PROGRAMMED DATA PROCESSOR - 4

PDP-4

DIGITAL EQUIPMENT CORPORATION • MAYNARD, MASSACHUSETTS

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Los Angeles  San Francisco  Washington  Parsippany, N.J.  Ottawa  Munich
Programmed Data Processor-4 (PDP-4) is a general purpose, high speed, solid state computer designed to be the control element in an information processing system or a complete scientific computer. It is a single address, parallel, binary machine with an 18-bit word length using 1's or 2's complement arithmetic. A random access magnetic core memory with a complete cycle time of 8 microseconds is used to achieve a computation rate of 62,500 additions per second. Other features include:

**FORTRAN II COMPILER** Including symbolic assembly with debugging and floating point arithmetic packages.

**REAL TIME CONTROL** Provides buffering and control for multiple input-output connections, program and data interrupt facilities, and a real time clock.

**MULTIPLE AUTO-INDEXING** Eight Auto-Indexing Memory locations simplify programming and increase the speed of table look-up and other routines.

**HIGH SPEED OPERATION** Basic instructions require only 8 or 16 microseconds to be completely executed.

**LINK BIT** Provides facilities which simplify and speed up multiple precision operations.

**STANDARD IN-OUT OPTIONS** Magnetic Drums, Display Scopes, Magnetic Tape, Line Printers, Punched Cards, Punched Tape, and Analog Converters.

**ECONOMICAL MEMORY EXPANSION** Provision is made for memory expansion up to 32K.

**EXTENDED ARITHMETIC UNIT (OPTIONAL)** Adds 23 instructions to a standard PDP-4 including Multiply, Divide, Normalize and Long-Shift.

Programmed Data Processor-4 has been developed to meet the requirements of the engineering and scientific profession. Special emphasis has been placed on a powerful input-output interface in the computer. Extensive applications in the system control and data reduction fields are well within PDP-4's capability.
STANDARD PDP-4

The PDP-4 includes all essential elements for optimum performance as a systems component. The standard machine consists of:

A CENTRAL PROCESSOR — which performs arithmetic operations, controls the memory, and handles information entering and leaving the machine;

AN OPERATOR CONSOLE — which contains all controls needed to observe and modify the status of the Central Processor;

A 4096-WORD MEMORY — which provides storage for information being collected or distributed and instructions for the Central Processor;

A REAL TIME CONTROL — which provides the computer with an additional capability to operate a large variety of input-output devices with different information handling rates.

A PAPER TAPE READER — which permits information and instructions to be read from 5, 7 or 8-hole perforated paper tape into the Central Processor at the rate of 300 lines per second.

Various options which extend the usefulness of the PDP-4 are described on Pages 7, 8 and 9.

CENTRAL PROCESSOR OPTIONS

FIRST EXTRA 4096-WORD

CORE MEMORY MODULE—TYPE 134

The Type 134 extends the memory capacity of the PDP-4 from 4096 to 8192 words. Additional modules require the use of a memory extension control (see below).

CORE MEMORY MODULE—TYPE 135

The Type 135 extends the memory capacity of the PDP-4 by 8192 words.

CORE MEMORY EXTENSION

CONTROL—TYPE 16

The Type 16 extends the memory control capability of the PDP-4 from 8192 to 32,768 words.

BLOCK TRANSFER DRUM SYSTEM—

TYPE 24

The drum system operates on a serial transfer basis in 256-word blocks. It is available in three capacities: 16, 32, 65 thousand words.

EXTENDED ARITHMETIC ELEMENT—

TYPE 18

The Extended Arithmetic Element (EAЕ) adds 23 micro coded instructions to PDP-4 which facilitate high speed multiplication, division, and shifting. The EAE contains an 18-bit register, the Multiplier Quotient (MQ); a 6-bit register, the Step Counter (SC); and a 3-bit Instruction Register.
REAL TIME CONTROL

The Real Time Control of the PDP-4 provides the following functions:

**DEVICE SELECTION** — consists of decoding elements to select and control external devices by various combinations of input-output transfer instructions. Pulses may be used to: (a) control external devices; (b) read out information from PDP-4 through the Information Distributor; (c) read in information to PDP-4 through the Information Collector, and (d) test the status of external devices.

**INFORMATION COLLECTION** — information is received from input devices (selected by the Device Selector) and is transferred to the Central Processor. Information is read in parallel (up to 18 bits) from multiple inputs.

**INFORMATION DISTRIBUTION** — permits distribution of information from the Central Processor to all output devices. Only the output device selected (or addressed) by the Device Selector samples and reads the information contained in the Information Distributor.

**INPUT-OUTPUT OPTIONS**

**Cathode Ray Tube Displays**

**Input-output options**

Paper Tape and Card Equipment

**CARD READER AND CONTROL—TYPE 41**

Operates at a rate of up to 200 cards per minute. Cards are read column by column. Column information may be read in alphanumerics or binary mode. The alphanumerics mode converts the 12-bit Hollerith Code of one column into the 6-bit binary-coded decimal code with code validity checking. The binary mode reads a 12-bit column directly into the PDP-4. Approximately one percent of a Card Reader program running time is required to read the 80 columns of information at the 200 cards per minute rate.

**CARD PUNCH CONTROL—TYPE 40**

Enables the operation of a standard IBM Type 523 Summary Punch with PDP-4. Cards are punched row by row at a rate of 100 cards per minute. Approximately 0.3 percent of program running time is required to operate the Card Punch at the 100-card-per-minute rate. Buffer holds one 80-bit row.

**PERFORATED TAPE PUNCH AND CONTROL—TYPE 75**

The Type 75 is a Teletype BRPE Punch with an operating speed of 62.3 lines or characters per second. It punches 5, 7 or 8-hole tape. (Shown with Standard Perforated Tape Reader.)
**In-Out Connections and Controls**

**18-BIT OUTPUT RELAY BUFFER — TYPE 140**
Provides contacts which operate devices of higher power rating. The relays have form "D" contacts, which open and close in approximately 3 milliseconds.

**INTERFACE FOR IBM 7090 CONNECTION — TYPE 150**
Provides communication between PDP-4 and IBM 7090 at a 10,000 cps, 18-bit word rate.

**DATA CONTROL — TYPE 131**
Controls and double buffers high speed transfers between the computer and external devices at word rates to 125 KC.

**CLOCK MULTIPLEXER — TYPE 132**
Provides 16 inputs to the PDP-4 enabling 16 memory registers to be used as 18-bit counter. Priority addressing system permits combined input counting rate to 125,000 cps.

**DATA INTERRUPT MULTIPLEXER — TYPE 133**
Provides high-speed transfer between PDP-4 Core Memory and three input-output devices. Maximum combined transfer rate: 125,000 cps, 18-bit words.

**Analog-to-Digital Equipment**

**GENERAL PURPOSE ANALOG TO DIGITAL CONVERTER — TYPE 138**
A general purpose analog to digital converter used to convert input analog voltages into digital numbers for computer entry.

**GENERAL PURPOSE 64 CHANNEL MULTIPLEXER CONTROL — TYPE 139**
Controls up to 64 channels of analog input to be multiplexed into the analog to digital converter.

**HIGH SPEED ANALOG TO DIGITAL CONVERTER — TYPE 142**
Converts analog signals to digital information with 10-bit accuracies in 8 microseconds for computer entry.

**HIGH SPEED MULTIPLEXER CONTROL — TYPE 141**
High speed multiplexer for use with the Type 142 Analog to Digital Converter.

Special purpose analog to digital converters, multiplexers, multiplex switches, digital to analog converters, plotters and loggers with various speeds, accuracies, and input ranges are available for special requirements.
The PDP-4 instruction format includes 4 bits for instruction code, 1 bit for indirect modified addressing and 13 bits for memory address or variations of the basic instructions.

When the indirect bit is a ONE, indirect addressing (or deferring) is specified. A defer memory cycle is required during which time the contents of the memory cell addressed are selected and the address part of this cell is used as the effective address of the original instruction. The instruction part of the cell and the indirect bit are ignored when obtaining the effective address. In addition, if the cell indirectly addressed is I0X17A, a ONE is added to the contents of that cell before the address part is used as the effective address (auto-indexing).

Operating times of PDP-4 instructions are in multiples of the 8 microsecond memory cycle. Add, deposit, and load for example, are two-cycle instructions completed in 16 microseconds. Input-output connections are programmed by specifying iot instructions which affect the state of selected devices. The instructions may be microprogrammed to allow one basic instruction to handle one or more devices by changing the bits of the command.

**MEMORY REFERENCE INSTRUCTIONS**

Addressable or memory reference instructions which contain a memory address. The address portion of the instruction word specifies the location of an operand in the memory.

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<thead>
<tr>
<th>Mnemonic Code</th>
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<th>Operation</th>
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<tr>
<td>cal</td>
<td>00 16</td>
<td></td>
<td>Same as jms 20. The address portion of this instruction is ignored. The cal instruction may be used for calling subroutines via a master central program which keeps track of exit addresses, allocates storage, and supplies parameters to the subroutines.</td>
</tr>
<tr>
<td>jms Y</td>
<td>10 16</td>
<td></td>
<td>Jump to subroutine. The PC is deposited in memory register Y. The next instruction will be taken from Y + 1, the beginning of the subroutine.</td>
</tr>
<tr>
<td>dzn Y</td>
<td>14 16</td>
<td></td>
<td>Deposit zero in memory. The contents of register Y are changed to zero. The original contents of Y are lost.</td>
</tr>
<tr>
<td>lac Y</td>
<td>20 16</td>
<td></td>
<td>Load AC. The CY(AC) is replaced by the C(AC). If the two numbers are different, the next instruction in the sequence is skipped. The C(AC) and CY(AC) are both unaffected by the instruction.</td>
</tr>
<tr>
<td>xsr Y</td>
<td>24 16</td>
<td></td>
<td>Exclusive OR. The exclusive OR (&quot;OR&quot;) function is performed on a bit-by-bit basis between the C(AC) and CY(AC). The result is left in the AC and the original C(AC) is lost.</td>
</tr>
<tr>
<td>add Y</td>
<td>30 16</td>
<td></td>
<td>Add (ONE's Complement). The C(Y) is added to the C(AC) in ONE complement arithmetic. If the carry out of bit O; the Link will be set to ONE. This type of add instruction is useful in multiple precision arithmetic.</td>
</tr>
<tr>
<td>tad Y</td>
<td>34 16</td>
<td></td>
<td>Add (TWO's Complement). The C(Y) is added to C(AC) in TWO's complement arithmetic. There is a carry out of bit O; the Link will be set to ONE. This type of add instruction is useful in multiple precision arithmetic.</td>
</tr>
</tbody>
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**AUGMENTED INSTRUCTIONS**

Augmented instructions provide micro programming capability by using the address portion of the instruction to select logical operations. These instructions do not address a memory register.

The following instruction leads itself into the AC.

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<td>opf 74xxxx</td>
<td>8</td>
<td></td>
<td>Operate. The operation is also the combining (shift) instruction. When a particular condition is present, the following instruction will be skipped. The various micro program events occur at different times to allow several events to be programmed which affect the same element. This is a micro program instruction using bits 4-17 to specify the desired operations. Combinations of the individual operations can be made. The operations are specified by bits as follows:</td>
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<td>8 In Out Transfer. This instruction which forms a micro program is used to select an input or output device. The instruction forms a micro program and has the following format:</td>
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Keys and toggle switches available on the PDP-4 control panel provide maximum ease of operation. Their functions are as follows:

**Console Keys**

**START**
Starts the processor. The first instruction is taken from memory cell specified by the setting of the ADDRESS switches. The START operation clears the AC and Link, and turns off the Program Interrupt.

**STOP**
Causes the processor to halt functional operations at the completion of the memory cycle in progress at the time of key operation.

**CONTINUE**
Causes the processor to resume operation beginning at the address specified by the Program Counter (PC).

**EXAMINE**
Sets the contents of the memory at the address specified by the Program Counter into the Accumulator and the Memory Buffer. The C(PC) will be indexed by one, and the Memory Address Register will contain the address of the location examined.

**DEPOSIT**
Sets the contents of the Accumulator Switches into the memory at the address specified by the Program Counter. The C(PC) will be indexed by one, and the Memory Address Register will contain the address of the location holding the information.

**Console Toggle Switches**

**POWER**
Turns on the power.

**SINGLE STEP**
Causes the processor to halt at the completion of each memory cycle. This switch is particularly useful in maintenance tasks. Repeated operation of the Continue Key will step the program one cycle at a time so that the state of the machine can be examined at each step.

**SINGLE INSTRUCTION**
Causes the processor to stop at the completion of each instruction.

**REPEAT**
Causes operations initiated by console keys to be repeated as long as the keys are depressed. The operations are performed at the rate set by the Speed Switch.

**SPEED**
Controls the speed of the repeat function.

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**PROGRAMMING AIDS**

The PDP-4 Programming System includes FORTRAN II, a Symbolic Assembly and Debugging System, maintenance routines, and numerous other programming aids.

**FORTRAN II**

PDP-4 FORTRAN II allows the programmer an unusual degree of freedom in many instances: For example, mixed expressions and n-dimensional arrays are allowed. An important feature is the retention of the original symbols from the FORTRAN source language tape through the final binary program, making the system easy to use and reducing debugging time. Compilation of the original FORTRAN source program is performed alone, with subprograms compiled and assembled separately. Hence, should mistakes occur in FORTRAN coding, only the main program need be recompiled.

**PDP-FORTRAN II FEATURES**

| FIXED POINT | 1-6 decimal digits absolute value $\leq 131,071$ |
| FLOATING POINT | 10 decimal digits precision. Exponent range $2^{127-1}$ to $-2^{127-1}$ |
| VARIABLE NAMES | 1-6 alphanumeric characters |
| SUBSCRIPTS | Any arithmetic expression representing an integer quantity: Variables in a subscript may themselves be subscripted to any depth. N-dimensional arrays are permitted. |
| STATEMENTS | Mixed expressions containing both fixed and floating point variables are permitted. A maximum of 300 characters are allowed (statement numbers not counted) |
| STATEMENT NUMBERS | 1-99999 |
| FUNCTIONS AND SUBROUTINES | Subroutines not contained in the FORTRAN library may be compiled by the use of Function and Subroutine statements. Functions and subroutines may be fixed or floating point valued as defined by initial letter of F-type function convention. Arguments may be arbitrary arithmetic expressions, including functions. |
| INPUT AND OUTPUT | MICRO-TAPE, paper tape, punched cards, teletype, display. Format may be specified by use of a FORMAT statement. |
| STATEMENTS AVAILABLE | Arithmetic statements, I/O statements with FORMAT, DO, Dimension, Common, IF, GOTO, Assign, Continue, Call, Subroutine, Function, Return. |
Symbolic Assembly and Debugging System

ASSEMBLY PROGRAM
A one-pass assembler that allows mnemonic symbols to be used for addresses and instructions. Constant and variable storage registers are automatically assigned. This assembler will produce relocatable or absolute binary output, as desired by the user.

RELOCATING LOADER
Performs relocation and linking of binary programs that have been assembled separately.

DDT-4 (DEC DEBUGGING TAPE-4)
Debugging may be done at run time using the teleprinter. Break points may be inserted into a program at arbitrary points so that the state and operation of a program may be observed. The source program symbols may be used for communication.

EDMUND THE EDITOR
Allows the editing of symbolic tapes.

Arithmetic Routines

DOUBLE PRECISION INTEGER PACKAGE
A collection of subroutines which allow the user to perform double precision arithmetic with 35-bit signed numbers.

MULTIPLY AND DIVIDE SUBROUTINES
Single precision signed one's complement.

DOUBLE PRECISION FLOATING POINT
Performs operations upon floating point numbers, with approximately 10 decimal digits of precision, and an exponent which may be as large as $2^{127-1}$ in magnitude.

AUTOMATIC MULTIPLY AND DIVIDE
Provided by the Extended Arithmetic Element Type 1B, also includes shift and normalize functions permitting fast floating point operations.

STANDARD FUNCTION GENERATORS
Routines to calculate floating point, arctan ($x$), sin ($x$), cos ($x$), $e^x$, log ($x$), $x^2$, $y^2$.

I/O Programs

MAGNETIC TAPE PACKAGE
Facilitates use of Type 57A and Type 54 Control units.

MICRO TAPE PACKAGE
For use with Micro Tape 555.

SYMBOL GENERATOR ROUTINES
A high speed plotting routine for use with the Type 33 Symbol Generator.

PEN FOLLOW
Tracks the light pen across the face of the Type 30 Precision CRT Display.

BUFFERED I/O PACKAGE
Permits simultaneous use of the paper tape reader, paper tape punch, card reader, card punch, high speed line printer, teleprinter and keyboard, buffering all input and output.

Utility Routines

CAL HANDLER
Facilitates the calling of subroutines. Permits greater freedom in the use of subroutines, including recursive calls.

MASTER TAPE DUPLICATOR
Verifies and duplicates tapes.

PUNCH ROUTINES
Allow punching in either block format binary or read-in mode format.

Maintenance Routines

CAL AN LER
Facilitates the calling of subroutines. Permits greater freedom in the use of subroutines, including recursive calls.

CONTEST
(Continuous Test) Repeatedly tests all basic machine functions.

MAINDEC 401 INSTRUCTION TEST
A sequence of programs which test the operation of all PDP-4 instructions except the IOT group.

MAINDEC 402 CHECKERBOARD
Provides continuous memory testing with four different patterns.

MAINDEC 403 ADDRESS SET
Maintenance programs to check the memory module for proper address selection.

READER AND PUNCH TEST
Checks the operation of the reader and punch using different patterns and variable times.

TELEPRINTER TEST
Tests the input and output facilities of the teleprinter by repeating the typed message, echo checking, etc.