F-61
9/64

6

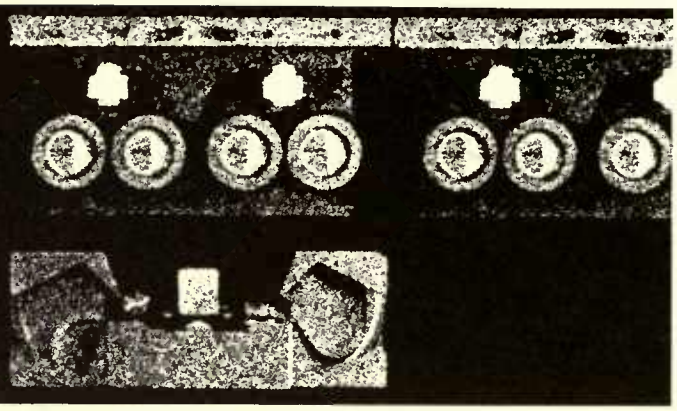
PROGRAMMED DATA PROCESSOR

DIGITAL EQUIPMENT CORPORATION • MAYNARD, MASSACHUSETTS

PROGRAMMED DATA PROCESSOR-6

36-bit word length ■ 15 index registers and/or accumulators
FORTRAN II — MACRO-6 assembler — utility programming library
Integrated hardware and software for time sharing ■ Microtape
Asynchronous operation, modular construction ■ Memory overlap
Core memories up to 262,144 words, 2 μsec, directly addressable
Fast memory 16 words, 0.4 microsecond ■ 128 input-output devices
363 instructions ■ fast floating point — multiply 14 μsec average
Program assignable operation codes ■ Byte manipulation, half word
Block transmission ■ Seven channel priority interrupt system
Programmed input-output transfers require no data channels
Multiple processors ■ Remote input-output ■ Mass memory

SYSTEM DESCRIPTION



Programmed Data Processor-6 (PDP-6) is a general-purpose digital computing system designed for scientific data processing. The flexibility of this system permits the user to specify the data handling capacity and the exact configuration needed to meet his requirements. The system can be expanded with presently available equipment or, at a later date, with equipment yet to be developed. Faster memories, for example, can be added as they become available.

PDP-6 design eliminates the need for off-line conversion equipment. Conversion of programs from cards or paper tape to magnetic tape can be done concurrent with normal program running. Users at peripheral Teleprinters can simultaneously prepare and debug their programs on line.

The PDP-6 system consists of processors, memories, and input/output devices. Since each is autonomous (no device is dependent upon another for its timing), a system configuration can include memory modules of different speeds, processors of different types sharing the same memory modules, and standard or unique input/output devices.

For maximum flexibility of system configurations, the PDP-6 system is built around two busses: processor-memory bus and processor-input/output bus. The memory bus permits each processor to directly address 262,144 words of core memory, automatically permits overlapping, and simplifies multiprocessor operation. An input/output bus of processor can service up to 128 devices.

The Operating System consists of a supervisory control program, system programs, and system subroutines. Included are a Symbolic Assembler and Macro Processor, a FORTRAN II Compiler, and debugging aids. A library of general utility programs is also provided.

Neither the processors nor any of the standard peripheral equipment require an air-conditioned environment or floor reinforcement. Ordinary 115-volt power is sufficient for all equipment.

PROCESSORS

A PDP-6 system can include any number of processors of the same or different types. The Type 166 is a 36-bit arithmetic processor with many powerful features, including 16 accumulators, 15 index registers, built-in floating point arithmetic, and byte operations capability. Memory protection and relocation registers are included for time-sharing operations.

The Type 167 I-O Processor gives direct memory access to high speed devices, such as drums, discs, and displays. It takes over local control of data transfers after receiving system commands and initial conditions from the arithmetic processor. Thereafter the two processors operate asynchronously, so that I-O transfers are carried out in parallel with arithmetic processing.

Up to three controls, such as the Type 236 Drum Control, can be connected to the Type 167 I-O Processor.

INPUT/OUTPUT

The input/output bus consists of device selection, data, control, and status sense lines. A seven-channel program-assignable priority interrupt system signals the processor when input/output devices require service. Word count and memory address registers are located in the processor and are available to all devices. This reduces the cost of various input/output controls, and permits data block transfers between tapes, card readers, printers, displays, and other devices.

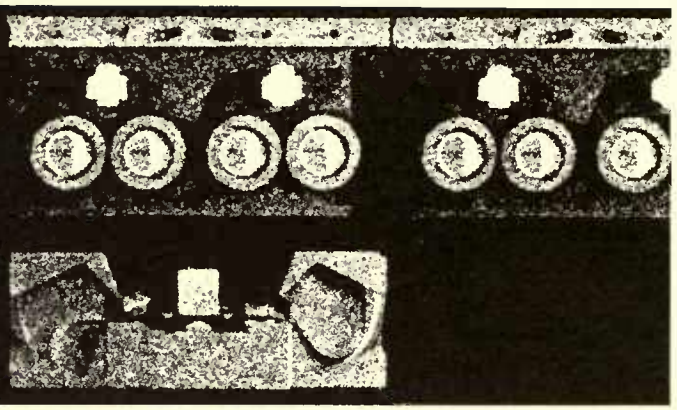
MEMORY

The PDP-6 core memory subsystem permits modular expansion using blocks of different sizes and speeds. The Types 163B and 163C core memory modules contain 8,192 and 16,384 words, respectively. Each has a word length of 36 bits, a cycle time of 2 microseconds, and an access time of 0.8 microseconds. The Type 162 Fast Memory Module contains 16 words with a 0.4-microsecond cycle. Slower core memories, such as the 5-microsecond Type 161, can be used where economy is an overriding criterion.

The memory-processor bus permits memory cycle overlap, gives all processors direct access to memory, and permits easy expansion and modification of the memory subsystem. In addition, the bus allows the processors to remain connected to memory only as long as needed to transfer information: That is, a processor can put a word on the bus and resume operations as soon as the memory acknowledges, without waiting for the memory to store the word. Similarly, when reading a word out of memory, the processor takes the information and operates on it immediately, without waiting for the memory to finish the rewrite portion of its cycle.

Maximum system efficiency is achieved when sequential memory references address alternate memory modules. The addressed module places data on the bus as soon as it is available in the memory buffer and disconnects itself from the bus while rewriting, freeing the processor to store the result or seek the next instruction in a second memory module before the first one has completed rewriting. Utilizing such overlapping memory references, PDP-6 users can effectively cut in half the time required for average random accesses. Multiple connections between the bus and each memory module permit module sharing on a priority basis for multiprocessor operations.

PROGRAMMING SYSTEM



The programming system for PDP-6 consists of a supervisory control program, system programs, and library routines. The entire system is designed to run on any PDP-6 system with at least 16,384 words of core memory, a console Teleprinter, and a Microtape system. However, the programming system is modular. Parts of it can run on machines with smaller memory capacity. For example, programs can be assembled with MACRO-6 using the above-mentioned input-output equipment and only 8,192 words of core memory.

A variety of programs are provided through the Digital program library, and a continuous in-house program design effort regularly improves and expands the library.

THE SUPERVISORY CONTROL PROGRAM

This is the name given to a collection of programs remaining permanently in memory to provide overall coordination and control of the total operating system. The segments of the program are:

Command Control Program, which handles all commands addressed to the system from the User-Consoles. These commands would include requests to log in or out, a request to use the edit program, requests to have a program placed on the run queue, requests to load a program, etc.

Program Scheduler, which is called at regular intervals to decide which program in memory is to be run. A running program is temporarily terminated each time its allotted time has run out, or when it requires input-output operations with a device that is busy. A program may be terminated temporarily by user intervention to the scheduler, or it may suspend its own operation. Temporary termination does not remove the program from memory. A program may be dumped on backing storage and permanently discontinued by calling the scheduler and allocator.

Facilities Allocator, which is called any time an I/O device or memory space is required. It may be called from a User-Console or by a running program. Under this program one User-Console is designated the operator console. As such it has special facilities available which are not available to other consoles, such as line printer assignments. Storage is permanently assigned for all resident programs, that is, those programs that are in memory at all times. Finally, "logical" tape assignments are made. Two Micro Tape units are designated the system library and the system scratch tape. Two other tapes may be assigned as Peripheral Input Tape, used to prepare jobs to be stacked from cards or paper tape, and System Input Tape, used to input a full tape. (Each User-Console may require a Micro Tape unless programs requiring files are to be run.)

Command Decoder preprocesses commands from the User-Console. This program is used to convert parameters, etc., before the command is sent to the program for which the command is intended.

I/O Control is called whenever an I/O device is to be used. This program assigns equipment, controls the I/O devices, controls data transfers between memory and the I/O device, and controls the buffering of data for the device. (Users provide the necessary buffering for devices which require file buffering.) All program I/O instructions are trapped, and the actual control of the I/O operation then passes to the I/O Control Program.

SYSTEM PROGRAMS

These are the programs designed to implement system functions which may be requested from the User-Console. This is in contrast to system subroutines which may be called by system programs or other programs. System programs are normally provided by Digital, but they may be provided by each installation for its users. The programs contain a

mode by which they may be terminated to return the communication link to the system. Some of the system programs are described below.

Editor Program, which provides a means for manipulating the text of a named file on a Micro Tape or in the user area of the drum (corresponding to Micro Tape). This file may be used for the creation of text or for later use as data or as a program to be translated by the FORTRAN compiler, etc. The commands provided for the editor allow text to be created, deleted, or moved about.

Peripheral Conversion Program, which handles all those jobs normally done by a separate peripheral processor. The priority interrupt system and multiple memory accumulators in the PDP-6 eliminate virtually all loss in running time. Such processing is done through the arithmetic processor.

Inter-Console Message Program, which switches message traffic between the various User-Consoles. This program provides a means by which the user may request manual operations by the operator and receive acknowledgment. Such an operation would be the mounting/dismounting of user tapes.

Linking Loader Program accepts programs in a form produced by the translators, and produces an area of core memory loaded with the program. Upon request, it may also produce a storage map of the loaded programs along with symbol tables. Several programs may be linked together in loading. The loader requests special library tapes to be loaded, and verifies that the program has been completely loaded.

Translator Dispatcher is called to load the FORTRAN, MACRO-6, or other translators. The translators are rather large programs that do not reside in memory, but are stored on the System Library tape until they are called into memory by the translator.

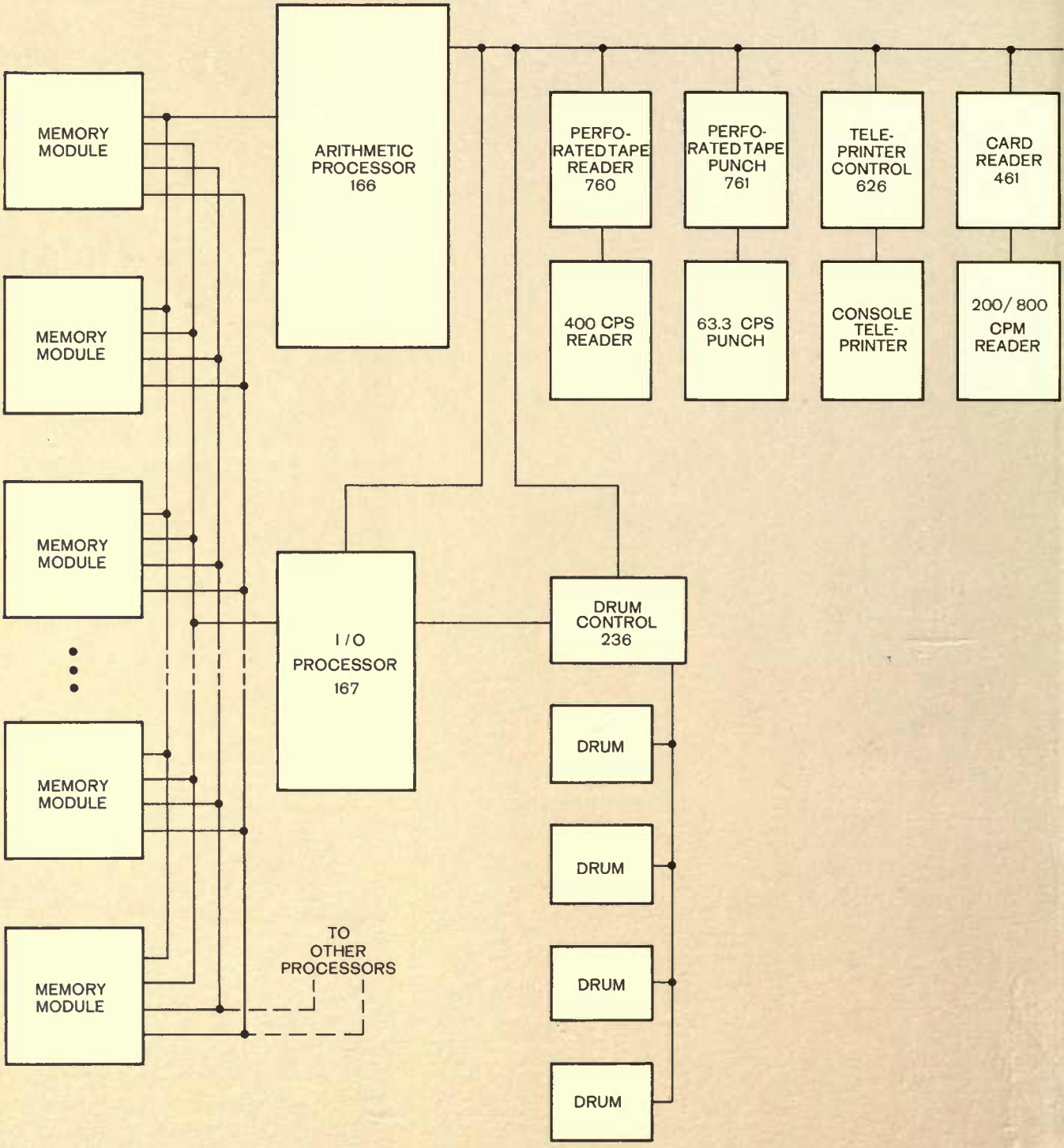
FORTRAN II Compiler accepts FORTRAN II input statements and produces relocatable binary output coding for later loading by the Linking Loader. Compiling is done in one pass. PDP-6 FORTRAN II is an extension of the conventional FORTRAN II language to give the user more facilities and to take advantage of PDP-6 hardware. The ASCII character set is used. Subscripts may consist of statements (fixed or floating). Any number of dimensions may be used to specify an array. Signed integers have 36-bit values, but when used as subscripts are truncated to 18 bits.

MACRO-6 Assembly Program translates MACRO-6 input language to a relocatable binary output for the Linking Loader. MACRO-6 is a two-pass assembly program and the language provides for instruction definitions and usage. Literal assignments are made by brackets []. Numbers may be expressed as binary, octal, decimal, and floating point. Text may be placed in a binary program by the occurrence of the "text" data generating statement, and "byte" will cause a string of bytes to be assigned and packed into a word. The "repeat" control statement causes the statements following the control to be repeated "n" times.

Debugging Program (DDT) is loaded with a program and allows all assembly language programs to be debugged. The program may be started or stopped, words in the program may be modified, and DDT may search the program looking for particular words. DDT may also be used in a "trace" or break point mode, and the program is run until a particular location (a break point) is encountered.

The System Subroutines include:

1. I/O Format Control which provides for the various format statements used in the FORTRAN II language. These subroutines are also available to other programs and may be called from the systems library tape.
2. Arithmetic Subroutines which include all the arithmetic subroutines required for FORTRAN II, such as, sine, cosine, $\log_e$, $\log_{10}$, exponent, tangent, arc-tangent, and square root.


MEMORY MODULE
MEMORY MODULE
MEMORY MODULE
MEMORY MODULE
MEMORY MODULE
ARITHMETIC PROCESSOR 166
I/O PROCESSOR 167
TO OTHER PROCESSORS
PERFO-RATED TAPE READER 760
PERFO-RATED TAPE PUNCH 761
TELE-PRINTER CONTROL 626
CARD READER 461
400 CPS READER
63.3 CPS PUNCH
CONSOLE TELE-PRINTER
200/800 CPM READER
DRUM CONTROL 236
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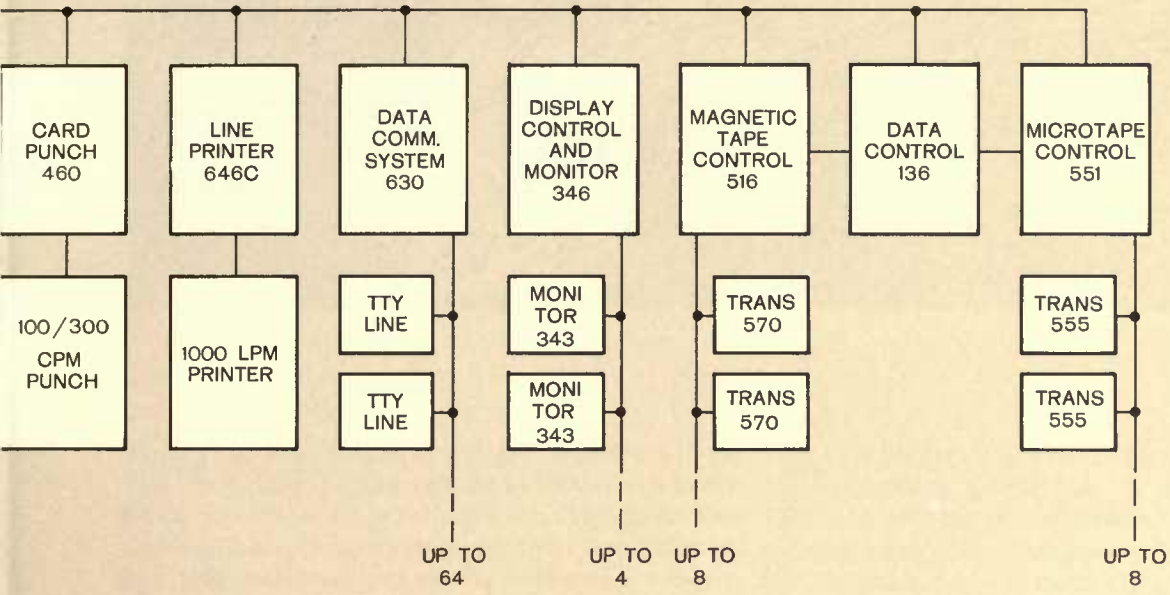


PDP-6 — A MODULAR SYSTEM

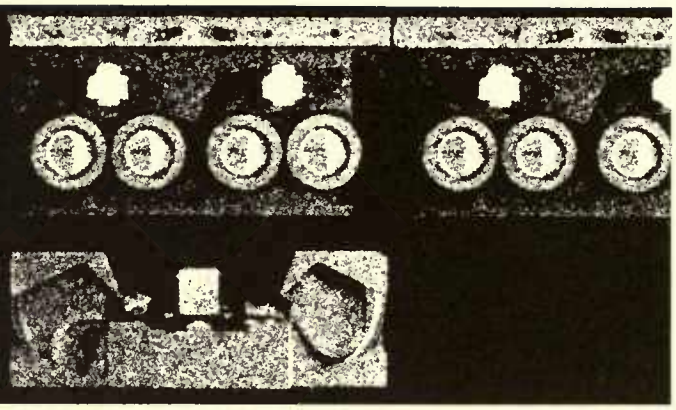
The diagram shows the three main parts of a PDP-6 system — memories, processors, and input-output equipment — interconnected with busses. Memories and input-output devices contain their own buffer registers and control circuits, including decoders to recognize commands from the processors. The Data Control Type 136 is a double-buffered device which is used not only with magnetic tape equipment, as shown here, but with any high speed, block transfer device, such as drum or disc.

The system shown in this diagram is a theoretical one of very high capacity, but it is entirely within the capability of PDP-6. Memory size, indicated by the modules on the left, can be as large as 262,144 words per processor, and up to four processors can address a given memory module. Very high speed devices, such as drum, tape, disc, and display, can have direct access to the memory system through the I-O Processor Type 167. The combination of the asynchronous nature of the system and the characteristics of the memory bus makes possible truly simultaneous memory references by two or more processors. Sequential memory references made by one processor can be overlapped.

PDP-6 is also a highly effective system in a minimum configuration. All system programs will operate in a system consisting of a Type 166 Arithmetic Processor, a Memory Module of 16,384 words, a Microtape system, and a Teleprinter. Later expansion of either the memory or input-output system can be made with no change whatever in the existing system. Memory modules can be of any speed: A low cost system might call initially for slower (5-microsecond) memories, later to be augmented by faster memories (down to 0.5-microsecond).

PDP-6 systems are thus completely adaptable to current and future requirements, both technical and budgetary.

TYPE 166 ARITHMETIC PROCESSOR

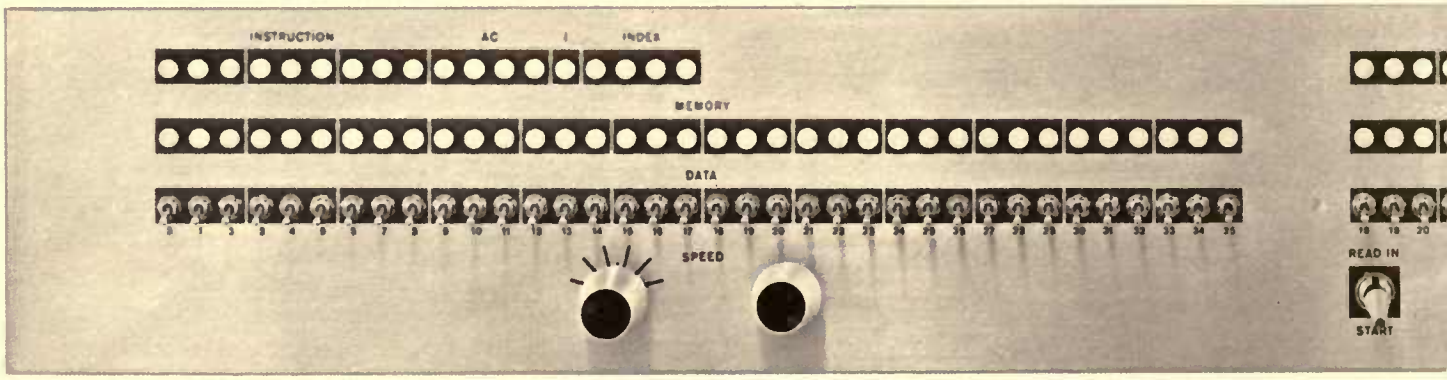


The Type 166 Arithmetic Processor is a general purpose processor capable of performing arithmetic, logical and input/output operations. It uses the first 16 locations in memory as accumulators, index registers, or ordinary memory locations. The results of each operation are transmitted automatically to one of these registers at the end of each instruction; thus the accumulator resides in memory.

Executive mode hardware is provided for time sharing. Programs to be run are placed in memory and relocated by the Relocation Register. Memory references outside of the area assigned to the user are detected by the Memory Protection Register, and a supervisory program is called to check for the cause of the illegal reference. In addition to this specific hardware, PDP-6 time-sharing capability is further enhanced by the processor's ability to address up to 262,144 words of memory directly and by the uniform representation of program symbols in ASCII code.

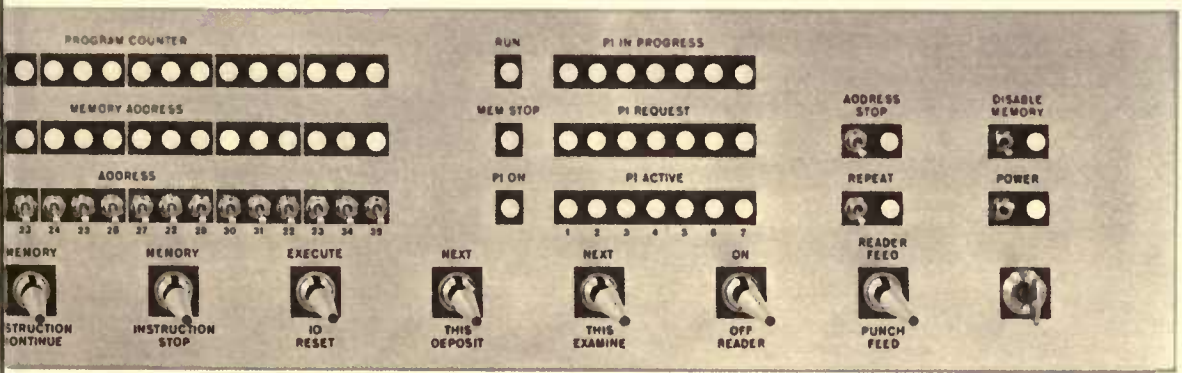
The 363 operation codes include fixed and floating point arithmetic, logical or Boolean, memory or accumulator modification and testing, half word, variable sized byte, block transmission, and input-output instructions. Instruction times vary, depending on the memory subsystem selected. Use of the Type 162 Fast Memory reduces instruction times significantly.

The table (right) shows the number and kind of instructions and their speed of execution. The fast times are based on starting with instruction and data in fast memory. The slow times are based on starting with both instruction and data in the same core memory and allow for one index reference. The fast times are not necessarily minimum, since instructions in the immediate mode (instruction contains operand) may run faster. Nor are the slow times maximum times, since an instruction may take considerably longer if there are several levels of indirect addressing. Exact times depend on the program context in which the instructions occur and on other factors; therefore the figures should not be used to calculate program running time.

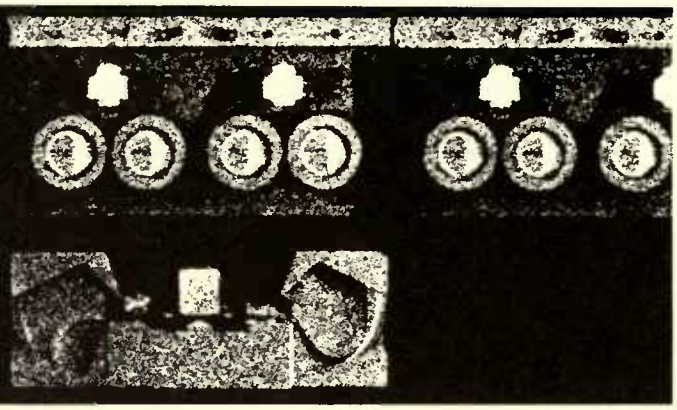


INSTRUCTIONS

Instructions	No. of Instructions			Instruction Times	
	Operations	Modes	Total Instructions	Fast	Slow
Full word moves	4	4	16	1.9μsec	4.0μsec
Half word moves	16	4	64	1.9	4.0
Byte manipulation	5		5	5.7	8.0
Block transfer	1		1	1.5+0.8n	2.4+1.2n
Exchange	1		1	2.8	4.0
Fixed point add	1	4	4	2.7	4.3
Fixed point subtract	1	4	4	2.9	4.5
Fixed point multiply	2	4	8	14.5	16.1
Fixed point divide	2	4	8	23.4	25.0
Floating point add	2	4	8	5.8	8.0
Floating point subtract	2	4	8	6.0	8.2
Floating point multiply	2, 1	4	9	12.4	14.5
Floating point divide	2	4	8	18.4	20.5
Boolean	16	4	64	2.7	4.3
Shifting (18 bits)	6		6	4.7	5.9
Memory, AC modification and testing	6	8	48	2.6	3.9
Arithmetic compare	2	8	16	2.7	4.4
Logical compare	16	4	64	2.7	4.4
Jumping	8		8	1.8	3.0
I/O					
basic	4		4	3.0	6.2
augmented	4		4	3.8	7.0
Push down	4		4	3.1	6.4



INPUT/OUTPUT EQUIPMENT



Digital offers a large selection of optional equipment for full utilization of the extensive input/output capacity of the system.

MICRO TAPE TRANSPORT TYPE 555

A fixed address magnetic tape facility for high speed loading, readout, and on-line program debugging. Read, write, and search speed is 80 inches a second. Density is 375 bits an inch. Total storage is three million bits. Features phase recording, rather than amplitude recording; redundant, nonadjacent data tracks, and a pre-recorded timing and mark track.

MICRO TAPE CONTROL TYPE 551

Controls up to eight Type 555 Micro Tape Transports. Searches in either direction for specified block numbers, then reads or writes data. Uses the Type 136 Data Control to assemble data and buffer transfers to the processor.

DATA CONTROL TYPE 136

Provides for assembly of 6, 12, 18, or 36-bit characters; six input/output devices can be controlled.

TELEPRINTER AND CONTROL TYPE 626

Permits on-line programming and debugging. Provides hardcopy outputs. Is standard Teletype equipment, operating at ten characters a second.

TELEPRINTER INTERFACE TYPE 630

Automatically scans up to 64 teleprinter (TTY) lines. Signals a program interrupt when teleprinter needs service.

CARD PUNCH CONTROL TYPE 460

Permits on-line punching of cards in any format, including IBM, at 100 or 300 cards a minute.

CARD READER AND CONTROL TYPE 461

Provides on-line reading of standard punched cards at 200 or 800 cards a minute in alphanumeric or binary codes.

HIGH SPEED PERFORATED TAPE PUNCH AND CONTROL TYPE 761

Punches 8-hole tape at 63.3 characters a second.

HIGH SPEED PERFORATED TAPE READER AND CONTROL TYPE 760

Reads perforated paper tape photo-electrically at 400 characters a second.

MAGNETIC TAPE CONTROL TYPE 516

Automatically controls up to eight tape transports Type 570 or IBM 729 series. Permits reading, writing, forward/backward spacing, rewind and unload, and rewind. Uses a Type 136 Data Control to assemble data and buffer transfers to the processor. Longitudinal and lateral parity is checked.

MAGNETIC TAPE TRANSPORT TYPE 570

Tape motion is controlled by pneumatic capstans and brakes, eliminating conventional pinch rollers, clamps, and mechanical arms. Tape speed is either 75 or 112.5 inches per second. Track density, program-selectable, is 200, 556, and 800 bits per inch. Tape width is one-half inch, with six data tracks and one for parity. Format is compatible with IBM NRZI. Dual heads permit read-checking while writing.

I-O PROCESSOR TYPE 167

Establishes a data transmission path between main memory and block transfer devices, such as drums, magnetic tape, disc files, or CRT displays.

MAGNETIC DRUM AND CONTROL TYPE 236

Drum stores 1,048,576 36-bit words organized into 128 tracks, each with 8,192 words consisting of 64 128-word blocks. A word is transferred in 6.4 microseconds, and the drum revolution time is 52 milliseconds.

DISPLAY CONTROL AND MONITOR TYPE 346

Plots points, lines, vectors, and characters on a 9⅜-inch-square raster of 1,024 points along each axis. Time between points plotted is 1.5 microseconds in the vector, increment, and character modes. In random point plotting, a time of about 35 microseconds is required per point.

DISPLAY MONITOR TYPE 343

Provides additional cathode ray tube display for multiple consoles.

HIGH SPEED LIGHT PEN TYPE 370

Detects data displayed by the Types 346 and 343 and inputs identifying signal to the computer.

ANALOG-TO-DIGITAL CONVERTER TYPE 138

Transforms an analog voltage to a binary number, selectable from six to eleven bits. Conversion time varies, depending on the number of bits and the accuracy required. Twenty-one combinations of switching point accuracy and number of bits can be selected on the front panel.

MULTIPLEXED ANALOG-TO-DIGITAL CONVERTER TYPE 138/139

The Type 139 Multiplexer Control permits up to 64 channels of analog information to be applied singly to the input of the Type 138 Analog-to-Digital Converter. Channels can be selected in sequence or by individual addresses.

HIGH-SPEED ANALOG-TO-DIGITAL CONVERTER TYPE 142

Transforms an analog voltage to a signed, 10-bit binary number in 6 microseconds. Conversion accuracy is $\pm 0.15\%$ $\pm 1/2$ least significant bit.

ANALOG-DIGITAL-ANALOG CONVERTER SYSTEM TYPE ADA-1

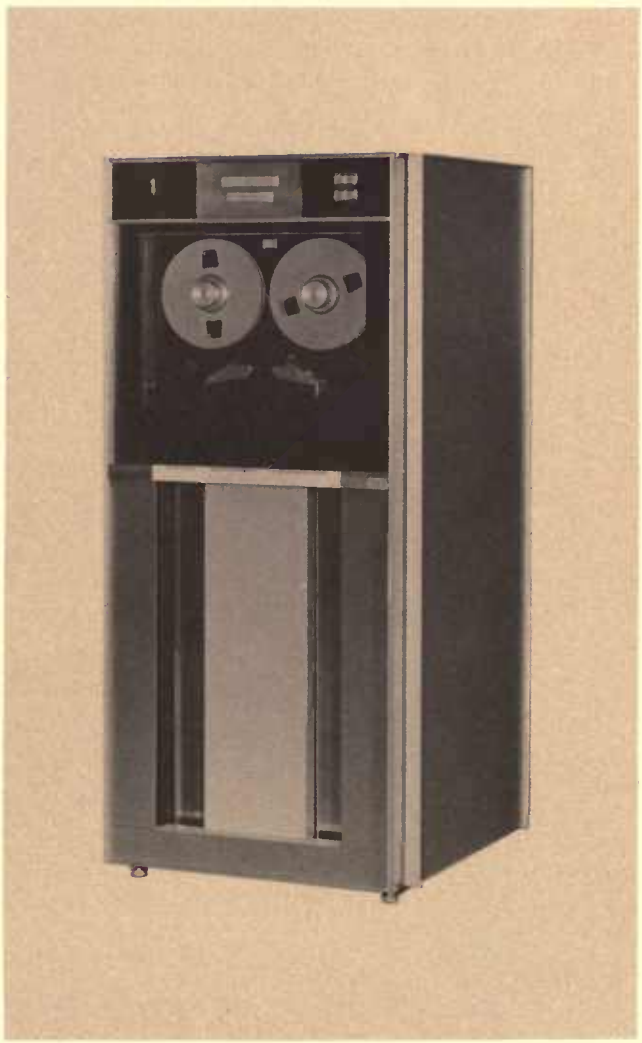
Performs fast, real-time data conversion between digital and analog computers. Maximum sample rate for D/A conversion is 200 kc; for A/D and interlaced conversions, 100 kc. Digital word length is 10 bits. Actual conversion times are 5 microseconds for A/D and 2 microseconds for D/A. Semiautomatic features enable the converter system to perform many of the functions that a computer normally performs for other converter interfaces.

AUTOMATIC LINE PRINTER AND CONTROL TYPE 646C

Prints 1000 lines a minute, 120 columns a line, any one of 64 characters a column.

AUTOMATIC LINE PRINTER AND CONTROL TYPE 646A

Prints 300 lines a minute, 120 columns a line, any one of 64 characters a column.



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