Digital Equipment Corporation
Maynard, Massachusetts

digital

MPS10

MICROPROCESSOR SET

LOGIC PRODUCTS

January 30, 1974

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LOGIC PRODUCTS MICROPROCESSOR SET MPS10

INTRODUCTION

A brief introduction to the "computer-on-a-chip," or "microprocessor," or whatever, is probably in order at this time. It has been extensively discussed in many magazine articles, described and dissected in countless symposiums and seminars; yet a good deal of mystery still surrounds it, and what its role will be in the data processing world.

What is a "microprocessor"

Very briefly, a microprocessor is an assembly of LSI chips put together in a computer-like central processor to implement arithmetic, logic, and input/output functions under program control. The achievement of this type of processing capability was made practical by the development of MOS/LSI circuits which could be deposited on an integrated circuit chip approximately 175 x 175 mils.

The situation described above, i.e., the availability of a computing capability on a single IC chip is the ideal situation and not quite achievable in real life with that single chip.

In the "real world" the above configuration can effect a useful "real-world" interface only if a number of additional IC chips are added. Usually this number approaches 25-40. There is rather a large gap between theory and practice, as many potential users have discovered.

Technology

The most popular current technology appears to be represented by P-channel MOS integrated circuits. This, however, determines that the overall computing speed of the device is relatively slow. The future anticipated use of N-channel MOS and, inevitably, bipolar TTL, will contribute greatly to increased speeds in future devices.

Advantages of microprocessor

- Makes many new products economically feasible due to its low cost
- Introduces integral computer architecture into such areas as electronic cash registers, data acquisition terminals, communications systems, traffic light systems, etc.
- Eliminates the need to design special-purpose logic to solve specific problems
- Faster product design time
- Product changes easier to implement
- Increase in reliability because of fewer interconnects

How does the microcomputer differ from a minicomputer

Although fundamentally identical to all computers, the microprocessor differs appreciably from, for example, minicomputers as we know them today.

The following chart is offered as a general guideline in identifying those gross parameters which separate minicomputers from microprocessors.

	Minicomputer	Microcomputer
CPU	Full instruction set	Reasonably limited instruction set
Memory	Both core and semiconductor available; addressable beyond 16K	Semiconductor only; addressable up to 16K, typically
Software	Complete and comprehensive software package available including, typically, Operating Sysem, Assembler, Editor, Compiler, Utility Packages, full diagnostics	Usually consists of Assembler, Editor, Postprocessor, utilitarian diagnostics; takes advantage of our user-developed software
Program Preparation	Can be accomplished on the host machine	Must be accomplished off-line on another machine; (good example of off-line machine is PDP-8)
Price	Medium	Low
Support/ Service	Full field service, documentation, warranty	No field service; documentation and warranty exist

Applications spectrum

If a full list of possible applications were delineated here, I think it would be apparent that most minicomputers and, indeed, all DIGITAL computer products, would also compete for fulfillment of these same applications. In reality, although an extremely broad spectrum of use may be attributed to such a product, the key factor in any consideration for use would be the individual user who, within any application area, appears to emerge as a dominant factor and is the person who is actually responsible for specifying the equipment. He conforms to a fairly well-defined profile as outlined below:

- Would be an OEM or a large end-user (corporate OEM)
- Is hardware-design-oriented and has in-house technical capability
- Likes to "tinker" with computer programming
- Industrial-oriented
- Communications-oriented
- Has a "problem" to be solved and is looking for minimum capability to "do the job"
- Has been working with, or is familiar with, dedicated controllers
- Is planning a product upgrading or a new product introduction (possibly replacing a fixed logic system)
- Is extremely price-sensitive
- Is not overly performance-sensitive (at least for now)
- Is more than likely already considering the use of a microprocessor

GENERAL APPLICATION AREAS

. Industrial Control

- Machine tool control
- Material flow

. Process Control

- Batch mixing
- Furnace monitoring
- Batch weighing

. Small Laboratory Automation

- Analog and digital instrument data acquisition
- Blood analyzers

. Data Communications

- Data concentrators
- Communications processors
- Minicomputer preprocessors
- Intelligent terminals

. Business Machines

- Optical character recognition
- Automatic banking
- Smart copying machines

. Health, Education, and Welfare

- Environmental control of large buildings
- Automatic teaching machines
- Remote pollution-monitoring systems

Particular Application Areas

Two authentic particular applications for a microprocessor are illustrated here -

1. Materials movement in a chemical plant

2. Data acquisition and reduction

APPLICATION #1

Material Movement in a Chemical Manufacturing Plant

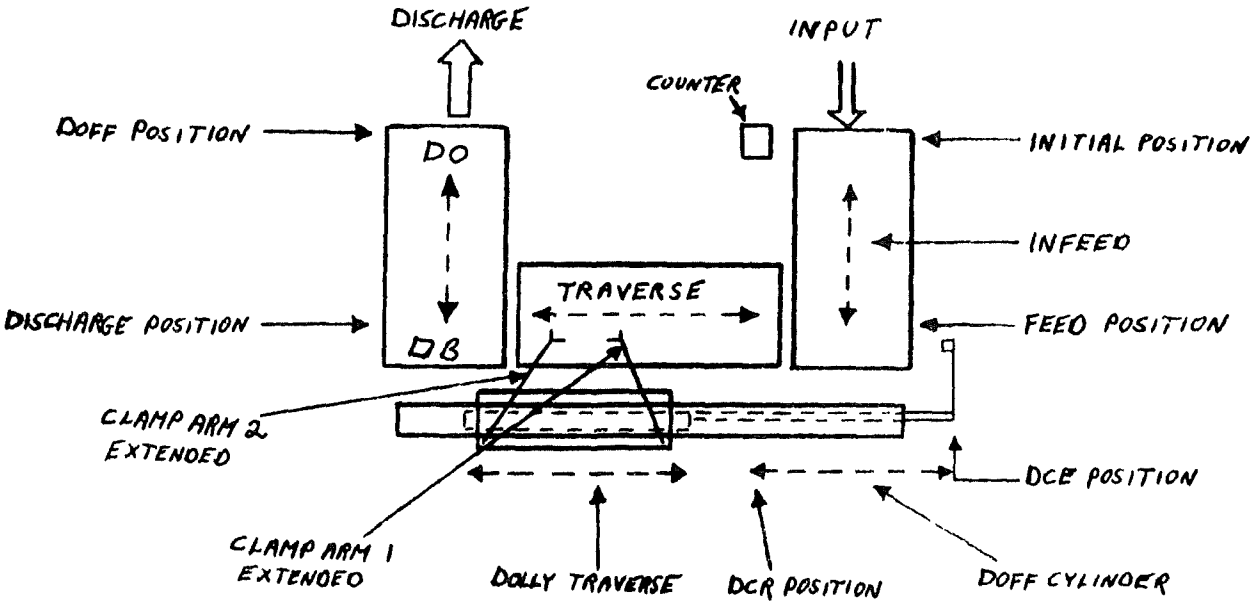
Staple Traverse

This application consists of a number of repetitive operations which involve the taking of an empty container from a conveyor, placing the container in a loading station, filling with some material, and then placing the full container back on the conveyor for moving to the next location.

The entire sequence, which requires such operations as vertical and horizontal movement of the container, detection of container limit stops, monitoring of clamping arms, dolly traversing, detection of full container, container count, etc., is now implemented by relay logic. Replacement of this logic with PM will result in considerable savings for the user in actual system cost and reduced maintenance time.

The system is shown diagrammatically below; a section of the flowchart is also shown.

STAPLE TRAVERSE



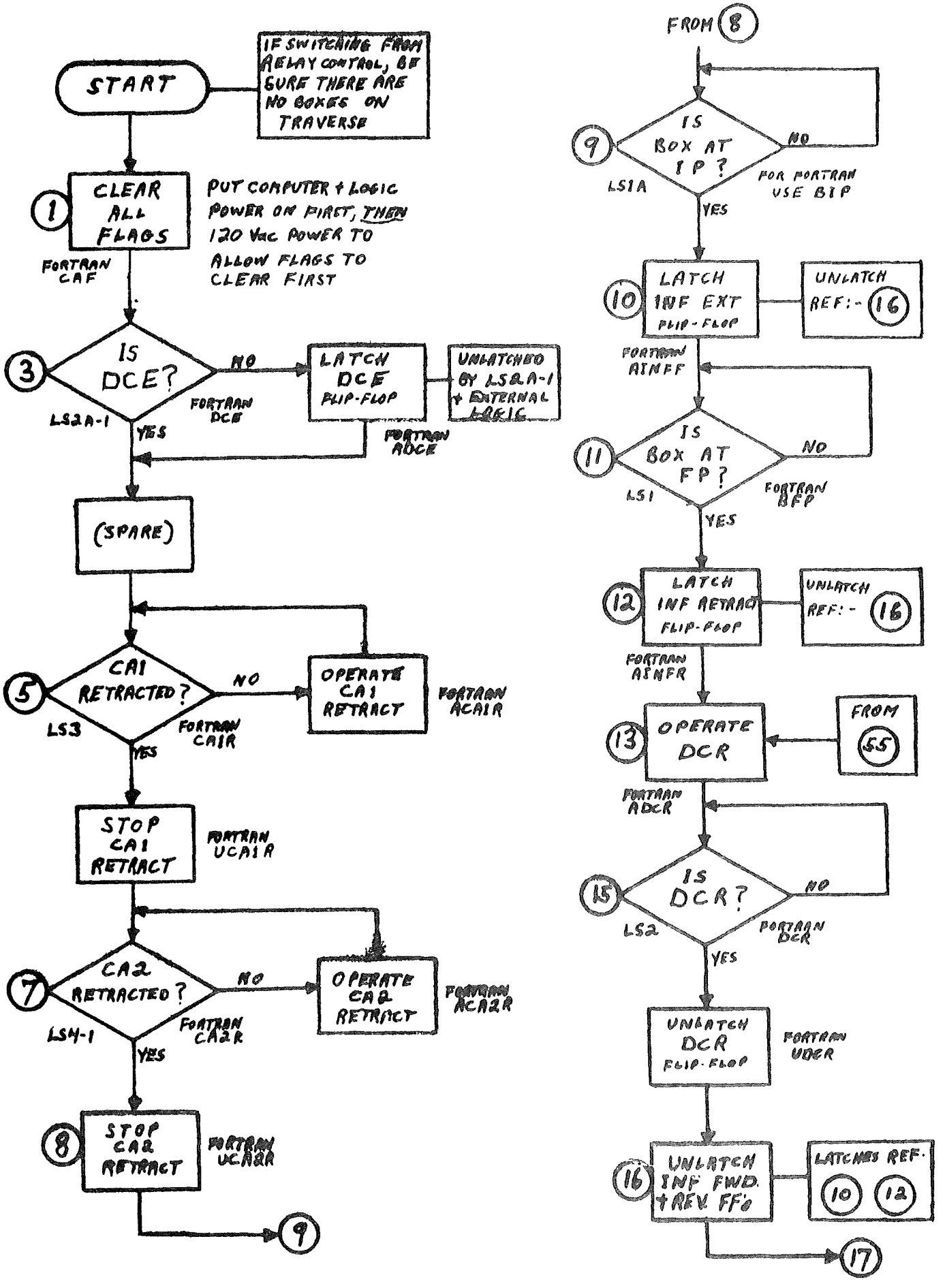
CODES FOR FLOWCHART

DO & DB = Discharge Out and Back
IP = Initial Position
FP = Feed Position
DCE = DOFF Cylinder Extended (or EXTEND command)
DCR = DOFF Cylinder Retracted (or RETRACT command)
CA1 = Clamp Arm 1
CA2 = Clamp Arm 2
DT = Dolly Traverse
DOP = DOFF Position
DIP = Discharge Position
INF = Infeed

BASIC SEQUENCE

Empty box placed at Initial Position. Infeed pulls box to Initial Position. DOFF Cylinder retracts taking box to Traverse. CA1 and CA2 extend and hold box, then traverse left and right until counter completes count. Another empty box has, in the meantime, been brought to the Feed Position. Counter signals complete, and DOFF Cylinder pushes empty box onto Traverse which pushes full box to DIP. Empty box traverses, full box goes to DOP and new empty box goes to FP.

STAPLE TRAVERSE FLOWCHART



APPLICATION #2

Typical Smart Terminal

Self-contained, "smart" data acquisition instrument capable of receiving signals--analog and digital--from external sources, including transducers, digital voltmeters, blood analyzers, etc.

The instrument would contain the Programmable Module series which would perform appropriate operations on the data received, such as limit checking, signal averaging, curve matching, trend searching, polynomial expansion, etc.

The manipulated data would be made available for transfer to a variety of output devices which would include, typically, minicomputers, Teletypes, VT05s, RT01s, and RT02s.

Markets for an instrument of this type (for which the lately announced PDM70 would make an ideal candidate) would be those OEMs selling in laboratory and process control operations.

When should a microprocessor replace hardwired logic

The question posed above is becoming increasingly common. The guidelines to dictate this choice are not too well developed at this time but some estimates place the breakpoint number of IC packages in a random logic design at anywhere from 30 to 70 packages. The old axiom, "When in doubt...." may be quite apropos here---when in doubt, choose a microprocessor.

Evaluating microprocessors

Evaluating microprocessor performance assumes a different dimension to the evaluation of other integrated circuits and presents many pitfalls. Generally speaking, the criterion for applicability is the overall performance of the microprocessor as applied to a particular application---and not such familiar parameters as clock rate, memory access time, throughput, etc.

The performance of any microprocessor is heavily dependent on parts external to the LSI chip itself and factors such as the kinds of instructions, memory addressing capability, interrupt handling, etc., all go together to determine true performance.

The cardinal rule would be for the user to define his problem, then review the processor instruction set for the ability to solve the problem, then buy the evaluation hardware.

Why the Intel Chip

We chose the Intel chip because of its availability and longevity in the field (actually is the only microprocessor chip commercially available in the strictest sense).

MPS10 Microprocessor Set

That leads us to the discussion of the new MPS10 Microprocessor Set from Logic Products. Obviously, it is a modular product for at least two very strong reasons:

1. Logical continuation of the M Series module line; this new product dovetails very well with the M Series line of modules

2. We offer a microprocessor capability with all the required peripheral ICs to effect the proper external interface to the user. This eliminates PC card layout time, shop fab, error detection, rerun through the shop, system fine-tuning, etc. We offer him debugged, checked-out operating modules.

What is the MPS10

The MPS10 is a set of five modules designed around a commercially available MOS/LSI processor chip (Intel 8008-1).

- M7341 - Processor Module (PM)
- M7342 - Monitor/Control Module
- M7344YA - 1K x 8 Read-Write Memory Module
- M7344YB - 2K x 8 Read-Write Memory Module
- M7344YC - 4K x 8 Read-Write Memory Module
- M7345 - PROM Module (socket capacity to 4K x 8)
- M7346 - External Event Detection Module

Tie-in with current Digital Equipment Corporation Computers

The Processor Module is not a minicomputer, and is not intended to compete with minicomputers--it is primarily designed as a dedicated controller--a replacement for fixed logic designs; to give some degree of intelligence to various types of data terminals; to perform virtually countless low-cost processing applications and decision-making functions. It should be considered to be an

extremely useful augmentation of, and addition to, DEC's existing arsenal of processing devices. Availability of the MPS10 will complement available DIGITAL minicomputers at the low-cost end of the cost/performance spectrum thereby broadening the applications support DIGITAL can offer the OEM and industrial user. It will also expand and broaden DEC's overall capability into a market area hitherto unplumbed and should be a very effective additional tool to offset continuing encroachment of competitors trying to reduce DEC's portion of the total processor market.

M7341 - Processor Module

The Processor Module (PM) is a standard DEC quad module containing the basic processing elements of the system. The processing capability is supplied by the standard Intel 8008-1 microprocessor chip, a complete computer system central processor unit which can be interfaced with memories of capacities up to 16K bytes. The processor communicates over an 8-bit data and memory bus, and makes 14 bits of address available for memory selection. The CPU contains an 8-bit parallel arithmetic unit, seven 8-bit data registers, and an 8 x 14 stack--all implemented by a dynamic RAM, and full control logic and instruction decoding.

Features

- 8-bit parallel CPU on a single chip
- 48 data-oriented instructions
- Instruction cycle time -- 12.5 μs (single cycle instruction)
- Complete instruction decoding and control
- Inputs, outputs, and clock lines, TTL-compatible
- Directly addresses up to 16K x 8 bits of memory
- Address stack contains eight 14-bit registers, including the Program Counter which allows nesting of subroutines up to seven levels
- Contains seven 8-bit registers
- Multiplexing of
  - 8 bits of I/O data
  - 8 bits of memory data
  - 8 bits STOP/EXTERNAL EVENT address
  - 8 bits initial START/BRANCH address
- 14 bits buffered, latched MEMORY address

- Control lines consisting of
  - Memory Read
  - Memory Write
  - I/O in
  - I/O out
  - STOP/EXTERNAL EVENT detection
  - I/O START/BRANCH interrupt
- Full-duplex serial-line interface implemented by UART (Universal Asynchronous Receiver/Transmitter)
- Data, address, and control lines made available at a Berg connector for easy interconnection with the Monitor and Control Module for maintenance and program debug purposes only

M7342 Monitor/Control Module

The Monitor/Control Module is primarily intended for general monitoring operations on the MPS10 system. These operations would typically include monitoring of data paths, memory, addresses, etc., during program debug and checkout, general system operational checks, diagnostic checks, etc.

Module Features

- Hex
- Facility for placing on bench, desk top, etc.
- Will interface with PM via standard cable
- Will allow interrogation of 8008 timing signals through a LED array
- Address data can be loaded into PM via 14-bit switch register
- Address and memory will be displayed via a 14-LED array
- Following controls supplied:
  - Address Load
  - Start
  - Halt
  - Deposit
  - Continue
  - Examine
  - Single cycle
  - Display Data
  - Display Address
- Integral scratch pad and ROM bootstrap memories
- Labeled face plate for switch and LED identification

M7344YA, M7344YB, M7344YC - Read-Write Memory Module

The M7344 Read-Write Memory Module (RAM) is a semiconductor read-write memory with a maximum storage capacity of 4096 x 8 bits on a quad module. The memory storage is implemented by the Intel 2102 1024 x 1 static random access memory element using normally off N-channel silicon-gate MOS technology. The chip uses static circuitry and, therefore, requires no clocks or refreshing to operate.

The module will be available in three versions:

M7344YA - 1K x 8
M7344YB - 2K x 8
M7344YC - 4K x 8

Module Features

- Quad
- Available in three configurations
  - 1K x 8
  - 2K x 8
  - 4K x 8
- Address decoding on module (16 lines)
- Memory-Read line
- Memory-Write line
- Address expansion line
- Data Ready line during Read operations
- Data Accepted line during Write operations
- Single +5-volt dc power

M7345 - Programmable Read-Only Memory (PROM)

The M7345 is a programmable Read-Only semiconductor memory module with a maximum storage capacity of 4096 8-bit bytes. The memory storage is implemented by the Intel 1702A 256 x 8 silicon gate erasable and electrically programmable static MOS memory. A transparent quartz lid allows the user to erase the internal bit pattern by exposing the chip to ultraviolet light. A new program can then be written into the memory. The entire process may be repeated as many times as required.

A total of 16 of these chips can be socket-mounted on the module to yield the maximum capacity of 4K x 8.

The board may be depopulated in any combination of single 1702A devices to the minimum capacity of 256 x 8.

The board will be made available with 24-pin DIP sockets to accommodate up to 16 1702A units. The user may buy the 1702A chips from an outside vendor or from DIGITAL.

Module Features

- Quad
- Contains 16 24-pin DIP sockets
- Any multiple of 256 x 8 is selectable on the module
- Address decoding performed on board
- Address expansion input
- Data Ready line for use during Read cycle
- Power requirements: +5 V dc; -15 V dc

M7346 - External Event Detection Module

The External Event Detection Module (EEDM) is a dual-purpose MPS10 module designed to implement priority interrupt schemes or provide a power failure detection capability. The module is contained on a single-height, extended-length PC board.

Module Features

- Interrupt priority scheme arranged in ascending order of priority; (AC LOW is highest priority)
- Eight interrupt lines available to user
- Ac voltage continuously monitored for LOW condition
- Eight dedicated memory locations for implementation of interrupt routine

Foundation Module

The facility to allow a user to develop his own customer interface circuitry will be supplied by a "Foundation Module."

No special module will be developed for this purpose, per se; instead, the full line of available Logic Products wire wrappable modules is recommended for this purpose. The most appropriate module for the customer's particular application may be chosen from a list of 17 W Series modules, typical of which are the W966 and W967 modules.

Notes on machine performance

The pitfalls in trying to establish the real performance ability of the machine were discussed earlier. Some effort has been expended in trying to establish some performance benchmarks, and typical examples are shown as follows:

Example 1 Addition of two 8-bit numbers

Case I: Register-to-register within the confines of the chip: 20 microsecond minimum

Case II: Numbers are located in memory (external to chip); sum to be stored back in memory: 200 microsecond minimum

Example 2 Servicing of "interrupt" through the M7346, External Event Detection Module

Time to set to Restart location: 20 μs min, 64 μs max.

Example 3 UART operation

A read and store data until detection of null condition was chosen as a typical UART operation. Time to read each character is approximately 270 μs; time to terminate operation after null detection is approximately 175 μs.

Example 4 Detection of external events through the 8-bit data port

104 μs min (highest priority)
528 μs max (lowest priority)

This refers only to the overhead time for servicing. The time for operations resulting from any external event is not included.

New Dimensions for Modules

A new dimension has been added for logic modules--that of software. However modest the processing capabilities of the Processor Module may be, it can still be recognized as being in the classic Von Neumann category and requires a set of machine instructions to operate.

SOFTWARE/PROGRAMMING

The Intel 8008-1 processor chip on the PM uses a set of 48 data-oriented instructions which may be divided into the following subsets:

Index Register Instructions (7)
Accumulator Group Instructions (28)
Program Counter & Stack Control Instructions (10)
Input/Output Instructions (2)
Machine Instructions (2)

Module Language Assembler (MLA)

- Translates symbolic programs to their paper tape punch-out binary codes, together with an optional printout listing on Teletype or paper tape punch, with error messages, if any.

- Operating instructions and output format closely resemble the PAL Assembler for the PDP-8.

- The binary output format is identical to the PDP-11 ABSLDR.

Editor Program

The Editor Program is the standard PDP-8 PAL Editor

Loader Program

The Loader Program will reside in the M7342 Monitor/Control Module ROM. The program will be used to load the binary tape output of the Assembly Program in the PM memory.

Operating Environment

The recommended minimum operating environment is 4K PDP-8, Teletype, and paper tape reader/punch.

DIAGNOSTIC PROGRAMS

1. Processor Module Diagnostic
2. PROM Diagnostic
3. RAM Diagnostic

Processor Module Diagnostic

- Comprehensive test of processing and I/O functions, including UART, on the Programmable Module
- Errors reported by error halts
- Use of M7342 Monitor and Control Module required

PROM Diagnostic

- Use of M7341 (PM) and M7342 (MCM) required
- PROM data is written into the M7342 RAM scratch pad
- Program reads and verifies PROM checksum

RAM Diagnostic

- Use of M7341 (PM) and M7342 (MCM) required
- Worst-case data patterns are written into RAM under test
- Error conditions are indicated by error halts

DOCUMENTATION AND SUPPORT

The primary support documentation will consist at least of the following:

1. User Reference Manual
2. Module Data Sheets
3. Comprehensive Descriptive Brochure
4. Logic Schematics

User Reference Manual

This manual will be divided into two major sections--Hardware Section and Software Section.

Hardware Section

This will comprise the following subjects:

- Introduction
- Operating Characteristics
- Functional Description
- Programming Considerations
- Applications Analysis

Software Section

This will comprise the following subjects:

- PDP-8 Host Operating Environment
- PDP-8 Paper Tape Symbolic Editor
- LSI-M Series Module Language Assembler
- Loader
- Programming Techniques
- Appendices
  - Summary of Editor Commands
  - Summary of Assembler Instructions and Pseudo Instructions
  - ASCII Character Set
  - Hexadecimal Character Set
  - Post-Processor
  - Application Analysis

Data Sheets

An individual data sheet will be available for each module in the set, giving the key characteristics of the module in sufficient detail to allow a potential user to determine whether the equipment meets his application requirements.

Product Brochure

A brochure offering a brief overview of the entire MPS10 including hardware and software.

DELIVERY

Availability of prototypes is tentatively set for March '74; availability of production units is tentatively set for June '74.

FIELD SERVICE

No field service will be offered. Defective modules must be returned to depot or to factory for repair.

WARRANTY

Modules are warranted for 90 days.

FURTHER INFORMATION

For further information, contact Logic Products Group, Sales Support, on Maynard extension 2785.

PRODUCT PROMOTION and SUPPORT PLAN*

Announcement to Sales Force (mailing) ---- week of 3 December 1973

Trade Press Announcements

ELECTRONIC NEWS ---------- week of 22 February 1974
COMPUTER WORLD ---------- " " " " "
EDP DAILY ---------- " " " " "

Article Publications

IEEE SPECTRUM (design article) ---------- issue of March 1974
COMPUTER DESIGN (survey article) ---------- " " April 1974
DIGITAL DESIGN (product article) ----- issue of March/April 1974

Direct Mail Campaign

PDP-8 User List ---------- 11 February 1974
Logic Products Users ---------- " " "
General Mailing (TIDS) ---------- 11 March 1974

Documentation

Preliminary Hardware Users' Reference Manual -- 28 February 1974
Preliminary Software Users' Reference Manual -- " " "
Preliminary Data Sheets ---------- 28 March 1974
Final Users' Reference Manual (Hardware & Software) ---------- 31 May 1974
Final Data Sheets ---------- " " "

Trade Shows

IEEE, New York ---------- 26-29 March 1974
National Computer Conference, Chicago ---------- 6-9 May 1974
WESCON, Los Angeles ---------- September 1974

LPS Training ---------- January 1974

Space Advertising (magazines to be defined)--------- May/June 1974

*Subject to schedule changes

COMPETITION

The following pages give a quick look at readily identifiable competition for the MPS10. We have tried only to examine competitive products that could be considered as truly modular.

The competitive matrix tries to encompass such areas as technology, physical arrangement, software/programming, and price. A valid price comparison proved extremely difficult to achieve because individual competitive equipment offerings vary widely according to the vendor. The "typical configuration" used for comparison purposes comprises the following pieces of equipment:

1 CPU Module
1 1K x 8 RAM memory module
1 Backplane (system unit, card rack, et al)
1 External Event Detection Module

The prices are predicated on an OEM discount basis and are estimated due to lack of full pricing and discount structure information at this point in time.

Types of product available

Grossly speaking, three basic types of microprocessor organizations have appeared on the market to date:

1. 4-bit, fixed instruction set, serial machines
   (Intel MCS-4, Fairchild PPS-25)

2. 8-bit, fixed instruction set, parallel machines
   (Intel 8008 and 8080, Intersil*, Motorola*

3. 8-bit, or wider, microprogrammed machines
   (National IMP16 series; AMI CT7300)

*Not announced as of this date

QUICK LOOK AT COMPETITION

4-Bit Machines

Alden Self-Transit	StaRRcom
PROLOG Corp.	PLS-403
Comstar Corp.	Star System 4
Allied Computing Technology	CBC-4N

8-Bit Machines

Allied Computing Technology	CBC-8N
Automatic Electronic Systems	AES-80
Computer Electronics Limited	CE-5000
R2E	Micral
Control Logic Corporation	L-500 Series
Intel	Sim 8 Series

16-Bit Machines

National Semiconductor Corporation	IMP16-C
Computer Automation	Naked Mini/LSI
General Automation	LSI 12/16
American Micro Systems	7300

	MODULE	CHIP	TTL	MOS	# of Bits	# of Instructions	Micro-programmed	Max. Memory Addressing	Instr. Cycle Time in μs	CARD RACK	CABINET	CONSOLE	PWR. SUP.
Logic Products PM Module	●			●	8	48		16K	12.5	●		●	●
Pro-Log Corp. PLS 403	●			●	4	46		10K	11	●			●
Comstar Star System 4	●			●	4	46		10K	11	●		●	●
Appl. Comp. Tech. CBC4-N	●			●	4	46		10K	11				
Control Logic L500	●			●	8	48		16K	12.5	●			●
Intel SIM-8	●	●		●	8	48		16K	12.5	●	●	●	
Varitel MC-80	●			●	8	48		16K	12.5				
Auto. Elect. Sys. AES-80	●		●		8	92	●	16K	0.2	●		●	●
CEL (UK) CE5000	●			●	8	48		16K	12.5	●	●	●	
R2E (France) Micral	●			●	8	48		16K	12.5	●			●
Alden Self-Transit staRRcom	●			●	8	48		64K	12.5	●	●	●	●
Amer. Microsys. 7300		●		●	8		●	512	4.0				
Natl. Semicon. IMP-16C	●	●		●	16	42	●	64K	1.5			●	

	ASSEMBLER	EDITOR	DIAGNOSTICS	UTILITY PROGRAMS	ON-LINE PROG. PREP.	OFF-LINE PROG. PREP.	$700-$800	$800-$1,000	$1,000-$1,500	
Logic Products PM Module	●	●	●			●	●			
Pro-Log Corp. PLS 403						●		●		
Comstar Star System 4		●	●	●		●		●		
Appl. Comp. Tech. CBC4-N						●	●			
Control Logic L500	●	●	●	●		●		●		
Intel SIM-8	●	●	●	●		●			●	
Varitel MC-80						●		●		
Auto. Elect. Sys. AES-80	●	●				●			●	
CEL (UK) CE5000	●	●	●	●		●			●	
R2E (France) Micral	●					●			●	
Alden Self-Transit staRRcom				●		●				
Amer. Microsys. 7300						●				
Natl. Semicon. IMP-16C						●	●			

APPENDIX

COMPARATIVE PRICING

and

COST/PERFORMANCE MATRICES

MPS10 APPLICATIONS

Problem #1

Four-axis stepping motor control for commercial sewing machine button hole applications.

Solution

PDP-8/M (PROM)	Programmable Module
1 PDP-8 (PROM/2K)	1 PM CPU
2 M1705	1 ROM Module (inc. 2 1702A chips)
1 M1703	1 RAM Module (1K)
1 KL8	1 M1502
	1 G720
	1 M783
	1 M7328
	2 Mounting hardware
	1 Power supply
Net Price $2,581	$1,333

Problem #2

Controller to implement the sequential placement of components on tape to be used in an automatic component insertion machine.

	PDP-8/M		RTM	PM
	(CORE)	(PROM)		
CPU	$2,342	$1,700	$ 689	$ 331
Memory	Yes (4K)	Yes (4K)	325 (256)	417 (1.5K)
Interface				
Common	394	394	394	394
Unique	292	292	298	312
Total	686	686	692	706
Mounting Hardware	Yes	Yes	156	115
Power Supply	Yes	Yes	421	234
Box	Yes	Yes	160	160
	$3,028	$2,386	$2,443	$1,943

PERSPECTIVE ON PROBLEM 2

I

	PROM 8	RTM	PM	
System Cost	$2386	$2257	$1943	
TTY	192	+112	YES	
Memory				
768 ROM	YES	+102	+39	
256 RAM	YES	- 64	-182	(effective)
TOTAL	$2578	$2407	$1800	

II

	PROM 8	RTM	PM
Performance/Price	1.00	1.07	1.45
Price/Performance	1.00	0.93	0.69

(PROM 8 taken at value 1.00)