MEGA-CD OUTLINE

SEGA ENTERPRISES, LTD.

VER. 1.0 12/13/91

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1. Explanation of Terms

ACCESS
Refers to the operation whereby data is read from a storage device such as a CD-ROM drive.

Image buffer
The data area to where data processed using numeric functions is written. The data structure is the same as that used by the GENESIS V-RAM.

Subcode
Data consisting of items such as CD timing information, CD-G (see page 17) graphics data, etc.

Sampling
A process whereby an original sound is divided into tiny slices and the value for each slice is converted into a digital code (PCM). The sampling frequency (Hz) indicates how small the slices are. The higher the sampling frequency (the smaller the slices), the higher the pitches (frequencies) that can be digitally encoded. This is the method used to digitize and store music on CDs. The CD sampling frequency is 44.1 kHz.

Seek time
This value indicates the amount of time required for the head of a data storage device, such as a CD ROM drive, to move to the location where specific data is recorded.

Stamp
This term refers to the smallest unit of data which can be processed using numeric functions. A single stamp can be either 16 x 16 dots (128 bytes) or 32 x 32 dots (512 bytes) in size.

Data cache
When a disk drive, such as a CD-ROM drive, reads data, it is stored in a data cache, where hardware-based error detection and correction takes place. In contrast to buffer RAM, the data cache is a function of the CD drive.

Pickup
This is the mechanical part of a storage device, such as a CD-ROM drive, which reads data directly from the disk. The term 'pickup' is used most commonly for optical heads.

<u>Fader</u>
This circuit performs volume adjustment. By changing the volume setting, fade-ins and fade-outs of several miliseconds can be accomplished. This eliminates the annoying 'Pops' which can otherwise be heard when settings are changed. Longer fade-ins and fade-outs lasting several seconds can be accomplished using software.

<u>Polygon</u>
This is a CG(Computer Graphics) form expression which refers to multi-sided forms (polygons) which are used singly or in multiples to display the images in the computer. 'Hard Drivin'' (Atari) and 'Winning Run' (Namco) use this method to draw images.

<u>CDC (CD data controller)</u>
This is an IC that performs error correction, according to the CD-ROM specification, on the CD data sent from the CDD.

<u>CDD (compact disc drive)</u>
The name of the mechanical portion of devices that reproduce music or data from CD. The expression 'CD drive' refers to the same thing.

<u>CD-ROM system (compact disc read-only memory system)</u>
The name for a system combining a GENESIS and a MEGA-CD.

<u>CD-ROM drive</u>
Refers to the CD drive section. Synonymous with 'CDD.'

<u>Compact disc</u>
The disc.

<u>D/A</u>
The circuit that converts digital data into analog data. Digital data stored in memory or some sort of storage device is converted into analog audio and video signals, etc.

<u>MEGA-CD</u>
The commercial name of a CD ROM drive designed specifically for the GENESIS and incorporating a CDD mechanism, SUB-CPU control block, CDC, etc.

<u>MEGA-CD system</u>
Refers to a single system consisting of a GENESIS and a MEGA-CD.

<u>MEGA-CD software</u>
CD-ROM software designed for use in a MEGA CD system.

2. Hardware Specifications

(1) MEGA-CD

* CPU
  MC-68000 / 12.5 MHz
* RAM

768 kilobytes (6 megabits)	for programs, picture data and sound data
64 kilobytes (512 kilobits)	PCM waveform memory
16 kilobytes (128 kilobits)	CD-ROM data cache
8 kilobytes (64 kilobits)	backup

* ROM

128 kilobytes (1 megabit)	CD game BIOS CD player software CD karaoke

* PCM
  8 channels, maximum sampling frequency: 32 kHz
* CD drive
  Access time: Maximum 1.5 sec.
  Average 0.8 sec.
* Other
  *CD player control window appears on the TV screen.
  *CD audio fade-in and fade-out are supported.
  *Rotation, enlargement and reduction calculation functions are supported.

(2) GENESIS

* CPU
  MC-68000, 7.67 MHz
  Z-80A 3.58 MHz
* RAM

64 kilobytes (512 kilobits)	work RAM (also functions as program RAM in CD mode)
64 kilobytes (512 kilobits)	V-RAM
8 kilobytes (64 kilobits)	Z-80 program RAM

* VDP
  Dot size: 320 (V) x 224 (H)
  Number of displayable colors: 64 from a palette of 512 per screen (highlight and shadow processing functions supported)
* Sound sources
  FM: 6 sound sources, PSG: 3 sound sources,
  Noise: 1 sound source, PCM: 1 sound source

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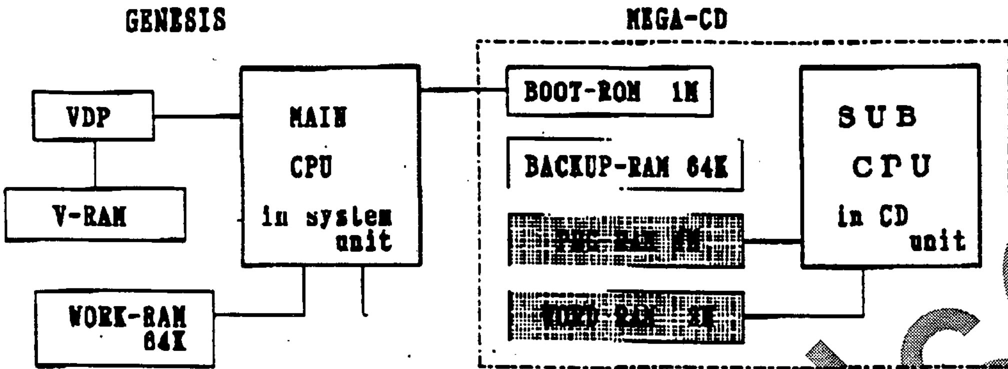
3. Internal Configuration

(1) Configuration Diagram



* Shaded areas indicate the 6 megabit buffer.
* All capacity figures are given in bits.

Fig. 1 MEGA-CD Hardware Configuration

(2) Description of Parts

(2-1) GENESIS

Main CPU

When the GENESIS and MEGA-CD are combined, the result is a system with two CPUs (excluding the Z-80A which handles audio functions).
In order to differentiate between them, the CPU in the GENESIS is designated as the MAIN-CPU and the one in the MEGA-CD as the SUB-CPU.

VDP (video display processor)

The VDP performs all control functions related to the GENESIS displays.
The VDP can only be controlled by the MAIN-CPU in the GENESIS, that is to say by the MAIN-CPU.

V-RAM (video RAM)

This RAM is built into the VDP and stores data to be displayed on the screen, such as character maps. In order to display anything on the screen it is necessary to put data into V-RAM.

Work RAM

This is RAM used exclusively by the MAIN-CPU. Since only the MAIN-CPU can access it, it contains the main game program, especially the code for controlling the VDP.

(2-2) MEGA-CD

SUB-CPU

The SUB-CPU (12.5 MHz) actually operates faster than the MAIN-CPU (7.67 MHz) and is mainly responsible for tasks which only the SUB-CPU can perform, such as CD-ROM monitoring and control. In addition, due to its greater speed it sometimes takes over numeric processing tasks from the MAIN-CPU, controls data transfers to and from the graphics numeric processing chip, etc.

Boot ROM

This ROM stores the basic operating program for the MEGA-CD as well as start-up graphics data. It is activated automatically when power is turned on to the MEGA-CD. Specifically, the boot ROM contains the design data and programs for the title screen and CD player operating screens, programs for the CD-G, etc.

Backup RAM

The backup RAM is used to store programs. Consisting of 64 kilobits of static RAM, it is backed up by a battery built into the MEGA-CD unit. The backup RAM area can be used by multiple applications up to the limits of its capacity. Backup RAM can be accessed only by the SUB-CPU.

PRG-RAM (program RAM)

This RAM area is used principally as the program area for the SUB-CPU. The programs stored here control the operation of the SUB-CPU. Though this area can be accessed by the MAIN-CPU, the SUB-CPU must stop operating while this is taking place. For this reason PRG-RAM is rarely accessed by the MAIN-CPU during games. (See next page for details.)

Word RAM

This RAM area is mainly used for data transfers between the MAIN-CPU and the SUB-CPU. Data from the CD-ROM which was read in by the SUB-CPU is passed to the MAIN-CPU via word RAM. Word RAM can be used in either of two modes: 1 M/1 M mode and 2 M mode. Switching between modes is accomplished by software. (See next page for details.)

<Quick Review Part 1>

* What are the MAIN-CPU and SUB-CPU?
* What is the 6 megabit buffer?
* What are the main uses of PRG-RAM and word RAM?

(3) Using the 6 Megabit Buffer

(3-1) PRG-RAM (4M)

Four megabits of the total 6 megabits in the buffer are used as PRG-RAM. As stated above, this RAM is almost always used as a program area controlled by the SUB-CPU. But this area can also be used as a buffer like regular RAM, since it is, of course, capable of storing data. In general, PRG-RAM is likely to contain the following:

① Programs for controlling and monitoring the CD-ROM.
② Programs for controlling the graphics numeric processing chip.
③ Programs for controlling data transfers to and from the MAIN CPU (word RAM control programs).
④ Programs to take over processing tasks from the MAIN-CPU.
⑤ Data read in from the CD-ROM. (In this case PRG-RAM is being used as a temporary buffer for data to be transferred to word RAM or PCM waveform memory.)

(3-2) Word RAM (2M)

In order to display data read from the CD-ROM by the SUB-CPU as game screens, the data must be transferred to the VDP, which is controlled by the MAIN-CPU. In other words, the data must be transferred from the SUB-CPU to the MAIN-CPU. This task is accomplished single-handedly by the word RAM. Word RAM is set up so that it can operate in either of the following two modes in order to handle these data transfers efficiently.

(3-2-1) 2 M Mode

In the 2 M mode, the entire 2 megabits of RAM can be accessed at once, However only one of either the MAIN-CPU or the SUB-CPU can access it at any given time. This mode is suitable for using the word RAM as a buffer for transferring large volumes of data.

* When using the coordinate conversion function of the graphics numeric processing chip (see page 10), the 2 M mode must be used.

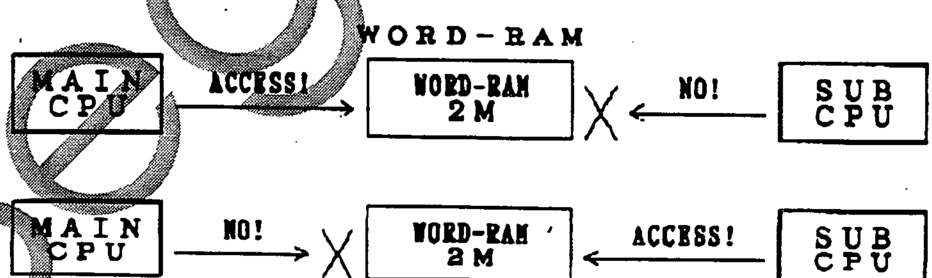


Fig. 2) Word RAM 2 M Mode Access!/No! Diagram

(3-2-2) 1 M/1 M Mode
In this mode word RAM is divided into two sections (WORDRAM 0 and WORDRAM 1), allowing both the MAIN-CPU and SUB-CPU each to access one of the sections at the same time. The two RAM areas can be swapped (exchanged) temporarily, allowing calculation results and the like to be exchanged quickly and thereby taking good advantage of the twin-CPU architecture of the system. This mode is also suitable for animation processing tasks in which data is read from the CD-ROM while other data is being displayed at the same time.

*When using the full graphics function of the graphics numeric processing chip (see page 12), the 1 M/1 M mode must be used.

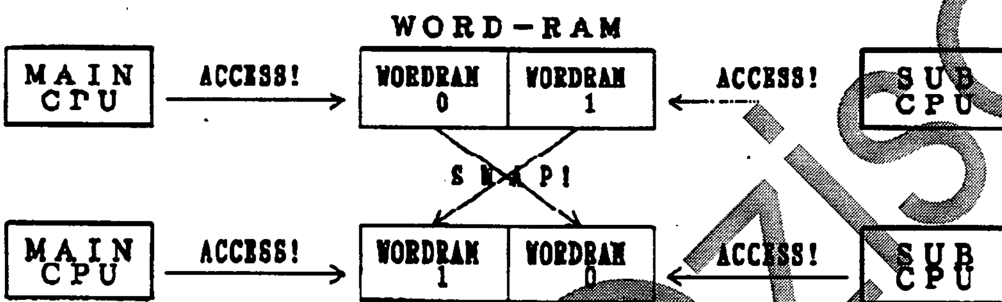


Fig. 3. Word RAM 1 M/1 M Mode Swap Diagram

<Quick Review Part 2>
* Give a specific example of a use for PRG-RAM.
* What are the special features of the two word RAM modes?

4. Detailed Description of Functions

(1) Twin CPUs

The system's two CPUs, the MAIN-CPU and SUB-CPU, function together as "twin" CPUs. This twin CPU operation can take two patterns. In the first, the faster processing speed of the SUB-CPU is utilized directly to boost the system's overall processing speed by having the SUB-CPU take over some of the processing tasks of the MAIN-CPU. In the second, the MAIN-CPU and SUB-CPU operate simultaneously in order to improve processing efficiency.
In this case the capabilities of the system are enhanced because two separate tasks can be performed at the same time.
As was pointed out in the notes on the preceding pages, display functions can only be handled by the MAIN-CPU and CD-ROM control is always performed by the SUB-CPU.

<Usage example>

① Displaying images while reading in data
While the SUB-CPU reads in data from the CD-ROM, the MAIN-CPU displays images on the screen.
-> Large volume animation processing
-> Full-graphics moving image processing, etc.

② Displaying images while performing another processing task
While the MAIN-CPU displays images on the screen, the SUB-CPU performs another processing task.
-> Graphics numeric processing and displaying its results
-> Faster polygon processing
-> Elimination of delay in large volume sprite displays

<Quick Review Part 3>
* What are the merits of the twin CPU architecture?
* What is not possible even with twin CPUs?

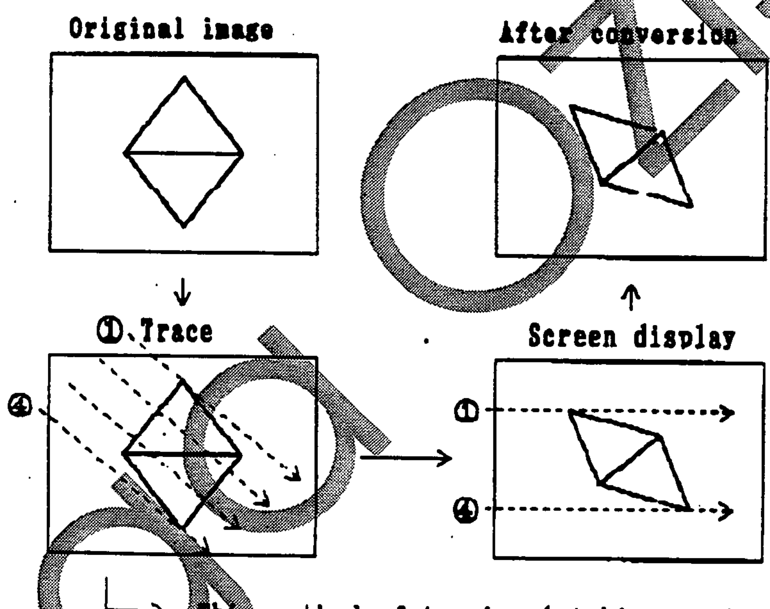
(2) Graphical Numeric Processing Function

The MEGA-CD incorporates a built-in graphics numeric processing chip to strengthen the graphics capabilities of the system. This chip is structurally linked to the word RAM area and all data transfers involving this chip take place in word RAM. The chip supports coordinate conversion functions such as rotation, enlargement and reduction and a full graphics function that allows images to be displayed by specifying each individual dot.

(2-1) Coordinate Conversion Function (Rotation, Enlargement and Reduction)

(2-1-1) Basic Principle

The basic principle behind the rotation, enlargement and reduction functions is simple coordinate conversion. An image is written to the TV screen as rows of successive dots following the scan lines which run from left to right, beginning in the upper left-hand corner of the screen and continuing downward line by line. The basic principle of coordinate conversion is to determine from where to trace the dots which form the original image.
The beginning point and direction of the trace then determines the conversion formula.



This method of tracing (picking up dots) becomes the conversion formula.

Fig. 4 Basic Principle of Coordinate Conversion

If the dots are picked up by tracing the original image at an angle as shown in Fig. 4, redrawing the lines in the normal manner straight from left to right will result in a coordinate converted (rotated) image. This is how coordinate conversion works.

In this case, the manner in which the original image is traced becomes the coordinate conversion formula. Specifically, since the TV displays images line by line, it is only necessary to specify the point where the picking up of each line should begin and the distance which needs to be traced (expressed as Δx and Δy). The graphics numeric processing chip will then do the necessary calculations and the results (the converted image data) are returned to us. By specifying the parameters in different ways, operations such as rotation, enlargement and reduction can be accomplished.

(2-1-2) Rotation

The number of degrees the image is rotated is determined by the angle of the trace lines ($\Delta y/\Delta x$). If we simply supply values of $\Delta x = 1$ and $\Delta y = 1$, the original image will be rotated counterclockwise 45 degrees ($\tan\theta = \Delta y/\Delta x = 1 \rightarrow = 45°$. But it is necessary to keep in mind that if the values $\Delta x = 1$ and $\Delta y = 1$ are used, the practical distance to the next point traced will be $\sqrt{2}$. When the image is actually displayed, rows of dots a distance of 1 apart are drawn, so the size of the converted image will end up as $1/\sqrt{2}$ that of the original image. This means that in order to rotate the original image 45 degrees, while maintaining its correct dimensions, the parameters must be specified as $\Delta x = 1/\sqrt{2}$ and $\Delta y = 1/\sqrt{2}$.

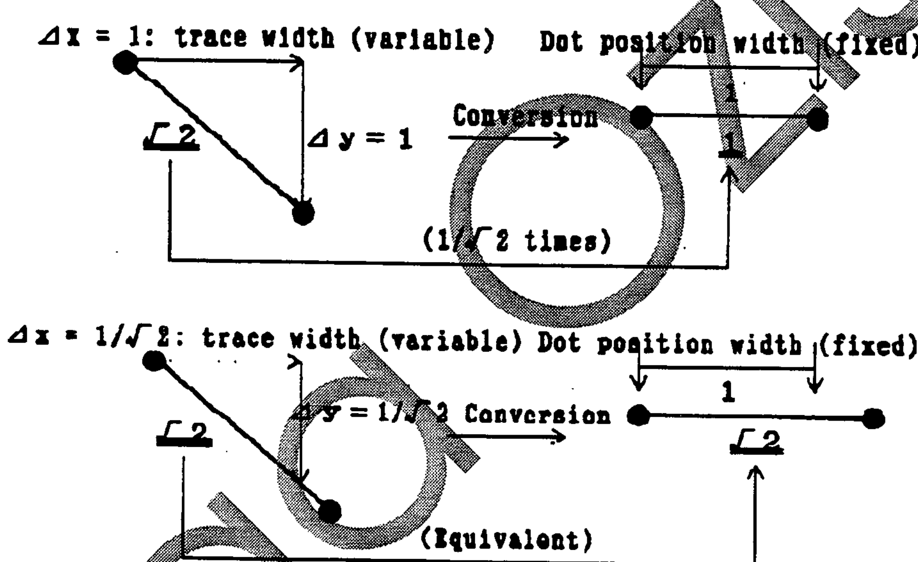


Fig. 5 Length Variation in Coordinate Conversion Processing.

MEGA-CD is capable of 2-axis rotation, but the coordinate conversion process described above constitutes only a single axis. If this rotation is combined with the 3 D effect described in 2 1 3), the rotated image is tilted forward or backward, resulting in a second axis. This is what is meant by 2-axis rotation.

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(2-1-3) Enlargement/Reduction

For enlargement or reduction which does not involve rotation, it is sufficient to specify the Δx value only ($\Delta y = 0$ in all cases). In this case, the closer together the lines of the original image are traced the larger the converted image will be (because the display dot positions are fixed). Consequently, specifying $\Delta x < 1$ results in enlargement and specifying $\Delta x > 1$ results in reduction.

(2-1-4) 3-D Effect

TV screens are displayed in units of scan lines running from left to right, and one set of Δx and Δy values is specified for each trace line, one of which corresponds to each scan line. Naturally, it is possible to change the values line by line, if we so wish. Taking advantage of this, it is possible to make the image appear to tilt forward by making the Δx values progressively smaller (resulting in more enlargement) as the lines continue toward the bottom of the screen, creating a 3-D effect. This makes it possible to make flat, 2-dimensional images appear to have depth.

One point requires caution: though the original image can be tilted forwards and backwards, it cannot be rotated to the left or right. This is due to the fact that parameters are set line by line. Therefore it is not possible to produce effects such as an image tilted forward and viewed from the right front or left front.

<Quick Review Part 4>

* What is the basic principle behind rotation, expansion and reduction?
* What sort of effects cannot be produced using the coordinate conversion functi on?

(2-2) Full Graphics Function

Another capability of the graphics numeric processing chip is its full graphics function. In contrast to the generally used display method in which images are composed of cell units, Full Graphics manipulates and displays graphical images using dot units. It is used in cases where it is meaningless to think in terms of cells or, especially, blocks, or if it is not possible to express an image using the cell concept. This function can be implemented in software on the GENESIS. We must first understand its implementation on the GENESIS in order to understand how the full graphics function differs.

The full graphics function displays images using dot units. The GENESIS implementation handles two dots as one byte. In other words, the actual display processing uses 2-dot units. This means that if it is necessary to shift part of an image by one dot, the center of one byte must be shifted one-half unit at a time. The processing required to do this is very unwieldy.

In contrast to the above, the MEGA-CD full graphics function handles one dot as one byte. This means that screen calculations using dot units can be done much faster. In addition, the data is arranged in the same order that it appears on the screen, making more efficient data compression possible (depending, of course, on the characteristics of the image).
(When compressing data organized into cell units, the data is split up into units of eight dots, arranged horizontally, for compression. If dot units are used, however, compression can be applied to horizontal dot strings of any length.) Basically, the full graphics function is used if the cell concept can not be applied (as in the previous example) or if an image simply cannot be displayed using the sprite function. This makes for very effective displays when used with the full animation processing capabilities possible with CD-ROM.

<Quick Review Part 5>

* In what sort of cases is the full graphics function used?
* What are the special characteristics of the MEGA-CD full graphics function?

(2-3) Important Points About Graphical Numeric Processing and Full Graphics Functions.

When using the coordinate conversion function and the full graphics function, it is important to be aware of the limitations described below.
It is particularly necessary that you keep in mind that though the numeric processing is very fast, thanks to the graphics numeric processing chip, the VDP itself remains unchanged.

① The two functions cannot be used at the same time.
It is not possible, for example, to try to redraw the screen using the full graphics function while simultaneously rotating the image.

② The VDP functions are unchanged.
The number of displayable colors and the number of colors in the palette are, of course, the same as they were for the standard GENESIS. In addition, the screen redraw time is the same, so a time of at least 4 interruputs is required to completely redraw the screen (15 frames per second).

③ V-RAM has not been supplemented.
The V-RAM capacity is unchanged, so when performing rotations, enlargements or reductions, or when using the full graphics function, this limitation must be borne in mind. In short, the display data size must not exceed the capacity of V-RAM. Keep in mind that the data size being referred to here is not the data size for the original image but the data size for the converted image. Also if the entire capacity of V-RAM is used to perform special processing, it will not be possible to display any other objects.
Care should therefore be taken when deciding on the size of the various elements of the screen.

④ The two functions impose limitations on the word RAM mode.
To use the coordinate conversion function, the word RAM mode must be '2 M,' while the full graphics function requires the '1 M/1 M' word RAM mode.

⑤ Stamp data is necessary.
Just as fix data is divided into blocks, the data must be divided into sections called stamps, consisting of 16 x 16 or 32 x 32 dots, for processing using the numeric function. This naturally necessitates associated map data, and sufficient RAM must be available to accommodate it all. Note that, as is the case with blocks, RAM capacity can be conserved by using the same spots extensively.

(3) Audio Functions
Simply using CD as the data storage medium means that the system's audio capabilities are substantially more powerful than those of the GENESIS. Though the system is not really suitable for dedicated audio applications, it still is capable of performance on a par with inexpensive CD-tuner-cassette units currently on the market.

(3-1) CD-DA (digital compact audio disc)
CD-DA is the name of the standard for the conventional music CD. It is based on specifications published in the international Red Book of standards.
In a nutshell, CD-DA compact discs must use a sampling frequency of 44.1 kHz, 16-bit quantization and two audio channels (stereo).
Naturally, MEGA-CD conforms with these (Red Book) specifications, allowing users to play commercially available music CDs with no risk of damage.
Twelve-centimeter CD-ROM disks conforming to the CD-DA standard can contain up to 75 minutes of music, as is the case with regular audio CDs.

MEGA-CD game disks, however, can contain a maximum of only 60 minutes of music due to special Sega stipulations necessitated by a variety of factors. MEGA-CD also conforms to yet another international standard: CD-ROM (Yellow Book). This standard provides for the storage of programs and design data on the CD-ROM disk, but since CD-DA and CD-ROM areas cannot overlap, the available CD-ROM capacity must be divided between them. In other words, the maximum 60 minutes of music space is reduced by however much space is required to hold the game data.

(3-2) 8-channel Stereo PCM Sound Source
PCM stands for 'pulse code modulation,' one of the commonly used digital recording methods. It slices the audio waveform up at regular intervals (the sampling frequency), the wave amplitude is digitized (converted into a number) and the resulting data is stored. In this way music can be recorded and played back. The thinner the slices (the higher the sampling frequency) the smaller the bits of sound (higher frequencies) that can be recorded and the greater the playback fidelity to the original. This is because a higher sampling frequency results in less error between the actual wave amplitude and the recorded data, and therefore less distortion.

The GENESIS can only use 1-channel PCM. MEGA-CD, on the other hand, is capable of simultaneously reproducing eight channels, each containing a different (sampled) sonic timbre. Also, since the GENESIS portion of the system is independent, it is theoretically possible to play six FM, three PSG, eight PCM from the MEGA-CD, as well as the CD-DA audio, all at the same time.

The maximum sampling frequency (sampling rate) for MEGA-CD is 32 kHz (for 8-bit, 8-channel operation). Considering that the GENESIS sampling rate is 8 kHz in almost all cases, it does not seem all that inferior compared with the CD-DA (44.1 kHz for 16-bit, 2-channel operation) audio of MEGA-CD. This is also true of cases where "voice" is heard.

<Quick Review Part 7>

* What is CD-DA?
* What is the difference between MEGA-CD's PCM sound sources and MEGA Drive's FM sound sources?

(3-3) 8-times Oversampling Digital Filter

The sampling rate for CD-DA audio is also 44.1 kHz, but most commercially available audio equipment supplements this with data interpolation at a fixed level during playback.

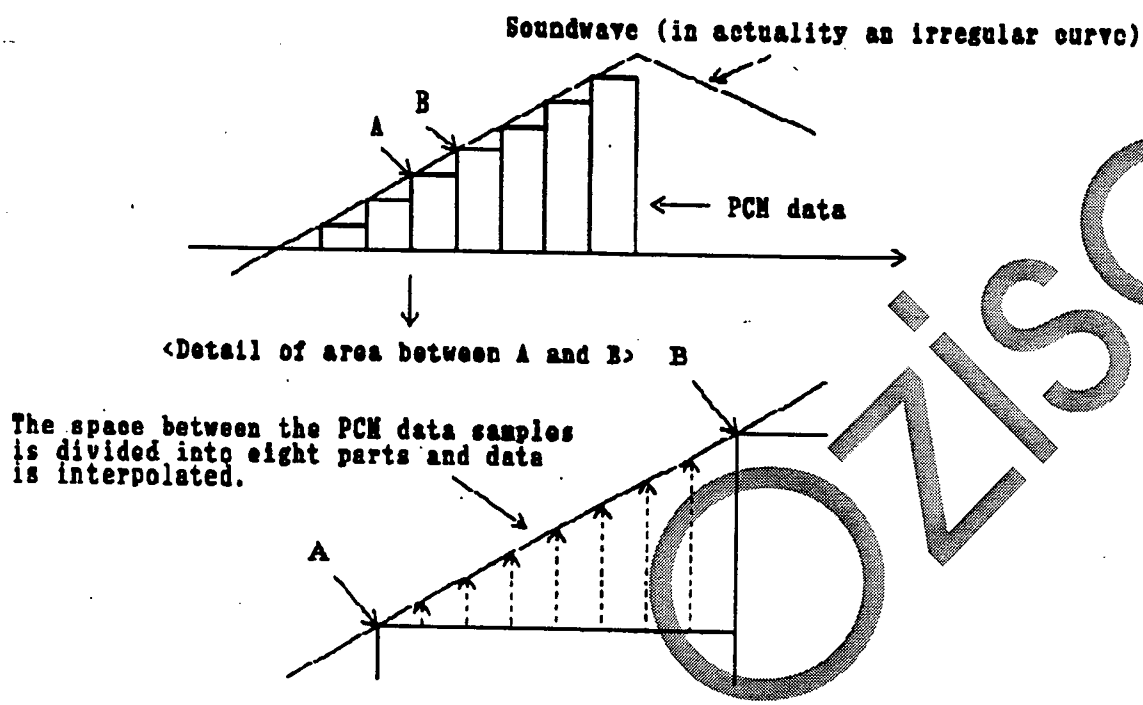

Fig. 6 PCM Audio Reproduction and Interpolation.

Fig. 6 above depicts in pictorial form the reproduction of sound using the PCM process. Since PCM recording digitizes the data, the reproduced sound, when looked at closely, appears to skip from one level to the next.
A smoother, more natural sound can be obtained by interpolating intermediate steps in order to narrow the gaps between samples and smooth out the skipping.
In this example this is performed at a density of 8-times (eight divisions).
This is what an 8-times oversampling digital filter does.
This has become the standard for audio equipment.

(3-4) Fade-In/Out

MEGA-CD allows control of the volume of the audio signal through software.
Fade-ins and fade outs can be applied not only to the previously available GENESIS sound sources, but to the CD-DA audio material as well.

(4) Appendices

(4-1) Moving Picture Processing Capability

Hardware limitations on the moving picture processing capabilities of the GENESIS mean that the maximum rate attainable with full screen, full size images (strictly speaking, images are limited to a size of 38 x 24 sells due to V-RAM considerations) is 15 screens per second (4 int per screen). Considering that most animated cartoons use between 8 and 12 frames per second, the GENESIS's capabilities would seem to provide adequate expressive possibilities. (Note, however, that the 'full animation' of Disney films and the like uses 24 frames per second, and the rate for standard video moving pictures is some 30 frames per second.)

Even under the above conditions, full screen images employing horizontal movement are possible using the horizontal 32-cell mode. However, if the rotation function is used in this case, distorted images will result because the original image is composed of cells that are wider than they are tall. If no rotations need to be used, the horizontal 32 cell mode is very suitable for creating lifelike moving pictures because of the large screen size.

The number of frames per second can be increased beyond eight if smaller screen sizes are used. But since the smallest processing unit for the MEGA Drive is 1 int (= 1/60 second), the absolute maximum number of frames per second attainable is 60. Theoretically it would be possible to achieve a rate of 60 frames per second by reducing the screen size to 1/4, but since even 'full animation' uses a rate of only 24 frames per second, a rate closer to that figure should be quiet sufficient.
As for as the number of colors is concerned, under normal conditions, normall scroll A/B is used to display 31 colors.

By adding the sprite capability the total number of colors displayed can be boosted to 61. However, limitations inherent in the sprite function limit the size of screens to the horizontal 40 cell mode, and if 61 colors are displayed the attainable screen size becomes half of that (20 horizontal cells).

The total data volume becomes quite large when many tens of screens are handled per second. The CD-ROM data capacity is 540 megabytes, and using moving images for extended periods of time will tax that capacity to the limit. As was stated above, the attainable rate of data compression is quite high if the MEGA-CD full graphics function is used, but specific values for the actual limitations have yet to be determined.

(4-2) Sound

MEGA-CD adds PCM and CD-DA audio to the FM and PSG available with the conventional GENESIS, for a total of four types of sound source.
When planning the utilization of these, the following points should be borne in mind.

① FM/PSG

On the GENESIS, portions of the Z80 memory area were allocated to a sound program, SE data and as a work area. Song data was stored in a bank in the cartridge ROM. Since the MEGA-CD does not use cartridges, all the above data, including the song data, must be loaded into the Z80's memory.
The available memory capacity is 64 kilobits (= 2000h). Since the song data must occupy part of this area, there is really only room for one or two songs. Note that using more songs than this will involve transferring the necessary data from the main memory area.

② PCM

The MEGA-CD incorporates a PCM waveform memory RAM area (512 kilobits).
It is used like V-RAM, but for sound. PCM control is the task of the SUB-CPU, so the actual place where PCM data is put is the 6 megabit buffer. Therefore, in order to use PCM audio, a work area for that purpose must be set aside in the buffer. Care should be taken to avoid conflicts with data for other sounds or pictures which are to be reproduced at the same time.
Due to the basic principle of the format, the volume of PCM data depends on the duration of the sound to be encoded and the sampling rate. The longer the sounds or music to be reproduced last, the more data there will be.

In like manner, a higher sampling rate represents a correspondingly larger volume of data. Even a long song can be encoded using a minimal volume of data if only one timbre is used, because only data for that one type of sound is required. This is something that you should always keep in mind.
In the case of voices, sampling is only necessary for the actual duration of the speech. Therefore only enough capacity to store that much data is necessary.

③ CD-DA

CD-DA audio involves playing digital sound data directly from the disk. Therefore, the disk cannot be accessed for any other purpose while the CD-DA audio is playing. This means that effects like full animation with data being read continuously from the disk accompanied by a full orchestral background are simply not possible. Note also that even if animation is performed by processing data from the buffer, the CD-DA audio will have to be interrupted whenever new data needs to be read in. These two points need to be borne in mind.

④ Special techniques

Special methods of using the PCM capability include, in addition to the above-mentioned technique of using animation data stored in the buffer, reading in large volumes of PCM data as required from the CD ROM and outputting it continuously, and sandwiching PCM data between picture data and reading them both in at the same time (phrase sampling). In the case of CD-DA audio, the very end of the song could be encoded using PCM in order to disguise the short gap caused when the pickup moves back (looping) to the beginning of the song, producing a continuous whole.

(4-3) Access Time
The access time of the MEGA-CD is far superior to that of other units. Its maximum seek time (the time from when the pickup receives the command and when it reaches its destination) is a mere 1.5 seconds. The MEGA-CD uses hardware to perform this task, making possible to significant reduction in the time required to read in data. In fact, if the capabilities of the twin CPUs are put to good use, the MEGA CD's effective seek time can be reduced to almost zero.

(4-4) CD-G Compatibility
In addition to CD-DA and CD-ROM, MEGA-CD is also compatible with the CD-G standard. CD-G is most commonly used in CD karaoke machines, and its format is basically identical to that of CD-DA, except that graphical data is stored in the tiny gaps between the tracks of audio data (the so called "subcode area," which is not used at all on standard audio CDs). The music portion of CD-G discs can be played on standard CD players with exactly the same audio quality as when the disc is played on a CD-G player. However, the rather unambitious specifications of the graphics portion limit it to a succession of still images which appear on the screen one after another. Sixteen colors out of a palette of 4,096 can be displayed at once. Note that this palette exceeds that of MEGA-CD. Therefore, when CD-G discs are played on MEGA-CD, the displayable colors are limited to 16 out of a palette of 512.

<Quick Review Part 8>
* What are the limitations on the moving picture processing capabilities of the MEGA-CD?
* What points should be kept in mind regarding the sound capabilities of the MEGA-CD?