

PDP-11: A SINGLE SOLUTION TO MULTIPLE PROBLEMS



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PDP-11 ENGINEERING FEATURES AT A GLANCE

High Performance CPU

Hardware push-down stacks, 413 hardwired instructions, and floating point arithmetic make the PDP-11 the fastest machine in its class.

Memory Versatility

Up to 124K words—can be a combination of bipolar (300 nanoseconds), MOS (495 ns), or core (900 ns).

High Reliability

For optimum reliability, proven Schottky logic and automatic power fail and restart are built into every PDP-11.

Disk Storage

Over 350 million words.

UNIBUS™ Architecture

All system elements and peripherals plug into a single, asynchronous, high-speed bus.

APPLICATIONS SYSTEMS

COGO-11

A powerful programming system used to solve coordinate geometry problems.

STRESS-11

A problem-oriented language that allows engineers to interact directly with the computer to analyze structures for forces, movements and displacements.

PLOT-11

A library that consists of a set of subroutines, callable from FORTRAN IV to run an X-Y plotter.

STAT-11

A series of programs that enable the user to do basic statistical analysis.

PCS-11

A system for planning, supervising, and controlling project-oriented work.

CSP-11

A system that provides the user with a commercial FORTRAN capability.

EG-11

An extensive library of FORTRAN subroutines that control interactive graphics terminals.

PROGRAMMING LANGUAGES

BASIC-PLUS

A powerful language using mathematical notations easily understood and used by the engineer.

A superset of Dartmouth BASIC. 50 program statements, 34 system commands, 24 operators, 3 types of variables, 40 functions, and comprehensive matrix and string manipulation.

FORTTRAN IV-PLUS

A language familiar to many engineers. Meets ANSI standards, with many extensions such as random access I/O, overlays, character handling capabilities and reentrant math library and object time systems.

MACRO-11

A symbolic language assembler that provides the convenience of coding in open-ended language or directly in machine-oriented symbolic instructions.

PDP-11 COBOL

Conforms to 1974 ANSI standard. Includes such powerful features as INSPECT, STRING/UNSTRING, and SEGMENTATION.

SYSTEM CAPABILITIES

Multiprogramming

Several users can simultaneously interact with the computer system in the foreground while a batch stream is running in the background.

Batch Processing

The powerful PDP-11 processor coupled with output spooling, yields exceptionally high batch throughput.

Timesharing

Up to 32 users can process programs ranging from small "desk calculator" tasks to large 16K-word jobs.

Resource Sharing

All peripheral devices are available to any user both in the multiprogramming and timesharing environments.

Remote Job Entry

2780 type remote job entry to IBM 360/370 system or to another PDP-11.



ENGINEERING APPLICATION CAPABILITY

COGO-11...For Solutions to Coordinate Geometry Problems

COGO-11 is an easy to use, but powerful, programming system used to solve coordinate geometry problems. While there is virtually no limitation to the kinds of geometric problems that may be solved with COGO-11, typical applications center on land surveying, subdivision work, highway design, and construction layout. COGO-11 is designed for engineers with little or no computer experience. Using it, coordinate geometry problems can be stated in normal engineering terminology. Working from as little as a sketch of his problem, the engineer writes a description of the problem as though he were solving it by hand, except that each of the problem-solving steps is stated as a COGO-11 command. The summary of these commands becomes the program for solving the problem. Data points are stored in tables and can be recalled and used directly as required without having to re-enter data for each calculation.

Separate tables store all the coordinate points, computed areas, distances, angles (on bearings) and horizontal alignments. As a result, previous calculations can be built upon to solve very complex problems.

STRESS-11...For Structural Analysis

To interactively solve structural problems, STRuctural Engineering System Solver (STRESS-11) is available. This problem-oriented language enables engineers to interact directly with the computer to analyze structures for forces, movements, and displacements while other tasks are being executed concurrently.

The engineer describes his structure from a coordinate system, assigns numerically-sequenced numbers to members and joints, and inputs data for these using a tabular format.

From this information and other descriptive material, solutions for most structural units, including plane frames, rigid frames, space frames, building frames, trusses, culverts, tunnel sections and plane grids, can be achieved using STRESS-11.

PLOT-11...For Precision Drawings

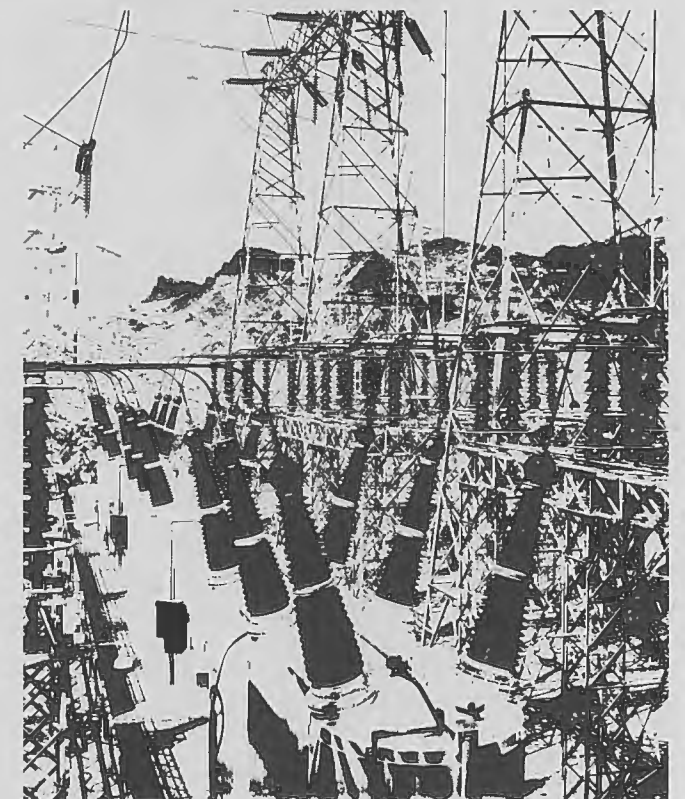
The PLOT-11 library consists of a set of subroutines callable from FORTRAN IV to run an X-Y plotter. It supports all Calcomp 500 and 900 series incremental drum plotters. Control of the plotter is transparent to the

programmer. The system provides automatic pen up, pen down, $\pm Y$ displacement and $\pm X$ displacement. Diagonal, curved, or irregular lines are produced by simultaneous movement of the pen and drum.

PLOT-11 provides the user with the capability to establish and control reference points and plotter movement under program control. It contains subroutines to scale the drawing, draw axes, draw symbols and numbers, and draw lines, points, and commonly-used functions.

STAT-11...For Statistical Analysis

STAT-11 is a series of programs that enable the user to do basic statistical analysis. It permits interactive remote terminal communication between the computer and the user who need not be familiar with computers or programming. STAT-11 questions the user in a simple conversational manner, taking the user through procedures necessary to enter data and parameters, and to perform the desired analyses.





STAT-11 provides the following types of analysis:

- Elementary statistics—including minimum, maximum, range, mean, standard deviation, and standard error.
- Cross tabulation.
- Correlation.
- Rank correlation—Kendall Tau coefficient.
- CHI-square— Optional Fisher Exact Probability.
- t-test—Under one of four different hypotheses.
- Regression—Linear, stepwise, multiple.
- Scatter diagram, histogram, line plot, and data transformation.

PCS-11...For Project Control

PCS-11 is a system for project control, schedule evaluation, and cost evaluation. Consistent with dynamic project management, PCS-11 provides a flexible tool in planning and in reporting project progress. With PCS-11, important and critical facts are immediately available to managers for evaluation and consideration—an invaluable factor in management decision making.

As a cost control tool, PCS-11 can be used to develop realistic schedules and cost pictures, to allocate manpower and resources to better advantage, and to identify areas that might cause costly delays.

CSP-11...For Commercial FORTRAN Applications

CSP-11 (Commercial Subroutine Package-11) facilitates certain commercial programming functions for the PDP-11 FORTRAN user.

While multiprogramming on the PDP-11 enables commercial applications to be processed in other languages concurrently with FORTRAN, CSP-11 provides the complete RSX FORTRAN IV installation with commercial extensions often needed.

EG-11...For Engineering Graphics

Graphics is a primary language of engineering. It is a visual medium, in which engineers can intuitively assemble and assimilate information about the physical environment. It is the form in which most engineering problems are conceived, and in which many solutions are presented. The EG-11 makes it possible for the engineer and his computer to communicate—in graphics!

The software is a set of FORTRAN calls that enables an engineer to do graphics work in a high level language. He may draw a vector or vectors in any selected line type and then activate the light pen to introduce or move a tracking object on the screen to make changes prior to plotting.

VERSATILE SYSTEM SOFTWARE

RSX-11...For Multiprogramming

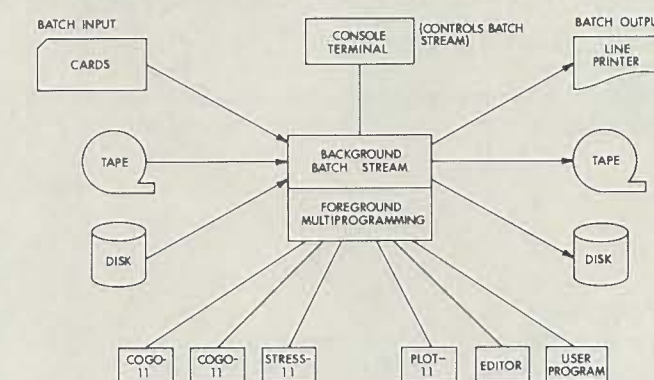
DIGITAL's RSX-11 is a powerful, flexible operating system designed with all of the elements required for multiprogramming. With RSX-11, the PDP-11 central processor can accommodate up to six user jobs in the foreground while another activity, generally a batch job, is processed in the background.

Features

- Optimum real-time response through dynamic allocation of system resources.
- Straight forward development of user application programs through on-line batch processing.
- Large-scale data management capability through an extensive set of file processing techniques.
- Virtual memory for automatic-extension of in-core data to the disks.
- Supports PDP-11 COBOL, FORTRAN IV-PLUS, and MACRO-11 programming languages.

Multiprogramming Under RSX-11

In the example illustrated, a background batch stream is accepting input programs written in FORTRAN, MACRO, etc. from punched cards, magnetic tape, and disk. The programs can be compiled and/or executed and the results output to the line printer, magnetic tape or the disk.



Concurrently, multiple programs are being executed in the foreground. Two terminals are working with COGO-11, one with STRESS-11, one with PLOT-11, one with EDITOR, and one terminal is running a previously-compiled, user written program. The user working with the EDITOR may be preparing programs for later execution in FORTRAN, MACRO, or any other language. Or he could be interactively creating data files for use in another program.

In a traditional computer operating system, the entire computer system would have to be dedicated to one user running COGO, STRESS, or FORTRAN, or editing

a program. Using applications languages like STRESS and COGO interactively is generally not viable because the entire computer system would be tied up by one user. Consequently, they are generally used in a batch environment.

With RSX-11, however, STRESS and COGO can be used in the most efficient manner. Batch for frequently-run problems with massive amounts of data. Or interactively where the engineer wants immediate results, for infrequently-run problems, or for trying various alternative approaches to a design.

RSTS/E...For Timesharing

RSTS/E, Resource Sharing Timesharing System/Extended, provides complete system access to 32 timesharing users simultaneously. Terminal response to even the largest "compute-bound" jobs is generally under 2 seconds. Even more important, the system is designed for optimum job execution speed. Jobs may range from a small "desk calculator" task to a large 32K byte program, even larger if program segments are chained together.

Providing system and application versatility are the wide variety of terminals and peripherals supported by RSTS/E. User terminals can range from 10 character-per-second Teletypes® to high-speed 240 cps CRT terminals, local or remote. Data may be entered interactively from user terminals, from high-speed paper tape or punched cards. Data files may be stored on fixed head disks, removable cartridge or stacked disks, or magnetic tape. The output may be to a user terminal, line printer, magnetic tape, or directly to another computer.

Features

- Up to 32 users may read or write the same program or data file.
- Three levels of read or write file access: Owner (programmer or user), Group (all with same project number), Universal.
- Three types of variables and variable arrays—Floating point with up to 17 digits of accuracy, integers for indices and counters, character strings of unlimited length.
- Continuous allocation of processor time, memory space, file space, and peripheral access for best-fit/best-throughput basis.
- On-line reporting of job status, memory usage, disk and peripheral usage, run time, connect time and log-ins.
- Supports BASIC-PLUS, a powerful extension of Dartmouth BASIC.

Extensive Language Support Capabilities

The PDP-11 user can use any of four programming languages: FORTRAN, BASIC, COBOL, or MACRO Assembler.

FORTRAN IV

PDP-11 FORTRAN IV conforms to ANSI standards and is also compatible with IBM 1130 FORTRAN. Source programs may be input from punched cards, DECtape, paper tape, disk or alphanumeric terminals.

Features

- Random access I/O.
- Mixed-mode arithmetic support.
- Generalized expressions are allowed as array subscripts.
- Implicit statements allow the user to conveniently control the variations in data types.
- Arithmetic can be performed with or without hardware Floating Point Unit.
- Character handling capability with LOGICAL *1.
- Ability to conserve core memory by selecting ONE WORD integers.
- Ability to generate relocatable binary code directly from the compiler or generate intermediate assembly code for customer modifications.
- Improved error diagnosis: Error traceback specifies where an error has occurred and provides linkages back to main program.
- Extensive compiler diagnostics with accompanying text.
- A complete, comprehensive and reentrant math library and object time system.

Listing

The PDP-11 FORTRAN IV compiler provides four listing features which help users to debug and document programs:

- Source program listing.
- Compiled program listing in an object code (machine language) format.
- A list of internal and external program symbols.
- A list of program errors (as part of the source listing).

Overlays

Users may specify that modules be overlaid into the same core area occupied by other previous programs. This frees users from limiting their programs to the size of available core memory.

Disk, DECtape, and magtape can be used to hold portions of the program to be overlaid. Thus, program size is limited only by the available bulk storage of the system.

Data Conversion

ENCODE/DECODE statements make it easy for the programmer to convert from integer or real numbers into ASCII character strings and vice versa. For example, a programmer can store information directly in ASCII form and at any time use a DECODE statement to convert it to binary. Thus, the same data can be formatted in several ways. Standard FORTRAN does not provide this flexibility, since characters are formatted and converted to binary by a READ/WRITE statement only.

Random Access I/O

PDP-11 FORTRAN IV random access statements let the user rapidly access data on disk or DECtape. Through random access methods, the user refers directly to a specific data record without scanning from the beginning of the file.

Extensive Error Diagnostics

PDP-11 FORTRAN provides an unusually extensive list of error messages, 225 in all. The compiler and Run Time packages not only provide the diagnostic number, but also supply a line of English explanation. As the compiler produces a listing, each statement or line is labeled with a sequence number which is useful in pinpointing an error during execution. If the error has occurred in an overlaid portion of the program, the traceback feature pinpoints where the error was and provides a linkage back to the main program.

BASIC-PLUS

BASIC-PLUS is a significant extension to Dartmouth BASIC, increasing its utility and power. The language is easy to learn and work with, yet puts the enormous power of the system at the user's fingertips. The immediate mode of operation enables the terminal to be used for simple calculations. Dynamic debugging is faster since programs may be interrupted at any point, checked, corrected, and operation resumed.

BASIC-PLUS automatically checks all program commands for accuracy when they are entered. Errors are reported immediately. Since each program line is compiled as it is entered, there are no frustrating delays, even on the RUN command.

Calculations in BASIC-PLUS are generally executed using floating point variables. The magnitude range of numbers lies between 0.14×10^{-38} and 1.7×10^{38} . Two

levels of precision are available: 7 decimal digits (2 computer words) or 17 decimal digits (4 computer words).

BASIC-PLUS also allows the use of integers. These are whole numbers in the range—32,768 to 32,767. The most common uses of integers are in counting, indexing, and subscript operations. Since integers only occupy one computer word, their use often increases the execution efficiency of programs.

BASIC-PLUS provides a comprehensive set of mathematical functions to the user—trigonometric, logarithmic, absolute value, truncation, pi, random number generator, and square root. Logical and relational operators are also available.

Resource Sharing

RSTS/E terminal users may have exclusive use of any peripheral on the system (except the public disk(s) which is a shared device). Not only can all devices be accessed by users at any time, but also any device can be accessed from a BASIC-PLUS program. Users may use a device as long as needed, and then return it for assignment to another user or program. The ability to enter, store, and retrieve programs and data files using high-speed peripheral devices makes PDP-11 time-sharing a true general-purpose, problem-solving and data management system.





Virtual Memory Arrays

The concept of virtual memory essentially makes the system disks an extension of main memory. This permits the user to manipulate large arrays or tables of data without cutting into his program size and indeed, process larger masses of data than will fit in the entire main memory of the system. Furthermore, the user can access large amounts of data without the need for explicit read/write programming.

Extended Program Statement Coding

The effectiveness of PDP-11 timesharing in solving problems in a broad variety of application areas is significantly increased with the addition of numerous extensions to the structure (syntax) of the BASIC program statements. These highly flexible program statements, previously found only in advanced scientific languages like ALGOL, permit more concise expression of complex program steps.

String Operations

Many applications require efficient processing of alphanumeric data such as names, addresses and entire sentences and paragraphs. BASIC-PLUS provides for the processing of character strings of various lengths, the maximum length being limited only by the available memory. When used with virtual memory, character strings are a maximum of 512 characters in length.

A comprehensive group of string operations is provided in BASIC-PLUS. Strings may be appended to one another. Strings may be compared to one another to see, for example, if a keyboard response is correct or to alphabetize a list of names.

Functions are available to extract, examine, or search for a string of characters contained within a larger string.

Matrix Operations

The user of PDP-11 timesharing may improve processing and programming efficiency by organizing his numeric data into one- and two-dimensional arrays or matrices. The BASIC-PLUS matrix commands add, subtract, multiply, and invert entire data matrices in a single operation. Commands are also available to initialize a matrix to zeroes, ones, or the identity matrix.

Both numeric and character string matrices may be input, read, and printed with single commands. If the matrices won't fit in main memory, the BASIC-PLUS virtual memory facility can be used as an extension of main memory as needed. Thus, array size never restricts program size, or vice versa; PDP-11 timesharing offers unlimited array capability even with the largest programs.

Record Input and Output

Record I/O permits the user to not only manipulate data to and from external devices, but also to manipulate how

the data enters and leaves the I/O buffers of the actual device.

It is this technique that permits industry-compatible magnetic tape to be written and accessed in a format compatible with the computer systems of other manufacturers. Another benefit of using Record I/O for disk files is its efficiency with respect to speed and minimization of disk space.

MACRO-11

MACRO-11 is a powerful assembly language. It accepts alphanumeric representations of PDP-11 instructions and outputs code in relocatable binary (object) or absolute binary form. The assembler provides full macro capability to simplify the programming of frequently used program segments and/or data. The user merely specifies the name of the macro, provides the required arguments, and the macro processor automatically substitutes the required code into the assembly.

Graduated Language

MACRO-11 allows the programmer to operate at any given level of sophistication. All default assumptions are selected to favor the casual user, so that one needn't be concerned with features he is not interested in.

Line-Oriented

MACRO-11 is line-oriented in that it reads a line of source, then processes and lists it prior to reading another line. A line is defined as a character string terminated by a line feed, form feed, or vertical tab.

Multiple Use of Once-Defined Ranges

The macro facility allows coding sequences (ranges) to be defined once and then invoked continuously by referencing the macro's name. The definition of the macro may include dummy arguments which are replaced with real arguments when the macro is invoked.

Generated Labels

When a macro is called, it is often convenient to generate symbols without explicitly passing them in the macro call. Such a case is when a label is required in the macro. If the label itself is not passed as an argument, a unique label will be generated on each call, thus avoiding multiply-defined labels.

Concatenation

Concatenation may be used to join a single macro argument with either other characters in the macro definition or other arguments. Such concatenation is

indicated by placing a single quote character between the strings to be joined.

Nesting and Redefinition

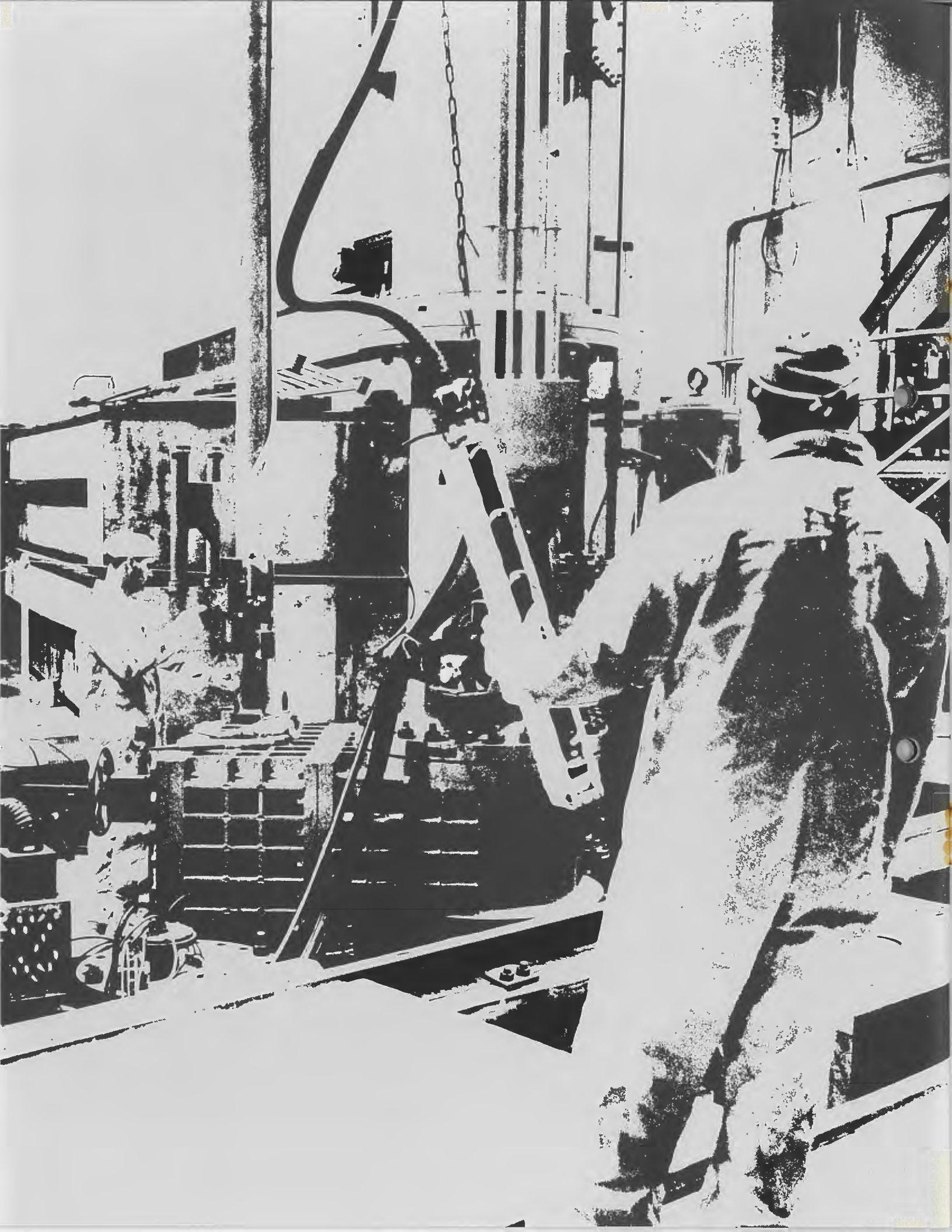
Macro definitions may contain other macro definitions (Nesting) or macro calls. They may even call themselves (Recursion) or redefine themselves. Arguments of the macro being called may be used in the macros it calls or defines with complete generality. When a macro contains a macro definition, the inner macro is not defined until the outer macro is called. If this definition is a redefinition of the macro, the original is completely expanded and the new definition is not used until the next call.

Listing Control

Neat and properly formatted listings can reduce the number of errors due to oversight. This is particularly important on the PDP-11 with its many varied addressing modes. The wide variety of PDP-11 configurations implies an equal variety of listing devices like teletype-writers, line printers, and display terminals. Therefore, variations of the listing format will also be necessary. Listing controls not implemented in a particular version of the assembler will be ignored by the assembler.

Other Features

- At the user's option, the assembler provides a complete listing of the symbolic program including the page/line number, memory location, octal representation, and user-generated mnemonics and comments. The user may also request a partial listing.
- To help in debugging, a list of symbols can be requested. These symbols consist of all user-defined symbols, arranged alphabetically, followed by the page/line number of each line in which the symbol appears. Lines that contain instructions capable of destroying a particular symbol are also flagged.
- MACRO-11-generated object code is relocatable. Assignment to physical memory locations is deferred until the code is linked with other object programs.
- Separately-assembled object programs communicate with each other through global declarations. Programs and subroutines to be linked contain common symbolic tags. When the linking program discovers such a tag, it searches for the desired routine and performs the linking operation.
- The source program can also contain conditional assembly directives. By assigning a value to a particular variable, the programmer directs MACRO-11 to assemble certain sections of code and ignore other sections.



PDP-11 COBOL

COBOL, Common Business Oriented Language, is a high-level computer language that allows the user to concentrate his efforts in developing applications software without understanding the intricacies of a computer system. Because it uses English-like statements, the language is easy to learn and use.

Capabilities

PDP-11 COBOL is a compiler conforming in language element, representation, symbology, and coding format to American National Standard Institute COBOL-74.

PDP-11 COBOL Processing Modules

AMERICAN NATIONAL STANDARD MODULE NAME	FUNCTION
Nucleus	All language elements necessary for internal processing.
Table Handling	Defining and manipulating tabular data
Sequential I/O	For processing sequential files.
Relative I/O	Defining and accessing relative files, including dynamic access.
Segmentation	Specifying overlay of the Procedure Division at object time.
Library	Copying predefined COBOL text into the source program; changing text while copying.

Both the Sequential and Relative I/O modules of PDP-11 COBOL compiler meet full ANSI-74 high level standards as well as offering high level extensions in the Nucleus, Table Handling, Segmentation, and Library modules.

Features

- Full high-level ACCEPT and DISPLAY features.
- Full high-level INSPECT, STRING, and UNSTRING verbs.
- Full high-level Relative I/O module.
- Full high-level Sequential I/O module.
- Low level Segmentation module.
- Full low level Library function, with partial high level REPLACING facility.

- Conditional variables—Data Division level 88.
- Nested conditionals.

2780 RJE EMULATION...FOR COMPUTER-TO-COMPUTER COMMUNICATIONS

In addition to stand-alone batch, multiprogramming, and timesharing, the PDP-11 offers IBM 2780 Remote Job Entry Terminal capability. Using this, the PDP-11 can read punched cards, transmit and receive records at data rates up to 4800 baud, and print formatted output. Its operation is indistinguishable to the IBM OS/360 or 370 RJE Subsystem from an actual 2780 Data Transmission Terminal. Communication with the IBM 360 or 370 CPU conforms with IBM's Binary Synchronous (BISYNC) Communication Procedure over leased, dial-up or multi-point lines.

CONVERSION AIDS

To minimize conversion efforts between 1130 FORTRAN programs and full ANSI standard PDP-11 FORTRAN IV and to provide a means of converting 1130 data files to PDP-11 mode, two application packages are available: F/SCAN-11 and EBASCI. The objective is to provide 1130 users with the most economical and transparent means to transfer their operation to native PDP-11 mode so that the price/performance increases and flexibility for expanded applications may be easily realized.

F/SCAN-11

F/SCAN-11 (FORTRAN/System Conversion Analyzer-11) accepts IBM 1130 FORTRAN source statements and converts them to PDP-11 FORTRAN IV. In addition to user program conversion, applications written and available in 1130 FORTRAN are now compatible with the PDP so that installation conversion can be achieved.

EBASCI

EBASCI is a utility program that translates EBCDIC files to ASCII format. EBASCI accepts input from either labelled or unlabelled magnetic tapes and writes output to any device capable of accepting it.

HIGH-PERFORMANCE HARDWARE

Fast, Powerful Central Processing Unit

The PDP-11 central processing unit was designed as a high-performance component for large systems. Hardware push-down stacks provide fast temporary storage for frequently used data and for storage of program information during interrupts and subroutine calls. Stacks not only simplify interrupt and subroutine handling, but, by automatically nesting interrupts and subroutines, they facilitate the use of reentrant and recursive programming. Software bookkeeping and overhead in large systems is thus reduced.

The basic PDP-11 is capable of performing more than 3,000,000 operations per second. Combined with the large instruction set of 413 hardwired instructions, its overall execution speed makes the PDP-11 the fastest machine in its class.

Contributing further to the speed and precision of the PDP-11 is the hardware Floating Point Processor. The Floating Point Processor operates with single- and double-precision numbers to provide 7 and 17 decimal digits of accuracy. Single-precision multiplications are performed in 5.6 microseconds and double in 9.3 microseconds.

UNIBUS Architecture Provides Easy Expansion

Key to the many strengths of the PDP-11 family is the fact that all systems elements (processor, memory, peripherals, terminals) plug into a single asynchronous high-speed bus. Known as a UNIBUS, this bidirectional bus provides easy interfacing and simplifies the construction of multiprocessor or shared peripheral configurations.

UNIBUS architecture keeps PDP-11 systems from becoming outmoded. Due to its asynchronous nature, the UNIBUS is compatible with devices that operate over a wide range of speeds. Therefore, faster devices, terminals, or memory can be easily added or replace older versions without obsoleting the system.

Contributing to system reliability and speed, with the UNIBUS, fast devices have direct access to the memory—no multiplexers or synchronizing DMA hardware are required. These devices can send, receive or exchange information without processor intervention and without intermediate buffering in memory.

Memory Versatility and Protection

Memory systems of the PDP-11 also reflect its high performance design philosophy. Memory expands to 248K bytes (124K words) and is both byte and word addressable. Memory may be core, solid state, or the optimum combination of the two.

Bipolar solid-state memories operate at 300 nanoseconds; MOS solid-state memories at 450 nanoseconds; and traditional core memories at 900 nanoseconds.

In the PDP-11, a memory management subsystem relocates, partitions, protects and allocates the use of all memories in up to 48 variable-sized segments. Thus, programs are broken down into manageable pieces and stored wherever memory space is available. This assures efficient use of all available memory yet provides complete protection of user programs and the system monitor.

Reliability

The PDP-11 provides high reliability in a variety of ways. The hardware is based on solid-state Schottky logic circuits, proven over a complete range of operating conditions on the 10,000-plus PDP-11 computers in use today.

Automatic powerfail and restart are built-in to the PDP-11. When the system senses a power brown-out or failure, it traps the CPU to a powerfail routine. Logic power in the machine safeguards the operations of the user by providing time to store the registers and shut down the system in an orderly fashion.

EXPERIENCE YOU CAN RELY ON

digital

Over 10,000 PDP11s are installed and in use today, serving a variety of applications. Engineering services include:

- **Computation**—In-house timesharing, engineering calculations, and linear programming.
- **Simulation**—Population growth, pipeline, and power distribution network modeling.
- **Resource Scheduling**—Equipment and manpower planning.
- **Administration**—General accounting, equipment usage, and project reporting.

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