Laboratory No 3

Investigation of the training 16-bit microprocessor system

1. The aim of the work

To acquaint with the structure of the training 16-bit microprocessor system (MPS) MDA–8086, the register model of the microprocessor and the distribution of memory fields; to clear up the functions of the key and display monitor.

2. General knowledge

2.1. Microprocessor

In the MPS a 16-bit microprocessor Intel® 8086, produced using the MOP technology is applied. There are about 29000 transistors in the microprocessor core.

The main architectural properties of this microprocessor which increase its efficiency more than 10 times compared with the microprocessor Intel® 8080 are the following:

- the instruction set is expanded (multiplication, division, processing of symbol lines);
- the possibility of selection from the memory and execution of instructions at the same time;
- more flexible organization of interrupts;
- provided possibility of working in multiprocessor systems;
- expanded possibilities of memory addressing.

The main characteristics of the microprocessor Intel® 8086 are the following:

- clock frequency – 5, 8 and 10 MHz (0.33, 0.66 and 0.75 million operations per second, respectively);
- manufacturing technology – 3 μm;
- data bus width – 16 bits;

- address bus width – 20 bits;
- addressable memory – 1 MB;
- the number of main instructions – 133;
- power supply voltage – +5 V;
- power consumption – 1.75 W.

Note**:** *In the MPS the microprocessor Intel® 8086, the clock frequency of which is – 14.7456 MHz, is applied.*

The internal architecture of the microprocessor from the point of view of the programmer (programming model) is presented in Figure 1.

The 16-bit data registers **AX**, **BX**, **CX** and **DX** are applied in performing arithmetical and logical operations. Among these registers accumulator **AX** occupies an exceptional place. One of operands is usually stored in it and after the execution of the operation – its result is stored.

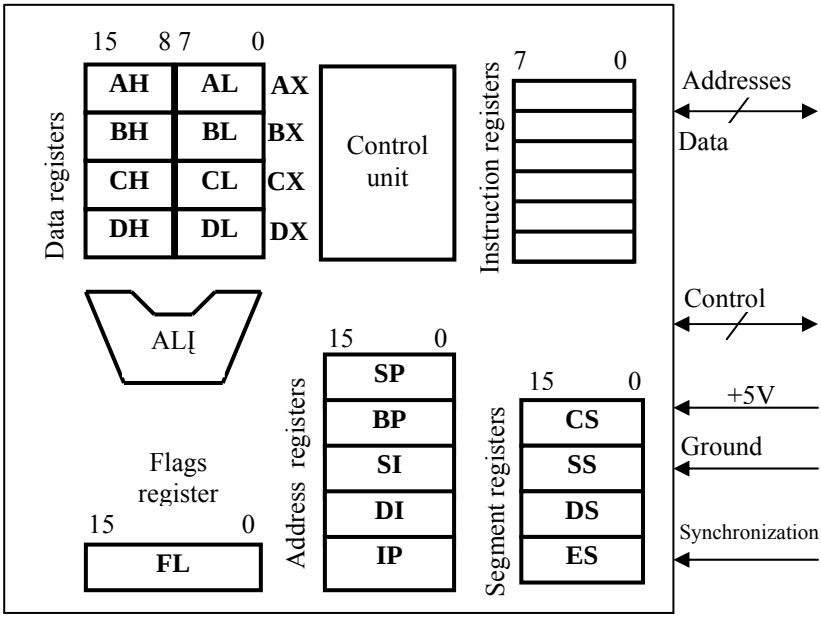

Fig. 1. The programming model of the microprocessor Intel® 8086

Registers **BX**, **CX** and **DX** are applied not only in arithmetical and logical operations, but they also have a special purpose. The base register **BX** is applied in calculating addresses, **CX** in cyclic procedures operates as a counter of cycles, **DX** – in some input and output operations the port addresses are stored.

Each of the mentioned registers consists of two parts – **H** (High) and **L** (Low), having 8 bits, which can be accessed separately. From the point of view of program compatibility, the data registers are coincide as follows:

Intel® 8086	Intel® 8080
AL	**A**
BH	**H**
BL	**L**
CH	**B**
CL	**C**
DH	**D**
DL	**E**

The group of address registers consists of the so-called pointer and index registers. In the instruction pointer **IP** and the stack pointer **SP** the information about instruction and stack addresses is stored, but comprehensive instruction and stack addresses are found by summing up the contents of these and other registers (e.g., **CS** and **SS**). The register **BP** is a base one when accessing the stack and calculating the address, most often applied with other registers. Registers **SI** and **DI** are intended for indexing. **SI** is the operand transmitter index register, **DI** – the receiver index register. Relative addresses are stored in them not exceeding the data segment limits. Although registers **SI** and **DI** can be applied separately, but when calculating the address they are often combined with registers **BX** and **BP**.

The segment registers group consists of four 16-bit registers: **CS** – the program or code register, **DS** – the data register, **SS** – the

stack register and **ES** – the additional or extra data register. In all these registers initial addresses of corresponding segments are stored.

In the 16-bit flags register **FL** the processor status word (PSW) is fixed. Values of its bits are presented in Table 1.

Table 1. Values of flags register **FL** bits.

Bit	Flag	Flag value when logic 1 is in the bit
0	**C** (Carry)	Carry (borrow) from the highest bit
2	**P** (Parity)	Even number of units in a lower byte
4	**A** (Auxiliary carry)	Carry (borrow) from the third result bit
6	**Z** (Zero)	Operation result is equal to zero
7	**S** (Sign)	Operation result is negative
8	**T** (Trap)	Interrupt after each instruction
9	**I** (Interrupt)	Peripheral interrupts are allowed
10	**D** (Direction)	Symbol line is processed from the end
11	**O** (Overflow)	Overflow of the highest bit

It can be seen from the presented table that the lower PSW byte of the microprocessor Intel® 8086 corresponds to the PSW of the microprocessor Intel® 8080.

The instruction register consists of 6 byte FIFO (First Input First Output) type queue, which is constantly supplemented when the system bus is free. It significantly speeds up the microprocessor operation because after performing a routine instruction, another instruction most often already is in an instruction register.

2.2. Distribution of memory fields

Random-access memory (64KB)	Addresses
Interrupt vectors, user stack	$0000{:}0000_{16}$ – $0000{:}1000_{16}$
User field	$0000{:}1000_{16}$ – $0000{:}FFFF_{16}$
Non-volatile memory (64 KB)	**Addresses**
Key and display monitor	$F000{:}0000_{16}$ – $F000{:}FFFF_{16}$

2.3. Output ports

The instruction **OUT** is applied to the parallel programmed adapter (PPA) to program and output data through any port. For this purpose in the MPS three 82C55AC-2 microcircuits U29, U30 and U45 each having three 8-bit ports A, B and C, and one control register are used. The ports of the microcircuit U30 are marked „**C01**". The ports of the microcircuit U29 are called „**C02**", and those of the microcircuit U45 – „**C03**". All ports can be addressed separately (e.g., **C01A**, **C02C**, etc.) or in pairs (e.g., **C01A** – **C02A**, **C01B** – **C02B**, etc.), so that one 16-bit port can be organized. MPS port addresses are presented in Table 3.

Table 3. MPS port addresses

Microcircuit	Port	Address
U30	**C01A**	18_{16}
	C01B	$1A_{16}$
	C01C	$1C_{16}$
U29	**C02A**	19_{16}
	C02B	$1B_{16}$
	C02C	$1D_{16}$
U45	**C03A**	20_{16}
	C03B	22_{16}
	C03C	24_{16}

Output operations through ports can be demonstrated by applying: seven-segment display, light diodes and level meter, connected to the ports **C02A**, **C02B** and **C02C**, respectively, and a three-color dot matrix connected to the port **C01C**.

Information required for the port programming is presented in Table 4.

Table 4. Information required for the port programming

Port	Control port address	Control word for output
C01	$1E_{16}$	80_{16}
C02	$1F_{16}$	80_{16}
C03	26_{16}	80_{16}

For example, ports **C02** for output are programmed as follows:

Memory cell address	Program code		Comment
	Hexadecimal	Mnemonic	
0000:1000	B0	**MOV AL,80**	Control word transmission to the accumulator **AL**
0000:1001	80		Control word
0000:1002	E6	**OUT 1F,AL**	Control word output
0000:1003	1F		Port address
0000:1004	CC	**INT 3**	Control transition to the monitor program (this instruction is always written at the end of the program)

2.4. Key monitor

The MPS key monitor is switched on by permuting the **P1** switch to the **KIT** position. The monitor program in the non-volatile memory occupies 64 KB and is stored in U7 and U8 microcircuits. By applying a keyboard the following operations are performed:

- reading and modification of memory cell contents;
- reading of register contents;
- input and execution of assembler programs;
- execution of assembler programs in a step mode;

The MPS keyboard has 8 function and 16 hexadecimal keys.

The purpose of function keys is as follows:

„**RESET**“ – aborts any operation of the microprocessor and returns MPS to the initial state. By pressing this key,

MDE8086 Kit V9.5

Midas2109-5964/5,

is displayed on the MPS liquid crystal display, which means that the monitor program is ready to accept the command from the keyboard.

„**MON**“ – aborts the program execution and transmits control to the monitor program.

„**REG**“ – is applied to display the content of registers (switches on the register display).

„**AD**“ – is applied to indicate the memory cell address.

„**DA**“ – is applied to enter data to the memory.

„**:**“ **–** is applied to separate the segment address from the effective address (displacement).

„**+**“ – is applied to increment the segment address and the effective address (displacement) (to increase by unity) or to control the register display.

„**–**“ – is applied to decrement the segment address and the effective address (displacement) (to decrease by unity) or to control the register display.

„**STP**“ – is applied to execute the user program by a step.

„**GO**“ – is applied to execute the user program or execute the monitor functions.

The MPS liquid crystal display has 2 lines of 16 bits each. If
MDE8086 Kit V9.5
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is displayed on the LCD, it means that the monitor is waiting for one of the commands written on the function keys. By pressing a respective key the further operation of the monitor program will depend on the entered command.

The key monitor program can execute 5 commands. For the description of commands we will apply the following syntax:

( ) – a key;
[ ] – an optional element of the command syntax;
[ ]* – one or some optional elements of the command syntax;
< > – an element determined by the user.
All commands of the key monitor are presented in Table 2.

Table 2. Key monitor commands

Command	Command syntax
Review or modify contents of memory cells	(**AD**) <segment address> [(+)(–)] (**:**) <effective address> [(+)(–)] [(**DA**)] [<data>](+)(–)]*
Review or modify contents of the memory cells not indicating their address	(**DA**) [<data>](+)(–)]*
Review content of registers	(**REG**) [(+)(–)]
Execute the user program	(**GO**)
Execute the user program in a step mode	(**STP**)

2.5. Display monitor

The MPS display monitor is switched on by permuting the **P1** switch to the **PC** position. The display monitor program, just as the key monitor program, is stored in the memory microcircuits U7 and U8. By applying this program, MPS can be connected to the personal computer and apply its display and the keyboard.

The readiness of the monitor to accept the command is displayed by **8086 >** at the beginning of the command line. Following this sign the command code of one symbol and 1–3 parameters (arguments) are entered. Between the command code and arguments a space can be made. If there are more arguments – a comma is typed and the command line is ended by pressing the „**Enter**“ key.

Command parameters are entered by hexadecimal numbers, except the command of the register contents review and modification, where register names are used as command arguments.

Address arguments consist of the segment address and their effective address (displacement) detached by a colon.

By switching on the MPS or by pressing the key „**RESET**“, the display monitor switches to the initialization program, and

Serial monitor!
Midas2109-5964/5

is displayed on the liquid crystal display,

**** 8086 Monitor 9.5 ****
**** Midas2109-5964/5 ****
8086 >

is displayed on the personal computer display screen, which shows that the monitor is waiting for a new command. The MPS keyboard, except keys „**RESET**“ and „**MON**“, is blocked.

All 9 display monitor commands are entered on the personal computer keyboard, in capital letters (Table 5).

Table 5. Display monitor commands

Command	Commands syntax
Review or modify the contents of memory cells	**E** <segment address> : <effective address> [<data>]* [.] ↵Enter
Output the content of the memory area	**D** [<segment address> : <effective address>] [,<number of bytes>] ↵Enter
Review or modify the register contents	**R** [<register name>] ↵Enter [<data>]* ↵Enter
Move the data area in memory	**M** <segment address> : <effective address>, <number of bytes>, <segment address> : <effective address> ↵Enter
Fill the memory area with any data	**F** <segment address> : <effective address>, <number of bytes>, <data> ↵Enter
Load the user program from the file	**L** ↵Enter
Execute the user program	**G** <segment address> : <effective address> ↵Enter
Execute the user program in a step mode	**T** ↵Enter [↵Enter]*
Help	**?** ↵Enter

3. Task

1. Set the MPS key monitor mode.
2. Draw and fill the tables:

Table 6. Results of tests with registers

Register	Register content
AX	
...	
FL	

Table 7. Results of review and modification of MPS memory cell contents

Memory cell address	Memory cell content		
	Initial	Modified	After pressing „**RESET**“
0000:10X0			
0000:10X1			
0000:10X2			
F000:FXX0			
F000:FXX1			
F000:FXX2			

Note: *write an optional number instead of X and XX..*

3. Switch the MPS to the display monitor mode and connect with the personal computer through the serial communication port.

4. Switch on the computer, load „Tera Term Pro“ program and configure the link channel with MPS.

Characteristics of information transmitted by MPS in series:

- data transfer rate – 9600 bits per second;
- symbol length – 8 bits;
- parity control is not applied;
- number of „stop“ bits – 1.

5. Draw and fill tables 7, 8, 9 and 10.

Table 8. Results of tests with registers

Register	Register content		
	Initial	Modified	After pressing „**RESET**“
AX			
...			
FL			

Table 9. Results of data carry in memory.

Initial data		Data carried by command „**M**“	
Memory cell address	Data	Memory cell address	Data
0000:10X0		**0000:10X0**	
0000:10X1		**0000:10X1**	
0000:10X2		**0000:10X2**	
0000:10X3		**0000:10X3**	
0000:10X4		**0000:10X4**	

Table 10. Results of memory fill with data

Initial data		Memory cells filled with data by command „**F**“	
Memory cell address	Data	Memory cell address	Data
0000:10X0		**0000:10X0**	
0000:10X1		**0000:10X1**	
0000:10X2		**0000:10X2**	
0000:10X3		**0000:10X3**	
0000:10X4		**0000:10X4**	

6. Output the data byte to the seven-segment display (Fig. 2). Write down the required instructions.

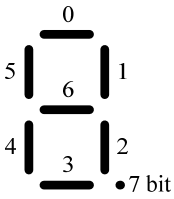

Fig. 2. Seven-segment display and numbers of its bits

7. Copy the display monitor commands, executed in tasks 5 and 6, and their execution results by applying the program „MS Office Word“, to the memory device and apply in the report with required comments.

4. Contents of the report

1. The aim of the work.
2. Key monitor commands and results of their execution.
3. Display monitor commands and results of their execution.
4. Conclusions.

5. Test questions

1. The main characteristics of the microprocessor Intel® 8086.
2. How is the MPS memory distributed?
3. Key (display) monitor functions.
4. Enumerate the key monitor commands.
5. What computer port is the MPS connected to?
6. How to setup the MPS and the computer communication channel?
7. Enumerate the display monitor commands.

References

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