

MPF-I

USER'S MANUAL

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THE FIRST 50 YEARS OF THE 20TH CENTURY WITNESSED THE INVENTION OF THE INTERNAL COMBUSTION ENGINE, WHICH GREATLY EXTENDED THE PHYSICAL STRENGTH OF THE HUMAN BODY

IN THE 2ND HALF OF THE CENTURY, THE BIRTH OF THE MICROPROCESSOR FURTHER EXTENDED OUR MENTAL STRENGTH. APPLICATIONS OF THIS AMAZING PRODUCT IN VARIOUS INDUSTRIES HAVE INTRODUCED SO MUCH IMPACT ON OUR LIFE, HENCE, IT IS CALLED THE SECOND INDUSTRIAL REVOLUTION.

CONGRATULATIONS!

Your Micro-Professor will lead you to the world of microprocessor. Unpacking the MPF-I, you will have found the Micro-Professor, an adaptor, and a manual. The standard configuration of your MPF-I includes one MPF-I microcomputer set, two pieces of built-in male header, one unit of book-type package, one AC-DC adaptor, and a copy of User's and Experimental Manual.

In addition to those standard items, three options are for your function expansion which you can buy from local distributor choice:

- 1) SSB-MPF, which is a speech synthesizer board based on Texas Instruments' TMS5200/5220, and which can reproduce sound and voices stored in its memory.
- 2) EPB-MPF, which is an EPROM programmer board for TMS2508, TMS2516, TMS2532, Intel 2578, Intel 2716, and Intel 2732.
- 3) BASIC-MPF, which is a 2K byte tiny BASIC interpreter.

Still, there are some accessories for your choice. You can select

- 1) SSB-CPK, Z80-CTC (counter and timer) and Z80-PIO (parallel I/O) chip kit.
- 2) MPF-BBD, 1.42" x 3.15" breadboard.
- 3) MPF-2KRAM, 2K x 8 RAM 6116, 58725 or others in function equivalent
- 4) MPF-2KROM, blank 2K bytes EPROM TMS2516, I2716 or equivalent.
- 5) MPF-4KROM, blank 4K bytes EPROM TMS2532, I2732 or equivalent.

Notes: I. When your MPF-I is in use, the power regulator 7805, which is installed in the upper right corner of the MPF-I, may heat up. A temperature of 70 C is normal. Just keep your hands off the power regulator.

II. Cassette interface:

1. Use high quality audio tape and tape recorder.
2. When read data from cassette, the volume switch of your tape recorder should be turned to its maximum.
3. In case you have problems using your cassette recorder for data storage or retrieval properly, the battery of cassette recorder may run out of power. Change with new batteries.

If any problem occurs while you use our MPF-I, we wish you to contact us or your local dealers immediately.

NOTE TO USER

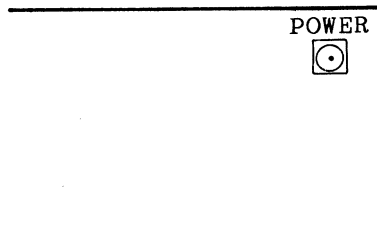
This manual is not meant to serve as an introduction to computer programming; the reader is supposed to have had some previous experience on microcomputer and microprocessor. The reader without any previous background on basic concept of computer is suggested to refer "An Introduction to Microcomputers Volume 0 the Beginner's Book" by Adam Osborne, Osborne and Associates Inc. before he starts reading this manual. The reader is also suggested to refer textbook on Z-80 assembly programming such as "Z80 - Assembly Language Programming Manual" published by Zilog Inc.

READ ME FIRST

The manuals that accompany your Micro-Professor are designed for reference and to suggest experiments by showing examples. To get started, it is suggested that you follow the procedures given below.

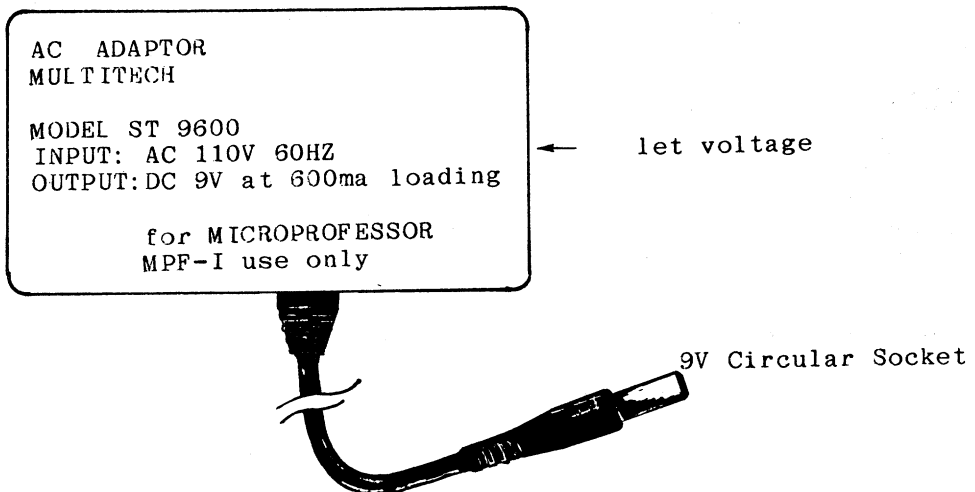
UNPACKING AND INSTALLATION

Open the "book" containing the Micro-Professor(MPF-I). Locate the power connector in the upper right-hand corner Art. A



Art. A Location of the MPF-I power connector

Find the AC adaptor. The adaptor Art. B is a black box labeled "AC ADAPTOR MULTITECH". You should make certain that the voltage input shown on the adaptor matches the voltage supplied by your outlet. In the United States it is assumed (unless a special order is made) that the supply is 117VAC-which is usually referred to as one-ten (110V). You should also check the frequency; the label on the adaptor will show the frequency in Hertz(Hz).



Art. B AC ADAPTOR

Plug the 9V circular socket into the power receptacle on the MPF-I. The side opposite the AC Adaptor label is to be plugged into your outlet.

```
*****
* CAUTION DO NOT TOUCH THE PRONGS WHEN PLUGGING *
* THE AC ADAPTOR INTO YOUR OUTLET *
*****
```

When power is applied to the MPF-I the following series of patterns should appear

```

                                u      First pattern
                                U P
                                M P F
                                M P F -
                                M P F - -
                                M P F - - -      Final pattern

```

Strong background light will make the displays hard to read. If at all possible avoid bright lighting.

TESTING AND FAMILARIZATION

In the exercise below you will be shown how to enter and execute a short program. Performing this exercise will test some of the MPF-I functions and familiarize you with the MPF-I. The program used in this section adds two numbers and stores the result in memory.

PROGRAM IN ENGLISH

Load the first number into the A register and the second number into the B register. Add the contents of the B register to the contents of the A register and put the result (sum) in the A register. store the value in the A register in memory location 1830H (H stands for hexadecimal). Finally halt the Micro-Professor.

Source Program in Assembly Language

```

ORG      1800H      ; Start code at 1800 hexadecimal
LD       A,05      ; Load the A register with 5
LD       B,04      ; load the B register with 4
ADD      A,B       ; A ← A + B
LD       (1830H),A ; Store A at memory location 1830H
HALT    ; Stop execution of program

```

ASSEMBLY LISTING

All program are entered into the MPF-I in hexadecimal. Therefore, you first write your program in assembly language and then translate it into hexadecimal. All of the demonstration programs written in the MPF-I manuals will also list the machine language code - which is in in hexadecimal. A complete assembly listing is shown below.

LOCATION COUNTER	MACHINE LANGUAGE	STATEMENT NUMBER	ASSEMBLY LANGUAGE	
1800		1	ORG 1800H	;Start code at 1800 hexadecimal
1800	3E05	2	LD A,05	;Load the A register with 5
1802	0604	3	LD B,04	;Load the B register with 4
1804	80	4	ADD A,B	;A ← A + B
1805	323018	5	LD (1830H),A	;Store A at memory location 1830H
1808	76	6	HALT	;Stop execution of program

Fig. 0-1 Assembly Language Listing

LOADING THE MACHINE LANGUAGE CODE

You will now enter the machine language code shown in the assembly language listing (Fig. 0-1). If you haven't already done so, connect your MPF-I to the power source. Now press the system reset key **[RS]**. Section 3.1.1 of the reference manual contains a brief explanation of reset key actions.

Since the available RAM (random access memory) starts at hexadecimal location 1800, the entry of machine language code will start at 1800H. Press the address key **[ADDR]**, a random address will be displayed on the four leftmost digits; these digits will be referred to as

8 8 8 8

ADDRESS FIELD

0 0

DATA FIELD

The address field. Enter the starting address for the machine language code by pressing **[1] [8] [0] [0]**. The same result can be obtained by pressing the program counter key **[PC]** (this only works when your program starts at 1800H). Now inform the Micro-Professor that data is to be entered by pressing **[DATA]**. Refer to line 2 of the assembly language listing. Line 2 contains two bytes of machine language code 3E and 05. Key in the first byte by pressing **[3]** and **[E]**. The display should now show

1 8 0 0 **3E**

ADDRESS FIELD DATA FIELD

Advance the address field display by pressing **[+]**. The display will show

1 8 0 1 **X X**

X= unknown data

ADDRESS FIELD DATA FIELD

Enter the second byte of hexadecimal data by pressing **[0]** then **[5]**. The display will now show

1 8 0 1 **0 5**

ADDRESS FIELD DATA FIELD

Line 3 of the listing also contains two bytes of hexadecimal data; enter these bytes by keying **[+]**, **[0]**, **[6]** In a similar manor enter **[+]**, **[0]**, **[4]** the rest of the program, namely

[+] [8] [0] [+] [3] [2] [+] [3] [0] [+] [1] [8] [+] [7] [6]

CHECKING FOR DATA ENTRY ERRORS

The program had been entered. It is wise to check for entry errors. Press **ADDR** **1** **8** **0** **0**. Are the rightmost two displays (data field) equal to 3E? If not press **DATA** and enter **3** **E**. To examine the next byte press **+**. Is there a 05 in the data field? If the display is correct, continue inspection of all the remaining data using the **+** key. If the present byte or any successive bytes are incorrect, enter the correct data.

Section 3.1.2 contains a formal description of how to enter data.

PROGRAM EXECUTION

There are two ways to begin execution at address 1800H. The simplest is to press **RS**, **PC**, and then **GO**. The second method allows execution to begin at any address. Press **RS**, **ADDR**, the beginning execution address, e.g. **1** **8** **0** **0**, then **GO**. When you press **GO** the screen will eventually go back less than a second and stay blank. The program has reached the HALT instruction and is waiting for the next operator action.

CHECKING THE RESULTS

To regain control of the keyboard functions press **RS**. The answer to 5+4 was stored at location 1830H. Key in **ADDR** **1** **8** **3** **0**. The display should show

1	8	3	0	0	9
ADDRESS FIELD				DATA FIELD	

The action of the **PC** and **GO** keys are explained in section 3.1.4 and 3.2.1 respectively.

PROGRAM EXAMPLES

Section 5.10 contains five programming examples. Using the knowledge gained in exercise above enter the hexadecimal code shown in each program and then execute the program. Perform the same steps with the MPF-I Experiment Manual in Experiment-12, 13, 14, 17, 18.

IF YOU MAKE AN ERROR

- 1) A byte was incorrectly entered. Write the correct over the incorrect byte.
- 2) One or more bytes were left out. Read section 3.3.3 then remove the bytes one by one.
- 3) One or more bytes need to be added. Read section 3.3.2 then add each byte.
- 4) To trace the execution of each instruction see section 3.2.2. Warning: If you are not familiar with the concept of single stepping you will need to read this section several times. You may find it necessary to consult additional learning material.

LEARNING AND EXPERIMENTING

For self learning, proceed to section III. Section III contains a series of experiments. Read the theory (background) of each experiment and then do the exercises. If you do not understand parts of an experiment, do not be discouraged. Some of the experiments are quite advanced. You can refer to the MPF-I Student Workbook, published by Multitech Industrial Corp.

MPF- I USER'S MANUAL

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1. MPF-I Specification

1.1. Hardware Specifications

(1) CPU: (Central Processing Unit)

Zilog Z-80 CPU with 158 instructions and 2.5 MHz maximum clock rate. The MPF-I system clock is 1.79 MHz.

(2) ROM: (Read Only Memory)

Single +5V EPROM 2516(2532), total 2K(4K) bytes.
Monitor EPROM Address: 0000-07FF(OFFF).

(3) RAM: (Random Access Memory)

Static RAM: 6116, total 2K bytes.
Basic RAM Address: 1800-1FFF.

(4) Memory Expansion Area:

Single +5V EPROM 2516/2716/2532/2732 EPROM or 6116 static RAM on-Board Expansion Address: 2000-2FFF

(5) I/O Port:

Programmable I/O Port 8255, a total 24 parallel I/O lines are used for keyboard scanning and seven segment LED display control.

I/O addresses: 00-03.

Programmable PIO, a total of 16 parallel I/O lines,
I/O address: 80-83H

Programmable CTC, a total of 4 independent counter timers channels, I/O address: 40-43H

(6) Display:

6-digit, 0.5", 7-Segment red LED display

(7) Keyboard:

36 keys including 19 function keys, 16 hex-decimal keys and 1 user-defined key.

(8) Speaker and Speaker Driver Circuits:

A 2.25" - diameter speaker is provided for user's expansion.

(9) User Area:

A 3.5" x 1.36" wire wrapping area is provided for user's expansion.

(10) Audio Tape Interface:

Can be connected to any cassette. Data transmission rate is 165 baud per second (bps).

(11) System Clock Rate:

3.58 MHz crystal is divided by 2, cycle time is 0.56 micro-sec.

(12) System Power Consumption:

Single 5V power supply, current consumption 500 mA.

(13) Main Power Input:

Power adaptor Input 110V 9V/500mA

(14) Physical characteristics

Height : 1.60 mm (W/O case)
Width : 15.75 cm (W/O case)
Depth : 22.30 cm (W/O case)
Weight : 1.41 lb (With Case)

1.2. Software Specifications

MPF-I contains a high performance 2K-byte monitor program. It is designed to respond to user input. The monitor commences execution when power is applied. In addition to the key monitor functions, the monitor contains a memory checking routine.

The following is a simple description of the key functions:

- (1)

RS

 : system reset.
- (2)

ADDR

 : set memory address.
- (3)

REG

 : set a register name.
- (4)

DATA

 : input data to memory or a register.
- (5)

PC

 : recall program counter.
- (6)

+

 : increment memory address or a register by one.
- (7)

-

 : decrement memory address or register by one.
- (8)

STEP

 : single step the user's program.
- (9)

SBR

 : set breakpoint in user's program.
- (10)

CBR

 : clear breakpoint in user's program.
- (11)

MONI

 : terminate the executing program and return the control to the monitor.
- (12)

GO

 : commence execution at address shown on the display.
- (13)

INS

 : insert 1 byte into memory.
- (14)

DEL

 : delete 1 byte from memory.
- (15)

MOVE

 : move a block of data from one area to another.
- (16)

RELA

 : relative address calculation.
- (17)

TAPE WR

 : store data from memory onto audio tape.
- (18)

TAPE RD

 : retrieve data from audio tape.
- (19)

INTR

 : maskable interrupt, connected to CPU's INT pin.
- (20)

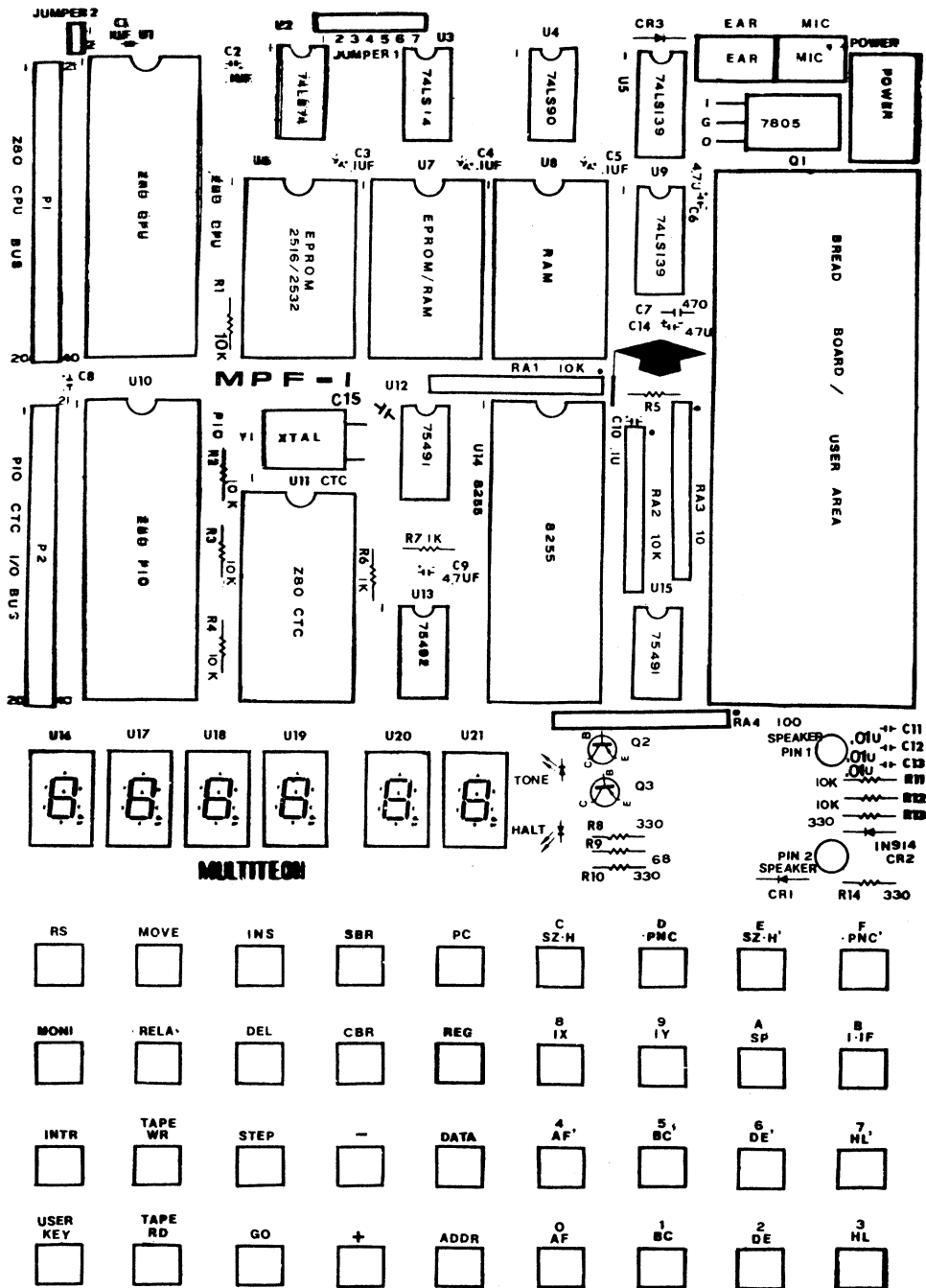
USER KEY

 : user defined key, connected to input port 00, bit 6.
- (21) * :

AF	BC	DE	HL	AF	BC	DE	HL	IX	IY	SP	I-IF	SZ-H	.PNC	SZ-H	.PNC
0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F

 : hexa-digit or register name.

1.3. Physical Configuration



MP 8121

2. General Description

2.1. Functions of Monitor Program

The MPF-I monitor provides the necessary functions for the user to develop his program. These functions include:

- (1) The ability to enter the user's program into RAM and to check and modify the program.
- (2) Execute the user's program which is stored beginning from the address on the displays.
- (3) Using 'Single Step' or 'Set Break Point' function, the user can execute programs step by step or modularly. After each step, control is transferred to the monitor and the current status of the CPU is saved. The user can check or modify registers and memory before executing the next step of the program. This function is very useful in debugging a program.
- (4) Other support functions, include audio tape control, and relative address calculation. Using the functions provided by the MPF-I. The user can develop his own special purpose microcomputer system based on MPF-I.

2.2. Notations Used in This Manual

- (1) Hexadecimal number system and seven-segment LED display format:

hexadecimal number	decimal number	binary number	seven-segment display
0	0	0000	0
1	1	0001	1
2	2	0010	2
3	3	0011	3
4	4	0100	4
5	5	0101	5
6	6	0110	6
7	7	0111	7
8	8	1000	8
9	9	1001	9
A	10	1010	A
B	11	1011	b
C	12	1100	C
D	13	1101	d
E	14	1110	E
F	15	1111	F

Fig. 2-1 Number system

-
- (2) Each display is assigned a number for reference purposes as shown in Fig. 2-2.

123456. Fig. 2-2 the display number

- (3) When the contents of the display are unknown or do not matter an 'X' will be indicated.
- (4) A square stands for a key button, as shown in figure 2-3.



Fig. 2-3 Symbols for buttons

- (5) <address> stands for a memory address which is 4 hexadecimal digits entered by the user. If more than four digits are entered, the last four digits are accepted by MPF-I. If less than 4 digits are entered, leading digits are assumed to be 0.
- (6) <data> stands for 1 byte of data which is 2 digits entered by the user. The rules are the same as for <address>.
- (7) If some key <address>, or <data> is enclosed by '[]', e.g. [<address>], it may be omitted.

2.3. Error Messages:

When an illegal key is entered, the monitor program will blank out the Display to indicate an error condition has occurred. Some program errors will cause an error pattern such as

-Err

 to be displayed. When this occurs, locate and enter the appropriate key.

2.4. RAM Addressing

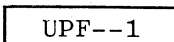
The addresses of the basic RAM are from 1800 to 1FFF. The addresses reserved for expansion RAM are from 2000 to 2FFF. 1F9F - 1FF3 of the basic RAM are allocated to the monitor. The user should read chapter, 4 before using this area of memory.

3. Introduction to Operation

This chapter is divided into three parts: basic operations, program debugging, and support functions. Notations are described in 2.2.

3.1. Basic Operations

3.1.1 System Reset Key -

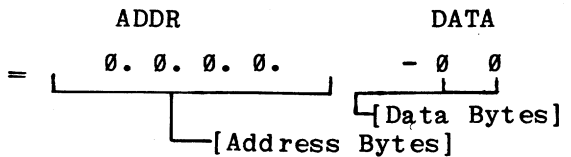
Pressing the Reset Button will display 

On a power-up, the six digit (UPF--1) are shifted out one-by-one from right to left. The monitor program is initialized either the reset button is pressed or on a power-up.

3.1.2 Examine or modify the contents of memory: and Keys
 <address>[[<data>]] [<data>]

EXAMPLE: Check the contents of memory locations 0000-0003

KEY	DISPLAY	COMMENTS
<input type="text" value="ADDR"/>	<input type="text" value="x.x.x.x.x"/>	The four index points notify user to input ADDRESS.
<input type="text" value="AF 0"/>	<input type="text" value="0.0.0.0.6"/>	The contents of ADDR 0 are 6 Note: Display format for ADDR



refer to Description for addition information I-12)

<input type="text" value="+"/>	<input type="text" value="00010.0"/>	Note that the <input type="text" value="+"/> KEY increments the ADDR counter by ONE.
<input type="text" value="+"/>	<input type="text" value="00021.0"/>	Contents of ADDR 0002 is 10.
<input type="text" value="+"/>	<input type="text" value="0003F.E"/>	Contents of ADDR 0003 is FE.

EXAMPLE: Change the contents of 1800 into AB, 1801 into CD.

KEY	DISPLAY	COMMENTS
<input type="text" value="ADDR"/>	<input type="text" value="x.x.x.x.x"/> └──┘ {ADDR field}	4 index points in ADDRESS field notify USER to input ADDRESS.
<input type="text" value="BC 1"/> <input type="text" value="IX 8"/> <input type="text" value="AF 0"/> <input type="text" value="AF 0"/>	<input type="text" value="1.8.0.0.x.x"/>	enter 1800 by pressing the appropriate KEYS.
<input type="text" value="DATA"/>	<input type="text" value="1800 x.x"/> └──┘ {DATA field}	Pressing the data function KEY allows the user to input data into DATA Field.

HL
3

SP
A

18003A.

Enter 3A into the DATA FIELD.

IIF
B

1800A.B.

enter B into the Data field.
If DATA is more than two
digits the last two will be
used.

+

1801x.x.

ADDR Feild increases by one.
The 2 points in the
DATA Field notify user to
input Data.

SZ-H
C

PNC
D

1801C.D.

Enter Data by pressing the
C and D Keys.

EXAMPLE: Update the contents of 0000

KEY

ADDR

AF
0

DISPLAY

0.0.0.0.6

COMMENTS

ADDRESS is 0000

DATA

00000.6.

The contents of ROM cannot
be changed so the display is
blanked. After releasing
the Key the Display will
return as before.

BC
5

00000.6.

[description]:

Addr means address. After pressing this key the display is in the standard format, i.e., the left four digits stand for the address and the right two digits represent the data. The address field is indicated by four points and requires 4 digits. If more than 4 digits are keyed in, only the last 4 are accepted. If less than 4 digits are entered, the 4 hex digits on the display are assumed to be the address.

When DATA is pressed, the indication points will be shifted to the rightmost two digits prompting the user to enter data. The content of the addressed RAM location will be replaced by the entered data. Pressing + or - will increase or decrease the address field. If the indication points are already in the data field, then it is unnecessary to press DATA. After pressing ADDR, the user may press + or - directly.

If the user attempts to change the contents of ROM, the display will blank out. After releasing the key, the display will be restored.

3.1.3 Examine & Update Registers REG and DATA Keys

REG <register name>[DATA [<data>] + [<data>] +

EXAMPLE: Check the contents of SP,HL, IY registers. Change the contents of register A to 12, and register F to 34.

KEY	DISPLAY	COMMENTS
REG	r E G -	SET MPF-I into REGister Mode.
SP A	× × × × S P	The names and contents of the registers are displayed when the register Key is depressed.
HL 3	× × × × H L	
IY 9	× × × × I Y	To display a specific register, first depress the REG Key, then press the register name AF, IY, etc.
AF 0	× × × × A F	
DATA	× × × × A F	The two points under the Data field of register F notify USER to input Data into the Data field.
HL 3 AF 4	× × 3 . 4 A F	
+	× . × . 3 4	The two indication points move to the Data field of register A. Register A is now changed to 12
BC 1 DE 2	1 . 2 . 3 4 A F	
	<div style="margin-left: 40px;"> [F register] [A register] </div>	

[description]:

<register name> is the name of the register. Each register is addressed by one key. When is pressed, the display becomes , prompting the user to key in the name. After pressing register name, the right field of the display is the register mnemonic, the left field is the register content. For example, means the contents of the stack pointer is 1234. <register name> is a one key command. If the user wants to check several registers, he just presses <register name> once for each register.

It is necessary to press , or if the user wants to update the contents. The change is done on a byte basis. When , or is pressed, the display will show two points, notifying the user to input data and indicating that the register is being changed. Pressing or will move the indication points in the direction shown in figure 3-1.

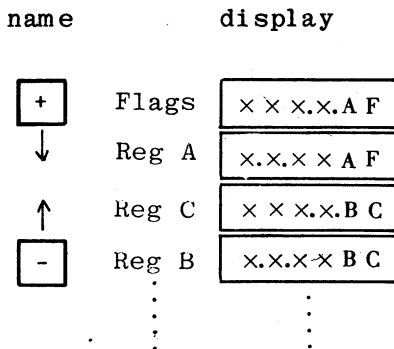
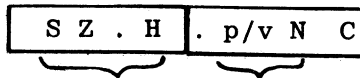


Fig. 3-1 The moving rule for REG indication points

The followings are some special register mnemonics:

1. The alternate registers AF', BC', DE', HL' are indicated by the decimal point at the right.
2. IX, IY is indicated by |I, |Y.
3. Register I and interrupt IFF 2 is indicated by IF.

The meaning of each bit in F is shown in figure 3-2.



FH (Flag High) FL (Flag Low)

'.' = does not matter

Fig. 3-2 Flag register

MPF-I decodes the flag register and displays it in 4 bit groups. To display one of four bit groups, refer to the table below

Selection Key

FH	SZ.H
FL	PNC
FH.	SZ.H'
FL.	PNC'

When decoded flags are modified, only the least significant bit (LSB) of the input key is used. The next time you check AF register, the contents will be updated automatically.

EXAMPLE: Check the carry flag and update it

KEY	DISPLAY	COMMENTS
REG AF O	××29AF	Contents of F is 29.
PNC D	1001FL	Check the carry bit.
DATA	100.1.FL	
AF O	1000.FL	Reset carry flag.
REG AF O	××28AF	F is updated automatically.

3.1.4 Program Counter - PC Key

Reset user's program counter. The basic RAM of MPF-I is 2K bytes. It can be expanded to 4K bytes. When the monitor is reset, it finds the lowest RAM address(1800) and sets the user's program counter to this address. If PC is pressed after RS , the left of the display is the lowest RAM address. See Example A

Example-A

KEY	DISPLAY	COMMENTS
RS	UPF -- 1	
PC	1800xx	Lowest RAM ADDRESS.

3.2. Program Debugging

3.2.1 Program Execution — Key

This key is valid only when the display is in the standard Addr-Data format. After pressing this key, the CPU jumps to the address on the display. Before transferring control to the user's program, it restores all the user's registers. User's registers can be preset by pressing .

EXAMPLE: Executing program

KEY	DISPLAY	COMMENTS
<input type="checkbox"/>	<input type="text" value="1 F A F S P"/>	The left field of the display is not an address.
	<input type="text" value=""/>	Display is blank, indicating an error.
	<input type="text" value="1 F A F S P"/>	Display returns to normal after releasing the key.
<input type="checkbox"/>	<input type="text" value="1800 x x"/>	The left field is an address.
<input type="checkbox"/>	<input type="text" value="x x x x x x"/>	CPU starts execution from 1800.

3.2.2 Single Step - STEP Key

STEP is similar to NO. It is valid only when the display is in Addr-Data form. Pressing this key causes the CPU to execute the instruction pointed to by the current setting of the PC register. After execution, the monitor regains control and displays the new PC and its contents. The user may examine and modify registers and memory contents after each step.

EXAMPLE: Store a program in RAM and execute it by single steps

KEY	DISPLAY	COMMENT
RS	UPF - - 1	Reset system.
PC	1800×.×	Program from 1800. (280 instructions)
HL 3 SZ-H E	18003.E.	
+ AF 0	18010.0.	LD A,0
+ HL 3 SZ-H C	18023.C.	INC A
+ AF 4 HL 7	18034.7.	LD B,A
PC	18003.E.	Display is in the Addr-Data form, address is 1800.
STEP	18023.C.	First step, PC becomes 1802.
REG AF 0	00××AF	Register A is 0.
PC STEP	18034.7.	Second step, PC becomes 1803.
REG AF 0	01××AF	Register A incremented.
PC STEP	1804×.×	Third step, PC becomes 1804.
REG BC 1	01××BC	Register B becomes 01.

When executing using single step, the monitor uses user's stack to store interrupt return address. The user's stack pointer must point to RAM. If not, Err-SP

will be displayed. If user's stack pointer points to

system stack area, SYS-SP will be displayed. Stack overlap will cause an error when 'RET' instruction is executed. In these two cases, you must change the stack pointer or press the reset key. After reset, the system will set user's SP to its default value, the user then need not worry about his stack pointer. (See section 4.5)

3.2.3 Set Break Point - Key

When a program is long, single step execution can be very time consuming. Setting break points allows the program to execute more than one instruction and then halt. Pressing step many times has almost the same effect but takes longer. The monitor regains control whenever user's PC passes a specified break point address. The user may examine or modify memory and registers when his program has reached a break point.

SBR means set break point. When the display is in Addr-Data form with address pointing to RAM area, pressing this key causes the displayed address to be set as a break point.

EXAMPLE: Store the following program in RAM. Use SBR to see the results of the execution

address	machine code	instruction
1800	3E00	LD A,0
1802	3C	INC A
1803	47	LD B,A
1804	04	INC B
1805	48	LD C,B
1806	FB	EI

KEY	DISPLAY	COMMENTS
RS	UPF - - 1	RESET
ADDR BC 1 IX B AF 0 AF 0	1.8.0.0.××	Set Starting ADDR
DATA HL 3 SZ-H E	1800 3.E.	Initialize Data Field
+ AF 0 AF 0	18010.0.	Increment Program Counter
+ HL 3 SZ-H C	18023.C.	Increment Program Counter
+ AF 4 HL 7	18034.7.	Increment Program Counter
+ AF 0 AF 4	18040.4.	Increment Program Counter
+ AF 4 IX B	18054.8.	Increment Program Counter
+ PNC F I-IF B	1806 F.B.	Increment Program Counter
SBR	1.8.0.6.F.B.	Set Breakpoint at 1806
ADDR BC 1 IX B AF 0 AF 0	1.8.0.0.3 E	Program starts at 1800
GO	1807 ×.×.	The program is executed from 1800-1806. The program halts at 1807. Note this is the ADDR of next instruction.
REG	rEG -	To verify results use REG Key
AF 0	01 × × AF A reg F reg	The contents of the A reg is correct.
BC 1	0202BC B reg C reg	The value in the B register are correct.
I-IF B	0001IF	The interrupt Flip Flop is set. This is the result of EI (Enable Interrupt).
PC -	1.8.0.6.F.B.	Change instruction from EI to DI (Disable interrupt)
PNC F HL 3	1.8.0.6.F.3.	Enter F3 into Data field.
ADDR BC 1 IX B AF 0 AF 0	1.8.0.0.3 E	Set starting ADDR of program.
GO	1807 ×.×.	Execute
REG I-IF B	0000IF	Check 1FF

Note: Bit has been reset.
(result of DI instruction)

[Description]:

- (1) It is illegal to set break points in ROM area. If you do so, the monitor will blank out the display.
- (2) If one instruction has more than one byte, a break point must be set at the first byte. Otherwise, errors will occur.
- (3) When the display is in the Addr-Data form and the address field is the break address, six index points are set to indicate that the address is a break point.
- (4) The contents of a break address can still be modified by ADDR key.
- (5) When the user's program executes to the break point, the display is in the Addr-Data form. The address field is the user's PC.
- (6) After program executed the break point, all the status and registers are saved.
- (7) See 3.2.2 for stack rules.
- (8) Only one break point may be set.

3.2.4 Clear Break Point CR Key

If the user want to eliminate the break point in his program, he can press CR to clear the break point. This key is accepted at any time. After pressing it, the display will become F.F.F.F.F.. (Break point is set to FFFF.)

3.2.5 Immediately Break - MON Key

When executing a program, many errors may occur. For example, a program will lose control when the CPU executes a nonexistent operation code (opcode), or when a program has an infinite loop.

Moni means monitor. Any time you press this key, the same mechanism as used by single step will transfer control to the monitor. Then User's PC and its contents are displayed. When the HALT instruction is executed, pressing MON will return control to monitor and retrieve the contents of the new PC. After MON is pressed, the monitor will check the user's SP. The rules are the same as for single step and break point.

EXAMPLE: HALT and return to MPF-I monitor

KEY	DISPLAY	COMMENTS
<div style="display: flex; justify-content: space-around;"> <div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">RS</div> <div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">PC</div> </div>	1800x.x.	
<div style="display: flex; justify-content: space-around;"> <div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">HL 7</div> <div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">DE 8</div> </div>	18007.6.	Store HALT in 1800.
<div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">GO</div>		CPU halts, the display is blanked, the LED HALT is turned on.
<div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">MON</div>	1801x.x.	The display is of the Addr-Data form. The address field is the user's PC. All registers are reserved.

EXAMPLE: Pressing this key when monitor is being executed

KEY	DISPLAY	COMMENTS
<div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">RS</div>	UPF - - 1	The monitor is scanning the keyboard. The system treats the monitor as the user's program. The user's SP is in the system stack.
<div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">MON</div>	SYS - SP	

3.3. Support Functions

3.3.1 Block Transfer - MOVE Key

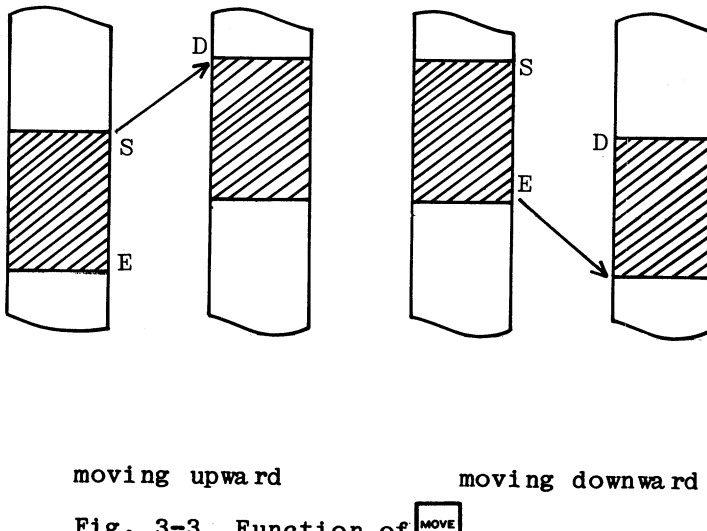
MOVE <address> + <address> + <address> GO

EXAMPLE: Move the data in 1800 - 18FF to 1810 - 190F

KEY	DISPLAY	COMMENTS			
MOVE	X.X.X.X.- S	S is the mnemonic of starting address.			
BC 1	IX 8	AF 0	AF 0	1.8.0.0.- S	Starting address = 1800
+	X.X.X.X.- E	E is the mnemonic of ending address.			
BC 1	IX 8	-PNC' F	-PNC' F	1.8.F.F.- E	Ending address = 18FF
+	X.X.X.X.- d	D is the mnemonic of destination address.			
BC 1	IX 8	BC 1	AF 0	1.8.1.0.- d	Destination address = 1810
GO	1810 X.X.	Transfer completed, the last byte moved is 1810			

[Description]:

After pressing the key, the display becomes . S means the starting address of the data to be transferred.. After pressing , the display becomes , E means the ending address of the data to be transferred. Press again and the display becomes . D means the destination address of the data to be moved. When finished, the display is of the Addr-Data form. The address field is the last byte moved. Movement can be upward or downward. When moving upward, the last address is the lower limit of the destination area. When moving downward, the last address is the upper limit of the destination area, as shown in figure 3-3. Because of the fast speed of the microcomputer, the transfer can be finished instantaneously. After pressing the result will be displayed at once.



moving upward

moving downward

Fig. 3-3 Function of
(arrow indicates the first byte moved)

If the destination area overlaps the system stack, the system stack will be destroyed. The user should pressed to reset the system.

3.3.2 Data Deletion - DEL Key

This key is valid when the display is of the Addr-Data form. Pressing this key causes the data of the displayed address to be deleted. All the data above this address is shifted down one position.

EXAMPLE: Assume the present contents of RAM and the desired contents are as follows:

	ADDRESS	OLD DATA	DATA AFTER DELETING
	1800	00	00
	1801	11	11
delete address->	1802	11	22
	1803	22	33
	1804	33	44
	1805	44	XX

KEY	DISPLAY	COMMENTS
<div style="display: flex; justify-content: space-around; border-bottom: 1px solid black;"> ADDR BC 1 IX 8 AF 0 DE 2 </div>	1.8.0.2.11	
DEL	180222	To change the display to the Addr-Data form and enter the address to be deleted. The old contents of 1802 have been deleted and data above it have been shifted down. The new contents of 1802 are 22, which was the original contents of 1803.
		Check.
<div style="display: flex; justify-content: space-around; border-bottom: 1px solid black;"> ADDR BC 1 IX 8 AF 0 AF 0 </div>	1.8.0.0.00	
+	18011.1.	
+	18022.2.	
+	18033.3.	
+	18044.4.	

[Description]:

Data in ROM can not be deleted. The valid regions for this key are 1800 - 1DFF. When the deleted address is between 1800 - 1DFF, all the data after this address shift down one position. The last one (1DFF) is filled with 0.

3.3.3 Data insertion - INS Key

INS <data>

When the display is of the Addr-Data form, the input data will be inserted after the displayed address.

EXAMPLE: Assume the contents of RAM are as follows:

	ADDRESS	OLD DATA	DATA AFTER INSERTION
	1800	00	00
	1801	11	11
	1802	22	22
insert 33 here ->	1803	44	33
	1804	55	44
	1805	66	55

KEY	DISPLAY	COMMENTS
ADDR BC 1 IX 8 AF 0 DE 2	1.8.0.2.2.2	To change the display to the Addr-Data form and enter the address of the insertion. Insert one byte after 1802, address field becomes 1803. Key in data 33.
INS	18030.0.	
HL 3 HL 3	18033.3.	Check
ADDR BC 1 IX 8 AF 0 AF 0	1.8.0.0.0.0	
+	18011.1.	
+	18022.2.	
+	18033.3.	
+	18044.4.	
+	18055.5.	

[Description]:

The valid region for this key is the same as DEL. After insertion, the last byte of the inserted block is lost.

The inserted address is one byte after the displayed address. Pressing this key causes all the data after the displayed address to be shifted up one position. Then the address field is incremented by one and the user may enter the data he wants to insert.

3.3.4 Relative Address Calculation - RELA Key

Instructions JR and DJNZ require relative addresses. MPF-I supports the calculation of relative addresses through the RELA key.

RELA <address> + <address> GO

EXAMPLE: Assume there is a JR instruction in your program. The address of opcode is 1800, the address to jump to is 1804.

KEY	DISPLAY	COMMENTS
RELA	X.X.X.X.- S	S is the mnemonic of starting address.
BC 1 IX 8 AF 0 AF 0	1.8.0.0.- S	Starting address = 1800
+	X.X.X.X.- d	D is the mnemonic of destination address.
BC 1 IX 8 AF 0 AF 4	1.8.0.4.- d	Destination = 1804
GO	180102.	MPF-I computes the relative address and stores the result in the next byte of the JR opcode. The result is also displayed.

[Description]:

After pressing RELA, the display becomes X.X.X.X.- S. S represents the starting point of JR or DJNZ. Pressing +, the display becomes X.X.X.X.- D. d represents the destination address of JR or DJNZ. Pressing GO, MPF-I computes the relative address then stores it in the 2nd byte of opcode. The display becomes of the Addr-Data form. The address containing the relative address is displayed. If the result exceeds decimal +127 or -128, the display becomes - E r r.

3.3.5 Storing Data onto Tape - TAPE WR Key

Cassette tape is a large capacity non-volatile storage medium. MPF-I contains hardware and software drivers.

TAPE WR <file name> + <address> + <address> GO

EXAMPLE: store the data of 1800 -18FF on tape, use 1234 as file name.

KEY	DISPLAY	COMMENTS
TAPE WR	X.X.X.X.- F	F is the mnemonic of filename.
BC 1 DE 2 HL 3 AF 4	1.2.3.4 - F	filename = 1234
+	X.X.X.X.- S	S is the mnemonic of starting address.
BC 1 IX 8 AF 0 AF 0	1.8.0.0.- S	Starting address = 1800
+	X.X.X.X.- E	E is the mnemonic of ending address.
BC 1 IX 8 -PNC F -PNC F	1.8.F.F.- E	Ending address = 18FF
(PLAY & REC)		Connect the microphone of the tape recorder to MPF-I MIC. Start recording by pressing PLAY and REC key of recorder.
GO		Begin to output data. During transfer, the display is dark, but the TONE-OUT LED is on.
	18FF X.X.	When transfer is completed, the ending address is displayed.

[Description]:

Pressing , the display becomes . F means file name. It is used to distinguish different data sets stored on a single cassette. It is also used to read back data. Press and the display becomes . S represents the starting address of the data to be written. Press again and the display becomes . E represents the ending address of the data to be written. Before pressing , you must connect the microphone of the recorder to MIC jack of MPF-I and press PLAY and REC to start recording. If the recorder is not ready and you press , data is still sent out. This data will not be recorded on tape. During transfer the display is blank, the TONE-OUT LED is on and a tone sounds.

3.3.6 Reading Data from Tape - TAPE RD Key

TAPE RD <filename> GO

EXAMPLE: Read the data from a tape recorder, filename is 1234, the data on the tape was written by using the TAPE WR key, see storing data onto tape.

KEY	DISPLAY	COMMENTS
<div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 5px;">TAPE RD</div> <div style="display: flex; justify-content: space-around; margin-bottom: 5px;"> <div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">BC 1</div> <div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">DE 2</div> <div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">HL 3</div> <div style="border: 1px solid black; padding: 2px; width: 20px; text-align: center;">AF 4</div> </div> <div style="border: 1px solid black; padding: 2px; width: fit-content; margin-bottom: 5px;">GO</div> <p>(PLAY)</p>	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin-bottom: 10px;">X.X.X.X.- F</div> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin-bottom: 10px;">1.2.3.4.- F</div> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin-bottom: 10px;"> </div> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin-bottom: 10px;">.</div> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin-bottom: 10px;">1 2 3 4 - F</div> <div style="border: 1px solid black; padding: 5px; width: fit-content; margin-bottom: 10px;">- - - - -</div> <div style="border: 1px solid black; padding: 5px; width: fit-content;">1 8 F F X.X.</div>	<p>F is the mnemonic of filename. Filename = 1234 Connect the recorder (using earphone jack) to the EAR jack in MPF-I. Start execution. The display is blank while MPF-I is searching for the filename. Press PLAY on the recorder. The recorder output volume should be turned to maximum. MPF-I echoes the signal read from tape on its own speaker (if the volume is too low, then there will be no sound). Every file name read by the monitor will be displayed for 1.5 seconds. When the desired file is found, '.' is changed into '-'. When finished, the last address read in is displayed.</p>

[Description]:

Before execution, the user must connect the recorder (using earphone jack) to the EAR jack in MPF-I. Turn the volume of the recorder to maximum. Then press ∞, and finally, start the recorder (PLAY). Initially, the display isWhen the desired file is found, the display becomes -----.

Starting and ending addresses are already stored on the tape so there is no need to input them. The user just needs to input the file name. A check is also recorded on the tape which MPF-I will check when reading back. If not matched, the display will be - E r r. If matched, the last input byte will be displayed.

If the data read from the tape is stored in a system stack, errors will occur. Care must be taken when you prepare tape data by ****. The tape data is echoed on the MPF-I speaker, so it is very easy to determine whether the tape is empty or not. This allows you to check a tape before recording data on it, so you do not destroy data that has been previously recorded.

4. Software and Hardware Description

4.1. Memory Address

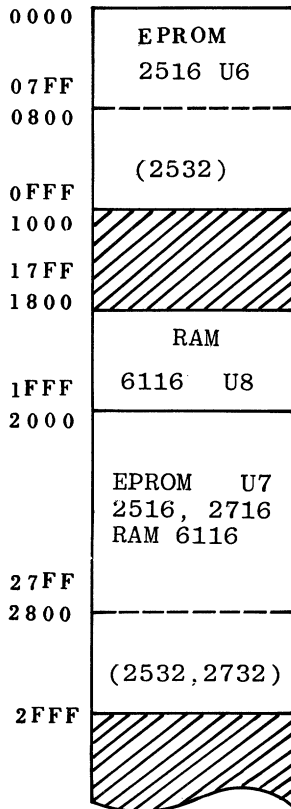


Fig 4-1 Memory map

[Description]:

(1) U6 EPROM: monitor

U7 RAM or EPROM: reserved for expansion

U8 RAM: basic RAM of which 1FAF-1FFF are used
by monitor

(2) Address lines are fully decoded in MPF-I. Traces
don't need to be cut or jumpers added on the PC
board if 2516, 2716, or 2532 are inserted in U7.

a. The following lines need to cut and jumpered if
a 2732 is inserted in U7.

Cut	lines	Jumpered lines
PIN 1,2	of jumper	PIN 2,3 of jumper
PIN 3,4	of jumper	PIN 4,5 of jumper
PIN 5,6	of jumper	PIN 6,7 of jumper

b. The following lines need to cut and jumpered if a
6116 is inserted in U7.

Cut	lines	Jumpered lines
PIN 3,4	of jumper	PIN 4,5 of jumper

4.2. Input/Output (I/O)Address)

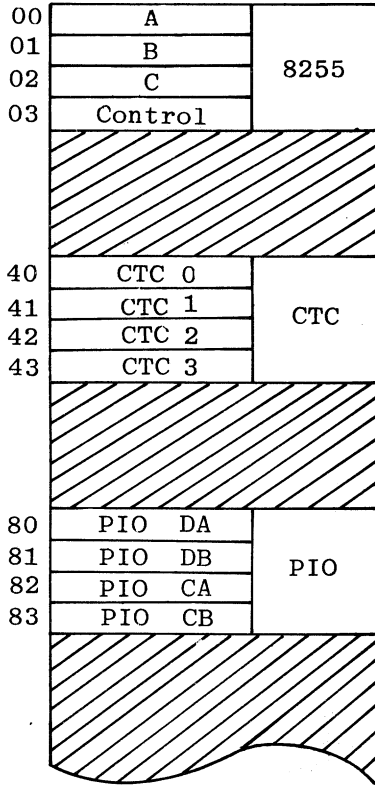


Fig. 4-2 I/O address map

[Description]:

- (1) The 8255 is a programmable peripheral interface with 24 parallel I/O lines. These 24 I/O lines are divided into three 8-bit ports. (See 8255 data sheet for details).
- (2) The control word of 8255 is 03. Port A is an input port, ports B and C are output ports.
 - (a) Port A (address 00):
 - bit 7: tape input,
 - bit 6: connected to

USER
KEY

 key, active low,
 - bit 5 - 0: connected to 6 rows of the keyboard matrix. The input signal becomes low only when keys in the active column are pressed.
 - (b) Port B (address 01) controls the seven segments and decimal point of the display. Figure 4-3 shows the name of each segment and the corresponding bit in port B. All output bits are active high.

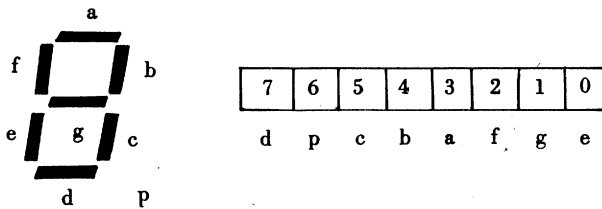


Fig. 4-3 The corresponding bits of the 7-segment display

(c) Port C (address 02):
bit 7: tape output; also connected to the speaker and the LED TONE-OUT. LED is turned on when output is 0.
bit 6: monitor break control. Any attempt to change this bit is forbidden.
bit 5 - 0: is connected to 6 columns of display & keyboard matrix. Bit 0 is the rightmost display, bit 5 is the leftmost display. All these bits are active high.

(3) The Z80 Counter Timer Controller (CTC) is a programmable component with four independent channels that provide counting and timing function for microcomputer systems based on the Z80-CPU.
The I/O addresses of CTC are from 40H to 43H.

(4) The Z80 parallel I/O (PIO) is a programmable, two port device which provides a TTL compatible interface between peripheral devices and the Z80-CPU.
The I/O address of PIO are from 80H to 83H.

(5) Address lines are not fully decoded only A0, A1, A6 and A7 are used. A2 through A5 are undecoded lines.

4.3. Program Interrupt

The nonmaskable interrupt is used by the monitor. The user is not allowed to use it. Pin 16 of the CPU (INT) is connected to jumper I on the left edge of the PC board and to . When the monitor code at address 0038 is executed, control will be transferred to the address stored in 1FFE & 1FFF. During this process, all CPU status are an affected. The default contents of 1FFE & 1FFF are 0066. This is the entry point of the service routine. 0038 is executed in the following situations:

- (1) Mode 1 interrupt is acknowledged;
- (2) Instruction 'RST 38H' (opcode FF) is executed;
- (3) The data bus are pulled high. If mode 0 interrupt is acknowledged without the interrupt vector, RST 38H will be executed.
- (4) When there is an error in program execution and jumps to a nonexistent memory. The opcode fetched by CPU is FF.

If the contents of 1FEE & 1FEF are not changed after power on, the effect of executing 0038 is the same as for pressing key or break point. The user may define his own service routine by changing the contents of 1FEE & 1FEF.

4.4. Software Break-Introduction RST 30H(Opcode F7)

RST 30H has the same effect as break. It is called software break because no hardware operation is involved.

It is usually used as the terminator of a user's program. It is also very useful in multi-break-point program debugging.

4.5. Stack

Figure 4-4 shows the stack configuration. The default value of the user's stack pointer is 1F9F. Each time the user's program breaks, the monitor checks his SP. `SYS-SP` will be displayed if the user's SP points to the system stack. If there is stack related instruction (e.g. RET) in the user's program, an error may occur when user's stack and system stack overlap.

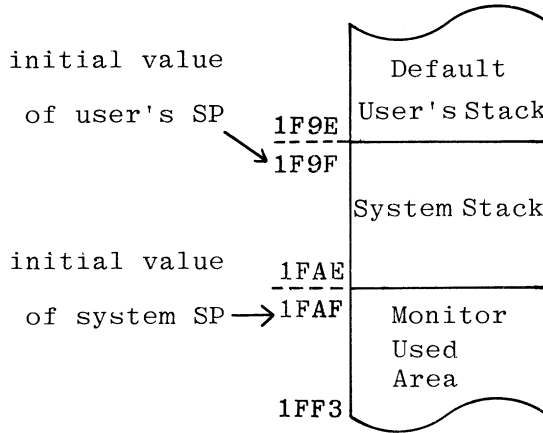


Fig. 4-4 Stack distribution map

`SYS-SP` can occur in the following situations:

- (1) Pressing `MON` when monitor is controlling the CPU. This operation will destroy all user's registers and should be avoided.
- (2) Executing the monitor itself by pressing `STEP`

4.6. Reset

There are two possible results. When the monitor is reset,

(1) Power on

- (a) Disable interrupt (IFF set to 0);
- (b) I register set to 0;
- (c) Interrupt mode set to 0;
- (d) User's PC is set to 1800.
- (e) User's SP is set to 1F9F;
- (f) Break point is disabled.
- (g) Set the content of 1FFE to 66 and set the content of 1FFF to 00. When the code beginning at 0038 is executed the CPU will jump to 0066. This is equivalent to press .
- (h) MPF-I is displayed one character at a time from right to left.

(2) Press .

- (a) - (e) are the same as (1). The contents of 1FFE & 1FFF and break point are unaffected. 'UPF--1' is displayed, (all digits) simultaneously.

4.7. Tape Data Format

(1) Bit format:

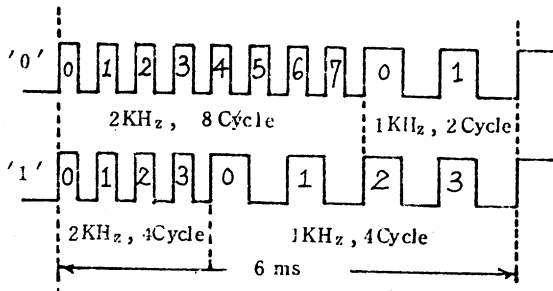


Fig. 4-5 Tape bit format

(2) Byte format:

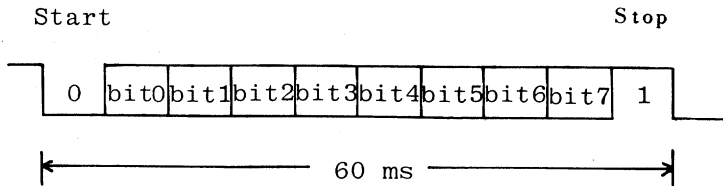


Fig. 4-6 Tape byte format

(3) File format:

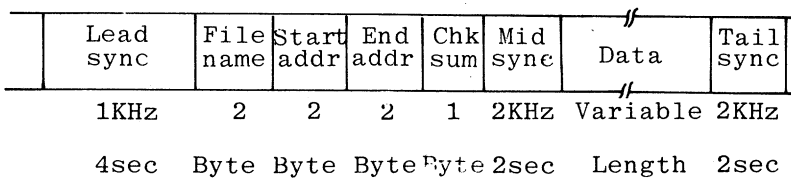


Fig. 4-7 Tape file format

5. Monitor Subroutines

5.1. Summary

ADDRESS	MNEMONIC	FUNCTION
0624	SCAN1	Scan keyboard and display one cycle.
05FE	SCAN	Scan keyboard and display until a new key-in.
0689	HEX7	Convert a hexadecimal digit into the 7-segment display format.
0678	HEX7SG	Convert two hexadecimal digits into 7-segment display format.
05F6	RAMCHK	Check if the given address is in RAM.
05E4	TONE	Generate sound.
05DE	TONE1K	Generate sound at 1K Hz.
05E2	TONE2K	Generate sound at 2K Hz.

5.2. SCAN1

[Address]: 0624

[Function]: Scan keyboard and display 1 cycle from right to left. Execution time is about 10ms (9.97ms exactly).

[Input]: IX points to the display buffer.

[Output]: (1) If no key-in, then carry flag = 1;

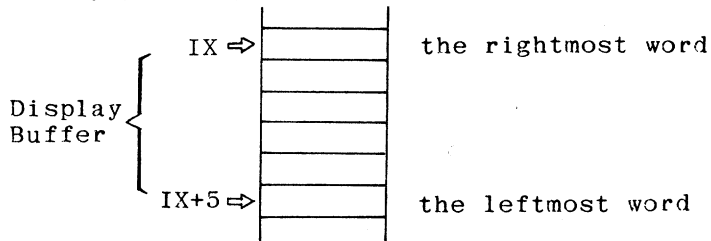
(2) If key-in, carry flag = 0 and the position-code of the key is stored in register A. (See appendix A.)

[Register]: Destroy AF, A'F', B'C', D'E'

[Supplement]:

(1) 6 bytes are required for storing 6 word patterns.

(2) IX points to the rightmost word, IX+5 points to the leftmost word.



(3) See appendix A for the relation between each bit and the seven segments.

5.3. SCAN

[Address]: 05FE

[Function]: Similar to SCAN1 except:

- (1) SCAN1 scans one cycle, but SCAN will scan till a new key-in.
- (2) SCAN1 returns the position while SCAN returns the internal code of the key pressed (see appendix A).

[Input]: IX points to the display buffer.

[Output]: Register A contains the internal code of the key pressed.

[Register]: Destroy AF, B, HL, AF', BC', DE'.

5.4. HEX7

[Address]: 0689

[Function]: Convert a hexadecimal number into its
7-segment display format.

[Input]: The least significant 4 bits of register A
contain the hexadecimal number (0-F).

[Output]: The result is also stored in register A.

[Register]: Destroy AF only.

5.5. HEX7SG

[Address]: 0678

[Function]: Convert two hexa-decimal numbers into a 7-segment display format.

[Input]: The first number is stored in the right 4 bits of A. The second number is stored in the left 4 bits of A.

[Output]: The first display pattern is stored in (HL), the second is in (HL+1), HL is increased by 2.

[Register]: Destroy AF, HL.

5.6. RAMCHK

[Address]: 05F6

[Function]: Check if the given address is in RAM.

[Input]: The address to check is in HL.

[Output]: If it is in RAM then Zero flag = 1, otherwise
Zero flag = 0.

[Register]: Destroy AF

5.7. TONE

[Address]: 05E4

[Function]: Generate sound.

[Input]: (1) C controls the frequency of the sound.
The period is about $(44+C \times 13) \times 2 \times 0.56$ micro-sec,
and the frequency is $200 / (10 + 3 \times C)$ KHz.
(2) HL contains the number of cycles. (max. value
is 32768).

[Output]: None

[Register]: Destroy AF, B, DE, HL.

5.8. TONE1K

[Address]: 05DE

[Function]: Generate a sound of 1KHz.

[Input]: Number of periods is in HL.

[Output]: None.

[Register]: Destroy AF, BC, DE, HL.

5.9. TONE2K

[Address]: 05E2

[Function]: Generate a sound of 2KHz.

[Input]: The number of periods is in HL.

[Output]: None

[Register]: Destroy AF, BC, HL, DE.

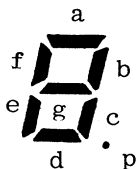
5.10. Program Examples

EXAMPLE 1: Display 'HELPUS', HALT when STEP is pressed.

```

1 ;DISPLAY 'HELP US' UNTIL STEP-KEY PUSHED:
1800          2          ORG          1800H
1800 DD212018  3          LD          IX,HELP
1804 CDFE05    4  DISP  CALL          SCAN
1807 FE13     5          CP          13H          ;KEY-STEP
1809 20F9     6          JR          NZ,DISP
180B 76       7          HALT
          8 ;
1820          9          ORG          1820H
1820 AE       10  HELP  DEFB          0AEH          ;'S'
1821 B5       11          DEFB          0B5H          ;'U'
1822 1F       12          DEFB          01FH          ;'P'
1823 85       13          DEFB          085H          ;'L'
1824 8F       14          DEFB          08FH          ;'E'
1825 37       15          DEFB          037H          ;'H'
          16 ;
          17  SCAN  EQU          05FEH
          18          END
    
```

Details of the display buffer are given below:



Position	Display Format	Segment of Illumination	d p c b a f g e							Data	Addr		
			d	p	c	b	a	f	g			e	
Right ↑ ↓ Left	S	a,c,d,f,g,	1	0	1	0	1	1	1	1	0	AE	1820
	U	a,b,c,d,e,f,	1	0	1	1	0	1	0	1	0	B5	1821
	P	a,b,e,f,g,	0	0	0	1	1	1	1	1	1	1F	1822
	L	d,e,f,	1	0	0	0	0	1	0	1	0	85	1823
	E	a,d,e,f,g,	1	0	0	0	1	1	1	1	1	8F	1824
	H	b,c,e,f,g,	0	0	1	1	0	1	1	1	1	37	1825

Please refer to Appendix A

EXAMPLE 2: Flash 'HELP US'

Use routine SCAN1 to display 'HELPU S' and blank alternately. Display each pattern 500ms by looping SCAN1 50 times.

```

1      ;FLASH 'HELP US':
1800      2      ORG      1800H
1800 212618 3      LD      HL, BLANK
1803 E5      4      PUSH   HL
1804 DD212018 5      LD      IX, HELP
1808 DDE3    6      LOOP   EX   (SP), IX
180A 0632    7      LD      B, 50
180C CD2406 8      HELFSEG CALL  SCAN1
180F 10FB    9      DJNZ   HELFSEG
1811 18F5   10      JR      LOOP
11      ;
1820      12      ORG      1820H
1820 AE     13      HELP   DEFB   0AEH      ; 'S'
1821 B5     14      DEFB   0B5H      ; 'U'
1822 1F     15      DEFB   01FH      ; 'P'
1823 85     16      DEFB   085H      ; 'L'
1824 8F     17      DEFB   08FH      ; 'E'
1825 37     18      DEFB   037H      ; 'H'
1826 00     19      BLANK  DEFB   0
1827 00     20      DEFB   0
1828 00     21      DEFB   0
1829 00     22      DEFB   0
182A 00     23      DEFB   0
182B 00     24      DEFB   0
25      ;
26      SCAN1 EQU    0624H
27      END
```

The content of 180B determines the flash frequency. You may change it to any value.

EXAMPLE 3: Display the key code of the key pressed.

```
1 ;DISPLAY INTERNAL CODE
1800 2 ORG 1800H
1800 DD210019 3 LD IX,OUTBF (1800H)
1804 CDFE05 4 LOOP CALL SCAN (05FE)
1807 210019 5 LD HL,OUTBF
180A CD7806 6 CALL HEX7SG (0678H)
180D 18F5 7 JR LOOP
8 ;
1900 9 ORG 1900H
1900 00 10 OUTBF DEFB 0
1901 00 11 DEFB 0
1902 00 12 DEFB 0
1903 00 13 DEFB 0
1904 00 14 DEFB 0
1905 00 15 DEFB 0
16 ;
17 SCAN EQU 05FEH
18 HEX7SG EQU 0678H
19 END
```

When a key is pressed, the internal code for that command is displayed in the data field. The user may compare it with Appendix A.

If you want to display the position code of the keys, you may change the program as follows:

```

1 ;DISPLAY POSITION CODE
1800          2          ORG      1800H
1800 DD210019 3          LD       IX,OUTBF
1804 CD2406   4 LOOP     CALL     SCAN1
1807 38FB     5          JR       C,LOOP
1809 210019   6          LD       HL,OUTBF
180C CD7806   7          CALL     HEX7SG
180F 18F3     8          JR       LOOP
          9

```

EXAMPLE 4: Convert 3 continuous bytes into 7-segment display format. Store the results in 1903 - 1908 then display them.

```

1 ;DISPLAY 3 BYTES IN RAM TO 6 HEXA-DIGITS
1800          2          ORG      1800H
1800 110019   3          LD       DE,BYTE0
1803 210319   4          LD       HL,OUTBF
1806 0603     5          LD       B,3
1808 1A       6 LOOP     LD       A,(DE)
1809 CD7806   7          CALL     HEX7SG
180C 13       8          INC      DE
180D 10F9     9          DJNZ     LOOP
          10 ;CONVERSION COMPLETE, BREAK FOR CHECK
180F DD210319 11         LD       IX,OUTBF
1813 CDFE05   12         CALL     SCAN
1816 76       13         HALT
          14 ;
1900          15         ORG      1900H
1900 10       16 BYTE0   DEFB    10H
1901 32       17         DEFB    32H
1902 54       18         DEFB    54H
1903          19 OUTBF   DEFS    6
          20 ;
          21 HEX7SG EQU    0678H
          22 SCAN   EQU    05FEH
          23         END

```

The three bytes of binary data are stored in 1900 - 1902. The user can set a break point at 180F to check if the conversion is correct before displaying the result.

EXAMPLE 5: Simulate a police car siren

The sound of a police car siren is simulated by alternating two different frequencies. Register C controls the frequency of the sound and register pair HL controls the length of the sound.

```
1 ;POLICE CAR SIREN:
2   ORG      1800H
3 LOOP    LD      C,0
4         LD      HL,0COH
5         CALL   TONE
6         LD      C,0COH
7         LD      HL,100H
8         CALL   TONE
9         JR      LOOP
10 ;
11 TONE    EQU    05E4
12        END
```

(1) Low frequency: C=0 (equivalent to 256), HL=COH (192), so the period is $(44+13 \times 256) \times 2 \times 0.56 = 3777$ micro-sec.

frequency: $1/3777 = 265\text{Hz}$

length of the sound: $3777 \text{ micro-sec} \times 192 = .73\text{sec}$

(2) High frequency: C=COH (192), HL=100H (256), so the period is $(44+13 \times 192) \times 2 \times 0.56 = 2845$ micro-sec.

frequency: $1/2845 = 352\text{Hz}$

length of the sound: $2845 \text{ micro-sec} \times 256 = .73\text{sec}$

6. Memory Check

6.1. Check EPROM 0000-07FF

The sum of all monitor codes is zero. Routine ROMTEST at 06A6 uses this property to check the monitor EPROM.

```
ROMTEST:
06A6      210000      LD      HL,0
06A9      010008      LD      BC,800H
06AC      CD3105      CALL   SUM
06AF      2801        JR      Z,SUMOK
06B1      76          HALT                    ;IF ERROR
06B2      C7          SMUOK  RST      0          ;DISPLAY 'UPF--1'
;

0531      AF          SUM      XOR      A
0532      86          SUMCAL  ADD      A,(HL)
0533      EDA1        CPI
0535      EA3205      JP      PE,SUMCAL
0538      B7          OR      A
0539      C9          RET
```

This program calculates the sum of all EPROM codes. If the result is 00, 'UPF--1' is displayed.

The key sequence is as follows:

RS ADDR DE 6 SP A DE 6 GO

- (1) Correct: the display is UPF - - 1
- (2) Error: HALT LED will come on.

6.2. Check RAM Region 1800-1FFF

```

RAMTEST:
0694      210018      LD      HL,1800H
0697      010008      LD      BC,800H
069A      CDF605  RAMT  CALL     RAMCHK
069D      2801        JR      Z,TNEXT
069F      76          HALT                    ;IF ERROR
06A0      EDA1      TNEXT CPI
06A2      EA1E07     JP      PE,RAMT
06A5      C7        RST      0      ;DISPLAY 'UPF--1'
;

```

```

RAMCHK:
05F6      7E          LD      A,(HL)
05F7      2F          CPL
05F8      77          LD      (HL),A
05F9      7E          LD      A,(HL)
05FA      2F          CPL
05FB      77          LD      (HL),A
05FC      BE          CP      (HL)
05FD      C9          RET

```

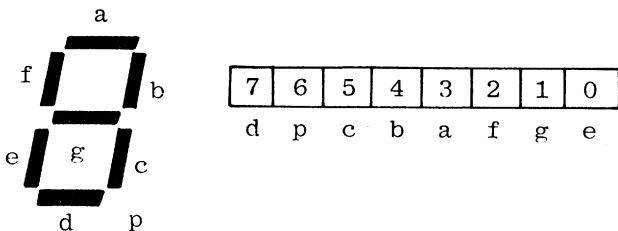
This program tests every byte in region 1800 - 1FFF. If the byte is good, it continues testing till all bytes have been tested. If there is any bad byte, the HALT LED will come on. You can press , , to get the address that has the error. Then press to get the content of that byte. If you want to continue testing, you may press . The key sequence is as follow:

(1) Correct: is displayed.

(2) Error: HALT LED will come on.

APPENDIX

A. Display format, position-code and internal-code



DISPLAY FORMAT :

COED	BD 30 9B BA 36 AE AF 38 BF BE 3F A7 8D B3
DATA	0 1 2 3 4 5 6 7 8 9 A B C D
DISP	0 1 2 3 4 5 6 7 8 9 A b c d
CODE	8F OF AD 37 89 B1 97 85 2B 23 A3 1F 3E 03
DATA	E F C H I J K L M N G P Q R
DISP	E F G H I J K L M N O P Q r
CODE	A6 87 B5 B7 A9 07 B6 8A 83 A2 32 02 C0 00
DATA	S T U V W X Y Z () + - ,
DISP	S T U V W X Y Z () + - ,

1. Position-Code (CALL SCANI) :

1E SBR	18 CBR	12 '0'	0C '1'	06 '2'	00 '3'
1F '-'	19 PC	13 '4'	0D '5'	07 '6'	01 '7'
20 DATA	1A REG	14 '8'	0E '9'	08 'A'	02 'B'
21 '+'	1B ADDR	15 'C'	0F 'D'	09 'E'	03 'F'
22 INS	1C DEL	16 GO	10 STEP	0A	04
23 MOVE	1D RELA	17 TPWR	11 TPRD	0B	05

2. Internal-Code (CALL SCAN) :

15 SBR	1A CBR	00 '0'	01 '1'	02 '2'	03 '3'
11 '-'	18 PC	04 '4'	05 '5'	06 '6'	07 '7'
14 DATA	1B REG	08 '8'	09 '9'	0A 'A'	0B 'B'
10 '+'	19 ADDR	0C 'C'	0D 'D'	0E 'E'	0F 'F'
16 INS	17 DEL	12 GO	13 STEP	22	20
1C MOVE	1D RELA	1E TPWR	1F TPRD	23	21

APPENDIX B

Theory of Hardware Circuit

A. System Clock

U3a, U3b, and 3.58M Hz crystal produce 3.58MHz signal. This signal is sent to U2a pin 3 to produce $3.58\text{MHz} \div 2 = 1.79\text{MHz}$ system clock.

B. Reset Signal

U2b is used to trim the Reset signal produced by power on or pressing key. The trimmed RST is sent to CPU and CTC. RST is sent to the 8255.

C. Memory Addressing

MREQ	A15	A14	A13	A12	A11	A10	---	A0	Selected Chip	Address
0	0	0	0	0	X	X	---	X	U6	0000-0FFF
0	0	0	1	0	X	X	---	X	U7	2000-2FFF
0	0	0	0	1	1	X	---	X	U8	1800-1FFF

U6 is the monitor for MPF-I, it may be a TMS2516, or an Intel 2716. U7 is a spare socket for future expansion usage, it may be a RAM or a ROM, Circuit design is default for 2716, 2516, 2532(EPROM) when user intends to plug in Intel 2732, or HM 6116(RAM), he should consult the note on Sheet 4 of the schematic. U8 is a system RAM, the memory size is 2K bytes.

D. Input/Output port addressing

U96 (74LS139) is an I/O port decoder.

IORQ	A7	A6	Selected I/O	Port Address
0	0	0	8255	00 - 03
0	0	1	CTC	40 - 43
0	1	0	PIO	80 - 83

Note; I/O port is not fully decoded, e.g. the 16 combinations 00 - 03, 04 - 07, 08 - 0B,.....3C - 3F, all select the s 8255. The CTC & PIO are also selected by 16 different combinations.

E. Matrix Keyboard and Display

U14 (8255) has 3 I/O ports, PBO-PB7 control individual segments in a display, U15 and U12 are segment drivers, PC0-PC5 select which display is to be activated, U13 (75492) is a 6-digit digit driver.

The LED display uses a Multiplexing method, only one is selected at a time, from right to left. Due to its rapid multiplexing rate. The displays appear to be on continuously.

Whenever the displays are accessed keyboard activity is also checked via U14 (8255) PA0-PA5. If no key is pressed, PA0-PA5 are high, when there is one key pressed, via keyboard scan routine the CPU will detect which key is pressed. In MPF-I there are $6 \times 6 = 36$ keys, but only 32 keys are checked through the keyboard matrix.

F. User-Key

The user-key is not assigned a function and is reserved for user's future use. The state of this key is detected via PA6 of 8255. via PA6 of 8255.

G. Audio Tape Interface.

The program or data to be stored in Magnetic Tape is serially sent out via PC7 of 8255. The filtering & decaying circuit are composed of C13, R11, C12, R12 and R13. This decayed signal is to MIC ("Microphone") inlet of Tape recorder, Q2 drives an LED and speaker. PC7 is also used as the port for audio output.

A recorded file may be read back to the RAM from the ("Earphone") EAR outlet of Tape recorder. The input interface circuit is composed of R14, CR2, CR1 and C11. This circuit converts EAR input signal to TTL level signal and detected by CPU via PA7 of 8255.

H. Step, Break point and Monitor Break

PC6 is normally high. This signal send to R0 input of U4 (7490) will preset U4 output to 0000, and make NMI of Z-80 high. When PC reach Breakpoint or MPF-I execute single step, PC6 will output low, U4 starts counting, after 5th OP code fetch, NMI becomes low. This will interrupt program execution and jump back to monitor program.

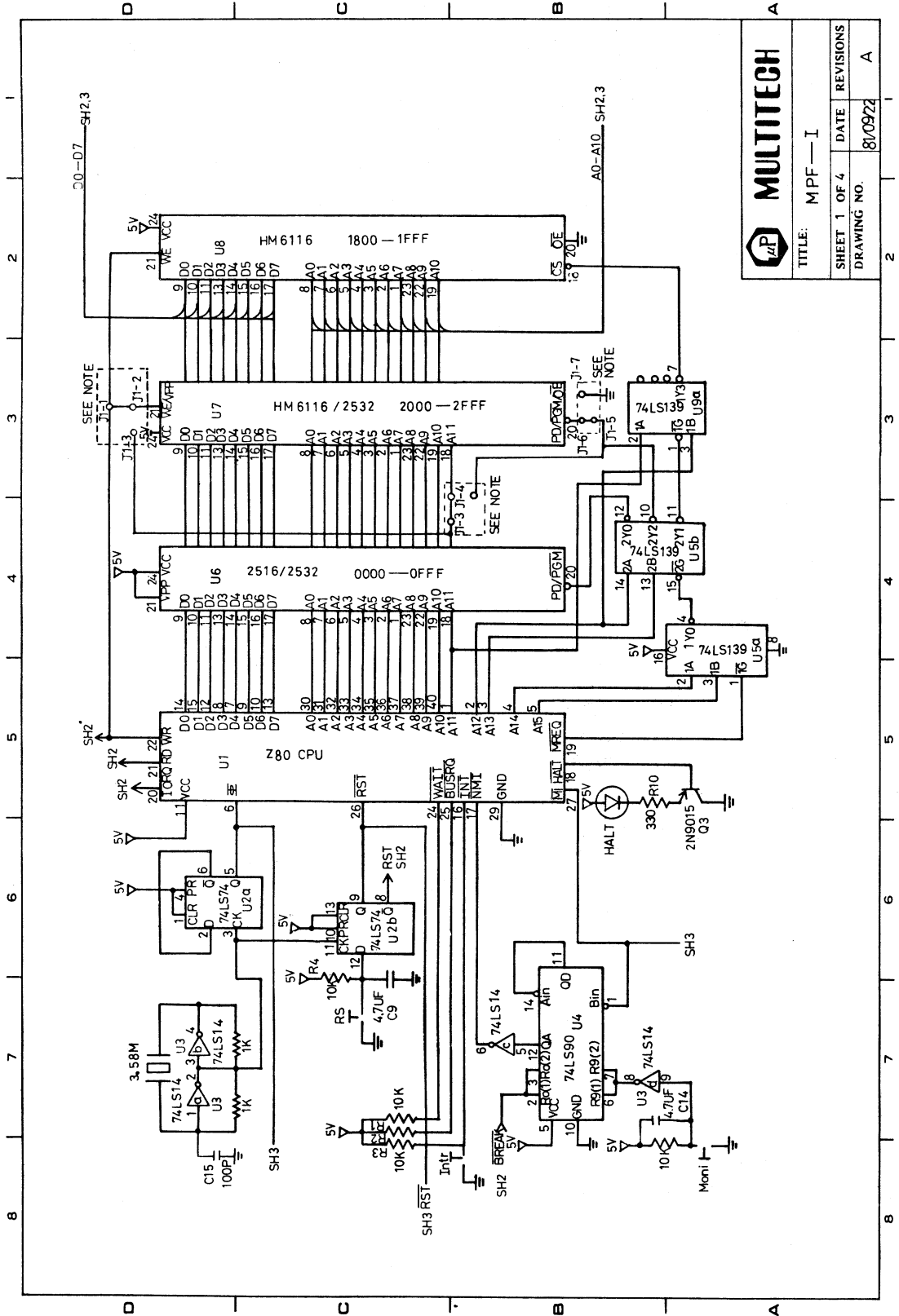
Logic State of U4 (74LS90)

	R9	R0	Qa	Qd	Qc	Qb	NMI	Comment
Normal State	0	1	0	0	0	0	1	U4 preset to 0000
BREAK becomes low	0	0	0	0	0	0	1	$R0 = \overline{BREAK} = 0$
1st MI	0	0	0	0	0	1	1	7490 Start counting
2nd MI	0	0	0	0	1	0	1	Qd, Qc, Qb is Mod, 5
3rd MI	0	0	0	0	1	1	1	Counter
4th MI	0	0	0	1	0	0	1	
5th MI	0	0	1	0	0	0	0	Qa from 0-1 when Qd from 1-0
Pressing Key <input type="checkbox"/> MON	1	0	1	1	0	0	0	U4 Preset to 1001

After MON key is pressed, R9 of U4 is high, Qa becomes high and NMI becomes Low. So CPU jump back to monitor program execution due to nonmaskable interrupt.

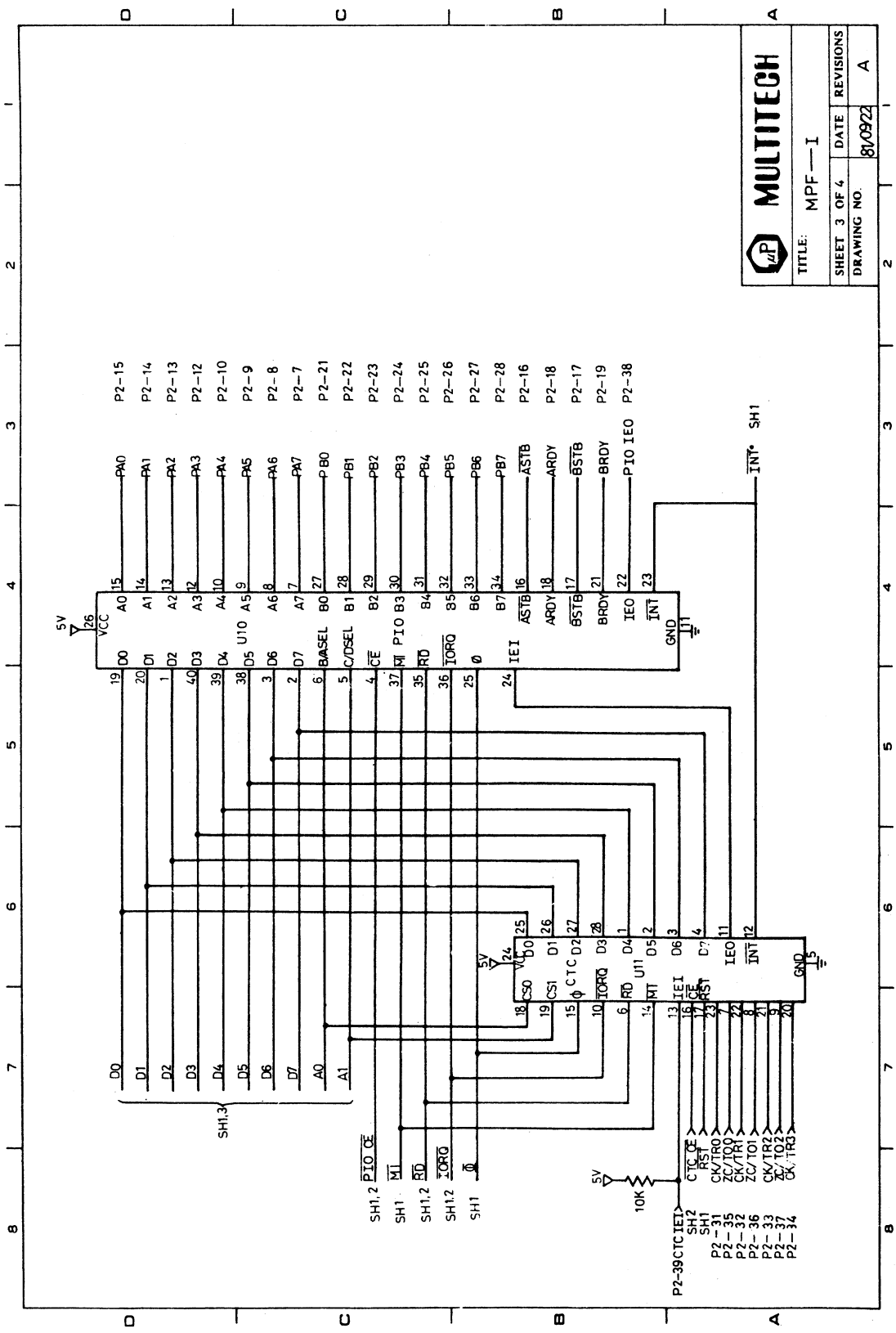
I. PIO and CTC

U11 (CTC) and U10 (PIO) are daisy-chained, CTC has the higher interrupt priority, CTC IEI, PIO IE0, CTC channel signals and PIO I/O port are reserved on P2 edge connector for user future expansion.



TITLE: MPF-I

SHEET 1 OF 4	DATE	REVISIONS
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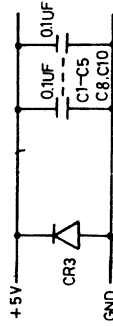
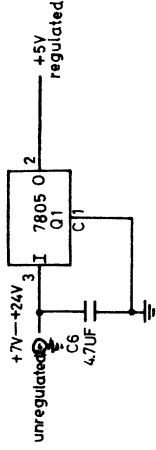


P1 PIN FUNCTION

PIN NO	SIGNAL	PIN NO	SIGNAL
1	A11	21	A10
2	A12	22	A9
3	A13	23	A8
4	A14	24	A7
5	A15	25	A6
6	A16	26	A5
7	D4	27	A4
8	D3	28	A3
9	D5	29	A2
10	D6	30	A1
11	NC	31	A0
12	D2	32	GND
13	D7	33	REFSH
14	D0	34	INT
15	D1	35	RESET
16	INT	36	BUSRO
17	NMI	37	WAIT
18	HALT	38	BUSAK
19	MREQ	39	WR
20	IORO	40	RD

P2 PIN FUNCTION

PIN NO	SIGNAL	PIN NO	SIGNAL
1	NC	21	PB0
2	NC	22	PB1
3	NC	23	PB2
4	NC	24	PB3
5	NC	25	PB4
6	NC	26	PB5
7	PA7	27	PB6
8	PA6	28	PB7
9	PA5	29	NC
10	PA4	30	GND
11	GND	31	CK/TR0
12	PA3	32	CK/TR1
13	PA2	33	CK/TR2
14	PA1	34	CK/TR3
15	PA0	35	ZC/TO0
16	ASTB	36	ZC/TO1
17	BSTB	37	ZC/TO2
18	ARDY	38	PIO IE0
19	3RDY	39	CTC IE1
20	NC	40	NC



NOTE: 1. U7 is optional, it may be 2516, 2716, 2532, 2732, 6116
 2. Jumper 1 is used for selecting certain memory type

Memory Type	Memory Address	CuIs	Jumpers
2516 2716	2000-27FF	NIL	NIL
2532	2000-2FFF	NIL	NIL
2732	2000-2FFF	PIN1 TO PIN2 PIN3 TO PIN4 PIN5 TO PIN6	PIN2 TO PIN3 PIN4 TO PIN5 PIN6 TO PIN7
6116	2000-2FFF	PIN3 TO PIN4 PIN5 TO PIN6	PIN4 TO PIN5 PIN7 TO PIN8

*PIN 1 - PA2
 PIN 2 - PA4
 PIN 3 - PA6*



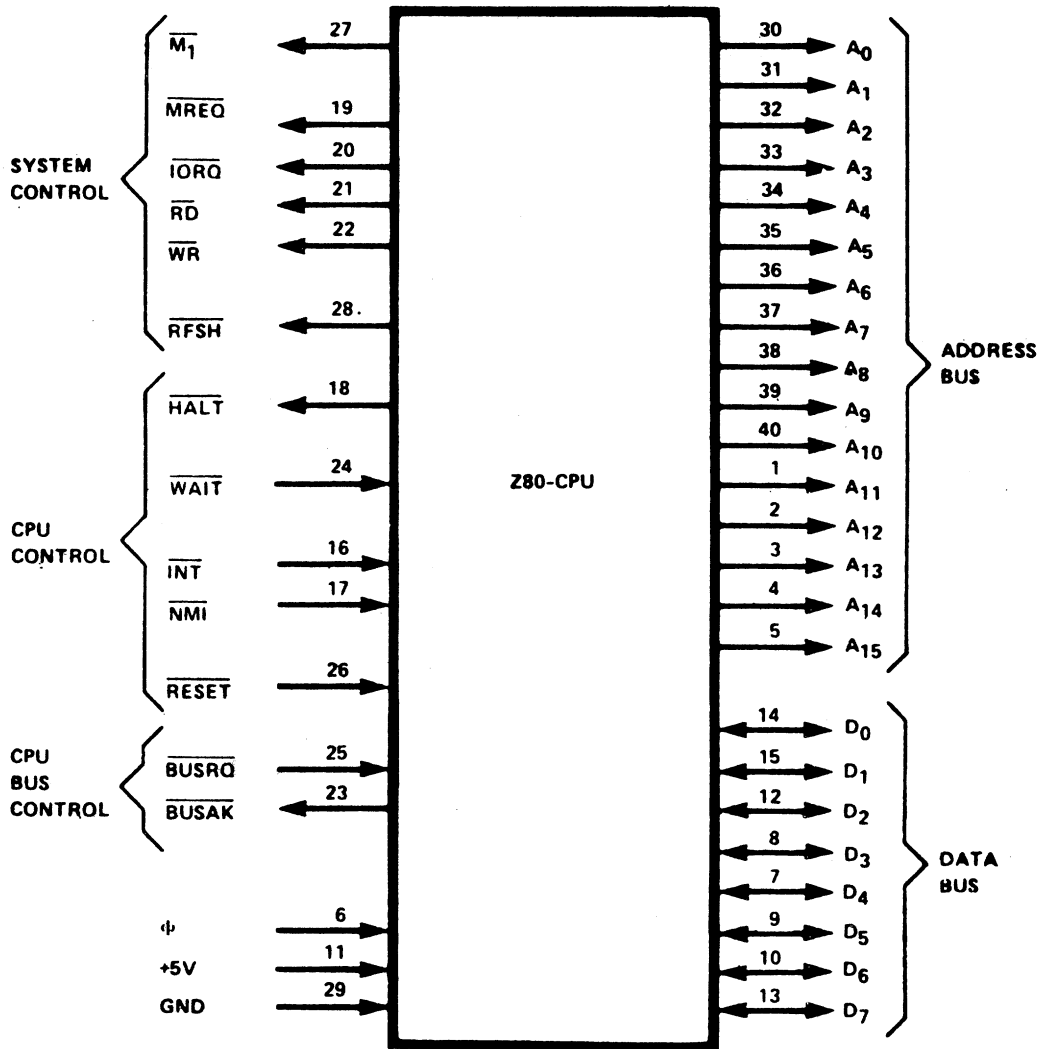
MULTITECH

TITLE: PF --- I

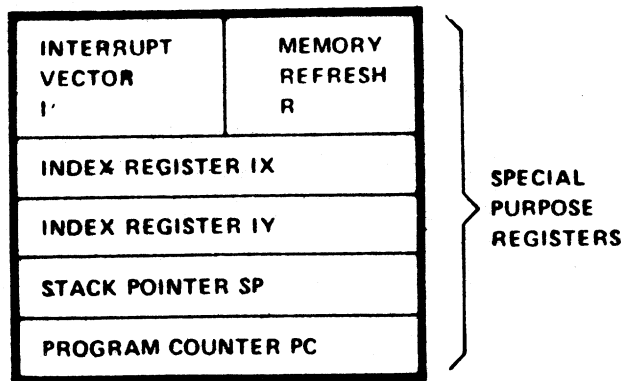
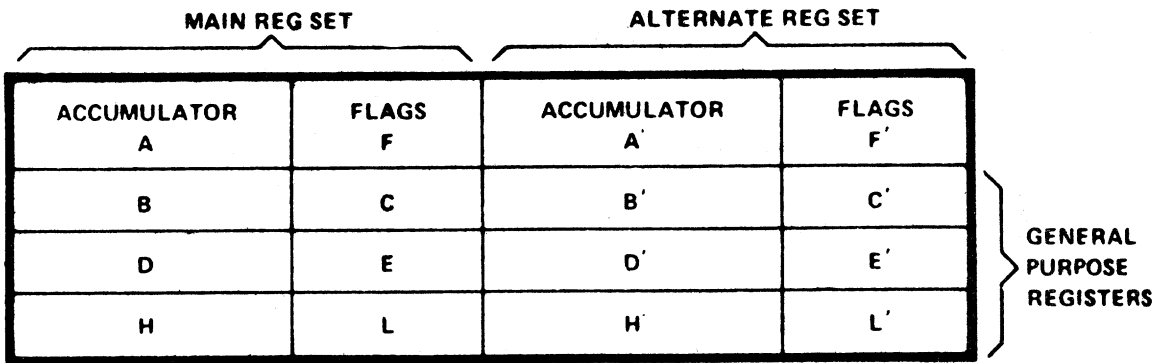
SHEET 4 OF 4	DATE	REVISIONS
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APPENDIX C

Z80-CPU Programming reference.



CPU PIN-OUTS



Z80-CPU REGISTER CONFIGURATION

SUMMARY OF FLAG OPERATION

Instruction	D7				P/ V	D0		Comments	
	S	Z	H	N		C			
ADD s; ADC s	↑	↑	X	↑	X	V	0	↑	8-bit add or add with carry
SUB s; SBC s; CP s; NEG	↑	↑	X	↑	X	V	1	↑	8-bit subtract, subtract with carry, compare and negate accumulator
AND s	↑	↑	X	↑	X	P	0	0	Logical operations
OR s; XOR s	↑	↑	X	↑	X	P	0	0	
INC s	↑	↑	X	↑	X	V	0	•	8-bit increment
DEC s	↑	↑	X	↑	X	V	1	•	8-bit decrement
ADD DD, SS	•	•	X	X	X	•	0	↑	16-bit add
ADC HL, SS	↑	↑	X	X	X	V	0	↑	16-bit add with carry
SBC HL, SS	↑	↑	X	X	X	V	1	↑	16-bit subtract with carry
RLA; RLCA; RRA; RRCA	•	•	X	0	X	•	0	↑	Rotate accumulator
RL s; RLC s; RR s; RRC s; SLA s; SRA s; SRL s	↑	↑	X	0	X	P	0	↑	Rotate and shift locations
RLD; RRD	↑	↑	X	0	X	P	0	•	Rotate digit left and right
DAA	↑	↑	X	↑	X	P	•	↑	Decimal adjust accumulator
CPL	•	•	X	1	X	•	1	•	Complement accumulator
SCF	•	•	X	0	X	•	0	1	Set carry
CCF	•	•	X	X	X	•	0	↑	Complement carry
IN r, (C)	↑	↑	X	0	X	P	0	•	Input register indirect
INI; IND; OUTI; OUTD	X	↑	X	X	X	X	1	•	Block input and output
INIR; INDR; OTIR; OTDR	X	1	X	X	X	X	1	•	Z = 0 if B ≠ 0 otherwise Z = 1
LDI; LDD	X	X	X	0	X	↑	0	•	Block transfer instructions
LDIR; LDDR	X	X	X	0	X	0	0	•	P/V = 1 if BC ≠ 0, otherwise P/V = 0
CPH; CPHR; CPD; CPDR	X	↑	X	X	X	↑	1	•	Block search instructions Z = 1 if A = (HL), otherwise Z = 0 P/V = 1 if BC ≠ 0, otherwise P/V = 0
LD A, I; LD A, R	↑	↑	X	0	X	IFF	0	•	The content of the interrupt enable flip-flop (IFF) is copied into the P/V flag
BIT b, s	X	↑	X	1	X	X	0	•	The state of bit b of location s is copied into the Z flag

The following notation is used in this table:

Symbol	Operation
C	Carry/bank flag. C=1 if the operation produced a carry from the MSB of the operand or result.
Z	Zero flag. Z=1 if the result of the operation is zero.
S	Sign flag. S=1 if the MSB of the result is one.
P/V	Parity or overflow flag. Parity (P) and overflow (V) share the same flag. Logical operations affect this flag with the parity of the result while arithmetic operations affect this flag with the overflow of the result. If P/V holds parity, P/V=1 if the result of the operation is even, P/V=0 if result is odd. If P/V holds overflow, P/V=1 if the result of the operation produced an overflow.
H	Half-carry flag. H=1 if the add or subtract operation produced a carry into or borrow from bit 4 of the accumulator.
N	Add/Subtract flag. N=1 if the previous operation was a subtract. H and N flags are used in conjunction with the decimal adjust instruction (DAA) to properly correct the result into packed BCD format following addition or subtraction using operands with packed BCD format.
↑	The flag is affected according to the result of the operation.
•	The flag is unchanged by the operation.
0	The flag is reset by the operation.
1	The flag is set by the operation.
X	The flag is a "don't care".
V	P/V flag affected according to the overflow result of the operation.
P	P/V flag affected according to the parity result of the operation.
r	Any one of the CPU registers A, B, C, D, E, H, L.
s	Any 8-bit location for all the addressing modes allowed for the particular instruction.
ss	Any 16-bit location for all the addressing modes allowed for that instruction.
ii	Any one of the two index registers IX or IY.
R	Refresh counter.
n	8-bit value in range <0, 255>
nn	16-bit value in range <0, 65535>

8-BIT LOAD GROUP 'LD'

		SOURCE																
		IMPLIED		REGISTER								REG INDIRECT			INDEXED		EXT. ADDR.	
		I	R	A	B	C	D	E	H	L	(HL)	(BC)	(DE)	(IX+d)	(IY+d)	(nn)	IMME.	
REGISTER	A	ED 57	ED 5F	7F	78	79	7A	7B	7C	7D	7E	0A	1A	DD 7E d	FD 7E d	3A n n	3E n n	
	B			47	40	41	42	43	44	45	46			DD 46 d	FD 46 d		06 n	
	C			4F	48	49	4A	4B	4C	4D	4E			DD 4E d	FD 4E d		0E n	
	D			57	50	51	52	53	54	55	56			DD 56 d	FD 56 d		16 n	
	E			5F	58	59	5A	5B	5C	5D	5E			DD 5E d	FD 5E d		1E n	
	H			87	80	81	82	83	84	85	86			DD 66 d	FD 66 d		26 n	
	L			8F	88	89	8A	8B	8C	8D	8E			DD 6E d	FD 6E d		2E n	
DESTINATION	(HL)			77	70	71	72	73	74	75							36 n	
	(BC)			02														
	(DE)			12														
INDEXED	(IX+d)			DD 77 d	DD 70 d	DD 71 d	DD 72 d	DD 73 d	DD 74 d	DD 75 d								DD 36 d n
	(IY+d)			FD 77 d	FD 70 d	FD 71 d	FD 72 d	FD 73 d	FD 74 d	FD 75 d								FD 36 d n
EXT. ADDR.	(nn)			32 n n														
IMPLIED	I			ED 47														
	R			ED 4F														

8-BIT LOAD GROUP

Mnemonic	Symbolic Operation	Flags							Op-Code			No. of Bytes	No. of M Cycles	No. of T States	Comments		
		S	Z	H	P/V	N	C	76	543	210	Hex						
LD r, s	r - s	•	•	X	•	X	•	•	•	01	r	s		1	1	4	r, s Reg.
LD r, n	r - n	•	•	X	•	X	•	•	•	00	r	110		2	2	7	000 B
										-	n	-					001 C
LD r, (HL)	r - (HL)	•	•	X	•	X	•	•	•	01	r	110		1	2	7	010 D
LD r, (IX+d)	r - (IX+d)	•	•	X	•	X	•	•	•	11	011	101	DD	3	5	19	011 E
										01	r	110					100 H
										-	d	-					101 L
LD r, (IY+d)	r - (IY+d)	•	•	X	•	X	•	•	•	11	111	101	FD	3	5	19	111 A
										01	r	110					
										-	d	-					
LD (HL), r	(HL) - r	•	•	X	•	X	•	•	•	01	110	r		1	2	7	
LD (IX+d), r	(IX+d) - r	•	•	X	•	X	•	•	•	11	011	101	DD	3	5	19	
										01	110	r					
										-	d	-					
LD (IY+d), r	(IY+d) - r	•	•	X	•	X	•	•	•	11	111	101	FD	3	5	19	
										01	110	r					
										-	d	-					
LD (HL), n	(HL) - n	•	•	X	•	X	•	•	•	00	110	110	36	2	3	10	
										-	n	-					
LD (IX+d), n	(IX+d) - n	•	•	X	•	X	•	•	•	11	011	101	DD	4	5	19	
										00	110	110	36				
										-	d	-					
										-	n	-					
LD (IY+d), n	(IY+d) - n	•	•	X	•	X	•	•	•	11	111	101	FD	4	5	19	
										00	110	110	36				
										-	d	-					
										-	n	-					
LD A, (BC)	A - (BC)	•	•	X	•	X	•	•	•	00	001	010	0A	1	2	7	
LD A, (DE)	A - (DE)	•	•	X	•	X	•	•	•	00	011	010	1A	1	2	7	
LD A, (nn)	A - (nn)	•	•	X	•	X	•	•	•	00	111	010	3A	3	4	13	
										-	n	-					
										-	n	-					
LD (BC), A	(BC) - A	•	•	X	•	X	•	•	•	00	000	010	02	1	2	7	
LD (DE), A	(DE) - A	•	•	X	•	X	•	•	•	00	010	010	12	1	2	7	
LD (nn), A	(nn) - A	•	•	X	•	X	•	•	•	00	110	010	32	3	4	13	
										-	n	-					
										-	n	-					
LD A, I	A - I			X	0	X	IFF	0	•	11	101	101	ED	2	2	9	
										01	010	111	57				
LD A, R	A - R			X	0	X	IFF	0	•	11	101	101	ED	2	2	9	
										01	011	111	5F				
LD I, A	I - A	•	•	X	•	X	•	•	•	11	101	101	ED	2	2	9	
										01	000	111	47				
LD R, A	R - A	•	•	X	•	X	•	•	•	11	101	101	ED	2	2	9	
										01	001	111	4F				

Notes: r, s means any of the registers A, B, C, D, E, H, L
 IFF the content of the interrupt enable flip-flop (IFF) is copied into the P/V flag

Flag Notation: • = flag not affected, 0 = flag reset, 1 = flag set, X = flag is unknown,
 ↓ = flag is affected according to the result of the operation.

**16-BIT LOAD GROUP
'LD'
PUSH' AND 'POP'**

		SOURCE								MM. EXT.	EXT. ADDR.	REG. ADDR.	
		REGISTER											
		AF	BC	DE	HL	SP	IX	IY					
REGISTER	AF											F1	
	BC								01 n n	ED 4B n n		C1	
	DE								11 n n	ED 5B n n		D1	
	HL								21 n n	2A n n		E1	
	SP					F9		DD F9	FD F9	31 n n	ED 7B n n		
	IX									DD 21 n n	DD 2A n n	DD E1	
	IY									FD 21 n n	FD 2A n n	FD E1	
EXT. ADDR.	(nn)		ED 43 n n	ED 53 n n	22 n. n	ED 73 n n	DD 22 n n	FD 22 n n					
PUSH INSTRUCTIONS →	REG. IND.	(SP)	F6	C6	D6	E6			DD E5	FD E5			

NOTE: The Push & Pop Instructions adjust the SP after every execution.

POP INSTRUCTIONS ↑

16-BIT LOAD GROUP

Mnemonic	Symbolic Operation	Flags								Op-Code				No. of Bytes	No. of M Cycles	No. of T States	Comments
		S	Z		H	P/V	N	C	76	543	210	Hex					
LD dd, nn	dd ← nn	•	•	X	•	X	•	•	•	00	dd0	001		3	3	10	dd Pair 00 BC 01 DE 10 HL 11 SP
LD IX, nn	IX ← nn	•	•	X	•	X	•	•	•	11	011	101	DD 21	4	4	14	
LD IY, nn	IY ← nn	•	•	X	•	X	•	•	•	11	111	101	FD 21	4	4	14	
LD HL, (nn)	H ← (nn+1) L ← (nn)	•	•	X	•	X	•	•	•	00	101	010	2A	3	5	16	
LD dd, (nn)	dd _H ← (nn+1) dd _L ← (nn)	•	•	X	•	X	•	•	•	11	101	101	ED	4	6	20	
LD IX, (nn)	IX _H ← (nn+1) IX _L ← (nn)	•	•	X	•	X	•	•	•	11	011	101	DD 2A	4	6	20	
LD IY, (nn)	IY _H ← (nn+1) IY _L ← (nn)	•	•	X	•	X	•	•	•	11	111	101	FD 2A	4	6	20	
LD (nn), HL	(nn+1) ← H (nn) ← L	•	•	X	•	X	•	•	•	00	100	010	22	3	5	16	
LD (nn), dd	(nn+1) ← dd _H (nn) ← dd _L	•	•	X	•	X	•	•	•	11	101	101	ED	4	6	20	
LD (nn), IX	(nn+1) ← IX _H (nn) ← IX _L	•	•	X	•	X	•	•	•	11	011	101	DD 22	4	6	20	
LD (nn), IY	(nn+1) ← IY _H (nn) ← IY _L	•	•	X	•	X	•	•	•	11	111	101	FD 22	4	6	20	
LD SP, HL	SP ← HL	•	•	X	•	X	•	•	•	11	111	001	F9	1	1	6	
LD SP, IX	SP ← IX	•	•	X	•	X	•	•	•	11	011	101	DD	2	2	10	
LD SP, IY	SP ← IY	•	•	X	•	X	•	•	•	11	111	101	F9 FD	2	2	10	
PUSH qq	(SP-2) ← qq _L (SP-1) ← qq _H	•	•	X	•	X	•	•	•	11	qq0	101		1	3	11	qq Pair 00 BC 01 DE 10 HL 11 AF
PUSH IX	(SP-2) ← IX _L (SP-1) ← IX _H	•	•	X	•	X	•	•	•	11	011	101	DD	2	4	15	
PUSH IY	(SP-2) ← IY _L (SP-1) ← IY _H	•	•	X	•	X	•	•	•	11	111	101	FD E5	2	4	15	
POP qq	qq _H ← (SP+1) qq _L ← (SP)	•	•	X	•	X	•	•	•	11	qq0	001		1	3	10	
POP IX	IX _H ← (SP+1) IX _L ← (SP)	•	•	X	•	X	•	•	•	11	011	101	DD	2	4	14	
POP IY	IY _H ← (SP+1) IY _L ← (SP)	•	•	X	•	X	•	•	•	11	111	101	FD E1	2	4	14	

Notes: dd is any of the register pairs BC, DE, HL, SP
 qq is any of the register pairs AF, BC, DE, HL
 (PAIR)_H, (PAIR)_L refer to high order and low order eight bits of the register pair respectively.
 e.g. BC_L = C, AF_H = A

Flag Notation: • = flag not affected, 0 = flag reset, 1 = flag set, X = flag is unknown
 †. flag is affected according to the result of the operation

**EXCHANGES
'EX' AND 'EXX'**

		IMPLIED ADDRESSING				
		AF'	BC, DE' & HL'	HL	IX	IY
IMPLIED	AF	08				
	BC, DE & HL		D9			
	DE			E8		
REG. INDIR.	(SP)			E3	DD E3	FD E3

BLOCK TRANSFER GROUP

BLOCK SEARCH GROUP

DESTINATION		SOURCE	
		REG. INDIR.	(HL)
		REG. INDIR.	(DE)
		ED	'LDI' - Load (DE) ← (HL)
		A0	Inc HL & DE, Dec BC
		ED	'LDIR' - Load (DE) ← (HL)
		B0	Inc HL & DE, Dec BC, Repeat until BC = 0
		ED	'LDD' - Load (DE) ← (HL)
		A8	Dec HL & DE, Dec BC
		ED	'LDDR' - Load (DE) ← (HL)
		B8	Dec HL & DE, Dec BC, Repeat until BC = 0

HL points to source
DE points to destination
BC is byte counter

SEARCH LOCATION		REG. INDIR.	
		REG. INDIR.	(HL)
		REG. INDIR.	(HL)
		ED	'CPI'
		A1	Inc HL, Dec BC
		ED	'CPIR' - Inc HL, Dec BC
		B1	repeat until BC = 0 or find match
		ED	'CPD' - Dec HL & BC
		A9	
		ED	'CPDR' - Dec HL & BC
		B9	Repeat until BC = 0 or find match

HL points to location in memory to be compared with accumulator contents
BC is byte counter

EXCHANGE GROUP AND BLOCK TRANSFER AND SEARCH GROUP

Mnemonic	Symbolic Operation	Flags							Op-Code			No. of Bytes	No. of M Cycles	No. of T States	Comments		
		S	Z	H	P/V	N	C	76	543	210	Hex						
EX DE, HL	DE ← HL	•	•	X	•	X	•	•	•	11	101	011	EB	1	1	4	Register bank and auxiliary register bank exchange
EX AF, AF'	AF ← AF'	•	•	X	•	X	•	•	•	00	001	000	08	1	1	4	
EXX	(BC ← BC') (DE ← DE') (HL ← HL')	•	•	X	•	X	•	•	•	11	011	001	D9	1	1	4	
EX (SP), HL	H ← (SP+1) L ← (SP)	•	•	X	•	X	•	•	•	11	100	011	E3	1	5	19	
EX (SP), IX	IX _H ← (SP+1) IX _L ← (SP)	•	•	X	•	X	•	•	•	11	011	101	DD	2	6	23	
EX (SP), IY	IY _H ← (SP+1) IY _L ← (SP)	•	•	X	•	X	•	•	•	11	111	101	FD	2	6	23	
LDI	(DE) ← (HL) DE ← DE+1 HL ← HL+1 BC ← BC-1	•	•	X	0	X	↓	0	•	11	101	101	ED	2	4	16	Load (HL) into (DE), increment the pointers and decrement the byte counter (BC)
										10	100	000	AO				
LDIR	(DE) ← (HL) DE ← DE+1 HL ← HL+1 BC ← BC-1 Repeat until BC = 0	•	•	X	0	X	0	0	•	11	101	101	ED	2	5	21	If BC ≠ 0 If BC = 0
										10	110	000	BO	2	4	16	
LDD	(DE) ← (HL) DE ← DE-1 HL ← HL-1 BC ← BC-1	•	•	X	0	X	↓	0	•	11	101	101	ED	2	4	16	
										10	101	000	A8				
LDDR	(DE) ← (HL) DE ← DE-1 HL ← HL-1 BC ← BC-1 Repeat until BC = 0	•	•	X	0	X	0	0	•	11	101	101	ED	2	5	21	If BC ≠ 0 If BC = 0
										10	111	000	B8	2	4	16	
CPI	A ← (HL) HL ← HL+1 BC ← BC-1	↓	↓	X	↓	X	↓	1	•	11	101	101	ED	2	4	16	
										10	100	001	A1				
CPIR	A ← (HL) HL ← HL+1 BC ← BC-1 Repeat until A = (HL) or BC = 0	↓	↓	X	↓	X	↓	1	•	11	101	101	ED	2	5	21	If BC ≠ 0 and A ≠ (HL) If BC = 0 or A = (HL)
										10	110	001	B1	2	4	16	
CPD	A ← (HL) HL ← HL-1 BC ← BC-1	↓	↓	X	↓	X	↓	1	•	11	101	101	ED	2	4	16	
										10	101	001	A9				
CPDR	A ← (HL) HL ← HL-1 BC ← BC-1 Repeat until A = (HL) or BC = 0	↓	↓	X	↓	X	↓	1	•	11	101	101	ED	2	5	21	If BC ≠ 0 and A ≠ (HL) If BC = 0 or A = (HL)
										10	111	001	B9	2	4	16	

Notes: ① P/V flag is 0 if the result of BC-1 = 0, otherwise P/V = 1
 ② Z flag is 1 if A = (HL), otherwise Z = 0.

Flag Notation: • = flag not affected, 0 = flag reset, 1 = flag set, X = flag is unknown,
 ↓ = flag is affected according to the result of the operation.

8-BIT ARITHMETIC AND LOGIC

SOURCE

	REGISTER ADDRESSING							REG. INDIR.	INDEXED		IMMED.
	A	B	C	D	E	H	L	(HL)	(IX+d)	(IY+d)	n
'ADD'	87	80	81	82	83	84	85	86	DD 86 d	FD 86 d	C6 n
ADD w CARRY 'ADC'	8F	88	89	8A	8B	8C	8D	8E	DD 8E d	FD 8E d	CE n
SUBTRACT 'SUB'	97	90	91	92	93	94	95	96	DD 96 d	FD 96 d	D6 n
SUB w CARRY 'SBC'	9F	98	99	9A	9B	9C	9D	9E	DD 9E d	FD 9E d	DE n
'AND'	A7	A0	A1	A2	A3	A4	A5	A6	DD A6 d	FD A6 d	E6 n
'XOR'	AF	A8	A9	AA	AB	AC	AD	AE	DD AE d	FD AE d	EE n
'OR'	B7	B0	B1	B2	B3	B4	B5	B6	DD 86 d	FD 86 d	F6 n
COMPARE 'CP'	BF	B8	B9	BA	BB	BC	BD	BE	DD 8E d	FD BE d	FE n
INCREMENT 'INC'	3C	04	0C	14	1C	24	2C	34	DD 34 d	FD 34 d	
DECREMENT 'DEC'	3D	05	0D	15	1D	25	2D	35	DD 35 d	FD 35 d	

8-BIT ARITHMETIC AND LOGICAL GROUP

Mnemonic	Symbolic Operation	Flags							Op-Code		No. of Bytes	No. of M Cycles	No. of T States	Comments
		S	Z	H	P/V	N	C	76 543 210	Hex					
ADD A, r	A ← A + r	†	†	X	†	X	V	0	†	10 000 r	1	1	4	r Reg.
ADD A, n	A ← A + n	†	†	X	†	X	V	0	†	11 000 110 - n -	2	2	7	000 B 001 C 010 D 011 E 100 H 101 L 111 A
ADD A, (HL)	A ← A + (HL)	†	†	X	†	X	V	0	†	10 000 110	1	2	7	011 E
ADD A, (IX+d)	A ← A + (IX+d)	†	†	X	†	X	V	0	†	11 011 101 10 000 110 - d -	DD 3	5	19	100 H 101 L 111 A
ADD A, (IY+d)	A ← A + (IY+d)	†	†	X	†	X	V	0	†	11 111 101 10 000 110 - d -	FD 3	5	19	
ADC A, s	A ← A + s + CY	†	†	X	†	X	V	0	†	001				s is any of r, n, (HL), (IX+d), (IY+d) as shown for ADD instruction. The indicated bits replace the 000 in the ADD set above.
SUB s	A ← A - s	†	†	X	†	X	V	1	†	010				
SBC A, s	A ← A - s - CY	†	†	X	†	X	V	1	†	011				
AND s	A ← A ∧ s	†	†	X	†	X	P	0	0	100				
OR s	A ← A ∨ s	†	†	X	†	X	P	0	0	110				
XOR s	A ← A ⊕ s	†	†	X	†	X	P	0	0	101				
CP s	A ← s	†	†	X	†	X	V	1	†	111				
INC r	r ← r + 1	†	†	X	†	X	V	0	•	00 r 100	1	1	4	
INC (HL)	(HL) ← (HL) + 1	†	†	X	†	X	V	0	•	00 110 100	1	3	11	
INC (IX+d)	(IX+d) ← (IX+d) + 1	†	†	X	†	X	V	0	•	11 011 101 00 110 100 - d -	DD 3	6	23	
INC (IY+d)	(IY+d) ← (IY+d) + 1	†	†	X	†	X	V	0	•	11 111 101 00 110 100 - d -	FD 3	6	23	
DEC s	s ← s - 1	†	†	X	†	X	V	1	•	101				s is any of r, (HL), (IX+d), (IY+d) as shown for INC. DEC same format and states as INC. Replace 100 with 101 in OP Code.

Notes: The V symbol in the P/V flag column indicates that the P/V flag contains the overflow of the result of the operation. Similarly the P symbol indicates parity. V = 1 means overflow, V = 0 means not overflow, P = 1 means parity of the result is even, P = 0 means parity of the result is odd.

Flag Notation: • = flag not affected, 0 = flag reset, 1 = flag set, X = flag is unknown.
† = flag is affected according to the result of the operation.

GENERAL PURPOSE AF OPERATIONS

Decimal Adjust Acc, 'DAA'	27
Complement Acc, 'CPL'	2F
Negate Acc, 'NEG' (2's complement)	ED 44
Complement Carry Flag, 'CCF'	3F
Set Carry Flag, 'SCF'	37

MISCELLANEOUS CPU CONTROL

'NOP'	00
'HALT'	76
DISABLE INT '(DI)'	F3
ENABLE INT '(EI)'	FB
SET INT MODE 0 'IM 0'	ED 46
SET INT MODE 1 'IM 1'	ED 56
SET INT MODE 2 'IM 2'	ED 5E

8080A MODE

RESTART TO LOCATION 0038H

INDIRECT CALL USING REGISTER
I AND 8 BITS FROM INTERRUPTING
DEVICE AS A POINTER.

GENERAL PURPOSE ARITHMETIC AND CPU CONTROL GROUPS

Mnemonic	Symbolic Operation	Flags							Op-Code		No. of Bytes	No. of M Cycles	No. of T States	Comments	
		S	Z		H	P/V	N	C	76 543 210	Hex					
DAA	Converts acc. content into packed BCD following add or subtract with packed BCD operands	‡	‡	X	‡	X	P	•	‡	00 100 111	27	1	1	4	Decimal adjust accumulator
CPL	$A - \bar{A}$	•	•	X	1	X	•	1	•	00 101 111	2F	1	1	4	Complement accumulator (One's complement)
NEG	$A - \bar{A} + 1$	‡	‡	X	‡	X	V	1	‡	11 101 101 01 000 100	ED 44	2	2	8	Negate acc. (two's complement)
CCF	$CY - \bar{CY}$	•	•	X	X	X	•	0	‡	00 111 111	3F	1	1	4	Complement carry flag
SCF	$CY - 1$	•	•	X	0	X	•	0	1	00 110 111	37	1	1	4	Set carry flag
NOP	No operation	•	•	X	•	X	•	•	•	00 000 000	00	1	1	4	
HALT	CPU halted	•	•	X	•	X	•	•	•	01 110 110	76	1	1	4	
DI	IFF - 0	•	•	X	•	X	•	•	•	11 110 011	F3	1	1	4	
EI	IFF - 1	•	•	X	•	X	•	•	•	11 111 011	FB	1	1	4	
IM 0	Set interrupt mode 0	•	•	X	•	X	•	•	•	11 101 101 01 000 110	ED 46	2	2	8	
IM 1	Set interrupt mode 1	•	•	X	•	X	•	•	•	11 101 101 01 010 110	ED 56	2	2	8	
IM 2	Set interrupt mode 2	•	•	X	•	X	•	•	•	11 101 101 01 011 110	ED 5E	2	2	8	

Notes: IFF indicates the interrupt enable flip-flop
CY indicates the carry flip-flop.

Flag Notation: • = flag not affected, 0 = flag reset, 1 = flag set, X = flag is unknown,
‡ = flag is affected according to the result of the operation.

16-BIT ARITHMETIC

		SOURCE						
		BC	DE	HL	SP	IX	IY	
DESTINATION	'ADD'	HL	09 09	19 19	29 29	39 39		
		IX	DD 09	DD 19		DD 39	DD 29	
		IY	FD 09	FD 19		FD 39		FD 29
	ADD WITH CARRY AND SET FLAGS 'ADC'	HL	ED 4A	ED 5A	ED 6A	ED 7A		
	SUB WITH CARRY AND SET FLAGS 'SBC'	HL	ED 42	ED 52	ED 62	ED 72		
	INCREMENT 'INC'		03	13	23	33	DD 23	FD 23
	DECREMENT 'DEC'		0B	1B	2B	3B	DD 2B	FD 2B

16-BIT ARITHMETIC GROUP

Mnemonic	Symbolic Operation	Flags								Op-Code			No. of Bytes	No. of M Cycles	No. of T States	Comments	
		S	Z		H	P/V	N	C	76	543	210	Hex					
ADD HL, ss	HL ← HL+ss	•	•	X	X	X	•	0	†	00	ss1	001		1	3	11	ss Reg. 00 BC
ADC HL, ss	HL ← HL+ss+CY	†	†	X	X	X	V	0	†	11	101	101	ED	2	4	15	01 DE 10 HL 11 SP
SBC HL, ss	HL ← HL-ss-CY	†	†	X	X	X	V	1	†	11	101	101	ED	2	4	15	
ADD IX, pp	IX ← IX + pp	•	•	X	X	X	•	0	†	11	011	101	DD	2	4	15	pp Reg. 00 BC 01 DE 10 IX 11 SP
ADD IY, rr	IY ← IY + rr	•	•	X	X	X	•	0	†	11	111	101	FD	2	4	15	rr Reg. 00 BC 01 DE 10 IY 11 SP
INC ss	ss ← ss + 1	•	•	X	•	X	•	•	•	00	ss0	011		1	1	6	
INC IX	IX ← IX + 1	•	•	X	•	X	•	•	•	11	011	101	DD	2	2	10	
INC IY	IY ← IY + 1	•	•	X	•	X	•	•	•	11	111	101	FD	2	2	10	
DEC ss	ss ← ss - 1	•	•	X	•	X	•	•	•	00	ss1	011		1	1	6	
DEC IX	IX ← IX - 1	•	•	X	•	X	•	•	•	11	011	101	DD	2	2	10	
DEC IY	IY ← IY - 1	•	•	X	•	X	•	•	•	00	101	011	2B				
										11	111	10†	FD	2	2	10	
										00	101	011	2B				

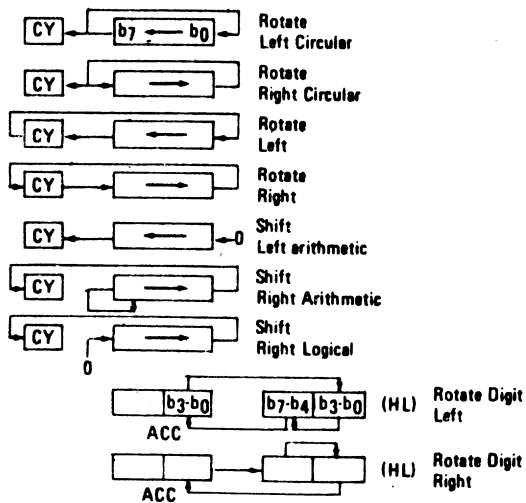
Notes: ss is any of the register pairs BC, DE, HL, SP
pp is any of the register pairs BC, DE, IX, SP
rr is any of the register pairs BC, DE, IY, SP.

Flag Notation: • = flag not affected, 0 = flag reset, 1 = flag set, X = flag is unknown.
† = flag is affected according to the result of the operation.

ROTATES AND SHIFTS

Source and Destination

TYPE OF ROTATE OR SHIFT	Source and Destination											A	
	A	B	C	D	E	H	L	(HL)	(IX+d)	(IY+d)			
'RLC'	CB 07	CB 00	CB 01	CB 02	CB 03	CB 04	CB 05	CB 06	CB d 06	DD FD CB d 06		'RLCA'	07
'RRC'	CB 0F	CB 08	CB 09	CB 0A	CB 0B	CB 0C	CB 0D	CB 0E	CB d 0E	DD FD CB d 0E		'RRCA'	0F
'RL'	CB 17	CB 10	CB 11	CB 12	CB 13	CB 14	CB 15	CB 16	CB d 16	DD FD CB d 16		'RLA'	17
'RR'	CB 1F	CB 18	CB 19	CB 1A	CB 1B	CB 1C	CB 1D	CB 1E	CB d 1E	DD FD CB d 1E		'RRA'	1F
'SLA'	CB 27	CB 20	CB 21	CB 22	CB 23	CB 24	CB 25	CB 26	CB d 26	DD FD CB d 26			
'SRA'	CB 2F	CB 28	CB 29	CB 2A	CB 2B	CB 2C	CB 2D	CB 2E	CB d 2E	DD FD CB d 2E			
'SRL'	CB 3F	CB 38	CB 39	CB 3A	CB 3B	CB 3C	CB 3D	CB 3E	CB d 3E	DD FD CB d 3E			
'RLD'									ED 6F				
'RRD'									ED 67				



ROTATE AND SHIFT GROUP

Mnemonic	Symbolic Operation	Flags							Op-Code		No. of Bytes	No. of Cycles	No. of States	Comments		
		S	Z	H	P/V	N	C	76	543	210					Hex	
RLCA		•	•	X	0	X	•	0	‡	00 000 111	07	1	1	4	Rotate left circular accumulator	
RLA		•	•	X	0	X	•	0	‡	00 010 111	17	1	1	4	Rotate left accumulator	
RRCA		•	•	X	0	X	•	0	‡	00 001 111	0F	1	1	4	Rotate right circular accumulator	
RRA		•	•	X	0	X	•	0	‡	00 011 111	1F	1	1	4	Rotate right accumulator	
RLC r		‡	‡	X	0	X	P	0	‡	11 001 011	CB	2	2	8	Rotate left circular register r	
RLC (HL)		‡	‡	X	0	X	P	0	‡	11 001 011	CB	2	4	15	r Reg. 000 B 001 C 010 D 011 E 100 H 101 L 111 A	
RLC (IX+d)		‡	‡	X	0	X	P	0	‡	11 011 101	DD	4	6	23		
RLC (IY+d)		‡	‡	X	0	X	P	0	‡	11 001 011	CB					
		‡	‡	X	0	X	P	0	‡	- d -						
		‡	‡	X	0	X	P	0	‡	00 000 110						
		‡	‡	X	0	X	P	0	‡	00 000 110						
RL s		‡	‡	X	0	X	P	0	‡	00 000 010					Instruction format and states are as shown for RLC's. To form new Op-Code replace 000 of RLC's with shown code	
RRC s		‡	‡	X	0	X	P	0	‡	001						
RR s		‡	‡	X	0	X	P	0	‡	011						
SLA s		‡	‡	X	0	X	P	0	‡	100						
SRA s		‡	‡	X	0	X	P	0	‡	101						
SRL s		‡	‡	X	0	X	P	0	‡	111						
RLD		‡	‡	X	0	X	P	0	•	11 101 101	ED	2	5	18		Rotate digit left and right between the accumulator and location (HL).
RRO		‡	‡	X	0	X	P	0	•	01 101 111	6F	2	5	18	The content of the upper half of the accumulator is unaffected	

Flag Notation: • = flag not affected, 0 = flag reset, 1 = flag set, X = flag is unknown, ‡ = flag is affected according to the result of the operation.

BIT MANIPULATION GROUP

		REGISTER ADDRESSING						REG. INDIR.	INDEXED		
		A	B	C	D	E	H	L	(ML)	(IX+d)	(IY+d)
TEST 'BIT'	BIT										
	0	CB 47	CB 40	CB 41	CB 42	CB 43	CB 44	CB 45	CB 46	DD CB d 46	FD CB d 46
	1	CB 4F	CB 48	CB 49	CB 4A	CB 4B	CB 4C	CB 4D	CB 4E	DD CB d 4E	FD CB d 4E
	2	CB 57	CB 50	CB 51	CB 52	CB 53	CB 54	CB 55	CB 56	DD CB d 56	FD CB d 56
	3	CB 5F	CB 58	CB 59	CB 5A	CB 5B	CB 5C	CB 5D	CB 5E	DD CB d 5E	FD CB d 5E
	4	CB 67	CB 60	CB 61	CB 62	CB 63	CB 64	CB 65	CB 66	DD CB d 66	FD CB d 66
	5	CB 6F	CB 68	CB 69	CB 6A	CB 6B	CB 6C	CB 6D	CB 6E	DD CB d 6E	FD CB d 6E
	6	CB 77	CB 70	CB 71	CB 72	CB 73	CB 74	CB 75	CB 76	DD CB d 76	FD CB d 76
7	CB 7F	CB 78	CB 79	CB 7A	CB 7B	CB 7C	CB 7D	CB 7E	DD CB d 7E	FD CB d 7E	
RESET BIT 'RES'	0	CB 87	CB 80	CB 81	CB 82	CB 83	CB 84	CB 85	CB 86	DD CB d 86	FD CB d 86
	1	CB 8F	CB 88	CB 89	CB 8A	CB 8B	CB 8C	CB 8D	CB 8E	DD CB d 8E	FD CB d 8E
	2	CB 97	CB 90	CB 91	CB 92	CB 93	CB 94	CB 95	CB 96	DD CB d 96	FD CB d 96
	3	CB 9F	CB 98	CB 99	CB 9A	CB 9B	CB 9C	CB 9D	CB 9E	DD CB d 9E	FD CB d 9E
	4	CB A7	CB A0	CB A1	CB A2	CB A3	CB A4	CB A5	CB A6	DD CB d A6	FD CB d A6
	5	CB AF	CB A8	CB A9	CB AA	CB AB	CB AC	CB AD	CB AE	DD CB d AE	FD CB d AE
	6	CB B7	CB B0	CB B1	CB B2	CB B3	CB B4	CB B5	CB B6	DD CB d B6	FD CB d B6
	7	CB BF	CB B8	CB B9	CB BA	CB BB	CB BC	CB BD	CB BE	DD CB d BE	FD CB d BE
SET BIT 'SET'	0	CB C7	CB C0	CB C1	CB C2	CB C3	CB C4	CB C5	CB C6	DD CB d C6	FD CB d C6
	1	CB CF	CB C8	CB C9	CB CA	CB CB	CB CC	CB CD	CB CE	DD CB d CE	FD CB d CE
	2	CB D7	CB D0	CB D1	CB D2	CB D3	CB D4	CB D5	CB D6	DD CB d D6	FD CB d D6
	3	CB DF	CB D8	CB D9	CB DA	CB DB	CB DC	CB DD	CB DE	DD CB d DE	FD CB d DE
	4	CB E7	CB E0	CB E1	CB E2	CB E3	CB E4	CB E5	CB E6	DD CB d E6	FD CB d E6
	5	CB EF	CB E8	CB E9	CB EA	CB EB	CB EC	CB ED	CB EE	DD CB d EE	FD CB d EE
	6	CB F7	CB F0	CB F1	CB F2	CB F3	CB F4	CB F5	CB F6	DD CB d F6	FD CB d F6
	7	CB FF	CB F8	CB F9	CB FA	CB FB	CB FC	CB FD	CB FE	DD CB d FE	FD CB d FE

BIT SET, RESET AND TEST GROUP

Mnemonic	Symbolic Operation	Flags							Op-Code		No. of Bytes	No. of M Cycles	No. of T States	Comments		
		S	Z		H	P/V	N	C	76 543 210	Hex				r	Reg.	
BIT b, r	$Z - \overline{T}_b$	X	†	X	1	X	X	0	•	11 001 011	CB	2	2	8	r	Reg.
BIT b, (PL)	$Z - (\overline{HL})_b$	X	†	X	1	X	X	0	•	11 001 011	CB	2	3	12	000	B
										01 b r					001	C
BIT b, (IX+d) _b	$Z - (\overline{IX+d})_b$	X	†	X	1	X	X	0	•	11 011 101	DD	4	5	20	010	D
										11 011 101					011	E
										11 001 011					100	H
										- d -					101	L
BT b, (IY+d) _b	$Z - (\overline{IY+d})_b$	X	†	X	1	X	X	0	•	01 b 110	FD	4	5	20	111	A
										11 111 101					b	Bit Tested
										11 001 011					000	0
										- d -					001	1
										01 b 110					010	2
SET b, r	$r_b - 1$	•	•	X	•	X	•	•	•	11 001 011	CB	2	2	8		
										11 b r						
SET b, (HL)	$(HL)_b - 1$	•	•	X	•	X	•	•	•	11 001 011	CB	2	4	15		
SET b, (IX+d)	$(IX+d)_b - 1$	•	•	X	•	X	•	•	•	11 b 110	DD	4	6	23		
										11 011 101						
										11 001 011						
SET b, (IY+d)	$(IY+d)_b - 1$	•	•	X	•	X	•	•	•	- d -	FD	4	6	23		
										11 b 110						
										11 111 101						
										11 001 011						
										- d -						
RES b, s	$s_b - 0$ $s \equiv r, (HL),$ $(IX+d),$ $(IY+d)$									11 b 110						
										11						

To form new Op Code replace **11** of SET b, s with **10**. Flags and time states for SET instruction

Notes: The notation s_b indicates bit b (0 to 7) or location s.

Flag Notation: • = flag not affected, 0 = flag reset, 1 = flag set, X = flag is unknown, † = flag is affected according to the result of the operation.

JUMP GROUP

CONDITION

			UN- COND.	CARRY	NON CARRY	ZERO	NON ZERO	PARITY EVEN	PARITY ODD	SIGN NEG.	SIGN POS.	REG. B=0
JUMP 'JP'	IMMED. EXT.	nn	C3 R	D4 R	B2 R	EA R	C2 R	EA R	E2 R	YA R	F2 R	
JUMP 'JP'	RELATIVE	PC+e	18 e-2	38 e-2	30 e-2	28 e-2	20 e-2					
JUMP 'JP'	REG. INDIR.	(HL)	E8									
JUMP 'JP'		(IX)	DD E9									
JUMP 'JP'		(IY)	FD E9									
DECREMENT B, JUMP IF NON ZERO 'DNJZ'	RELATIVE	PC+e										10 e-2

JUMP GROUP

Mnemonic	Symbolic Operation	Flags								Op-Code				No. of Bytes	No. of M Cycles	No. of T States	Comments	
		S	Z		H	P/V	N	C	76	543	210	Hex						
JP nn	PC - nn	•	•	X	•	X	•	•	•	11	000	011	C3	3	3	10		
JP cc, nn	If condition cc is true PC - nn, otherwise continue	•	•	X	•	X	•	•	•	-	n	-	11 cc 010	3	3	10	cc	Condition
		•	•		•		•		•	-	n	-					000	NZ non zero
		•	•		•		•		•	-	n	-					001	Z zero
		•	•		•		•		•	-	n	-					010	NC non carry
JR e	PC - PC + e	•	•	X	•	X	•	•	•	00	011	000	18	2	3	12		
		•	•		•		•		•	-	e-2	-						
JR C, e	If C = 0, continue If C = 1, PC - PC+e	•	•	X	•	X	•	•	•	00	111	000	38	2	2	7		If condition not met
		•	•		•		•		•	-	e-2	-						
JR NC, e	If C = 1, continue If C = 0, PC - PC+e	•	•	X	•	X	•	•	•	00	110	000	30	2	2	7		If condition not met
		•	•		•		•		•	-	e-2	-						
JR Z, e	If Z = 0, continue If Z = 1, PC - PC+e	•	•	X	•	X	•	•	•	00	101	000	28	2	2	7		If condition not met
		•	•		•		•		•	-	e-2	-						
JR NZ, e	If Z = 1, continue If Z = 0, PC - PC+e	•	•	X	•	X	•	•	•	00	100	000	20	2	2	7		If condition not met
		•	•		•		•		•	-	e-2	-						
JP (HL)	PC - HL	•	•	X	•	X	•	•	•	11	101	001	E9	1	1	4		
JP (IX)	PC - IX	•	•	X	•	X	•	•	•	11	011	101	DD	2	2	8		
		•	•		•		•		•	11	101	001						
JP (IY)	PC - IY	•	•	X	•	X	•	•	•	11	111	101	FD	2	2	8		
		•	•		•		•		•	11	101	001						
DJNZ, e	B - B-1 If B = 0, continue	•	•	X	•	X	•	•	•	00	010	000	10	2	2	8		If B = 0
		•	•		•		•		•	-	e-2	-						
	If B ≠ 0, PC - PC+e	•	•		•		•		•				2	3	13		If B ≠ 0	

Notes: e represents the extension in the relative addressing mode.
e is a signed two's complement number in the range <126, 129>
e-2 in the op-code provides an effective address of pc+e as PC is incremented by 2 prior to the addition of e.

Flag Notation: • = flag not affected, 0 = flag reset, 1 = flag set, X = flag is unknown,
‡ = flag is affected according to the result of the operation.

CALL AND RETURN GROUP

CONDITION

			UN-COND.	CARRY	NON CARRY	ZERO	NON ZERO	PARITY EVEN	PARITY ODD	SIGN NEG.	SIGN POS.	REG. B ≠ 0
'CALL'	IMMED. EXT.	nn	C0 n n	D0 n n	D4 n n	CC n n	C4 n n	EC n n	E4 n n	FC n n	F4 n n	
RETURN 'RET'	REGISTER INDIR.	(SP) (SP+1)	C8	D8	D0	C8	C8	E8	E8	F8	F8	
RETURN FROM INT 'RETI'	REGISTER INDIR.	(SP) (SP+1)	E0 40									
RETURN FROM NON MASKABLE INT 'RETN'	REGISTER INDIR.	(SP) (SP+1)	E0 45									

NOTE - CERTAIN FLAGS HAVE MORE THAN ONE PURPOSE. REFER TO Z80-CPU TECHNICAL MANUAL FOR DETAILS.

RESTART GROUP

		OP CODE	
CALL ADDRESSES	0000 _H	C7	'RST 0'
	0008 _H	CF	'RST 8'
	0010 _H	D7	'RST 16'
	0018 _H	DF	'RST 24'
	0020 _H	E7	'RST 32'
	0028 _H	EF	'RST 40'
	0030 _H	F7	'RST 48'
	0038 _H	FF	'RST 56'

CALL AND RETURN GROUP

Mnemonic	Symbolic Operation	Flags							Op-Code				No. of Bytes	No. of M Cycles	No. of T States	Comments		
		S	Z		M	P/V	N	C	78	543	210	Hex						
CALL nn	(SP-1) - PC _H (SP-2) - PC _L PC - nn	•	•	X	•	X	•	•	•	11	001	101	CD	3	5	17		
CALL cc, nn	If condition cc is false continue, otherwise same as CALL nn	•	•	X	•	X	•	•	•	11	cc	100	3	3	10	If cc is false		
										-	n	-					3	5
RET	PC _L - (SP) PC _H - (SP+1)	•	•	X	•	X	•	•	•	11	001	001	C9	1	3	10		
RET cc	If condition cc is false continue, otherwise same as RET	•	•	X	•	X	•	•	•	11	cc	000	1	1	1	5	If cc is false	
														1	3	11	If cc is true	
RETI	Return from interrupt	•	•	X	•	X	•	•	•	11	101	101	ED	2	4	14		
										01	001	101						4D
										100	PD	parity odd						
										011	C	carry						
RETN ¹	Return from non maskable interrupt	•	•	X	•	X	•	•	•	11	101	101	ED	2	4	14		
										01	000	101						45
										101	PE	parity even						
										110	P	sign positive						
RST p	(SP-1) - PC _H (SP-2) - PC _L PC _H - 0 PC _L - p	•	•	X	•	X	•	•	•	11	•	111	1	3	11			

cc	Condition
000	NZ non zero
001	Z zero
010	NC non carry
011	C carry
100	PO parity odd
101	PE parity even
110	P sign positive
111	M sign negative

t	p
000	00H
001	08H
010	10H
011	18H
100	20H
101	28H
110	30H
111	38H

¹ RETN loads IFF₂ - IFF₁

Flag Notation: • = flag not affected, 0 = flag reset, 1 = flag set, X = flag is unknown,
 † = flag is affected according to the result of the operation.

INPUT GROUP

		PORT ADDRESS		
		IMMED.	REG. INDIR.	
		n	(C)	
INPUT DESTINATION	REG. ADDRESS	A	D3 n	ED 78
		B		ED 40
		C		ED 48
		D		ED 50
		E		ED 58
		H		ED 60
		L		ED 68
'INI' - INPUT & Inc HL, Dec B		REG. INDIR	(HL)	ED A2
'INIR' - INP, Inc HL, Dec B, REPEAT IF B≠0				ED B2
'IND' - INPUT & Dec HL, Dec B				ED AA
'INDR' - INPUT, Dec HL, Dec B, REPEAT IF B≠0				ED BA

} BLOCK INPUT COMMANDS

OUTPUT GROUP

		REGISTER								REG. IND.
		A	B	C	D	E	H	L	(HL)	
'OUT'	IMMED.	n	D3 n							
	REG. IND.	(C)	ED 79	ED 41	ED 49	ED 51	ED 59	ED 61	ED 69	
'OUTI' - OUTPUT Inc HL, Dec b		REG. IND.	(C)							ED A3
'OTIR' - OUTPUT, Inc HL, Dec B, REPEAT IF B≠0		REG. IND.	(C)							ED B3
'OUTD' - OUTPUT Dec HL, Dec B		REG. IND.	(C)							ED AB
'OTDR' - OUTPUT, Dec HL, Dec B, REPEAT IF B≠0		REG. IND.	(C)							ED BB

} BLOCK OUTPUT COMMANDS

PORT DESTINATION ADDRESS

INPUT AND OUTPUT GROUP

Mnemonic	Symbolic Operation	Flags							Op-Code		No. of Bytes	No. of M Cycles	No. of T States	Comments	
		S	Z	H	P/V	N	C	76 543 210	Hex						
IN A, (n)	A - (n)	•	•	X	•	X	•	•	•	11 011 011	DB	2	3	11	n to A ₀ ~ A ₇ Acc to A ₈ ~ A ₁₅
IN r, (C)	r - (C) if r = 110 only the flags will be affected	‡	‡	X	‡	X	P	0	•	11 101 101 01 r 000	ED	2	3	12	C to A ₀ ~ A ₇ B to A ₈ ~ A ₁₅
INI	(HL) - (C) B - B - 1 HL - HL + 1	X	‡	X	X	X	X	1	•	11 101 101 10 100 010	ED A2	2	4	16	C to A ₀ ~ A ₇ B to A ₈ ~ A ₁₅
INIR	(HL) - (C) B - B - 1 HL - HL + 1 Repeat until B = 0	X	1	X	X	X	X	1	•	11 101 101 10 110 010	ED B2	2	5 (If B ≠ 0) 4 (If B = 0)	21 16	C to A ₀ ~ A ₇ B to A ₈ ~ A ₁₅
IND	(HL) - (C) B - B - 1 HL - HL - 1	X	‡	X	X	X	X	1	•	11 101 101 10 101 010	ED AA	2	4	16	C to A ₀ ~ A ₇ B to A ₈ ~ A ₁₅
INDR	(HL) - (C) B - B - 1 HL - HL - 1 Repeat until B = 0	X	1	X	X	X	X	1	•	11 101 101 10 111 010	ED BA	2	5 (If B ≠ 0) 4 (If B = 0)	21 16	C to A ₀ ~ A ₇ B to A ₈ ~ A ₁₅
OUT (n), A	(n) - A	•	•	X	•	X	•	•	•	11 010 011	D3	2	3	11	n to A ₀ ~ A ₇ Acc to A ₈ ~ A ₁₅
OUT (C), r	(C) - r	•	•	X	•	X	•	•	•	11 101 101 01 r 001	ED	2	3	12	C to A ₀ ~ A ₇ B to A ₈ ~ A ₁₅
OUTI	(C) - (HL) B - B - 1 HL - HL + 1	X	‡	X	X	X	X	1	•	11 101 101 10 100 011	ED A3	2	4	16	C to A ₀ ~ A ₇ B to A ₈ ~ A ₁₅
OTIR	(C) - (HL) B - B - 1 HL - HL + 1 Repeat until B = 0	X	1	X	X	X	X	1	•	11 101 101 10 110 011	ED B3	2	5 (If B ≠ 0) 4 (If B = 0)	21 16	C to A ₀ ~ A ₇ B to A ₈ ~ A ₁₅
OUTD	(C) - (HL) B - B - 1 HL - HL - 1	X	‡	X	X	X	X	1	•	11 101 101 10 101 011	ED AB	2	4	16	C to A ₀ ~ A ₇ B to A ₈ ~ A ₁₅
OTDR	(C) - (HL) B - B - 1 HL - HL - 1 Repeat until B = 0	X	1	X	X	X	X	1	•	11 101 101 10 111 011	ED BB	2	5 (If B ≠ 0) 4 (If B = 0)	21 16	C to A ₀ ~ A ₇ B to A ₈ ~ A ₁₅

Notes: ① If the result of B - 1 is zero the Z flag is set, otherwise it is reset.

Flag Notation: • = flag not affected, 0 = flag reset, 1 = flag set, X = flag is unknown,
‡ = flag is affected according to the result of the operation.

Z80—CPU INSTRUCTIONS SORTED BY OP-CODE

OBJ CODE	SOURCE STATEMENT
00	NOP
018405	LD BC,NN
02	LD (BC),A
03	INC BC
04	INC B
05	DEC B
0620	LD B,N
07	RLCA
08	EX AF,AF'
09	ADD HL,BC
0A	LD A,(BC)
0B	DEC BC
0C	INC C
0D	DEC C
0E20	LD C,N
0F	RRCA
102E	DJNZ DIS
118405	LD DE,NN
12	LD (DE),A
13	INC DE
14	INC D
15	DEC D
1620	LD D,N
17	RLA
182E	JR DIS
19	ADD HL,DE
1A	LD A,(DE)
1B	DEC DE
1C	INC E
1D	DEC E
1E20	LD E,N
1F	RRA
202E	JR NZ,DIS
218405	LD HL,NN
228405	LD (NN),HL
23	INC HL
24	INC H
25	DEC H
2620	LD H,N
27	DAA

282E	JR Z,DIS
29	ADD HL,HL
2A8405	LD HL,(NN)
2B	DEC HL
2C	INC L
2D	DEC L
2E20	LD L,N
2F	CPL
302E	JR NC,DIS
318405	LD SP,NN
328405	LD (NN),A
33	INC SP
34	INC (HL)
35	DEC (HL)
3620	LD (HL),N
37	SCF
382E	JR C,DIS
39	ADD HL,SP
3A8405	LD A,(NN)
3B	DEC SP
3C	INC A
3D	DEC A
3E20	LD A,N
3F	CCF
40	LD B,B
41	LD B,C
42	LD B,D
43	LD B,E
44	LD B,H,NN
45	LD B,L
46	LD B,(HL)
47	LD B,A
48	LD C,B
49	LD C,C
4A	LD C,D
4B	LD C,E
4C	LD C,H
4D	LD C,L
4E	LD C,(HL)
4F	LD C,A
50	LD D,B
51	LD D,C
52	LD D,D
53	LD D,E
54	LD D,H
55	LD D,L
56	LD D,(HL)
57	LD D,A

58	LD E,B
59	LD E,C
5A	LD E,D
5B	LD E,E
5C	LD E,H
5D	LD E,L
5E	LD E,(HL)
5F	LD E,A
60	LD H,B
61	LD H,C
62	LD H,D
63	LD H,E
64	LD H,H
65	LD H,L
66	LD H,(HL)
67	LD H,A
68	LD L,B
69	LD L,C
6A	LD L,D
6B	LD L,E
6C	LD L,H
6D	LD L,L
6E	LD L,(HL)
6F	LD L,A
70	LD (HL),B
71	LD (HL),C
72	LD (HL),D
73	LD (HL),E
74	LD (HL),H
75	LD (HL),L
76	HALT
77	LD (HL),A
78	LD A,B
79	LD A,C
7A	LD A,D
7B	LD A,E
7C	LD A,H
7D	LD A,L
7E	LD A,(HL)
7F	LD A,A
80	ADD A,B
81	ADD A,C
82	ADD A,D
83	ADD A,E
84	ADD A,H
85	ADD A,L
86	ADD A,(HL)
87	ADD A,A

88	ADC A,B
89	ADCA,C
8A	ADC A,D
8B	ADC A,E
8C	ADCA,H
8D	ADC A,L
8E	ADC A,(HL)
8F	ADCA,A
90	SUB B
91	SUB C
92	SUB D
93	SUB E
94	SUB H
95	SUB L
96	SUB (HL)
97	SUB A
98	SBC A,8
99	SBC A,C
9A	SBC A,D
9B	SBC A,E
9C	SBC A,H
9D	SBC A,L
9E	SBC A,(HL)
9F	SBC A,A
A0	AND B
A1	AND C
A2	AND D
A3	AND E
A4	AND H
A5	AND L
A6	AND (HL)
A7	AND A
A8	XOR B
A9	XOR C
AA	XOR D
AB	XOR E
AC	XOR H
AD	XOR L
AE	XOR (HL)
AF	XOR A
B0	OR B
B1	OR C
B2	OR D
B3	OR E
B4	OR H
B5	OR L
B6	OR (HL)
B7	OR A

B8	CP B
B9	CP C
BA	CP D
BB	CP E
BC	CP H
BD	CP L
BE	CP (HL)
BF	CP A
C0	RET NZ
C1	POP BC
C28405	JP NZ,NN
C38405	JP NN
C48405	CALL NZ,NN
C5	PUSH BC
C620	ADD A,N
C7	RST O
C8	RET Z
C9	RET
CA8405	JP Z,NN
CC8405	GALL Z,NN
CD8405	CALL NN
CE20	ADC A,N
CF	RST 8
D0	RET NC
D1	POP DE
D28405	JP NC,NN
D320	OUT (N),A
D48405	CALL NC,NN
D5	PUSH DE
D620	SUB N
D7	RST 10H
D8	RET C
D9	EXX
DA8405	JP C,NN
DB20	IN A,(N)
DC8405	CALL C,NN
DE20	SBC A,N
DF	RST 18H
E0	RET PO
E1	POP HL
E28405	JP PO,NN
E3	EX (SP),HL
E48405	CALL PO,NN
E5	PUSH HL
E620	AND N
E7	RST 20H
E8	RET PE
E9	JP (HL)

EA8405	JP PE,NN
EB	EX DE,HL
EC8405	CALL PE,NN
EE20	XOR N
EF	RST 28H
F0	RET P
F1	POP AF
F28405	JP P,NN
F3	DI
F48405	CALL P,NN
F5	PUSH AF
F620	OR N
F7	RST 30H
F8	RET M
F9	LD SP,HL
FA8405	JP M,NN
FB	EI
FC8405	CALL M,NN
FE20	CP N
FF	RST 38H
CB00	RLC B
CB01	RLC C
CB02	RLC D
CB03	RLC E
CB04	RLC H
CB05	RLC L
CB06	RLC (HL)
CB07	RLC A
CB08	RRC B
CB09	RRC C
CB0A	RRC D
CB0B	RRC E
CB0C	RRC H
CB0D	RRC L
CB0E	RRC (HL)
CB0F	RRC A
CB10	RL B
CB11	RL C
CB12	RL D
CB13	RL E
CB14	RL H
CB15	RL L
CB16	RL (HL)
CB17	RL A
CB18	RR B
CB19	RR C
CB1A	RR D
CB1B	RR E

CB1C	RR H
CB1D	RR L
CB1E	RR (HL)
CB1F	RR A
CB20	SLA B
CB21	SLA C
CB22	SLA D
CB23	SLA E
CB24	SLA H
CB25	SLA L
CB26	SLA (HL)
CB27	SLA A
CB28	SRA B
CB29	SRA C
CB2A	SRA D
CB2B	SRA E
CB2C	SRA H
CB2D	SRA L
CB2E	SRA (HL)
CB2F	SRA A
CB38	SRL B
CB39	SRL C
CB3A	SRL D
CB3B	SRL E
CB3C	SRL H
CB3D	SRL L
CB3E	SRL (HL)
CB3F	SRL A
CB40	BIT 0,B
CB41	BIT 0,C
CB42	BIT 0,D
CB43	BIT 0,E
CB44	BIT 0,H
CB45	BIT 0,L
CB46	BIT 0,(HL)
CB47	BIT 0,A
CB48	BIT 1,B
CB49	BIT 1,C
CB4A	BIT 1,D
CB4B	BIT 1,E
CB4C	BIT 1,H
CB4D	BIT 1,L
CB4E	BIT 1,(HL)
CB4F	BIT 1,A
CB50	BIT 2,B
CB51	BIT 2,C
CB52	BIT 2,D
CB53	BIT 2,E

CB54	BIT 2,H
CB55	BIT 2,L
CB56	BIT 2,(HL)
CB57	BIT 2,A
CB58	BIT 3,B
CB59	BIT 3,C
CB5A	BIT 3,D
CB5B	BIT 3,E
CB5C	BIT 3,H
CB5D	BIT 3,L
CB5E	BIT 3,(HL)
CB5F	BIT 3,A
CB60	BIT 4,B
CB61	BIT 4,C
CB62	BIT 4,D
CB63	BIT 4,E
CB64	BIT 4,H
CB65	BIT 4,L
CB66	BIT 4,(HL)
CB67	BIT 4,A
CB68	BIT 5,B
CB69	BIT 5,C
CB6A	BIT 5,D
CB6B	BIT 5,E
CB6C	BIT 5,H
CB6D	BIT 5,L
CB6E	BIT 5,(HL)
CB6F	BIT 5,A
CB70	BIT 6,B
CB71	BIT 6,C
CB72	BIT 6,D
CB73	BIT 6,E
CB74	BIT 6,H
CB75	BIT 6,L
CB76	BIT 6,(HL)
CB77	BIT 6,A
CB78	BIT 7,B
CB79	BIT 7,C
CB7A	BIT 7,D
CB7B	BIT 7,E
CB7C	BIT 7,H
CB7D	BIT 7,L
CB7E	BIT 7,(HL)
CB7F	BIT 7,A
CB80	RES 0,B
CB81	RES 0,C
CB82	RES 0,D
CB83	RES 0,E

CB84	RES 0,H
CB85	RES 0,L
CB86	RES 0,(HL)
CB87	RES 0,A
CB88	RES 1,B
CB89	RES 1,C
CB8A	RES 1,D
CB8B	RES 1,E
CB8C	RES 1,H
CB8D	RES 1,L
CB8E	RES 1,(HL)
CB8F	RES 1,A
CB90	RES 2,B
CB91	RES 2,C
CB92	RES 2,D
CB93	RES 2,E
CB94	RES 2,H
CB95	RES 2,L
CB96	RES 2,(HL)
CB97	RES 2,A
CB98	RES 3,B
CB99	RES 3,C
CB9A	RES 3,D
CB9B	RES 3,E
CB9C	RES 3,H
CB9D	RES 3,L
CB9E	RES 3,(HL)
CB9F	RES 3,A
CBA0	RES 4,B
CBA1	RES 4,C
CBA2	RES 4,D
CBA3	RES 4,E
CBA4	RES 4,H
CBA5	RES 4,L
CBA6	RES 4,(HL)
CBA7	RES 4,A
CBA8	RES 5,B
CBA9	RES 5,C
CBAA	RES 5,D
CBAB	RES 5,E
CBAC	RES 5,H
CBAD	RES 5,L
CBAE	RES 5,(HL)
CBAF	RES 5,A
CBB0	RES 6,B
CBB1	RES 6,C
CBB2	RES 6,D
CBB3	RES 6,E

CBB4	RES 6,H
CBB5	RES 6,L
CBB6	RES 6,(HL)
CBB7	RES 6,A
CBB8	RES 7,B
CBB9	RES 7,C
CBBA	RES 7,D
CBBB	RES 7,E
CBBC	RES 7,H
CBBD	RES 7,L
CBBE	RES 7,(HL)
CBBF	RES 7,A
CBC0	SET 0,B
CBC1	SET 0,C
CBC2	SET 0,D
CBC3	SET 0,E
CBC4	SET 0,H
CBC5	SET 0,L
CBC6	SET 0,(HL)
CBC7	SET 0,A
CBC8	SET 1,B
CBC9	SET 1,C
CBCA	SET 1,D
CBCB	SET 1,E
CBCC	SET 1,H
CBCD	SET 1,L
CBCE	SET 1,(HL)
CBCF	SET 1,A
CBD0	SET 2,B
CBD1	SET 2,C
CBD2	SET 2,D
CBD3	SET 2,E
CBD4	SET 2,H
CBD5	SET 2,L
CBD6	SET 2,(HL)
CBD7	SET 2,A
CBD8	SET 3,B
CBD9	SET 3,C
CBDA	SET 3,D
CBDB	SET 3,E
CBDC	SET 3,H
CBDD	SET 3,L
CBDE	SET 3,(HL)
CBDF	SET 3,A
CBE0	SET 4,B
CBE1	SET 4,C
CBE2	SET 4,D
CBE3	SET 4,E

CBE4	SET 4,H
CBE5	SET 4,L
CBE6	SET 4,(HL)
CBE7	SET 4,A
CBE8	SET 5,B
CBE9	SET 5,C
CBEA	SET 5,D
CBEA	SET 5,D
CBEF	SET 5,E
CBEC	SET 5,H
CBED	SET 5,L
CBEE	SET 5,(HL)
CBEF	SET 5,A
CBF0	SET 6,B
CBF1	SET 6,C
CBF2	SET 6,D
CBF3	SET 6,E
CBF4	SET 6,H
CBF5	SET 6,L
CBF6	SET 6,(HL)
CBF7	SET 6,A
CBF8	SET 7,B
CBF9	SET 7,C
CBFA	SET 7,D
CBFB	SET 7,E
CBFC	SET 7,H
CBFD	SET 7,L
CBFE	SET 7,(HL)
CBFF	SET 7,A
DD09	ADD IX,BC
DD19	ADD IX,DE
DD218405	LD IX,NN
DD228405	LD (NN),IX
DD23	INC IX
DD29	ADD IX,IX
DD2A8405	LD IX,(NN)
DD2B	DEC IX
DD3405	INC (IX+d)
DD3505	DEC (IX+d)
DD360520	LD (IX+d),N
DD39	ADD IX,SP
DD4605	LD B,(IX+d)
DD4E05	LD C,(IX+d)
DD5605	LD D,(IX+d)
DD5E05	LD E,(IX+d)
DD6605	LD H,(IX+d)
DD6E05	LD L,(IX+d)
DD7005	LD (IX+d),B
DD7105	LD (IX+d),C

DD7205	LD (IX+d),D
DD7305	LD (IX+d),E
DD7405	LD (IX+d),H
DD7505	LD (IX+d),L
DD7705	LD (IX+d),A
DD7E05	LD A,(IX+d)
DD8605	ADD A,(IX+d)
DD8E05	ADC A,(IX+d)
DD9605	SUB (IX+d)
DD9E05	SBC A,(IX+d)
DDA605	AND (IX+d)
DDAE05	XOR (IX+d)
DD8605	OR (IX+d)
DDBE05	CP (IX+d)
DDE1	POP IX
DDE3	EX (SP),IX
DDE5	PUSH IX
DDE9	JP (IX)
DDF9	LD SP,IX
DDCB0506	RRC (IX+d)
DDCB050E	RRC (IX+d)
DDCB0516	RL (IX+d)
DDCB051E	RR (IX+d)
DDCB0526	SLA (IX+d)
DDCB052E	SRA (IX+d)
DDCB053E	SRL (IX+d)
DDCB0546	BIT 0,(IX+d)
DDCB054E	BIT 1,(IX+d)
DDCB0556	BIT 2,(IX+d)
DDCB055E	BIT 3,(IX+d)
DDCB0566	BIT 4,(IX+d)
DDCB056E	BIT 5,(IX+d)
DDCB0576	BIT 6,(IX+d)
DDCB057E	BIT 7,(IX+d)
DDCB0586	RES 0,(IX+d)
DDCB058E	RES 1,(IX+d)
DDCB0596	RES 2,(IX+d)
DDCB059E	RES 3,(IX+d)
DDCB05A6	RES 4,(IX+d)
DDCB05AE	RES 5,(IX+d)
DDCB05B6	RES 6,(IX+d)
DDCB05BE	RES 7,(IX+d)
DDCB05C6	SET 0,(IX+d)
DDCB05CE	SET 1,(IX+d)
DDCB05D6	SET 2,(IX+d)
DDCB05DE	SET 3,(IX+d)
DDCB05E6	SET 4,(IX+d)
DDCB05EE	SET 5,(IX+d)

DDCB05F6	SET 6,(IX+d)
DDCB05FE	SET 7,(IX+d)
ED40	IN B,(C)
ED41	OUT (C),B
ED42	SBC HL,BC
ED438405	LD (NN),BC
ED44	NEG
ED45	RETN
ED46	IM 0
ED47	LD I,A
ED48	IN C,(C)
ED49	OUT (C),C
ED4A	ADC HL,BC
ED4B8405	LD BC,(NN)
ED4D	RETI
ED50	IN D,(C)
ED51	OUT (C),D
ED52	SBC HL,DE
ED538405	LD (NN),DE
ED56	IM 1
ED57	LD A,I
ED58	IN E,(C)
ED59	OUT (C),E
ED5A	ADC HL,DE
ED5B8405	LD DE,(NN)
ED5E	IM 2
ED60	IN H,(C)
ED61	OUT (C),H
ED62	SBC HL,HL
ED67	RRD
ED68	IN L,(C)
ED69	OUT (C),L
ED6A	ADC HL,HL
ED6F	RLD
ED72	SBC HL,SP
ED738405	LD (NN),SP
ED78	IN A,(C)
ED79	OUT (C),A
ED7A	ADC HL,SP
ED7B8405	LD SP,(NN)
EDA0	LDI
EDA1	CPI
EDA2	INI
EDA3	OUTI
EDA8	LDD
EDA9	CPD
EDAA	IND
EDAB	OUTD

EDB0	LDIR
EDB1	CPIR
EDB2	INIR
EDB3	OTIR
EDB8	LDDR
EDB9	CPDR
EDBA	INDR
EDBB	OTDR
FD09	ADD IY,BC
FD19	ADD IY,DE
FD218405	LD IY,NN
FD228405	LD (NN),IY
FD23	INC IY
FD29	ADD IY,IY
FD2A8405	LD IY,(NN)
FD2B	DEC IY
FD3405	INC (IY+d)
FD3505	DEC (IY+d)
FD360520	LD (IY+d),N
FD39	ADD IY,SP
FD4605	LD B,(IY+d)
FD4E05	LD C,(IY+d)
FD5605	LD D,(IY+d)
FD5E05	LD E,(IY+d)
FD6605	LD H,(IY+d)
FD6E05	LD L,(IY+d)
FD7005	LD (IY+d),B
FD7105	LD (IY+d),C
FD7205	LD (IY+d),D
FD7305	LD (IY+d),E
FD7405	LD (IY+d),H
FD7505	LD (IY+d),L
FD7705	LD (IY+d),A
FD7E05	LD A,(IY+d)
FD8605	ADD A,(IY+d)
FD8E05	ADC A,(IY+d)
FD9605	SUB (IY+d)
FD9E05	SBC A,(IY+d)
FDA605	AND (IY+d)
FDAE05	XOR (IY+d)
FDB605	OR (IY+d)
FDBE05	CP (IY+d)
FDE1	POP IY
FDE3	EX (SP),IY
FDE5	PUSH IY
FDE9	JP (IY)
FD9	LD SP,IY
FDCB0506	RLC (IY+d)

FDCB050E	RRC (IY+d)
FDCB0516	RL (IY+d)
FDCB051E	RR (IY+d)
FDCB0526	SLA (IY+d)
FDCB052E	SRA (IY+d)
FDCB053E	SRL (IY+d)
FDCB0546	BIT 0,(IY+d)
FDCB054E	BIT 1,(IY+d)
FDCB0556	BIT 2,(IY+d)
FDCB055E	BIT 3,(IY+d)
FDCB0566	BIT 4,(IY+d)
FDCB056E	BIT 5,(IY+d)
FDCB0576	BIT 6,(IY+d)
FDCB057E	BIT 7,(IY+d)
FDCB0586	RES 0,(IY+d)
FDCB058E	RES 1,(IY+d)
FDCB0596	RES 2,(IY+d)
FDCB059E	RES 3,(IY+d)
FDCB05A6	RES 4,(IY+d)
FDCB05AE	RES 5,(IY+d)
FDCB05B6	RES 6,(IY+d)
FDCB05BE	RES 7,(IY+d)
FDCB05C6	SET 0,(IY+d)
FDCB05CE	SET 1,(IY+d)
FDCB05D6	SET 2,(IY+d)
FDCB05DE	SET 3,(IY+d)
FDCB05E6	SET 4,(IY+d)
FDCB05EE	SET 5,(IY+d)
FDCB05F6	SET 6,(IY+d)
FDCB05FE	SET 7,(IY+d)

Z80-CPU INSTRUCTIONS SORTED BY MNEMONIC

OBJ CODE	SOURCE STATEMENT
8E	ADC A,(HL)
DD8E05	ADC A,(IX+d)
FD8E05	ADC A,(IY+d)
8F	ADC A,A

88	ADC A,B
89	ADC A,C
8A	ADC A,D
8B	ADC A,E
8C	ADC A,H
8D	ADC A,L
CE20	ADC A,N
ED4A	ADC HL,BC
ED5A	ADC HL,DE
ED6A	ADC HL,HL
ED7A	ADC HL,SP
86	ADD A,(HL)
DD8605	ADD A,(IX+d)
FD8605	ADD A,(IY+d)
87	ADD A,A
80	ADD A,B
81	ADD A,C
82	ADD A,D
83	ADD A,E
84	ADD A,H
85	ADD A,L
C620	ADD A,N
09	ADD HL,BC
19	ADD HL,DE
29	ADD HL,HL
39	ADD HL,SP
DD09	ADD IX,BC
DD19	ADD IX,DE
DD29	ADD IX,IX
DD39	ADD IX,SP
FD09	ADD IY,BC
FD19	ADD IY,DE
FD29	ADD IY,IY
FD39	ADD IY,SP
A6	AND (HL)
DDA605	AND (IX+d)
FDA605	AND (IY+d)
A7	AND A
A0	AND B
A1	AND C
A2	AND D
A3	AND E
A4	AND H
A5	AND L
E620	AND N
CB46	BIT 0,(HL)
DDCB0546	BIT 0,(IX+d)
FDCB0546	BIT 0,(IY+d)

CB47	BIT 0,A
CB40	BIT 0,B
CB41	BIT 0,C
CB42	BIT 0,D
CB43	BIT 0,E
CB44	BIT 0,H
CB45	BIT 0,L
CB4E	BIT 1,(HL)
DDCB054E	BIT 1,(IX+d)
FDCB054E	BIT 1,(IY+d)
CB4F	BIT 1,A
BC48	BIT 1,B
CB49	BIT 1,C
CB4A	BIT 1,D
CB4B	BIT 1,E
CB4C	BIT 1,H
CB4D	BIT 1,L
CB56	BIT 2,(HL)
DDCB0556	BIT 2,(IX+d)
FDCB0556	BIT 2,(IY+d)
CB57	BIT 2,A
CB50	BIT 2,B
CB51	BIT 2,C
CB52	BIT 2,D
CB53	BIT 2,E
CB54	BIT 2,H
CB55	BIT 2,L
CB5E	BIT 3,(HL)
DDCB055E	BIT 3,(IX+d)
FDCB055E	BIT 3,(IY+d)
CB5F	BIT 3,A
CB58	BIT 3,B
CB59	BIT 3,C
CB5A	BIT 3,D
CB5B	BIT 3,E
CB5C	BIT 3,H
CB5D	BIT 3,L
CB66	BIT 4,(HL)
DDCB0566	BIT 4,(IX+d)
FDCB0566	BIT 4,(IY+d)
CB67	BIT 4,A
CB60	BIT 4,B
CB61	BIT 4,C
CB62	BIT 4,D
CB63	BIT 4,E
CB64	BIT 4,H
CB65	BIT 4,L
CB6E	BIT 5,(HL)

DDCB056E	BIT 5,(IX+d)
FDCB056E	BIT 5,(IY+d)
CB6F	BIT 5,A
CB68	BIT 5,B
CB69	BIT 5,C
CB6A	BIT 5,D
CB6B	BIT 5,E
CB6C	BIT 5,H
CB6D	BIT 5,L
CB76	BIT 6,(HL)
DDCB0576	BIT 6,(IX+d)
FDCB0576	BIT 6,(IY+d)
CB77	BIT 6,A
CB70	BIT 6,B
CB71	BIT 6,C
CB72	BIT 6,D
CB73	BIT 6,E
CB74	BIT 6,H
CB75	BIT 6,L
CB7E	BIT 7,(HL)
DDCB057E	BIT 7,(IX+d)
FDCB057E	BIT 7,(IY+d)
CB7F	BIT 7,A
CB78	BIT 7,B
CB79	BIT 7,C
CB7A	BIT 7,D
CB7B	BIT 7,E
CB7C	BIT 7,H
CB7D	BIT 7,L
DC8405	CALL C,NN
FC8405	CALL M,NN
D48405	CALL NC,NN
CD8405	CALL NN
C48405	CALL NZ,NN
F48405	CALL P,NN
EC8405	CALL PE,NN
E48405	CALL PO,NN
CC8405	CALL Z,NN
3F	CCF
BE	CP (HL)
DDBE05	CP (IX+d)
FDDE05	CP (IY+d)
BF	CP A
B8	CP B
B9	CP C
BA	CP D
BB	CP E
BC	CP H

BD	CP L
FE20	CP N
EDA9	CPD
EDB9	CPDR
EDA1	CPI
EDB1	CPIR
2F	CPL
27	DAA
35	DEC (HL)
DD3505	DEC (IX+d)
FD3505	DEC (IY+d)
3D	DEC A
05	DEC B
0B	DEC BC
0D	DEC C
15	DEC D
1B	DEC DE
1D	DEC E
25	DEC H
2B	DEC HL
DD2B	DEC IX
FD2B	DEC IY
2D	DEC L
3B	DEC SP
F3	DI
102E	DJNZ DIS
FB	EJ
E3	EX (SP),HL
DDE3	EX (SP),IX
FDE3	EX (SP),IY
08	EX AF,AF'
EB	EX DE,HL
D9	EXX
76	HALT
ED46	IM 0
ED56	IM 1
ED5E	IM 2
ED78	IN A,(C)
DB20	IN A,(N)
ED40	IN B,(C)
ED48	IN C,(C)
ED50	IN D,(C)
ED58	IN E,(C)
ED60	IN H,(C)
ED68	IN L,(C)
34	INC (HL)
DD3405	INC (IX+d)
FD3405	INC (IY+d)

3C	INC A
04	INC B
03	INC BC
0C	INC C
14	INC D
13	INC DE
1C	INC E
24	INC H
23	INC HL
DD23	INC IX
FD23	INC IY
2C	INC L
33	INC SP
EDAA	IND
EDBA	INDR
EDA2	INI
EDB2	INIR
E9	JP (HL)
DDE9	JP (IX)
FDE9	JP (IY)
DA8405	JP C,NN
FA8405	JP M,NN
D28405	JP NC,NN
C38405	JP NN
C28405	JP NZ,NN
F28405	JP P,NN
EA8405	JP PE,NN
E28405	JP PO,NN
CA8405	JP Z,NN
382E	JR C,DIS
182E	JR DIS
302E	JR NC,DIS
202E	JR NZ,DIS
282E	JR Z,DIS
02	LD (BC),A
12	LD (DE),A
77	LD (HL),A
70	LD (HL),B
71	LD (HL),C
72	LD (HL),D
73	LD (HL),E
74	LD (HL),H
75	LD (HL),L
3620	LD (HL),N
DD7705	LD (IX+d),A
DD7005	LD (IX+d),B
DD7105	LD (IX+d),C
DD7205	LD (IX+d),D

DD7305	LD (IX+d),E
DD7405	LD (IX+d),H
DD7505	LD (IX+d),L
DD360520	LD (IX+d),N
FD7705	LD (IY+d),A
FD7005	LD (IY+d),B
FD7105	LD (IY+d),C
FD7205	LD (IY+d),D
FD7305	LD (IY+d),E
FD7405	LD (IY+d),H
FD7505	LD (IY+d),L
FD360520	LD (IY+d),N
328405	LD (NN),A
ED438405	LD (NN),BC
ED538405	LD (NN),DE
228405	LD (NN),HL
DD228405	LD (NN),IX
FD228405	LD (NN),IY
ED738405	LD (NN),SP
0A	LD A,(BC)
1A	LD A,(DE)
7E	LD A,(HL)
DD7E05	LD A,(IX+d)
FD7E05	LD A,(IY+d)
3A8405	LD A,(NN)
7F	LD A,A
78	LD A,B
79	LD A,C
7A	LD A,D
7B	LD A,E
7C	LD A,H
ED57	LD A,I
7D	LD A,L
3E20	LD A,N
46	LD B,(HL)
DD4605	LD B,(IX+d)
FD4605	LD B,(IY+d)
47	LD B,A
40	LD B,B
41	LD B,C
42	LD B,D
43	LD B,E
44	LD B,H,NN
45	LD B,L
0620	LD B,N
ED4B8405	LD BC,(NN)
018405	LD BC,NN
4E	LD C,(HL)

DD4E05	LD C,(IX+d)
FD4E05	LD C,(IY+d)
4F	LD C,A
48	LD C,B
49	LD C,C
4A	LD C,D
4B	LD C,E
4C	LD C,H
4D	LD C,L
0E20	LD C,N
56	LD D,(HL)
DD5605	LD D,(IX+d)
FD5605	LD D,(IY+d)
57	LD D,A
50	LD D,B
51	LD D,C
52	LD D,D
53	LD D,F
54	LD D,H
55	LD D,L
1620	LD D,N
ED5B8405	LD D,(NN)
118405	LD D,(NN)
5E	LD E,(HL)
DD5E05	LD E,(IX+d)
FD5E05	LD E,(IY+d)
5F	LD E,A
58	LD E,B
59	LD E,C
5A	LD E,D
5B	LD E,E
5C	LD E,H
5D	LD E,L
1E20	LD E,N
66	LD H,(HL)
DD6605	LD H,(IX+d)
FD6605	LD H,(IY+d)
67	LD H,A
60	LD H,B
61	LD H,C
62	LD H,D
63	LD H,E
64	LD H,H
65	LD H,L
2620	LD H,N
2A8405	LD HL,(NN)
218405	LD HL,NN
ED47	LD I,A

DD2A8405	LD IX,(NN)
DD218405	LD IX,NN
FD2A8405	LD IY,(NN)
FD218405	LD IY,NN
6E	LD L,(HL)
DD6E05	LD L,(IX+d)
FD6E05	LD L,(IY+d)
6F	LD L,A
68	LD L,B
69	LD L,C
6A	LD L,D
6B	LD L,E
6C	LD L,H
6D	LD L,L
2E20	LD L,N
ED7B8405	LD SP,(NN)
F9	LD SP,HL
DDF9	LD SP,IX
FDf9	LD SP,IY
318405	LD SP,NN
EDA8	LDD
EDB8	LDDR
EDA0	LDI
EDB0	LDIR
ED44	NEG
00	NOP
B6	OR (HL)
DDB605	OR (IX+d)
FDB605	OR (IY+d)
B7	OR A
B0	OR B
B1	OR C
B2	OR D
B3	OR E
B4	OR H
B5	OR L
F620	OR N
EDB8	OTDR
EDB3	OTIR
ED79	OUT (C),A
ED41	OUT (C),B
ED49	OUT (C),C
ED51	OUT (C),D
ED59	OUT (C),E
ED61	OUT (C),H
ED69	OUT (C),L
D320	OUT (N),A
EDAB	OUTD

EDA3	OUTI
F1	POP AF
C1	POP BC
D1	POP DE
E1	POP HL
DDE1	POPIX
FDE1	POPIY
F5	PUSH AF
C5	PUSH BC
D5	PUSH DE
E5	PUSH HL
DDE5	PUSH IX
FDE5	PUSH IY
CB86	RES 0,(HL)
DDCB0586	RES 0,(IX+d)
FDCB0586	RES 0,(IY+d)
CB87	RES 0,A
CB80	RES 0,B
CB81	RES 0,C
CB82	RES 0,D
CB83	RES 0,E
CB84	RES 0,H
CB85	RES 0,L
CB8E	RES 1,(HL)
DDCB058E	RES 1,(IX+d)
FDCB058E	RES 1,(IY+d)
CB8F	RES 1,A
CB88	RES 1,B
CB89	RES 1,C
CB8A	RES 1,D
CB8B	RES 1,E
CB8C	RES 1,H
CB8D	RES 1,L
CB96	RES 2,(HL)
DDCB0596	RES 2,(IX+d)
FDCB0596	RES 2,(IY+d)
CB97	RES 2,A
CB90	RES 2,B
CB91	RES 2,C
CB92	RES 2,D
CB93	RES 2,E
CB94	RES 2,H
CB95	RES 2,L
CB9E	RES 3,(HL)
DDCB059E	RES 3,(IX+d)
FDCB059E	RES 3,(IY+d)
CB9F	RES 3,A
CB98	RES 3,B

CB99	RES 3,C
CB9A	RES 3,D
CB9B	RES 3,E
CB9C	RES 3,H
CB9D	RES 3,L
CBA6	RES 4,(HL)
DDCB05A6	RES 4,(IX+d)
FDCB05A6	RES 4,(IY+d)
CBA7	RES 4,A
CBA0	RES 4,B
CBA1	RES 4,C
CBA2	RES 4,D
CBA3	RES 4,E
CBA4	RES 4,H
CBA5	RES 4,L
CBAE	RES 5,(HL)
DDCB05AE	RES 5,(IX+d)
FDCB05AE	RES 5,(IY+d)
CBAF	RES 5,A
CBA8	RES 5,B
CBA9	RES 5,C
CBA A	RES 5,D
CBAB	RES 5,E
CBAC	RES 5,H
CBAD	RES 5,L
CBB6	RES 6,(HL)
DDCB05B6	RES 6,(IX+d)
FDCB05B6	RES 6,(IY+d)
CBB7	RES 6,A
CBB0	RES 6,B
CBB1	RES 6,C
CBB2	RES 6,D
CBB3	RES 6,E
CBB4	RES 6,H
CBB5	RES 6,L
CBBE	RES 7,(HL)
DDCB05BE	RES 7,(IX+d)
FDCB05BE	RES 7,(IY+d)
CBBF	RES 7,A
CBB8	RES 7,B
CBB9	RES 7,C
CBBA	RES 7,D
CBBB	RES 7,E
CBBC	RES 7,H
CBBD	RES 7,L
C9	RET
D8	RET C
F8	RET M

D0	RET NC
C0	RET NZ
F0	RET P
E8	RET PE
E0	RET PO
C8	RET Z
ED4D	RETI
ED45	RETN
CB16	RL (HL)
DDCB0516	RL (IX+d)
FDCB0516	RL (IY+d)
CB17	RL A
CB10	RL B
CB11	RL C
CB12	RL D
CB13	RL E
CB14	RL H
CB15	RL L
17	RLA
CB06	RLC (HL)
DDCB0506	RLC (IX+d)
FDCB0506	RLC (IY+d)
CB07	RLC A
CB00	RLC B
CB01	RLC C
CB02	RLC D
CB03	RLC E
CB04	RLC H
CB05	RLC L
07	RLCA
ED6F	RLD
CB1E	RR (HL)
DDCB051E	RR (IX+d)
FDCB051E	RR (IY+d)
CB1F	RR A
CB18	RR B
CB19	RR C
CB1A	RR D
CB1B	RR E
CB1C	RR H
CB1D	RR L
1F	RR A
CB0E	RRC (HL)
DDCB050E	RRC (IX+d)
FDCB050E	RRC (IY+d)
CB0F	RRC A
CB08	RRC B
CB09	RRC C

CB0A	RRC D
CB0B	RRC E
CB0C	RRC H
CB0D	RRC L
0F	RRCA
ED67	RRD
C7	RST 0
D7	RST 10H
DF	RST 18H
E7	RST 20H
EF	RST 28H
F7	RST 30H
FF	RST 38H
CF	RST 8
9E	SBC A,(HL)
DD9E05	SBC A,(IX+d)
FD9E05	SBC A,(IY+d)
9F	SBC A,A
98	SBC A,B
99	SBC A,C
9A	SBC A,D
9B	SBC A,E
9C	SBC A,H
9D	SBC A,L
DE20	SBC A,N
ED42	SBC HL,BC
ED52	SBC HL,DE
ED62	SBC HL,HL
ED72	SBC HL,SP
37	SCF
CBC6	SET 0,(HL)
DDCB05C6	SET 0,(IX+d)
FDCB05C6	SET 0,(IY+d)
CBC7	SET 0,A
CBC0	SET 0,B
CBC1	SET 0,C
CBC2	SET 0,D
CBC3	SET 0,E
CBC4	SET 0,H
CBC5	SET 0,L
CBCE	SET 1,(HL)
DDCB05CE	SET 1,(IX+d)
FDCB05CE	SET 1,(IY+d)
CBCF	SET 1,A
CBC8	SET 1,B
CBC9	SET 1,C
CBCA	SET 1,D
CBCB	SET 1,E

CBCC	SET 1,H
CBCD	SET 1,L
CBD6	SET 2,(HL)
DDCB05D6	SET 2,(IX+d)
FDCB05D6	SET 2,(IY+d)
CBD7	SET 2,A
CBD0	SET 2,B
CBD1	SET 2,C
CBD2	SET 2,D
CBD3	SET 2,E
CBD4	SET 2,H
CBD5	SET 2,L
CBD8	SET 3,B
CBDE	SET 3,(HL)
DDCB05DE	SET 3,(IX+d)
FDCB05DE	SET 3,(IY+d)
CBDF	SET 3,A
CBD9	SET 3,C
CBDA	SET 3,D
CBDB	SET 3,E
CBDC	SET 3,H
CBDD	SET 3,L
CBE6	SET 4,(HL)
DDCB05E6	SET 4,(IX+d)
FDCB05E6	SET 4,(IY+d)
CBE7	SET 4,A
CBE0	SET 4,B
CBE1	SET 4,C
CBE2	SET 4,D
CBE3	SET 4,E
CBE4	SET 4,H
CBE5	SET 4,L
CBEE	SET 5,(HL)
DDCB05EE	SET 5,(IX+d)
FDCB05EE	SET 5,(IY+d)
CBEF	SET 5,A
CBE8	SET 5,B
CBE9	SET 5,C
CBEA	SET 5,D
CBEB	SET 5,E
CBEC	SET 5,H
CBED	SET 5,L
CBF6	SET 6,(HL)
DDCB05F6	SET 6,(IX+d)
FDCB05F6	SET 6,(IY+d)
CBF7	SET 6,A
CBF0	SET 6,B
CBF1	SET 6,C

CBF2	SET 6,D
CBF3	SET 6,E
CBF4	SET 6,H
CBF5	SET 6,L
CBFE	SET 7,(HL)
DDCB05FE	SET 7,(IX+d)
FDCB05FE	SET 7,(IY+d)
CBFF	SET 7,A
CBF8	SET 7,B
CBF9	SET 7,C
CBFA	SET 7,D
CBFB	SET 7,E
CBFC	SET 7,H
CBFD	SET 7,L
CB26	SLA (HL)
DDCB0526	SLA (IX+d)
FDCB0526	SLA (IY+d)
CB27	SLA A
CB20	SLA B
CB21	SLA C
CB22	SLA D
CB23	SLA E
CB24	SLA H
CB25	SLA L
CB2E	SRA (HL)
DDCB052E	SRA (IX+d)
FDCB052E	SRA (IY+d)
CB2F	SRA A
CB28	SRA B
CB29	SRA C
CB2A	SRA D
CB2B	SRA E
CB2C	SRA H
CB2D	SRA L
CB3E	SRL (HL)
DDCB053E	SRL (IX+d)
FDCB053E	SRL (IY+d)
CB3F	SRL A
CB38	SRL B
CB39	SRL C
CB3A	SRL D
CB3B	SRL E
CB3C	SRL H
CB3D	SRL L
96	SUB (HL)
DD9605	SUB (IX+d)
FD9605	SUB (IY+d)
97	SUB A

90	SUB B
91	SUB C
92	SUB D
93	SUB E
94	SUB H
95	SUB L
D620	SUB N
AE	XOR (HL)
DDAE05	XOR (IX+d)
FDAE05	XOR (IY+d)
AF	XOR A
A8	XOR B
A9	XOR C
AA	XOR D
AB	XOR E
AC	XOR H
AD	XOR L
EE20	XOR N

Example Values

```

nn EQU 584H
d EQU 5
n EQU 20H
e EQU 30H

```

Z80 - CPU INTERRUPT STRUCTURE

MASKABLE (\overline{INT})

Mode 0

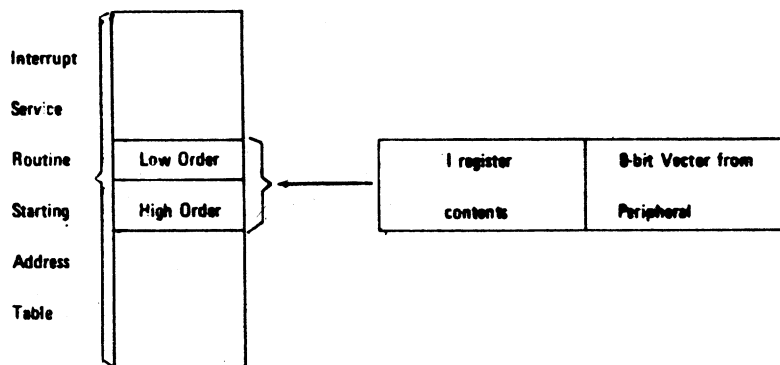
Place instruction onto Data Bus during $\overline{INTA} = \overline{MI} \bullet \overline{IORQ}$ like 8000A

Mode 1

Restart to 38H or 5610 ('RST 56')

Mode 2

Used by Z80 Peripherals



NON MASKABLE (\overline{NMI})

Restart to 66H or 10210

INTERRUPT ENABLE/DISABLE FLIP-FLOPS

Action	IFF ₁	IFF ₂	
CPU Reset	0	0	
DI	0	0	
EI	1	1	
LD A, I	•	•	IFF ₂ - Parity flag
LD A, R	•	•	IFF ₂ - Parity flag
Accept \overline{NMI}	0	IFF ₁	$\overline{IFF_1} \rightarrow IFF_2$
RETN	IFF ₂	•	IFF ₂ - IFF ₁
Accept \overline{INT}	0	0	
RETI	•	•	

• • indicates no change

Z80-PIO PIN ASSIGNMENT

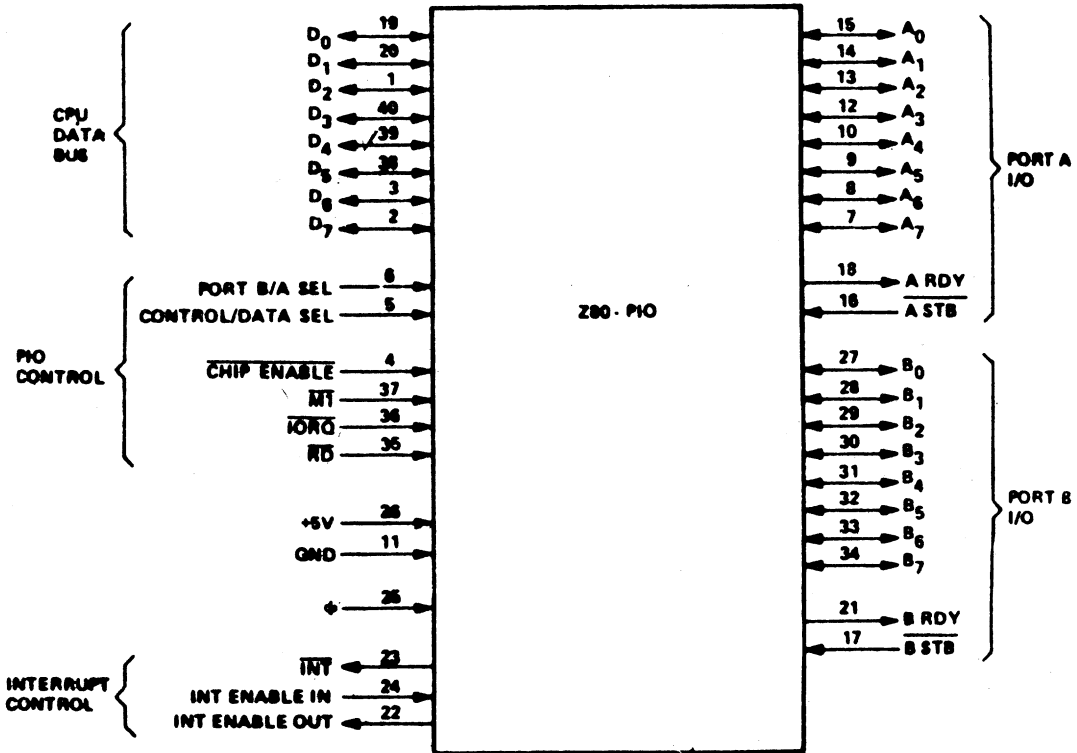


FIGURE 3.0-1
PIO PIN CONFIGURATION

PIO PROGRAMMING SU'

REGISTER SELECTION

SELECT LINES		REGISTER SELECTED
C/D	B/A	
0	0	A Data
0	1	B Data
1	0	A Control
	1	B Control

LOAD INTERRUPT VECTOR

D7								D0	
V7	V6	V5	V4	V3	V2	V1	0		Control Register

SET OPERATING MODE

D7								D0	
M1	M0	X	X	1	1	1	1		Control Register

Mode Number	M1	M0	Mode
0	0	0	Output
1	0	1	Input
2	1	0	Bidirectional
3	1	1	Bit Control

If Mode 3 selected, the next control word is

D7								D0	
I/O7	I/O6	I/O5	I/O4	I/O3	I/O2	I/O1	I/O0		Control Register

I/O = 1 Sets bit to Input

I/O = 0 Sets bit to Output

SET INTERRUPT CONTROL

D7							D0		
Int Enable	AND/OR	High/Low	Mask Follows	0	1	1	1		Control Register

In Mode 3 if Mask follows = 1, the next control word is

D7								D0	
MB7	MB6	MB5	MB4	MB3	MB2	MB1	MB0		Control Register

MB = 0 Monitor the bit

MB = 1 Mask the bit

ENABLE / DISABLE INTERRUPTS

D7							D0		
Int Enable	X	X	X	0	0	1	1		Control Register

3.0 CTC PIN DESCRIPTION

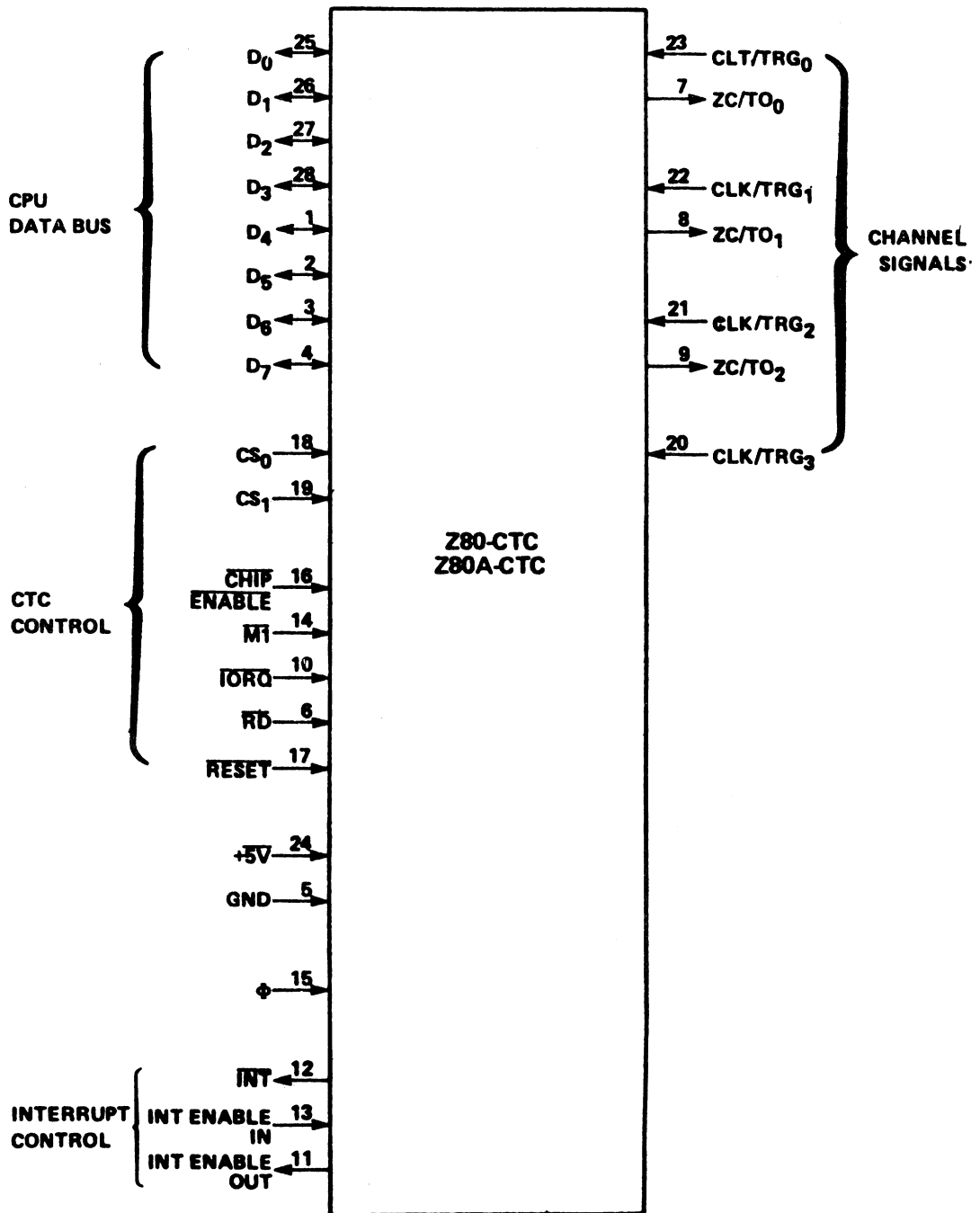


FIGURE 3.0-1
CTC PIN CONFIGURATION

CTC PROGRAMMING SUMMARY

REGISTER SELECTION

SELECT LINES		CHANNEL SELECTED	PRIORITY
CS ₁	CS ₀		
0	0	0	Highest
0	1	1	
1	0	2	
1	1	3	Lowest

READ = DOWN COUNTER

WRITE = CONTROL REGISTER

LOAD INTERRUPT VECTOR

CS₀ = CS₁ = 0

D7							D0	Control Register
V ₇	V ₆	V ₅	V ₄	V ₃	X	X	0	

XX is the binary equivalent of interrupting channel number

SET OPERATING MODE

D7		Timer Mode only					D0	Control Register
Interrupt Enable	Mode	Range	Slope	Trigger	Load Time Constant	Resct	1	
	Counter/Timer	256/16	+/-	On/Off				

If Load Time Constant = 1 the next control word is the Time Constant:

D7							D0
TC ₇	TC ₆	TC ₅	TC ₄	TC ₃	TC ₂	TC ₁	TC ₀

CTC Channel interrupts when 01H is decremented to 00H

Time Content	Decimal counts to interrupt
01H	1
.	.
.	.
FFH	255
00H	256

APPENDIX D

Reference Books:

1. Z80 Assembly Language programming Manual.
2. Intel Component Data Catalog.
3. The TTL handbook.