging Technique
OEM	Original Equipment Manufacturer
OTL	On-line Task Loader
OTS	Object Time System
PC	Program Counter
PDF	Processor-Defined Function
PDS	Program Development System
PDP	Programmed Data Processor
PIC	Position Independent Code
PIP	Peripheral Interchange Program
PP	Paper Tape Punch
PR	Paper Tape Reader
PSECT	Program Section
PST	Permanent Symbol Table
PTT	Post, Telegraph, and Telephone Administration
PUD	Physical Unit Directory
QIO	Queue I/O
ROM	Read-only Memory
RSTS/E	Resource-sharing Timesharing System/Extended
RSX-11	Real-time Resource Sharing Executive
RT-11	Real-time Foreground/Background System
RTS	Run Time System
RWED	Read, Write, Extend and Delete

SAV	Saved File or System Image File
SCI	System Control Interface
SCOM	System Communication Area
SGA	Shareable Global Area
SIP	System Image Preservation
SIPP	Save Image Patch Program
SP	Stack Pointer
SPC	Small Peripheral Controller
SPR	Software Performance Report
SST	Synchronous System Trap
SY	System Device
SYS	System File
SYSGEN	System Generation
TCP	Timesharing Control Primitives
TI	Terminal Interface
TKB	Task Builder
TKTN	Task Termination Notice
TMP	Temporary File
TSK	Task Image File
TT	Terminal Device
TTY	Terminal Device
UA	Unformatted ASCII
UB	Unformatted Binary
UFD	User File Directory
UIC	User Identification Code
USR	User Service Routine
UST	User Symbol Table
V	Volts
VDT	Video Display Terminal
VT50	DECscope Video Display Terminal

VT52	Table Top Alphanumeric Video Display Terminal
VT100	High-performance Video Terminal
XOR	Exclusive OR

APPENDIX C
ASCII CODES

CONTROL CHARACTERS

CHAR	OCTAL	BINARY
NUL	000	0000000
SOH	001	0000001
STX	002	0000010
ETX	003	0000011
EOT	004	0000100
ENQ	005	0000101
ACK	006	0000110
BEL	007	0000111
BS	010	0001000
HT	011	0001001
LF	012	0001010
VT	013	0001011
FF	014	0001100
CR	015	0001101
SO	016	0001110
SI	017	0001111
DLE	020	0010000
DC1	021	0010001
DC2	022	0010010
DC3	023	0010011
DC4	024	0010100
NAK	025	0010101
SYN	026	0010110
ETB	027	0010111
CAN	030	0011000
EM	031	0011001
SUB	032	0011010
ESC	033	0011011
FS	034	0011100
GS	035	0011101
RS	036	0011110
US	037	0011111
DEL	177	1111111

CONTROL CHARACTER KEY

NUL = All zeros
SOH = Start of heading
STX = Start of text
ETX = End of text
EOT = End of transmission
ENQ = Enquiry
ACK = Acknowledgement
BEL = Bell or attention signal
BS = Back space
HT = Horizontal tabulation
LF = Line feed
VT = Vertical tabulation
FF = Form Feed
CR = Carriage return
SO = Shift out
SI = Shift in
DLE = Data link escape
DC 1 = Device control 1
DC 2 = Device control 2
DC 3 = Device control 3
DC 4 = Device control 4
NAK = Negative acknowledgement
SYN = Synchronous/idle
ETB = End of transmitted block
CAN = Cancel (error in data)
EM = End of medium
SUB = Start of special sequence
ESC = Escape
FS = Information file separator
GS = Information group separator
RS = Information record separator
US = Information unit separator
DEL = Delete

PRINTABLE CHARACTERS

CHAR	OCTAL	BINARY
SP	040	0100000
!	041	0100001
"	042	0100010
#	043	0100011
$	044	0100100
%	045	0100101
&	046	0100110
'	047	0100111
(	050	0101000
)	051	0101001
*	052	0101010
+	053	0101011
,	054	0101100
-	055	0101101
.	056	0101110
/	057	0101111
0	060	0110000
1	061	0110001
2	062	0110010
3	063	0110011
4	064	0110100
5	065	0110101
6	066	0110110
7	067	0110111
8	070	0111000
9	071	0111001
:	072	0111010
;	073	0111011
<	074	0111100
=	075	0111101
>	076	0111110
?	077	0111111
@	100	1000000

PRINTABLE CHARACTERS

CHAR	OCTAL	BINARY
A	101	1000001
B	102	1000010
C	103	1000011
D	104	1000100
E	105	1000101
F	106	1000110
G	107	1000111
H	110	1001000
I	111	1001001
J	112	1001010
K	113	1001011
L	114	1001100
M	115	1001101
N	116	1001110
O	117	1001111
P	120	1010000
Q	121	1010001
R	122	1010010
S	123	1010011
T	124	1010100
U	125	1010101
V	126	1010110
W	127	1010111
X	130	1011000
Y	131	1011001
Z	132	1011010

PRINTABLE CHARACTERS

CHAR	OCTAL	BINARY
a	141	1100001
b	142	1100010
c	143	1100011
d	144	1100100
e	145	1100101
f	146	1100110
g	147	1100111
h	150	1101000
i	151	1101001
j	152	1101010
k	153	1101011
l	154	1101100
m	155	1101101
n	156	1101110
o	157	1101111
p	160	1110000
q	161	1110001
r	162	1110010
s	163	1110011
t	164	1110100
u	165	1110101
v	166	1110110
w	167	1110111
x	170	1111000
y	171	1111001
z	172	1111010

GLOSSARY

absolute address A binary number that is assigned as the address of a physical memory storage location.

absolute loader A stand-alone program which, when in memory, enables the user to load into memory data in absolute binary format.

access privileges Attributes of a file which specify the class of users allowed to access the file.

account number A discrete code used to identify a system user. It normally consists of two numbers, separated by a comma, called the project number and programmer number or the group number and member number. See also *user identification code*.

active task list A priority-ordered list of active tasks used normally in an event-driven multiprogrammed system to determine the order in which tasks receive control of the CPU.

address 1. A name, label, or number which identifies a register, a location in storage, or any other data source or destination.
2. The part of an instruction that specifies the location of an operand of that instruction.

adjacent node A node removed from the local node by a single physical line.

algorithm A prescribed set of well-defined rules or processes for the solution of a problem; a program.

alphanumeric Referring either to the entire set of 128 ASCII characters or the subset of ASCII characters which includes the 26 alphabetic characters and the ten numeric characters.

ancillary peripherals In the DSM-11 system, peripherals not under control of the data base supervisor.

ANSI American National Standards Institute.

append To add information to the end of an existing file.

application program A program that performs a task for a particular end-user's needs. Generally, an application program is any program written on a program development operating system that is not part of the basic operating system.

argument 1. A variable or constant which is given in the call of a subroutine as information to it.

2. A variable upon whose value the value of a function or other operation depends.
3. The known reference factor necessary to find an item in a table or array (i.e., the index).

array An ordered arrangement of subscripted variables.

ASCII The American Standard Code for Information Interchange, consisting of 128 7-bit binary codes for upper and lower case letters, numbers, punctuation, and special communication control characters.

assemble To translate from a symbolic program to a binary program by substituting binary operation codes for symbolic operation codes and absolute or relocatable codes and absolute or relocatable addresses for symbolic addresses.

assembler A program that translates symbolic source code ("assembly level language") into machine instructions by replacing symbolic operation codes with binary operation codes and symbolic addresses with absolute or relocatable addresses.

assembler directives The mnemonics used in an assembly language source program that are recognized by the assembler as commands to control and direct the assembly process.

assembly language A symbolic programming language that can normally be translated directly into machine language instructions and is, therefore, specific to a given computing system.

assembly listing A listing produced by an assembler that shows the symbolic code written by a programmer next to a representation of the actual machine instructions generated.

assigning a device Putting an I/O device under control of a particular user's job either for the duration of the job or until the user relinquishes control. See also *attach*.

asynchronous A mode of operation in which an operation is started by a signal that the operation on which it depends is completed. When referring to hardware devices, it is the method in which each character is sent with its own synchronizing information. The hardware operations are scheduled by ready and done signals rather than by time intervals. In addition, it implies that a second operation can begin before the first operation is completed.

asynchronous system trap A system condition which occurs as the result of an external event such as completion of an I/O request. On occurrence of the significant event, control passes to an AST service routine.

asynchronous transmission Time intervals between transmitted characters may be of unequal length. Transmission is controlled by start and stop elements at the beginning and end of each character. Also called Start-Stop transmission.

attach To dedicate a physical device unit for exclusive use by the task requesting attachment. See also *assigning a device*.

background processing The automatic execution of a low priority computer program when higher priority programs are not using the system resources.

backup file A copy of a file created for protection in case the primary file is unintentionally destroyed.

bad block A defective block on a storage medium that produces a hardware error when attempting to read or write data in that block.

base address An address used as the basis for computing the value of some other relative address.

base segment The always-memory-resident portion of a program that uses overlays. See also *root segment*.

batch processing A method of scheduling programs in which programs are accumulated and fed to the computer for execution with no programmer interaction.

batch stream The collection of commands and data interpreted by a batch processor that directs batch processing.

baud 1. A unit of signalling speed equal to the number of signal events per second.
2. For asynchronous transmissions, the unit of modulation rate corresponding to one unit interval per second. If, for example, the length of the unit's interval is 25 milliseconds, the modulation rate is 40 baud. Baud is frequently, though erroneously, used as a synonym for bits per second.

binary The number system with a radix of two.

binary code A code that uses two distinct characters, usually the numbers 0 and 1.

binary loader See *absolute loader*.

bit A binary digit.

bit map A table describing the state of each member of a related set. A bit map is most often used to describe the allocation of storage space. Each bit in the table indicates whether a particular block in the storage medium is occupied or free.

block 1. A group of specified size of physically adjacent words or bytes. A block size is particular to a device.
2. The smallest system-addressable segment on a mass-storage device in reference to I/O.

Boolean valued expression An expression which, when evaluated, produces either "true" or "false" as a result.

bootstrap 1. A technique or device designed to bring itself into a desired state by its own action.
2. To cause an operating system to load itself and prepare to run.

bootstrap loader A routine whose first instructions are sufficient to load the remainder of itself into memory from an input device and normally start a complex system of programs.

bottom address The lowest memory address in which a program is loaded.

bps Bits per second. A commonly used measure for data transfer rate. (Other notations are bit, b.p.s., bit/sec, etc.)

breakpoint A location at which program operation is suspended in order to examine partial results. A preset point in a program where control passes to a debugging routine.

buffer A storage area used to temporarily hold information being transferred between two devices or between a device and memory. A buffer is often a special register or a designated area of memory.

bug An instruction or sequence of instructions in a program that causes unexpected and undesired results.

bus One or more conductors used for transmitting signals or power from one or more sources to one or more destinations, but usually with many connections.

byte The smallest memory-addressable unit of information in a PDP-11 system. A byte is equivalent to eight bits.

call To transfer control to a specified routine.

calling sequence A specified arrangement of instructions and data necessary to pass parameters and control to a given subroutine.

carriage return key The key on a terminal keyboard most often used in PDP-11 systems to terminate input lines.

CCITT Comittee Consultatif Internationale Telegraphie et Telephonie, a committee which sets international communications standards.

Central Processing Unit (CPU) or **Central Processor** That part of a computing system containing the arithmetic and logical units, instruction control unit, timing generators, and memory and I/O interfaces.

character A single letter, numeral, or symbol used to represent information.

checkpoint A point in a program or routine at which job and system status are recorded, so that the job can later be restarted.

checksum A number used for checking the validity of data transfers.

clear 1. To erase the contents of a storage location by replacing the contents with zeros or spaces.
2. In binary code, to set to zero.

clock A time-keeping or frequency-measuring device within a computing system.

code A system of symbols and rules used for representing information.

coding Writing instructions for a computer using symbols meaningful to the computer itself, or to an assember, compiler, or other language processor.

collate To combine items from two or more ordered sets into one set having an order not necessarily the same as any of the original sets.

command or **command name** A word, mnemonic, or character which, by virtue of its syntax in a line of input, causes a predefined operation to be performed by a computer system.

command language The vocabulary used by a program or set of programs that directs the computer system to perform predefined operations.

Command Language Interpreter The program that translates a predefined set of commands into instructions that a computer system can interpret.

command string A line of input to a computer system that generally includes a command, one or more file specifications, and optional qualifiers.

Command String Interpreter A special program or routine that accepts a line of ASCII string input and interprets the string as input and output file specifications with recognized qualifiers.

common A section in memory which is set aside for common use by many separate programs or modules.

compatibility The ability of an instruction, source language, or peripheral device to be used on more than one computer.

compile To translate a source (symbolic) program into a binary-coded program. In addition to translating the source language, appropriate subroutines may be selected from a subroutine library. Linkage is supplied, and everything is output in binary code along with the main program.

compiler A program which translates a higher level source language into a language suitable for a particular machine.

completion routine A routine that is called at the completion of an operation.

compute bound A state of program execution in which all operations are dependent on the activity of the central processor, for example, when a large number of calculations is being performed. Contrast with *I/O bound*.

computer operator A person who performs standard system operations such as adjusting system operation parameters at the system console, loading a tape transport, placing cards in a card reader, and removing listings from the line printer.

concatenate To combine several files into one file, or several strings of characters into one string, by appending each file or string one after the other.

conditional assembly The assembly of parts of a symbolic program only when certain conditions are met.

configuration A particular selection of hardware devices or software routines or programs that function together.

consecutive access The method of data access characterized by the sequential nature of the I/O device involved. For example, a card reader is an example of a consecutive access device. Each card must be read after the preceding one, and no distinction is made between logical sets of data in or among the cards in the input hopper.

console The console of a central processor is the set of switches and display lights used by an operator or programmer to determine the status and control the operation of the computer.

console terminal A keyboard terminal which acts as the primary interface between the computer operator and the computer system and is used to initiate and direct overall system operation through software running on the computer.

constant A value which remains the same throughout a distinct operation. Compare with *variable*.

context switching The switching between one mode of execution and other, involving the saving of key registers and other memory areas prior to switching between jobs, and restoring them when switching back. A common example of context switching is the temporary suspension of a user program so that the monitor or executive can execute an operation.

contiguous file A file consisting of physically adjacent blocks on a mass-storage device.

control character A character whose purpose is to control an action rather than to pass data to a program. An ASCII control character has an octal code between 0 and 37. It is typed by holding down the CTRL key on a terminal keyboard while striking a character key.

control section A named, contiguous unit of code (instructions or data) that is considered an entity and that can be relocated separately without destroying the logic of the program.

core memory The most common form of main memory storage used by the central processing unit, in which binary data are represented by the switching polarity of magnetic cores.

core common See *common*.

crash A hardware crash is the complete failure of a particular device, sometimes affecting the operation of an entire computer system. A software crash is the complete failure of an operating system characterized by some failure in the system's protection mechanisms.

create To open, write data to, and close a file for the first time.

cross reference listing or table A printed listing that identifies all references in a program to each specific label in a program. A list of all or a subset of symbols used in a source program and statements where they are defined or used.

CTRL/C (↑C) The control character issued from a terminal which is most commonly used to return the operator to communication with the system-level program. In most PDP-11 systems, it is typed on the terminal keyboard to gain the attention of the operating system before commencing the login procedure, or to terminate the currently executing program and return to communication with the monitor. In some cases, it simply issues a call to the console listener or console service routine without interrupting current program execution.

CTRL/U (↑U) The control character issued from a terminal that tells the program currently accepting input to ignore the characters entered on the line up to the point where CTRL/U was typed.

CTRL/Z (↑Z) The control character used in RSX-11 systems to terminate the system program currently waiting for input from the terminal. It is essentially an end-of-file character.

data base A collection of interrelated data items organized by a consistent scheme that allows one or more applications to process the items without regard to physical storage locations.

data base management system A scheme used to create, maintain, and reference a data base.

debug To detect, locate, and correct coding or logic errors in a computer program.

DECnet A family of hardware/software products that create distributed networks from DIGITAL computers and their interconnecting data links.

DECtape A convenient, pocket-sized reel of magnetic tape developed by DIGITAL for extremely reliable data storage and random access.

default The value of an argument, operand, or field assumed by a program if a specific assignment is not supplied by the user.

delimiter A character that separates, terminates, or organizes elements of a character string, statement, or program.

detach a device Free an attached physical device unit for use by tasks other than the one that attached it.

device A hardware unit such as an I/O peripheral, e.g., magnetic tape drive or card reader. Also often used synonymously with volume.

device controller A hardware unit which electronically supervises one or more of the same type of devices. It acts as the link between the CPU and the I/O devices.

device driver A program that controls the physical hardware activities on a peripheral device. The device driver is generally the device-dependent interface between a device and the common, device-independent I/O code in an operating system.

device handler A program that drives or services an I/O device. A device handler is similar to a device driver, but provides more control and interfacing functions than a device driver.

device independence The ability to request I/O operations without regard for the characteristics of specific types of I/O devices.

device name A unique name that identifies each device unit on a system. It usually consists of a 2-character device mnemonic followed by an optional device unit number and a colon. For example, the common device name for DECtape drive unit one is "DT1:".

device unit One of a set of similar peripheral devices; e.g., disk unit 0, DECtape unit 1. Also used synonymously with *volume*.

diagnostic Pertaining to the detection and isolation of malfunctions or mistakes.

dial-up line A communications circuit that is established by a switched circuit connection.

DIGITAL Network Architecture (DNA) The common network architecture of DECnet.

digital transmission Transmission of data characters which are coded into discrete separate pulses or signal levels.

direct access See *random access*.

direct mode The mode of DSM-11 system operation which enables the programmer to enter commands and or functions for immediate execution, and to create or modify steps of a user's program.

directive A type of executive request issued by a program that provides a facility inherent in the hardware which is controlled and organized by the operating system. See also *programmed request*.

directory A table that contains the names of and pointers to files on a mass-storage device.

directory device A mass-storage retrieval device, such as disk or DECtape, that contains a directory of the files stored on the device.

disk 1. A mass storage device. Basic unit is an electromagnetic platter on which data are magnetically recorded. Features random access and faster access time than magnetic tape.
2. The platter itself.

double-buffered I/O An input or output operation which uses two buffers to transfer data. While one buffer is being used by the program, the other buffer is being read from or written to by an I/O device.

down-line load The process by which one node in a computer network transfers an entire system image or a program (task) image to another node and causes it to be executed.

dump To copy the contents of all or part of core memory, usually onto an external storage medium. Also, the copy so produced.

echo The printing by an I/O device, such as teletype or CRT, of characters typed by the programmer.

editor A program which interacts with the programmer to enter new programs into the computer and edit them as well as modify existing programs. Editors are language-independent and will edit anything in alphanumeric representation.

emulator A hardware device that permits a program written for a specific computer to be run on a different type of computer system.

executive The controlling program or set of routines in an operating system. The executive coordinates all activities in the system including I/O supervision, resource allocation, program execution, and operator communication. See also *monitor*.

executive mode A central processor mode characterized by the lack of memory protection and relocation by the normal execution of all defined instruction codes.

exponentiation A mathematical operation denoting increases in the base number by a factor previously selected.

expression A combination of operands and operators which can be evaluated by a computing system.

external storage A storage medium other than main memory, for example, paper tape, magnetic tape, or disks.

field 1. One or more characters treated as a unit.
2. A specified area of a record used for a single type of data.

file A logical collection of data treated as a unit. It occupies one or more blocks on a mass-storage device such as disk, DECtape, or magtape. A file can be referenced by a logical name.

file gap A fixed length of blank tape separating files on a magnetic tape volume.

file name The alphanumeric character string assigned by a user to identify a file, and which can be read by both an operating system and a user. A file name identifies a unique member of a group of files which: 1) has the same file name extension and version number (if any), 2) is located on the same volume, and 3) belongs in the same User File Directory (if any). A file name has a fixed maximum length which is system dependent (generally six or nine characters).

file specification A name that uniquely identifies a file maintained in any operating system. A file specification generally consists of at least three components: a device name identifying the volume on which the file is stored, a file name, and a file type. In addition, depending on the system, a file specification can include a User File Directory name or UIC, and a version number.

file structure A method of recording and cataloging files on mass-storage media.

file-structured device A device on which data are organized into files. The device usually contains a directory of the files stored on the device.

file type The alphanumeric character string assigned to a file either by an operating system or a user, and which can be read by both the operating system and the user. System-recognizable file types are used to identify files having the same format or type (e.g., FORTRAN source files might have the file type .FOR in its file specification). A file type follows the file name and is separated from it by a period. A file name extension has a fixed maximum length which is system dependent (generally three characters, excluding the preceding period).

flag A variable or register used to record the status of a program or device. In the latter case it is sometimes called a device flag.

floating point numeric A floating point number which, if stored in four words, is approximately in the range 10^{-38} to 10^{38}.

foreground 1. The area in memory designated for use by a high-priority program.
2. The program, set of programs, or functions that gain the use of machine facilities immediately upon request.

format The arrangement of the elements constituting any field, record, file, or volume.

formatted ASCII Refers to a mode in which data are transferred. A file containing formatted ASCII data is generally transferred as strings of 7-bit ASCII characters (bit eight is zero) terminated by a line feed, form feed or vertical tab. Special characters, such as NULL, RUBOUT, and TAB may be interpreted specially.

formatted binary Refers to a mode in which data are transferred. Formatted binary is used to transfer checksummed binary data (8-bit characters) in blocks. Formatting characters are start-of-block indicators, byte count, and checksum values.

formatted device A volume which has been prepared for use on a system under program control.

frame That part of the packet carrying data required by the link control protocol and defining the leading and trailing ends of the bit stream.

full-duplex The line can transmit data in both directions simultaneously. A full-duplex line allows a node to send and receive data at the same time.

fully connected network A network in which each node is directly connected with every other node.

function An algorithm accessible by name and contained in the system software. It performs commonly-used operations, such as the square root calculation function.

generation number See *version number.*

global A value defined in one program module and used in others. Globals are often referred to as entry points in the module in which they are defined, and externals in the other modules which use them. Also, in the DSM-11 system, a global array.

global array A data file stored in the common DSM-11 data base. Global arrays constitute an external system of symbolically referenced arrays.

global variable A global variable in the DSM-11 system is a subscripted variable which forms a part (or node) of a global array.

half-duplex The line can transmit data in either direction, but only in one direction at any given time. In other words, the line cannot be used to send and receive data simultaneously.

handler See *device handler.*

hard copy A printed copy on some kind of paper, generally in readable form, such as listings and other documents.

hardware The physical equipment components of a computer system.

HASP Houston Automatic Spooling Program. An IBM 360/370 OS software front-end which performs job spooling and controls communications between local and remote processors and Remote Job Entry (RJE) stations.

higher level language A programming language whose statements are translated into more than one machine language instruction. Examples are BASIC, FORTRAN, and COBOL.

host A computer connected to a network and implementing its protocols in such a way that its computing power is accessible through the network.

host node A node that provide services for another node. For example, the host node supplies program image files for a down-line load.

idle time That part of uptime in which no job could run because all jobs are halted or waiting for some external action such as I/O.

image mode Refers to a mode of data transfer in which each byte of data is transferred without any interpretation or data changes.

impure code The code which is modified during the course of a program's execution, e.g., data tables.

incremental compiler A compiler that immediately translates each source statement into an internal format, ready for execution.

indirect file or **indirect command file** A file containing commands that are processed sequentially, yet which could have been entered interactively at a terminal.

indirect mode The mode of DSM-11 system operation in which steps of a stored program can be executed. In this mode, neither commands nor functions can be entered at the terminal, nor can programs be created or modified.

indirect reference A feature of the MUMPS language which permits the symbolic representation of an argument or argument list in a command by a string variable. In operation, the string value of the variable is taken as the argument or argument list for the command. The indirection symbol, a back-arrow ← or underscore (_), must precede the variable reference.

initialize To set counters, switches, or addresses to starting values at prescribed points in the execution of a program, particularly in preparation for re-execution of a sequence of code. To format a volume in a particular file-structured format in preparation for use by an operating system.

input 1. Data to be processed.
2. The process of transferring data to memory from a mass storage device or from other peripheral devices which read data from other media.

instruction One unit of machine language, usually corresponding to one line of assembly language, which tells the computer what elementary operation to do next.

interactive A technique of user/system communication in which the operating system immediately acknowledges and acts upon requests entered by the user at a terminal. Compare with *batch*.

interface A shared boundary, for example, the wires and perhaps other electronics connecting two subsystems.

Internet A network linking DIGITAL computers to non-DIGITAL computers.

interpreter A computer program that translates and executes each source language statement before translating and executing the next statement.

interrupt A signal which, when activated, causes a transfer of control to a specific location in memory, thereby breaking the normal flow of control of the routine being executed. An interrupt is normally caused by an external event such as a done condition in a peripheral. It is distinguished from a trap which is caused by the execution of a processor instruction.

interrupt service routine The routine entered when an external interrupt occurs.

interrupt vector address A unique address which points to two consecutive memory locations containing the start address of the interrupt service routine and priority at which the interrupt is to be serviced.

I/O bound A state of program execution in which all operations are dependent on the activity of an I/O device. For example, when a program is waiting for input from a terminal. Compare *compute bound*.

I/O page That portion of memory in which specific storage locations are associated directly with I/O devices.

I/O rundown A process which delays the availability of a partition until all transfers to and from that partition have been stopped or have been allowed to complete. I/O rundown is invoked when a task is terminated and has outstanding transfers pending to or from its partition.

job A group of data and control statements which does a unit of work, e.g., a program and all its related subroutines, data and control statements; also, a batch control file.

journaling The parallel writing of updated records to a second medium in addition to the original file.

K 1. An abbreviation for the prefix kilo, i.e., 1000 in decimal notation.
2. In the computer field, two to the tenth power, which is 1024 in decimal notation. Hence, a 4K memory has 4096 words.

keyboard monitor A program that provides and supervises communication between the user at the system console and an operating system.

latency 1. The time from initiation of a transfer operation to the beginning of actual transfer; i.e., verification plus search time.
2. The delay while waiting for a rotating memory to reach a given location.

leader A blank section of tape at the beginning of a reel of magnetic tape or at the beginning of paper tape.

leased-line A line reserved for the exclusive use of a leasing customer without interchange switching arrangements. Also called a private line.

library 1. A file containing one or more relocatable binary modules which are routines that can be incorporated into other programs.
2. A class of MUMPS programs listed in the system program directory and available to all users of the system.

line 1. A string of characters terminated with a vertical tab, form feed, or line feed.
2. The network management component that provides a distinct physical data path.

linked file A file whose blocks are joined together by references (a link word or pointer imbedded in the block) rather than consecutive location.

linker A program that combines many relocatable object modules into an executable program module. It satisfies global references and combines control sections.

linking loader A program that provides automatic loading, relocation, and linking of compiler and assembler generated object modules.

listing The hard copy generated by a lineprinter.

literal An element of a programming language which permits the explicit representation of character strings in expressions and command and function elements. In most languages, a literal is enclosed in either single or double quotes to denote that the enclosed string is to be taken "literally" and not evaluated.

load 1. To store a program or data into memory.
2. To mount a tape on a device such that the read point is at the beginning of the tape.
3. To place a removable disk in a disk drive and start the drive.

load image file A program that can be executed in a stand-alone environment without the aid of relocation.

load map A table produced by a linker that provides information about a load module's characteristics, e.g., the transfer address and the low and high limits of the relocatable code.

load module A program in a format ready for loading and executing.

local node A frame of reference; the node at which the user is physically located.

local variable In the DSM-11 system, a local variable is a variable which is stored only in the partition in which a program is executed (as opposed to a global variable).

location An address in storage or memory where a unit of data or an instruction can be stored.

log in To identify oneself to an operating system as a legitimate user of the system and gain access to its services.

log out or **log off** To sign off a system.

logical block An arbitrarily defined, fixed number of contiguous bytes which is used as the standard I/O transfer unit throughout an operating system. For example, the commonly-used logical block in PDP-11 systems is 512 bytes long. An I/O device is treated as if its block length is 512 bytes, although the device may have an actual (physical) block length which is not 512 bytes. Logical blocks on a device are numbered from block 0 consecutively up to the last block on the volume. A logical block is synonymous with a physical block on any device that has 512-byte physical blocks. See also *virtual block*, *physical block*, *logical record*, and *physical record*.

logical device name An alphanumeric name assigned by the user to represent a physical device. The name can then be used synonymously with the physical device name in all references to the device. Logical device names are used in device-independent systems to enable a program to refer to a logical device name which can be assigned to a physical device at run time.

logical link A carrier of a single stream of full-duplex traffic between two user-level processes.

logical record A logical unit of data within a file whose length is defined by the user and whose contents have significance to the user. A group of related fields treated as a unit.

logical unit number A number associated with a physical device unit during a task's I/O operations. Each task in the system can establish its own correspondence between logical unit numbers and physical device units.

machine language The language, peculiar to each kind of computer, that that computer understands. It is a binary code which contains an operation code to tell the computer what to do, and an address to tell the computer on which data to perform the operation.

macro Directions for expanding abbreviated text. A boilerplate that generates a known set of instructions, data or symbols. A macro is used to eliminate the need to write a set of instructions which are used repeatedly. For example, an assembly language macro instruction enables the programmer to request the assembler to generate a predefined set of machine instructions.

main memory The set of storage locations connected directly to the Central Processing Unit. Also called (generically) core memory.

main program The module of a program that contains the instructions at which program execution begins. Normally, the main program exercises primary control over the operations performed and calls subroutines or subprograms to perform specific functions.

mapped system A system which uses the hardware memory management unit to relocate virtual memory addresses.

mass storage Pertaining to a device which can store large amounts of data readily accessible to the Central Processing Unit; for example, disk, DECtape, magnetic tape, etc.

master file directory The system-maintained file on a volume that contains the names and addresses of all the files stored on the volume.

matrix A rectangular array of elements. A table can be considered a matrix.

memory Any form of data storage, including main memory and mass storage, in which data can be read and written. In the strict sense, memory refers to main memory.

memory image A replication of the contents of a portion of memory.

memory mapping A mode of computer operation in which the high-order bits of a virtual address are replaced by an alternate value, providing dynamic relocatability of programs.

memory protection A scheme for preventing read and/or write access to certain areas of memory.

modulo A mathematical operation that yields the remainder function of division. Thus 39 modulo 6 equals 3.

monitor The master control program that observes, supervises, controls, or verifies the operation of a computer system. The collection of routines that controls the operation of user and system programs, schedules operations, allocates resources, performs I/O, etc.

monitor command An instruction issued directly to a monitor from a user.

monitor console The system control terminal.

Monitor Console Routine (MCR) The executive routine that allows the user to communicate with the system using an on-line terminal device. MCR accepts and interprets commands typed on the terminal keyboard and calls appropriate routines to execute the specified requests.

mount a device or volume To associate a physical mass storage media logically with a physical device unit. To place a volume on a physical mass storage drive unit; for example, place a DECtape on a DECtape drive and put the drive on-line.

multiplexing Use of one communications line circuit for two or more simultaneous data paths.

multipoint A communication line (circuit) with three or more communicating devices on it (terminals or computers). Use of this type of line normally requires a polling technique with an address for each device. Also called multidrop.

multiprocessing Simultaneous execution of two or more programs by two or more processors.

multiprogramming A processing method in which more than one task is in an executable state at any one time.

naked syntax A feature of the MUMPS language, providing an abbreviated method for accessing global variables, which controls the disk access time. The node reference includes only subscript(s) for the element; the global variable name is assumed from the last global reference in which a name was explicitly stated.

network A configuration of two or more computers linked to share information and resources. A computer having the capacity to participate in a network is called a node.

node 1. A dynamically allocated set of bytes from a node pool used for system communication and control in an RSX-11/IAS system.
2. An element of a global array in a DSM-11 system (also called a global variable).
3. A network management component consisting of a system that supports network software.

noncontiguous file A file whose blocks are not physically contiguous on the volume.

non-file-structured device A device, such as paper tape, lineprinter or terminal, in which data are not referenced as a file.

nonrouting (end) node A nonrouting node can send packets to other nodes in the network, but it cannot forward packets or route them through itself. It can be adjacent to one other node only; therefore, it is always an end node in a Phase III configuration.

null modem A device which interfaces between a local peripheral that normally requires a modem, and the computer near it that expects to drive a modem to interface to that device; an imitation modem in both directions.

object code Relocatable machine language code.

object module The primary output of an assembler or compiler; it can be linked with other object modules and loaded into memory as a runnable program. The object module is composed of the relocatable machine language code, relocation information, and the corresponding symbol table defining the use of symbols within the module.

object program The relocatable binary program which is the output of a compiler or assembler.

Object Time System The collection of modules that is called by compiled code in order to perform various utility or supervisory operations. For example, an Object Time System usually includes I/O and trap handling routines.

octal Pertaining to the base eight number system.

off-line Pertaining to equipment or devices not under direct control of the Central Processing Unit.

offset The difference between a base location and the location of an element related to the base location. The number of locations relative to the base of an array, string or block.

on-line Pertaining to equipment or devices directly connected and under control of the Central Processing Unit.

operating system The collection of programs, including a monitor or executive and system programs, that organizes a central processor and peripheral devices into a working unit for the development and execution of application programs.

output 1. The results of processing data.
2. The process of transferring data from memory to a mass storage device or from memory to a copying device such as a lineprinter or paper tape punch.
3. The process of moving information from a mass storage device to a copying device.
4. The peripheral device receiving the information described above.

overlay description language The set of instructions interpreted by a linker that defines the overlay structure of a task.

overlay segment A section of code treated as a unit which can overlay code already in memory and be overlaid by other overlay segments.

overlay structure A task overlay system consisting of a root segment and optionally one or more overlay segments.

p-section (program section) A section of memory that is a unit of the total task allocation. A source program is translated into object modules that consist of p-sections with attributes describing access, allocation, relocatability, etc.

pack 1. To compress data in storage by using an algorithm for its storage and retrieval.
2. A removable disk.

packet The unit of data switched through a Packet Switching Service, normally a user data field accompanied by a header carrying destination and other information and enclosed in a frame, possibly shared with other packets.

packet switching A data transmission process utilizing addressed packets, whereby a channel is occupied only for the duration of transmission of the packet.

parity bit A binary digit appended to a group of bits to make the sum of all the bits always odd (odd parity) or always even (even parity). Used to verify data storage.

parse To break a command string into its elemental components for the purpose of interpretation.

part number In the MUMPS language, the integer portion of a program step which is used to refer collectively to all steps having a common integer base.

partition A contiguous area of memory within which tasks are loaded and executed.

patch To modify a program by changing the binary code rather than the source code.

peripheral Any device distinct from the central processor which can provide input to or accept output from the computer.

Phase II node A node which runs a Phase II implementation of DECnet and, therefore, does not support routing. It can send packets only to adjacent nodes and it cannot forward packets it receives on to other nodes in the network. It can be adjacent to one or more full-routing nodes and/or to other Phase II nodes. Logically, it is an end node within a Phase III configuration.

Phase III node A node which runs under a Phase III implementation of DECnet and supports routing as either a full-routing or nonrouting (end) node. See also *routing node*.

physical address space The set of memory locations where information can actually be stored for program execution. Virtual memory addresses can be mapped, relocated, or translated to produce a final memory address which is sent to hardware memory units. The final memory address is the physical address.

physical block A physical record on a mass storage device.

physical device An I/O or peripheral storage device connected to or associated with a central processor.

physical record The largest unit of data that the read/write hardware of an I/O device can transmit or receive in a single I/O operation. The length of a physical record is device dependent. For example, a punched card can be considered the physical record for a card reader; it is 80 bytes long. The physical record for an RK11 disk is a block; it is 512 bytes long.

position independent code Code which can execute properly wherever it is loaded in memory, without modification or relinking. Generally, this code uses addressing modes which form an effective memory address relative to the central processor's Program Counter (PC).

priority A number associated with a task that determines the preference its requests for service receive from the executive, relative to other tasks requesting service.

privilege A characteristic of a user or program that determines what kinds of operations that user or program can perform. In general, a privileged user or program is allowed to perform operations normally considered to be the domain of the monitor or executive or which can affect system operation as a whole.

program development The process of writing, entering, translating, and debugging source programs.

programmed requests An instruction (available only to programs) that is used to invoke a monitor service.

programmer access code The system identification code that enables a user to gain access to a DSM-11 system in direct mode to create, modify, and execute programs.

project-programmer number See *account number*.

protocol A formal set of conventions governing the format and relative timing of message exchange between two communicating processes.

pseudo device A logical entity treated as an I/O device by the user or the system, but which is not actually any particular physical device.

PTT Abbreviation for the post, telegraph and telephone adminstrations which act as common carriers for telecommunications in many European and other countries.

public disk structure The disk volume or set of volumes which are used as a general storage pool available to any users having quotas on the public structure.

pure code Code that is never modified during execution. It is possible to let many users share the same copy of a program that is written as pure code.

qualifier A parameter specified in a command string that modifies some other parameter. See *switch*.

queue Any list of items; for example, items waiting to be scheduled or waiting to be processed according to system- or user-assigned priorities.

Radix-50 A storage format in which three ASCII characters are packed into a 16-bit word.

random access Access method in which the next location from which data is to be obtained is not dependent on the location of the previously obtained data.

read To transfer information from a peripheral device into core memory or into a register in the CPU.

real time processing Computation performed while a related or controlled physical activity is occurring, so that the results of the computation can be used in guiding the process.

record A collection of adjacent data items treated as a unit. See *logical record* and *physical record*.

record gap An area between two consecutive records.

recursive Pertaining to a process that is inherently repetitive. The result of each iteration of the process is usually dependent on the result of the previous iteration.

re-entrant The property of a program that enables it to be interrupted at any point by another program, and then resumed from the point where it was interrupted.

relocatable Describes a routine, module, or segment whose address constants can be modified to compensate for a change in origin.

remote batch terminal A combination of hardware items (usually a card reader, communication interface and a printer) and a communication link that allows the transmission of a series of records (the job) to a host computer. The host processes the records as a job stream and transmits the results of the job back to the lineprinter. Communiation is typically at the file level. See also *RJE emulator, RJE*.

remote node A frame of reference; any node other than the one at which the user is located in the network. Compare *local node*.

resident Pertaining to data or instructions that are normally permanently located in main memory.

resource sharing The joint use of resources available on a network by a number of dispersed users.

restart address The address at which a program can be restarted. It is normally the address of the code required to initialize variables, counters, etc.

root segment The segment of an overlay tree that, once loaded, remains resident in memory during the execution of a task.

routine A set of instructions arranged in proper sequence to cause the computer to perform a desired task.

routing node A full-routing node can forward packets to other nodes in the network and can be adjacent to all other types of nodes.

secondary storage Mass storage other than main memory.

segment 1. That part of a long program which may to resident in core at any one time.
2. To divide a program into segments or to store part of a program on a mass storage device to be brought into memory as needed.

sentinel file The last file on a cassette tape which represents the logical end-of-tape.

sequential access A data access method in which records or files are read one after another in the order in which they appear in the file or volume.

shareable program A (re-entrant) program that can be used by several users at the same time.

significant event An event or condition which indicates a change in system status in an event-driven system. A significant event is declared, for example, when an I/O operation completes. A declaration of a significant event indicates that the executive should review the eligibility of task execution, since the event might unblock the execution of a higher priority task. The following are considered to be significant events: I/O queuing, I/O request completion, a task request, a scheduled task execution, a mark time expiration, a task exit.

single user access The status of a volume that allows only one user to access the file structure of a volume.

single-stream batch A method of batch processing in which only one stream of batch commands is processed.

sliver A 32-word section of memory.

source language The system of symbols and syntax, easily understood by people, which is used to describe a procedure that a computer can execute.

sparse array Refers to the method of storage allocation used in MUMPS for local and global arrays in which space is allocated only as variables are explicitly defined (unlike some other languages which require dimension or size statements for preallocation of storage).

spooling The technique by which output to low-speed devices (e.g., lineprinters) is placed into queues on faster devices (e.g., disks) to await transmission to the slower devices.

statement An expression or instruction in a source language.

step number A number in the range 0.01 to 327.67 used to identify each line of a MUMPS program.

string A connected sequence of entities such as a line of characters.

subscript A numeric valued expression which is appended to a variable name to identify specific elements of an array. Subscripts are enclosed in parentheses. Multiple subscripts must be separated by commas. For example, a two-level subscript might be (2,5).

swapping The process of copying areas of memory to mass storage and back in order to use the memory for more than one purpose. Data are swapped out when a copy of the data in memory is placed on a mass storage device; data are swapped in when a copy on a mass storage device is loaded in memory.

swapping device A mass storage device especially suited for swapping because of its fast transfer rate.

switch An element of a command or command string that enables the user to choose among several options associated with the command. In PDP-11 software systems, a switch element consists of a slash character (/) followed by the switch name and, optionally, a colon and a parameter. For example, a command used to print three copies of a file on the lineprinter could be: "PRINT filename/COPIES: 3."

synchronous The performance of a sequence of operations controlled by an external clocking device. Implies that no operation can take place until the previous operation is complete.

synchronous system trap A system condition which occurs as a result of an error or fault within the executing task.

system device The device on which the operating system is stored.

system generation The process of building an operating system on or for a particular hardware configuration with software configuration modifications.

system manager The person at a computer installation responsible for the overall nature of its operation.

system operator See *operator*.

system program 1. A program that performs system-level functions.
2. Any program that is part of the basic operating system.
3. A system utility program.

system programmer A person who designs and codes the programs that control the basic operations of a computer system, as opposed to an application programmer.

system UCI The User Class Identifier (UCI) code in a DSM-11 system which is assigned to the first entry in the system's UCI table. The program and global directories associated with the System UCI are used to contain both system and library programs and globals.

task In RSX-11 terminology, a load module with special characteristics. In general, any discrete operation performed by a program.

TELENET The Packet-Switching Network available in the U.S.A.

terminal An I/O device, such as an LA36 terminal, which includes a keyboard and a display mechanism. In PDP-11 systems, a terminal is used as the primary communication device between a computer system and a person.

time quantum In time-sharing, a unit of time alloted each user by the monitor.

timesharing A method of allocating CPU time and other computer services to multiple users so that the computer, in effect, processes a number of programs concurrently.

time slice The period of time allocated by the operating system to process a particular program.

topology The physical or logical placement of nodes in a computer network.

transaction A single predefined data processing operation within an application.

transaction processor A collection of data tables and software capable of processing an application's transactions.

tributary station A station, other than the control station, on a centralized multipoint data communication system, which can communicate only with the control station when polled or selected by the control station.

turnkey 1. Pertaining to a computer system and its software which are sold together ready to go.
2. A computer console containing only one control, a power switch to turn the system on and off.

staging The delay of each update to a file until the end of the transaction instance requesting the update.

unattended operation The automatic features of a node's operation which permit the transmission and reception of messages on a unattended basis.

unbundling A practice by which a computer manufacturer does not sell computer equipment and software under one price structure, but sells them separately.

unformatted ASCII A mode of data transfer in which the low-order seven bits of each byte are transferred. No special formatting of the data occurs or is recognized.

unformatted binary A mode of data transfer in which all bits of a byte are transferred without regard to their contents.

UNIBUS The single, asynchronous, high-speed bus structure shared by the PDP-11 processor, its memory, and all of its peripherals.

unmapped system An RSX-11M or RSX-11S system that does not have a hardware memory management unit available for virtual address relocation.

user class identifier An identification code that enables a user to gain access to a DSM-11 system to execute programs.

user identification code The number or set of numbers that serves to distinguish a particular user or collection of files in a multiuser system. The common format for a user identification code is two numbers separated by a comma, enclosed in brackets, e.g., [3,11].

user program An application program.

utility Any general-purpose program included in an operating system to perform common functions.

variable The symbolic representation of a logical storage location which can contain a value that changes during a discrete processing operation.

virtual address space A set of memory addresses that is mapped into physical memory addresses by the paging or relocation hardware when a program is executed.

virtual array A RSTS/E file structure that is logically organized as a dimensioned array.

virtual block One of a collection of blocks constituting a file (or the memory image of that file). The block is virtual only in that its block number refers to its position relative to other blocks within the file, instead of to its position relative to other blocks on the volume. That is, the virtual blocks of a file are numbered sequentially beginning with one, while their corresponding logical block numbers can be any random list of valid volume-relative block numbers.

volume A mass storage media that can be treated as file-structured data storage.

word Sixteen binary digits treated as a unit in PDP-11 processor memory.

X.25 A communication protocol created by CCITT that recommends how a computer connects to a packet switched network. PTTs have accepted X.25 as their standard for Public Packet Switching Networks.

zero a device To erase all the data stored on a volume and re-initialize the format of the volume.

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NOTES

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