MSX2 TECHNICAL HANDBOOK

Edited by: ASCII Systems Division
Published by: ASCII Coprporation - JAPAN
First edition: March 1987

Text files typed by: Nestor Soriano (Konami Man) - SPAIN
                        March 1997

Changes from the original:

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CHAPTER 1 - MSX SYSTEM OVERVIEW

The MSX2 was designed to be fully compatible with the MSX1, but there are
many enhanced features in the MSX2. Chapter 1 introduces the enhanced
features of the MSX2, and shows block figures and standard tables. This
information is conceptual, but will be needed to understand dexcriptions in
volume 2 and later.

1. FROM MSX1 TO MSX2

To begin with, let us took back to the original purpose or intention of MSX
and then sum up the transition from MSX1 to MSX2.

1.1 What is MSX?

MSX was announced as a new 8-bit computer standard in the autumn of 1983. In
early days the word "compatibility" was not understood correctly and there
were misunderstandings that MSX could execute programs from other computers.
Since MSX can execute programs only for MSX, it was said that were was no
difference from the PC series (NEC) or FM series (Fujitsu) personal
computers, which could only execute programs using their format.

Several years passed before personal computers became popular. In the early
days only dedicated enthousiasts bought computers, which were difficult to
use, and, needless to say, incompatible. They were satisfied to tinker with
the computer and study it. But now computer use has expanded to include
several classes of users. In other words, the personal computer is becoming a
commodity item such as televisions or radio cassette recorders. Therefore,
"compatibility" is coming to be a problem. If each TV station needs a
different television set or if each radio cassette recorder needs a different
tape, do you suppose they would be popular? Software or programs of the
computer as a home electric product must be compatible.

The design team for MSX considered these problems. Since a computer is most
powerful when left flexible and easy to expand, a "final" standard format was
not practical. There are too many matters to define and hardware in
constantly improving. Therefore MSX started with fixing format of the most
fundamental harware and software such as DOS and BASIC, and the hardware bus
which is the basis for expansion. Since the computer is used by itself and
does not interact with other computers, the problem is small. But formats

must be fixed if the computer is to be connected to "peripherals" and handle or accumulate various data. Fortunately MSX had the approval of many home appliance electric companies and an MSX format was established early. This allowed the system to be well known so that several manufacturers could make compatible peripherals for the MSX standard.

Some of the useful features included in the MSX system include the use of double precision BCD for normal BASIC arithmetic and the same file format as MS-DOS. The real capabilities of the MSX machine will come to light as it is used across several fields.

1.2 Environment of the MSX

Over one million MSX machines had been sold by December 1985 and are used mainly as game machines or primers by primary and junior high school students. But MSX use has gradually spread to include such uses as communication terminals, Japanese word processing, factory automation, and audio visual control. For improving its capabilities, a disk system and MSX-DOS have been prepared, and languages such as C, FORTH, and LOGO are available. BIOS, which is the collection of input/output routines in BASIC ROM, and BDOS, which resides in the disk interface ROM and has compatibility with CP/M system calls have both been improved. So an excellent programming environment is now available. Chinese Character input, light pen and mouse input, and the RS-232C interface have been standardised, and stantardisation of other peripherals is proceeding. The keyboard and character set are consistent with international standards, and there are minor variations to satisfy the needs of individual countries.

Several new peripherals have been developed. Standard devices include printers, disk drives, and mice; audio/visual devices include laser drives, VTRs, synthesizer controllers, and video acquisition systems. Factory Automation devices include robot controllers, room temperature controllers, various adaptors for modem and telephone lines, and a health controller combined with a hemadynamometer has been developed. So you can see that the potential uses for MSX computers has really grown.

Many applications other than games are now supplied on disks and are becoming more practical. There are now Japanese word processors capable of clause transformation, data bases which can exchange data with higher-level systems, and CAI and CAD systems.

1.3 Extended Contents of MSX2

MSX2 was announced in May 1985 as a system having upgraded compatibility with MSX. Programs created under the MSX environment can be executed on MSX2 without any modifications, even at the assembly language level. Data and programs stored on cassette tapes or disks can be used without modification. Features added by the MSX2 system are improved screen display, higher resolution, more colours available, and higher graphics speed. A battery-powered clock and RAMDISK feature have also been added. In this manual the name MSX2 refers to the computer made along the MSX2 standard and the name MSX1 refers to the computer made along the previous MSX standard.

System configuration is shown in Figures 1.1 and 1.2 and Table 1.1 and indicate the differences between MSX1 and MSX2. The differences are described as follows:

Table 1.1 MSX2/MSX1 standard comparison

```
                           MSX2             |        MSX1
                 ------------------------------+--------------------------
CPU              |      Z80A or equivalent (clock 3.579545 MHz +- 1%)    |
                 |------------------------------+--------------------------|
                 | 48K (MSX-BASIC version 2.0)  |  32K (MSX-BASIC ver 1.0) |
          ROM    |      MAIN-ROM 32K            |       MAIN-ROM 32K       |
                 |      SUB-ROM    16K          |                          |
MEMORY    RAM    | 64K or more                  |   8K or more             |
          VRAM   | 64K or 128K                  |   16K                    |
                 |------------------------------+--------------------------|
LSI for VDP | V-9938 (MSX-VIDEO)               | TMS9918 or equivalent    |
                 |----------------------------------------------------------|
CMT              |              FSK   1200/2400 baud                        |
                 |----------------------------------------------------------|
PSG              |     8 octaves tri-chord output (AY-3-8910 compatible)    |
                 |----------------------------------------------------------|
Keyboard         | Alphanumeric                | Alphanumeric             |
                 | Graphic symbols             | Graphic symbols          |
                 |----------------------------------------------------------|
Floppy disk (*)  |      Based on MS-DOS format                             |
                 |----------------------------------------------------------|
Printer          | 8-bit parallel              | (*)                      |
                 |----------------------------------------------------------|
ROM cartridge    |                I/O bus                                  |
                 |      with slot for game cartridge and expansion bus     |
                 |----------------------------------------------------------|
Joystick         |            2                | 1 or 2 (*)               |
                 |------------------------------+--------------------------|
CLOCK-IC         | Standard                    | (*)                      |
                 |------------------------------+--------------------------|
RAM disk         | Standard                    | Different for            |
feature          |                             | each maker               |
                 ----------------------------------------------------------
```

(*) Optional

Figure 1.1 MSX2 system configuration

1. Minimum configuration

```
Sound I/O <--+    Video I/O   Printer I/O   Cartridge Slot x 1
             |        ^           ^           |
             |        |           |           |
             |        -----------------------------+---------
             |        |                      |     |
            +-- | Z80A                 V     |     |
             |                        ----         |
             | ROM 48K                |    |     |
             |                        |    |     |
Joystick x 2 --> | RAM 64K            |    |     |
             |                        |    |     |
             | VDP(V9938) VRAM 64K    ----     |
             |                             |
```

```
            | PPI         PSG                    |
            |                            |       |
 ------------         |   ----------------        |
| Cassette | --> |        |  Keyboard   |        |
 ------------         -----------------------------------------


2. Software support range         +-- Lightpen, Superimpose, Video
                                  |                   digitize
Sound I/O <--+    Video I/O   Printer I/O | Cartridge Slot x 3
            |         ^          ^     |   |
            |         |          |     |   |
            |         ----------------------------+---------
            |         |        +----+----+    |
          +-- | Z80A         V   V   V  |:::::::::::::::::::::
            |               ---- ---- ---- +:---- ---- ---- ----:
            | ROM 48K       | | |     | | | | | | | | | | | |  |:
            |               | | |     | | | | | | | | | | | |  |:
Joystick x 2 --> | RAM 64K       | | |     | | | | | | | | | | | |  |:
            |               | | |     | | | | | | | | | | | |  |:
Trackball,  | VDP(V9938) VRAM 128K ---- ---- ---- +:---- ---- ---- ----:
mouse, etc  |                            |:::::::::::::::::::::
            | PPI         PSG                    |
            |                           | Extended Cartridge
 ------------         |   ----------------    | Slot x 4
| Cassette | --> |        |  Keyboard   |    |
 ------------         ----------------------------------------
```

   Figure 1.2 MSX1 system configuration

1. Minimum configuration

```
Sound I/O <--+    Video I/O          Cartridge Slot x 1
            |         ^                    |
            |         |                    |
            |         ----------------------------+---------
            |         |                 |      |
          +-- | Z80A             V      |      |
            |                   ----     |      |
            | ROM 32K            |       |      |
            |                    |       |      |
Joystick x 1 --> | RAM 8K            |       |      |
            |                    |       |      |
            | VDP(TMS9918) VRAM 16K      ----      |
            |                            |
            | PPI         PSG                    |
            |                            |
 ------------         |   ----------------        |
| Cassette | --> |        |  Keyboard   |        |
 ------------         -----------------------------------------
```

2. Software support range

```
Sound I/O <--+    Video I/O   Printer I/O  Cartridge Slot x 3
            |         ^          ^            |
            |         |          |            |
```

```
              |        ----------------------------+---------
              |        |                  +----+----+   |
             +-- | Z80A          V    V    V   |::::::::::::::::::::
              |                  ---- ---- ----  +:---- ---- ---- ----:
              |  ROM 32K          |  | |        | | | | |  | | | | | |  |:
              |                   |  | |        | | | | |  | | | | | |  |:
Joystick x 2 --> | RAM 64K        |  | |       | |  | | |  | |  | |  | |  |:
              |                   |  | |        | | | | |  | | | | | |  |:
Trackball,    | VDP(TMS9918)VRAM 16K ---- ---- ----  +:---- ---- ---- ----:
mouse, etc    |                            |::::::::::::::::::::
              | PPI       PSG              |
              |                           | Extended Cartridge
 ------------       |                     | Slot x 4
| Cassette | --> |     |    Keyboard  |    |
 ------------        -------------------------------------
```

* MSX-BASIC

BASIC has also been extended from version 1.0 to version 2.0 in order to
support a new VDP, backup RAM, CLOCK-IC, and so on. Compatibility with MSX1
is maintained. When using the newly extended screen mode, be careful when
specifiyng range, since ranges are slightly different in MSX2.

MSX2 has three types of memory, ROM, RAM, VRAM, which are described below.

ROM

Standard ROM size is 48K bytes. The MSX ROM uses only 32K bytes. The extra
16K bytes portion of the MSX2 contains routines supporting the extended
features.

The "MAIN-ROM" consists of 32K bytes and contains the BASIC interpreter, and
the "extended ROM" or "SUB-ROM" consists of 16K bytes and contains routines
for the extended features.

RAM

Standard RAM size is 64K bytes, which is large enough so that MSX-DOS can be
executed. The RAM size of MSX1 varied from 8K to 64K bytes, so in some cases
large programs could not be executed without expanding RAM. MSX2 does not
have this problem.

VRAM

A minimum of 64K bytes are required for VRAM in order to execute the added
features of the screen display. VRAM is thus four times larger than in MSX1,
which had only 16 K bytes VRAM. But many machines actually use a VRAM size of
128K bytes, which is eight times larger. Machines with 128K bytes VRAM can
display 256 colours at the same time.

MSX machines which have 64K bytes VRAM but cannot be expanded to 128K bytes
are marked "VRAM64K" on their catalogue or packaging.

* VDP

The MSX series computers use a video display processor (VDP) type LSI chip
for controlling the screen output. The VDP used for MSX1 was the TMS9918, but
the MSX2 uses the V9938 (MSX-VIDEO), which has upper and full compatibility
with the TMS9918 and can execute software for TMS9918 without any
modification.

Table 1.2 shows the VDP standard and Table 1.3 shows each screen mode. V9938
is an excellent LSI chip with digitising, superimposing, and hardware
scrolling features. Chapter 4 of this manual describes it in detail.

Table 1.2 VDP specifications

	V9938	TMS9918
Screen mode	10 (see table 1.3)	4
Number of dots (horizontal x vertical)	512 x 212 maximum 424 dots for vertical can be achieved by interlace feature	256 x 192 maximum
Colour — Number of colours to specify	512 maximum	16 maximum
Colour — Number of colours to display at the same time	256 maximum	16 maximum
Character set	alphanumeric + graphic symbols 256 characters 8 x 8 dots	
Sprite colour	16 maximum per sprite	1 per sprite
Palette feature	Yes	No

Table 1.3 V9938 screen mode

Mode	Number of characters	Dots	Colours	Palette	Sprite
* Text 1	40 x 24		2 from 512	Yes	No
Text 2	80 x 24		4 from 512	Yes	No
* Multi-colour		64 x 48	16 from 512	Yes	Mode 1
* Graphic 1	32 x 24		16 from 512	Yes	Mode 1
* Graphic 2		256 x 192	16 from 512	Yes	Mode 1
Graphic 3		256 x 192	16 from 512	Yes	Mode 2
Graphic 4		256 x 212	16 from 512	Yes	Mode 2
Graphic 5		512 x 212	4 from 512	Yes	Mode 2
Graphic 6		512 x 212	16 from 512	Yes	Mode 2
Graphic 7		256 x 212	256 from 256	No	Mode 2

(*) Feature modes available from TMS9918 (however, palette feature only from V9938).

* Battery-powered Clock-IC

Battery-powered RAM is connected to the I/O port and is used for storage of setup information and for keeping track of the date and time. Setup information specifies the screen colour and mode at reset. This allows the user to set up the desired environment when the system is booted.

The CLOCK-IC works independently of the main power supply. After being set once new time settings are no longer required.

* RAM Disk Feature

When using BASIC on MSX1 machines which had 64K bytes RAM, only 32K bytes of RAM were used; the other 32K bytes were unused since the BASIC interpreter occupied the address space. On MSX2 machines this unused RAM can be used as a RAMDISK. For users who do not have a disk drive, this feature is very useful when loading or saving BASIC programs temporarily.

2. MSX2 SYSTEM OVERVIEW

This section gives a simple overview of the MSX2 software and hardware systems. To help you understand the concepts, diagrams which would be useful when developping softwarem, such as VRAM map, the I/O map, and the interface standard, are found in the APPENDIX of this manual.

2.1 Hardware overview

First of all, look at the block diagram in Figure 1.3 to understand the hardware configuration of the MSX2 as a whole.

   Figure 1.3 MSX2 block diagram

```
------------
| CPU Z80A |
------------
     |
     |        -----  -------------------------------
   +--|    |--| ROM 48K (MSX-BASIC ver 2.0) |
   |  |    |  |  -------------------------------
   |  |  S |  ----------------
   |  |    |--| MAIN RAM 64K |
   |  |  L |  --------------
   |  |    |  :::::::::::::::::  :::::::::::::::::
   |  |  O |::: MEMORY MAPPER ::::: RAM 64K to 4M :
   |  |    |  :::::::::::::::::  :::::::::::::::::
   |  |  T |  :::::::::::::
   |  |    |::: CARTRIDGE :  I/O Cartridge (Disk, RS-232C)
   |  |    |  :::::::::::::  RAM Cartridge
   |  -----            ROM Cartridge (Game, Application)
```

```
           |                          Slot Expansion Box, Etc.
           |
           |      -----------------   --- Joystick Input
       +--| PSG AY-3 8910 |---|
           |      ----------------   --- Audio Output
           |
           |      ::::::::::::::::::::::  :::::::::::::::::::::::::::::::
           |::: MSX-AUDIO (FM sound) ::::: Audio Memory Maximum of 256K :
           |      ::::::::::::::::::::::  :::::::::::::::::::::::::::::::
           |
           |      ----------------------
       +--| CASSETTE INTERFACE |:::::: Cassette
           |      ----------------------
           |
           |      ----------------------
       +--| PRINTER INTERFACE |::::::: Printer
           |      --------------------
           |
           |      --------------------------------
       +--| BATTERY BACKUP RAM + CLOCK IC |
           |      --------------------------------
           |
           |      -------------            -----------
       +--| PPI 8255A |--------+-----| Keyboard |
           |      -------------         |       -----------
           |                            |      --------------
           |                            +-----| Slot Holder |
           |                                  --------------
-------------
| MSX-VIDEO |---------------------- RGB/Video/RF Output
-------------
       |
       |      ------------::::::::::::::::::::::::::
       +--| VRAM 64K | VRAM 64K : Expansion RAM :
       |      ------------::::::::::::::::::::::::::
       |
       |      :::::::::::::::::
       |--: SUMPERIMPOSE :--------+--- Video Input
       |      :::::::::::::::::  |
       |                         |
       |      :::::::::::::       |
       +--: DIGITISE :------------+
        :::::::::::::
```

Note: The dotted lines represent optional features.
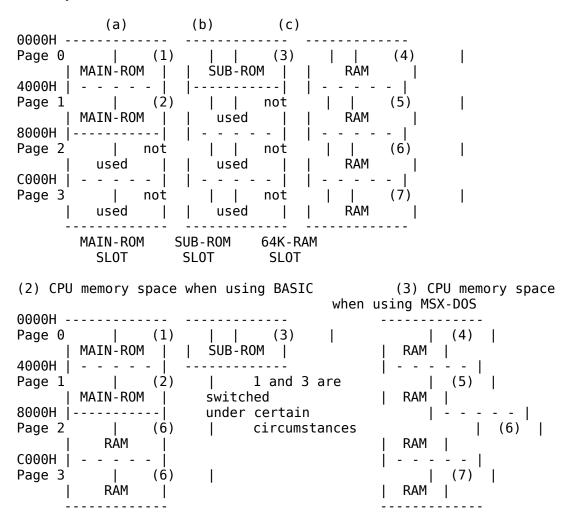

2.1.1 Address map

* Memory map

The MSX2 has three kinds of memory: MAIN-ROM, SUB-ROM, and RAM. Each memory
resides in an independent 64K address space and is allocated as shown in
Figure 1.4 (1) (each 64K space is called a "slot", which consists of four 16K
areas called "pages"). Figures 1.3 (2) and (3) show memory usage when using
BASIC and MSX-DOS, respectively.

For each class of memory, Figure 1.5 shows the memory map of Figure 1.4

(1)(a), Figure 1.6 for Figure 1.4 (1)(b), and Figure 1.7 for Figure 1.4
(1)(c). There is also a VRAM map and I/O map whose standards are defined.
They are found in the APPENDIX.

    Figure 1.4 MSX2 standard memory

(1) Physical allocation of standard memories

```
            (a)           (b)           (c)
0000H ------------- ------------- -------------
Page 0       |     (1) |   |     (3) |   |     (4)      |
      | MAIN-ROM |   | SUB-ROM |   |     RAM      |
4000H | - - - - |   |---------- |   | - - - - - |
Page 1       |     (2) |   |     not |   |     (5)      |
      | MAIN-ROM |   |   used   |   |     RAM      |
8000H |---------- |   | - - - - |   | - - - - - |
Page 2       |   not |   |     not |   |   |     (6)      |
      |   used   |   |   used   |   |     RAM      |
C000H | - - - - |   | - - - - |   | - - - - - |
Page 3       |   not |   |     not |   |   |     (7)      |
      |   used   |   |   used   |   |     RAM      |
      ------------- ------------- -------------
        MAIN-ROM   SUB-ROM   64K-RAM
          SLOT        SLOT        SLOT
```

(2) CPU memory space when using BASIC   (3) CPU memory space
                                          when using MSX-DOS
```
0000H ------------- -------------            -------------
Page 0       |     (1) |   |     (3)     |        | (4)  |
      | MAIN-ROM |   | SUB-ROM |        | RAM  |
4000H | - - - - |   -------------        | - - - - |
Page 1       |     (2) |        1 and 3 are        | (5)  |
      | MAIN-ROM |   switched             | RAM  |
8000H |---------- |   under certain       | - - - - - |
Page 2       |     (6) |        circumstances        | (6)  |
      |     RAM     |                      | RAM  |
C000H | - - - - |                      | - - - - - |
Page 3       |     (6) |   |                  | (7)  |
      |     RAM     |                      | RAM  |
      -------------                      -------------
```

Note: Four pages (4 to 7) of 64K RAM are not always in the same slot.

    Figure 1.5 MAIN-ROM memory map

```
0000H --------------
      |     BIOS     |
      |    Entry     |
015CH |------------ |
      | Additional |
      | BIOS Entry |
017AH |------------ |
      |    Empty     |
01B6H |------------ |
      |    BASIC     |
      | Interpreter|
```

```
7FFDH |------------|
      |    BDOS    |
7FFFH |    Entry   |
8000H |------------|
      |            |
```

Figure 1.6 SUB-ROM memory map

```
0000h -------------
      |    BIOS    |
      |    Entry   |
01FDH |------------|
      |    SLOT    |
      | Management |
      |   Control  |
0336H |------------|
      |    BASIC   |
      | Interpreter|
3FFFH |  and BIOS  |
      -------------
```

Figure 1.7 MAIN-RAM memory map

```
0000H  -------------
       |           |
       | RAM Disk  |
       |           |
       |   Area    |
       |           |
8000H  |-----------|
       |           |
       |   User    |
       |   Area    |
       |           |
F380H  |-----------|
       |  System   |
       | Work Area |
FD9AH  |-----------|
       | RAM Hook  |
       |   Area    |
FFCAH  |-----------|
       | Expanded  |
       | BIOS call |
       |   Entry   |
FFCFH  |-----------|
       | Interrupt |
       |  Control  |--> Note: Used for the disk
       | Hook Area |          and RS-232 interface
FFD9H  |-----------|
       | Interrupt |
       |  Control  |--> Note: Used for the RS-232
       |  Program  |          interface
       |   Area    |
FFE7H  |-----------|
       |  New VDP  |
       | Register  |
```

```
        | Subroutine|
        |    Area   |
FFF7H   |-----------|
        | Main ROM  |
        |   Slot    |
        | Address   |
FFF8H   |-----------|
        | Reserved  |
FFFCH   |-----------|
        |   Slot    |
        | Selection |
FFFFH   | Register  |
        -------------
```

2.1.2 Interfacing with peripherals

MSX2 interfacing with peripherals is standarised in detail.

The following is a list of standarised interfaces:

- Display interface
- Audio interface
- Cassette interface
- General-purpose input/output interface
- Printer interface

The printer interface was optional on the MSX1 but is standard on the MSX2.

The disk drive interface is still an option but may be considered part of the standard specification because the MSX2 has 64K bytes of RAM.

For detailed information about the cartridge specifications, see the appendix.

2.2 Software Overview

The MSX has two software environments: BASIC mode and DOS mode. BASIC mode enables easy development and execution of MSX-BASIC program and is the mode most often used by most users. A major reason why the use of personal computers has grown is that BASIC is easy to use.

The DOS mode enables various languages, utilities, and applications using MSX-DOS. Most programs in DOS can be executed on different machines. The computers automatically compensate for any differences in hardware. This allows the user to use accumulated software resources efficiently. MSX-DOS uses the same disk format as MS-DOS, which is popular on 16-bit machines. You should also note that software for CP/M, which has a great deal of applications available for 8-bit machines, can be executed only by doing file conversions.

A remarkable point is that BASIC and DOS use the same disk format in the MSX machines. This enables the sharing of resources. Both are, as shown in figure 1.8, on the united software environment which has BIOS (Basic I/O System) as a common basis. BDOS (Basic Disk Operating System), which is the basis of the disk operation, is also constructed on this BIOS. MSX offers the same programming environment to BASIC and DOS through common BDOS and BIOS.
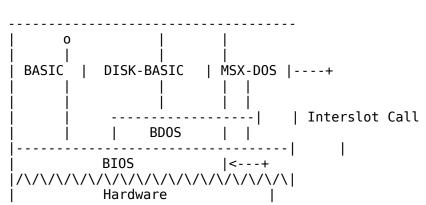
```
    Figure 1.8  Software hierarchy of MSX1 and MSX2

 -------------------------------------
 |        o        |          |
 |        |        |          |
 |  BASIC  |  DISK-BASIC  | MSX-DOS |----+
 |        |        |     |  |
 |        |        |     |  |
 |        |     ------------------|  | Interslot Call
 |        |     |   BDOS    |  |
 |-------------------------------------|     |
 |              BIOS              |<---+
 |/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\|
 |              Hardware              |
 -------------------------------------
 ##############################
```