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Saturn Overview Manual

(temporary version 1)

June 6, 1994

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REFERENCES

In translating/creating this document, certain technical words and/or phrases were interpreted with the assistance of the technical literature listed below.

1. *KenKyusha New Japanese-English Dictionary*
   1974 Edition

2. *Nelson's Japanese-English Character Dictionary*
   2nd revised version

3. *Microsoft Computer Dictionary*

4. *Japanese-English Computer Terms Dictionary*
   Nichigai Associates
   4th version

Introduction

This manual gives an overview of the hardware for Saturn, Sega's Multimedia Home Entertainment Device, which contains a 32-bit RISC (Reduced Instruction Set Computer) processor. This manual explains the features and functions of Saturn to those who develop game software.

Manual Layout

This manual consists of the following chapters, supplements, and index.

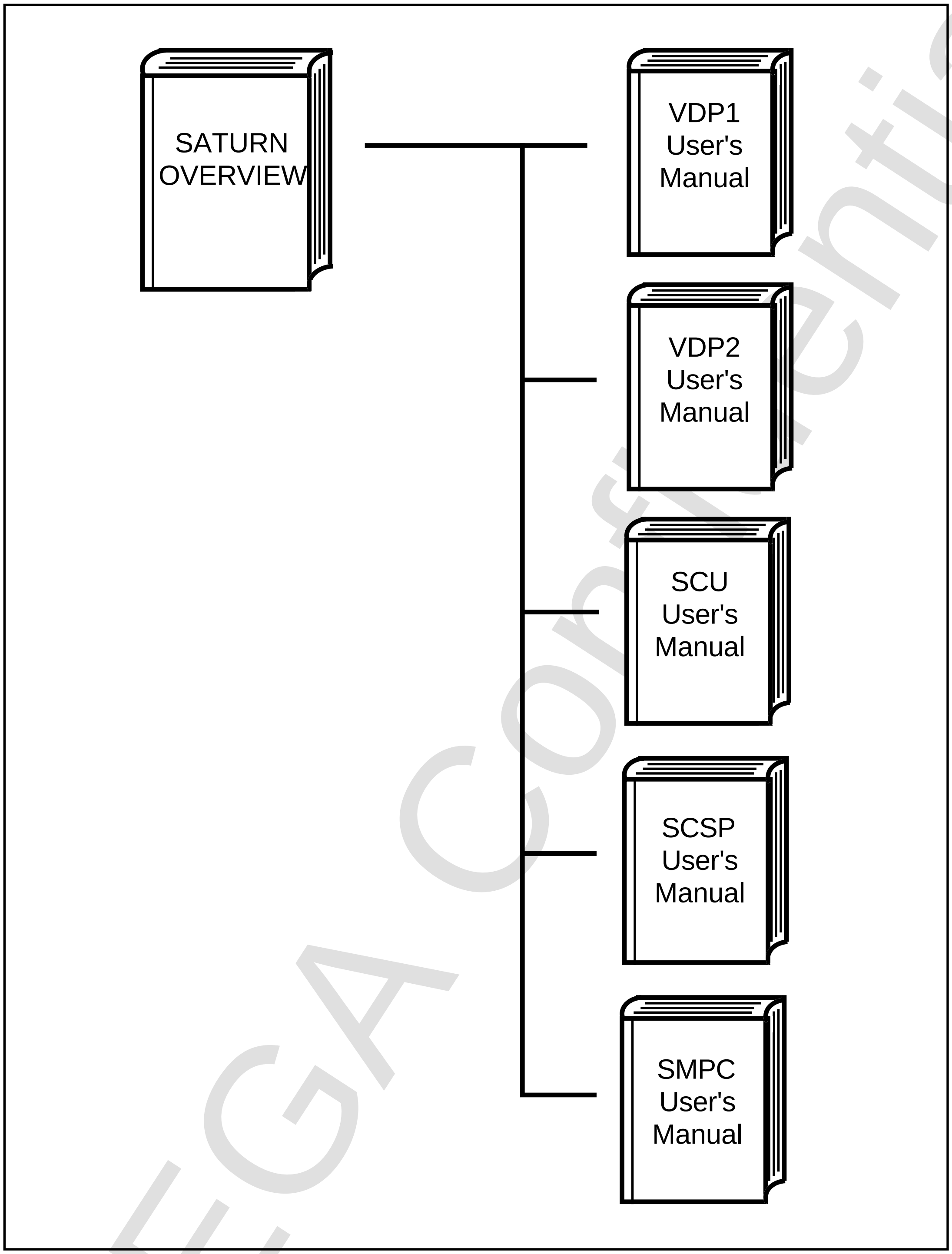
Chapter 1 — Introduction to Saturn
The features of Saturn are explained.

Chapter 2 — Structure
The internal structure of Saturn plus hardware specifications are explained.

Chapter 3 — Functions
The main functions of Saturn are explained.

- CPU
  The main CPU, sound CPU, I/O controller.
- SCU
  Control of each bus (A-bus, B-bus, CPU-bus), DMA transfer, and matrix calculation (DSP).
- VDP1
  Control of drawing and defines draw control.
- VDP2
  Control of the scroll screen and display.
- SCSP
  Sound control of the PCM/FM sound source.
- CD-ROM
  An overview of the CD-ROM and MPEG.
- Miscellaneous
  Explains the SMPC.

Related Manuals



Definitions

DSP (Digital Signal Processor)

This high-speed digital processor mainly performs rapid addition and subtraction.

Gouraud Shading

Gouraud is one type of computer algorithm.
This process computes the color of each position (dot, pixel) of each object being displayed. Places hit by light are bright, and places shadowed are dark.

C3

An error process that corrects errors when data is read from a CD.

Frame Buffer

Frame buffer is RAM that stores pictures to be displayed. The line buffer was limited to pictures arranged in a horizontal direction, but with the RAM of the TV screen size, there you are no longer limits in the horizontal direction.

Pixel

A unit that represents a picture element in a drawing.

PCM Sound Generator (Pulse Code Modulation Sound Generator)

A method of storing in memory PCM data created from sound, reading the sound from memory at the time that the sound is to be played, and outputting the sound.

Interlace

An image output scan system that obtains the screen image of a single frame by scanning it twice.

MPEG (Motion Picture (image coding) Expert Group)
An international standard of compression for color motion images (including voice) of television and video. This standard allows the playing of Full Screen, Full Color, Full Motion, and CD Quality Audio. Besides conforming to the international standard, it also has original special functions.

Parts
Divides textured and non-textured parts in a drawing done by the draw command.

Perspective
A technique for creating the impression of distance in computer graphics by showing distance objects as small and nearby objects as large.

Sprite
Image patterns that can be rapidly moved and re-drawn. By preparing a number of sprite patterns and re-drawing them while moving designated coordinates, an animation effect can be produced in which the game character appears to be moving.

High Resolution
Both the normal TV and special monitor are able to display at a high resolution, but the special monitor has a higher resolution.

Texture Mapping
A computer graphics technique that allows a pattern to be placed on an object.

PCM (Pulse Code Modulation)
A method of dividing sound (wave forms) according to a time axis, and converting the peak values into digital data. Data found by this method is called PCM data.

Effect Data
Expresses the resulting sound obtained when a sound created by the sound generator is affected by passing through the DSP.

Reverb
As one type of sound field effect, one can produce the atmosphere of a hall, stage room, steel plate, etc.

PLL (Phase Locked Loop)
Refers to the phase-locked circuit (IC) that follows to the input signal.

IPL (Initial Program Loading)
A list process language. It outputs the designation that loads programs from the designated I/O device to the processing device.

Clipping
Clipping removes all image data located outside of the designated draw access area.

PAL System (Phase Alternation by Line system)
Developed in West Germany, this is a color television broadcasting standard of 625 scan lines and 25 images per second.

NTSC System (National Television System Committee system)
Recognized by the FCC (Federal Communication Commission) and applied by Japan, the United States, South Korea,among others; this standard of color television broadcasting has 525 scan lines and 30 images per second.

List of Figures

List of Tables

Chapter 1 Introduction to Saturn

Contents

1.1 Highlights

- Leading Edge CD-ROM Drive

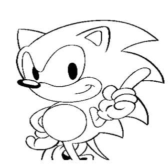
- High-Speed Micro-Processor

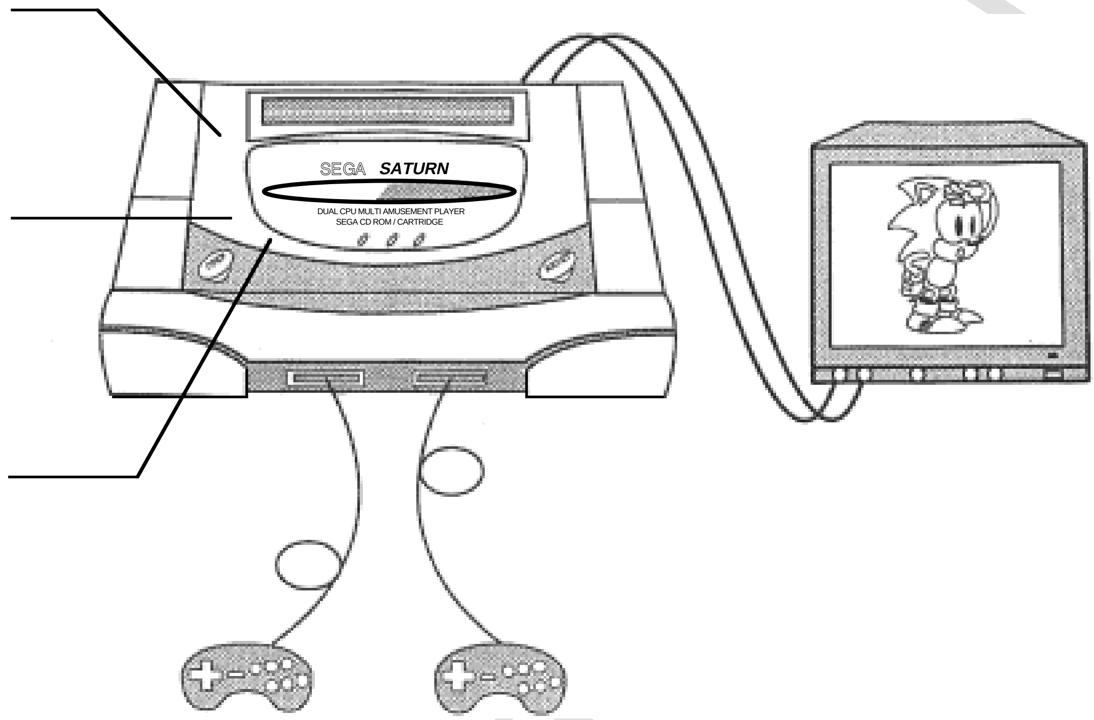
- Large-Capacity Memory

- The main CPU is a 32-bit RISC chip
    - SH-2 loader that supports a DSP-type computer.

- Memory
    - 32 Mbits (4 Mbytes)
    - 4 Mbit (512 Kbyte) CD-ROM

- Powerful Graphics Functions
    - Up to 16,777,216 colors
    - 24 million pixels/Sec (VDP1)
    - Sprite processor that can display polygons
    - High performance background processor

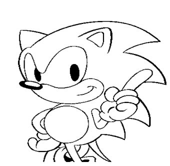




- Improved Sound Functions
  - 32 Channel PCM sound generator
  - FM sound generator
  - Audio-only effect DSP loader

- Leading Edge CD-ROM Drive
  - 32-bit RISC chip SH-1 loader
  - MPEG (optional)

- Development Language
  - C language, Assembly language



Chapter 2 Structure

Contents

2.1 Hardware Specifications

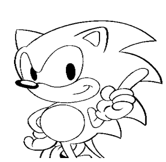
Saturn hardware specifications are shown below.

Table 2.1 Hardware Specifications <Main System>

CPU BLOCK	CPU	SH-2 X 2 32-bit RISC Chip 28.6MHz / 26.8 Internal Math Processor
	RAM	2MB
	ROM	512KB
	SCU	DMA 2 ch DSP 14.3 MHz
	SMPC	RTC 1 MHz (accuracy) Employs Peripheral Interface
VIDEO BLOCK	VDP1	Max. 400,000 pixels, 1/60 sec. transfer
	VDP2	Screen Resolution 320 dot (H) X 224 dot (V) up to 5 background screens
	RAM	VDP1: 1 MB VDP2: 512 KB
SOUND BLOCK	SCSP	PCM 32 ch, max. 44.1 KHz DSP 22.6 MHz Acoustic effects only
	RAM	512KB
	CPU	MC68EC000 16-bit CISC 11.3 MHz

Table 2.2 Hardware Specifications <Subsystem>

CPU	SH-1 32-bit RISC Chip 20.0 MHz
RAM	512 KB
MPEG AUDIO / VIDEO (optional)	RAM 512KB Screen Resolution 704 dot (H) X 480 dot (V) 30 frame/sec animation, 44.1 KHz 16-bit audio



2.2 System Configuration

With a DSP function built-in to the 32-bit RISC chip (SH-2) that is loaded on to the main CPU, the system configuration has greatly improved the processing performance.

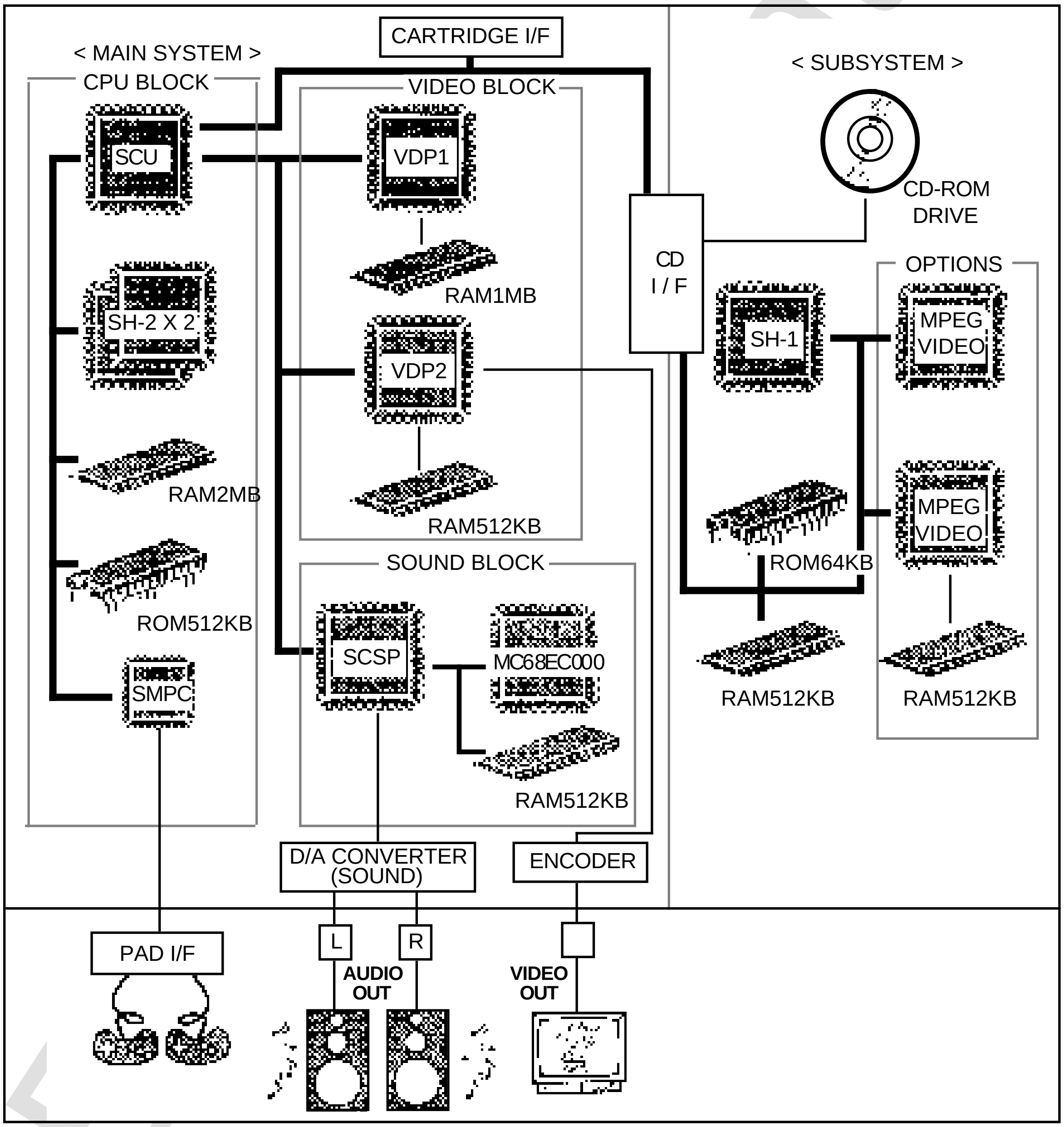


Figure 2.1 Block Diagram

2.3 Description of Each Part

The block diagram in Figure 2.1 is explained below.

Main System

SH-2 (X2)

Control of the entire system is done by the main CPU. With a RISC type high-speed CPU, there is a noticeable difference in processing performance over conventional systems. Processing power has been dramatically improved due to a processor inside that has an arithmetic unit similar to that of a DSP.

MC68EC000

The MC68EC000 carries a 16-bit CPU for sound. Processing speed is much faster than earlier systems.

RAM/ROM

The RAM has a total of 32 Mbits, with 16 Mbits in the main CPU, 4 Mbits in the sound CPU, and the remaining 12 Mbits allocated to video. ROM contains the initial hardware program and cartridge as well as the CD IPL program. It also contains a CD library.

SMPC (System Manager & Peripheral Control)

SMPC controls reset of the entire system and interfaces with peripheral devices such as a control pad. Also, with an internal RTC (Real Time Clock) you can get the date and time. When the power is off the RTC function is backed-up by a battery.

SCU (System Control Unit)

The SCU controls all buses (A-bus, B-bus, CPU-bus) and functions as a co-processor of the main CPU. Because the DMA controller is loaded internally, character data can be transferred to V-RAM when the main CPU is operating.

VDP1 (Video Display Processor 1)
VDP1 controls sprites (character). The limitation in the number of horizontal sprites of previous systems has been eliminated, allowing more sprites (characters) to be displayed. Polygons can also be displayed.

VDP2 (Video Display Processor 2)
VDP2 controls display of the background screen (scroll screen) as well as the display priority order. This has expanded the number of scroll screens that can be displayed at the same time to a maximum of five, and enables the screen to be moved up, down, right, and left and to be rotated.

SCSP (Saturn Custom Sound Processor)
The SCSP controls the sound of the PCM/FM sound generator. It supports the FM sound generator of conventional systems and can support PCM sound. Tone quality has improved to CD-D/A (Compact Disc - Digital / Audio) levels.

Cartridge I/F
This is the connector I/F for the cartridge. A maximum of 57 MB area has been provided.

PAD I/F
This is a control pad connector I/F. Two are planned to be loaded into the main system.

D/A Converter, Encoder
This changes the digital signal of sounds to an analog signal (D/A converter). In the case of color, analog RGB is converted to video signals (encoder).

Subsystem

CPU

The CPU manages mechanical control, error correction (C3), and CD file management.

RAM/ROM

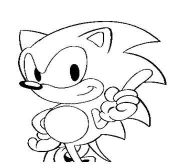
RAM is used as CD buffer RAM, MPEG work RAM, and in the data cache for CD error correction. ROM contains programs such as the CPU CD BIOS.

CD-ROM Drive

Saturn employs a X2 speed CD-ROM drive.

MPEG (optional)

This standard allows the playing of Full Screen, Full Color, Full Motion, and CD Quality Audio. Up to 72 minutes (30 frames per second) of images and sounds can be recorded on a single CD. In addition, there are various application capabilities that not only output the stretched images, but capture them within the system and enable their processing using MPEG technology.



Chapter 3 Functions

Contents

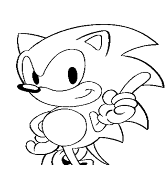
3.1 CPU

The main CPU has a 32-bit RISC chip with built-in DSP function. The sound block has a 16-bit CPU MC68EC000. The subsystem has a SH-1. The specification of each CPU is shown in Table 3.1.

Table 3.1 CPU Specifications

SH-2	• RISC Type Instruction Set • Internal and External 32-bit buses • Cache 4 Kbyte • Clock 28.6 MHz / 26.8 • Internal Math Processor
SH-1	• RISC Type Instruction Set • Internal A/D Converter • Internal 32-bit bus and External 16-bit bus • Clock 20 MHz • Cache 4 Kbyte • Internal Math Processor
MC68EC000	• Internal 16-bit bus and External 16-bit bus • CISC Type Instruction Set • Clock 11.3 MHz

- SMPC (System Manager) is the processor configuration.
  See “3.7 Other Items” for more about functions.



3.2 SCU

The SCU smoothly executes the interface of more than one processor connected to CPU-bus, A-bus, and B-bus. Further, inside is a DMA controller, interrupt controller, and DSP.

System Configuration

The SPMC is connected to the CPU-bus and controls the system reset signal as well as the control pad.

The A-bus is connected to a device that provides programs such as cartridges and CDs.

The SCU interrupt controller controls interrupt from A-bus, B-bus, and the SMPC. It also supports timer interrupt, can cause the screen display to synchronize and interrupt (INT signal) (Figure 3.1).

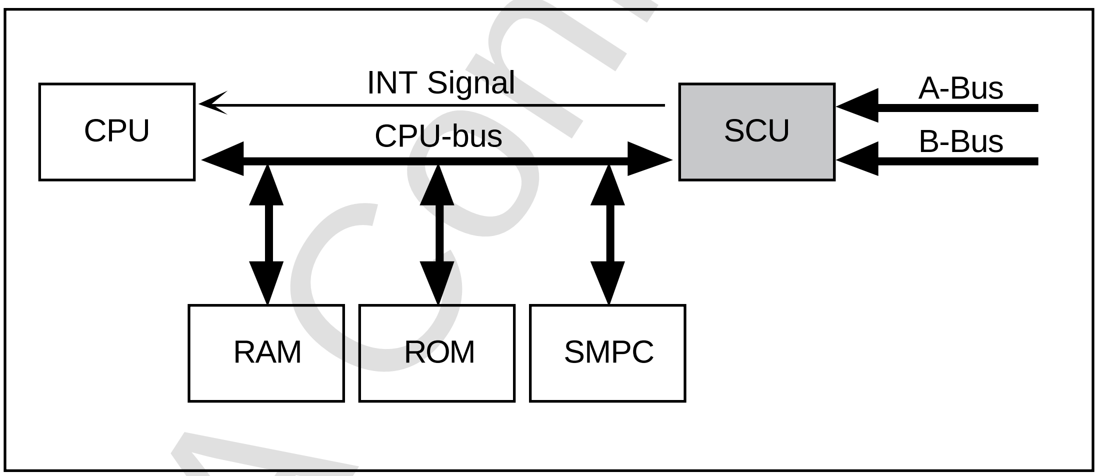
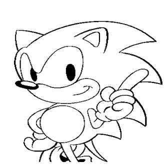


Figure 3.1 SCU System Configuration

System specifications of the SCU are shown in Table 3.2.

Table 3.2 SCU System Specifications

No	Item	Specification	Remarks
1	DSP	• 32bit X 32bit → 48bit • 14 MHz • Program RAM 32bit X 256word • DATA RAM 32bit X 64word X 4 • DMA command	
2	DMA	• CPU 3 ch, DSP 1 ch • 3 level, stack 1 set • Able to start by interrupt • Indirect mode	
4	Interrupt Control	• Timer (2ch) synchronized with screen • Interrupt control from external terminal	
5	A-bus Control	• A-bus (external bus) bus sizing • Wait control • Burst size setting • Refresh control	
6	B-bus Control	• B-bus (internal bus) control	• VDP1, VDP2, SCSP only



Functions

SCU functions are shown below.

- Data transfer within A-bus, B-bus, and CPU-bus
- Matrix calculations by DSP
- SCU internal interrupt control by interrupt controller

• Data transfer within Main CPU, Internal DSP, A-bus, and B-bus

The SCU has a CPU I/F, A-bus I/F, and B-bus I/F and smoothly executes the interface to multiple processors, which are connected through their respective I/F and buses. This also allows programs in the main CPU to be transferred to the DSP within the SCU. Also, while data is being transferred between the A-bus and B-bus, the work area can be accessed using the CPU-bus from the CPU, and process can be executed using independent buses in parallel.

• Interrupt Control

Interrupt that extends to other processors executes through the SCU. For example, to display the volume level on screen, a screen display request interrupt from the SCSP for the SCU occurs. SCU recognizes the interrupt and issues the interrupt while synchronized with the screen. Interrupt can then be issued with respect to any point (dot) on the screen.

Internal DSP

SCU has an internal DSP. This has been provided in order to implement processes difficult to implement when the load to the main CPU has been excessive.

Operating Frequency

The operating frequency of the DSP inside SCU runs at a frequency of 1/2 the main CPU. See the Main CPU manual concerning the operating frequency of the main CPU.

3.3 VDP1

VDP1 controls sprites.
Compared to conventional systems, drawing speed is exceptionally fast, and because there is no limit in the number of horizontal sprites, more sprites (characters) can be displayed. Polygons can be displayed as sprite applications.

System Configuration

The VRAM and two frame buffer screens are connected to VDP1 (Figure 3.2). The VRAM draw command is set through the SCU from the CPU. VDP1 reads draw commands from the VRAM and writes (draws) draw data to the frame buffer. Information controlling draw is set in the system register inside VDP1. Drawn frame buffer data is displayed in the TV through VDP2 that controls image display.

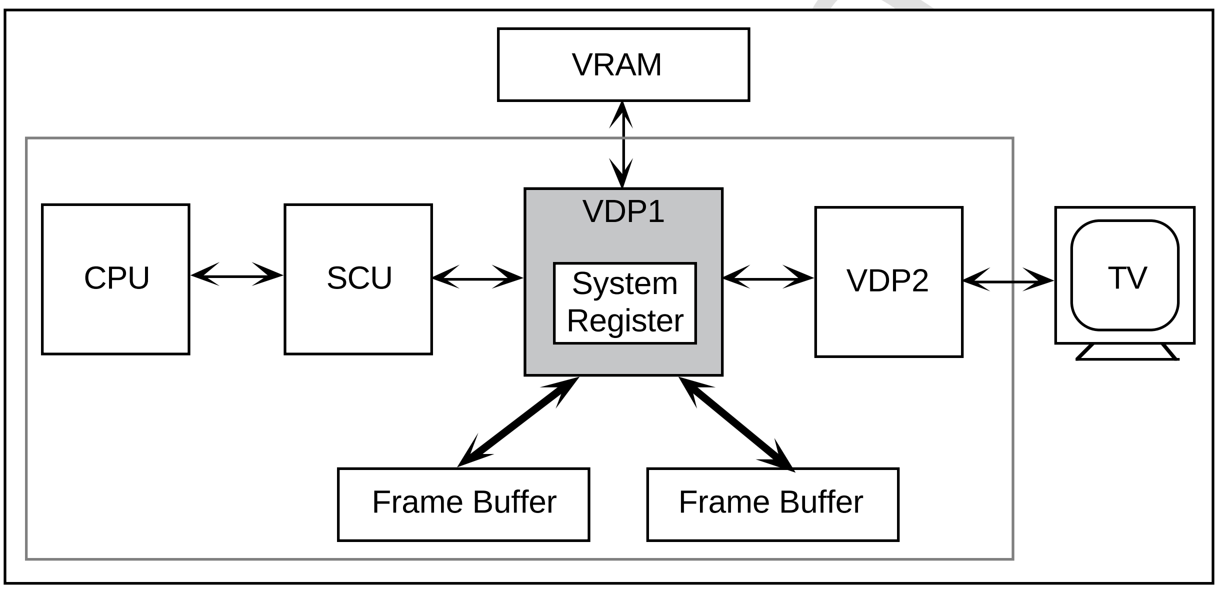


Figure 3.2 VDP1 System Configuration

Table 3.3 shows the VDP1 system specifications.

Table 3.3 VDP1 System Specifications

No	Item	Specification	Remarks
1	Texture Parts Display	• Regular Sprites (normal sprite, horz. 8~504 dot, vert. 1~255 dot) • Expand/Contract Sprite (any size can be designated by vertical horizontal 1 dot units) • Distorted Sprite (can designate any 4 vertices)	Up-down-left-right reverse by all sprites is possible
2	Non-Texture Parts Display	• Quadrilateral polygon • Polyline • Line	You can have a three sided polygon and polyline if two adjacent points have the same coordinates
3	Color Calculation	• Semi-transparent associated parts • Half brightness • Shadow • Mesh • Gouraud Shading	Gouraud shading can be combined with semi transparent or half brightness
4	Draw Method	• Double Frame Buffer Method (Can enlarge, reduce, rotate, and modify the entire plane of the frame buffer. Can designate the delete range and delete data of frame buffer. Can set write local coordinates. Can designate clipping of rectangular area.)	
5	Simultaneous Colors	• 16, 64, 128, 256, 32768 colors	16, 64, 128, 256 for high resolution
6	Memory Capacity	• VRAM 4 Mbit (Character Generator, for all types of tables) • Frame buffer 2 Mbit X 2 sides (Both 2 sides can be used as bit map. One side is displayed.)	

Functions

The main functions of the VDP1 are shown below.

- Draws parts (character line)
- Designates color mode
- Color calculation
- Mesh process
- Designates clipping coordinates and relative coordinates
- Display control of frame buffer

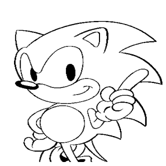
Parts, color mode, and coordinates are controlled by the VRAM command table. Control of the frame buffer display is done by the system register.

Parts

Parts drawn by VDP1 are divided into texture and non-texture parts depending on whether or not there is an original picture. Table 3.4 shows part classifications.

Table 3.4 Parts Classification

	Classification	Parts Name	Function	Defining Method
	Texture Parts	Regular sprite	Character, up-down, left-right reverse	Read direction of 1 vertex
PARTS		Rectangular sprite	Character, up-down, left-right reverse, enlarge-reduce, expand-contract are possible	Read direction of 2 vertices, or read direction of fixed points and width
		Transformed sprite	Character, up-down, left-right reverse, enlarge-reduce, expand-contract, rotation, twisting are possible	Read direction of 4 vertices
	Non-Texture Parts	Polygon	Quadrilateral Inside is painted solid	4 vertices
		Polyline	Quadrilateral	4 vertices
		Line	Straight Line	Start and End points



Texture Parts

Sprites draw character patterns. Character patterns define pixel data as character pattern tables in VRAM.

Regular Sprites

Normal rectangular sprite.
The pattern of the original picture can be inverted up , down, and left and right. This can be done in any sprite mode (Figure 3.3).

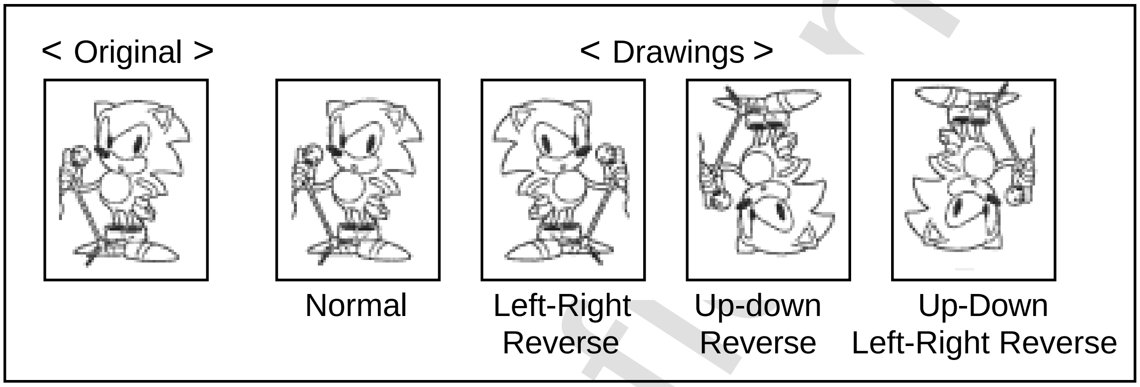


Figure 3.3 Regular Sprites

Scaled Sprites

For sprites that can be enlarged and reduced, it is only possible to zoom in and out vertically and horizontally (Figure 3.4).

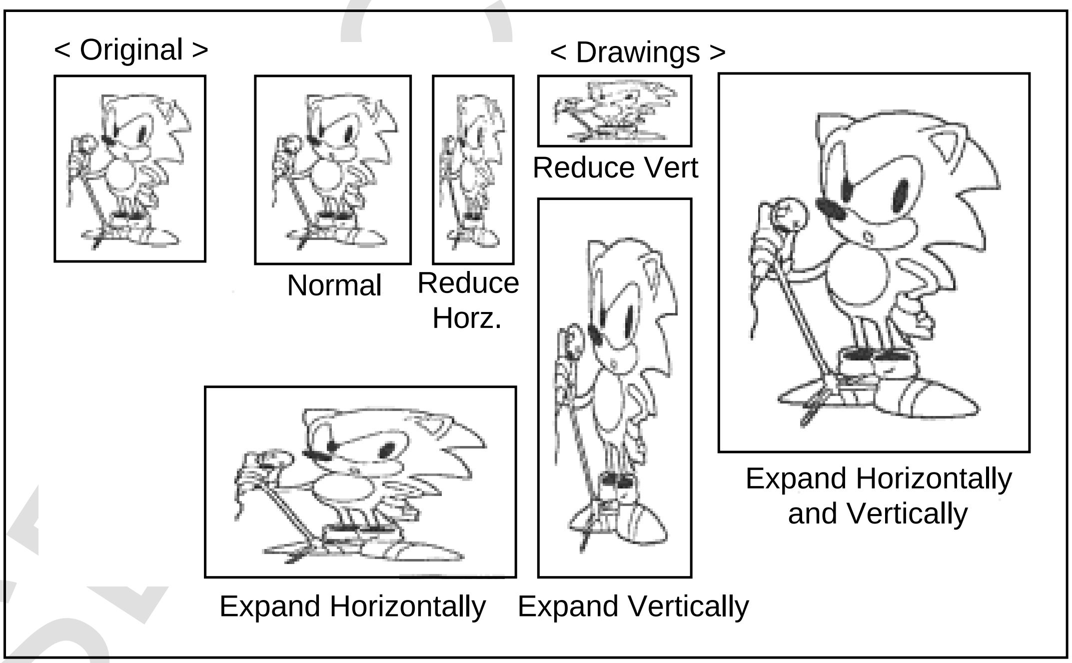


Figure 3.4 Scaled Sprites

Distorted Sprites

These are sprites that can be distorted. The original picture can be distorted to any shape by designating four vertices of the character and enlarging, reducing, rotating, and reversing the picture in any way. If viewed as a polygon, it would be the same as a texture-mapped polygon.

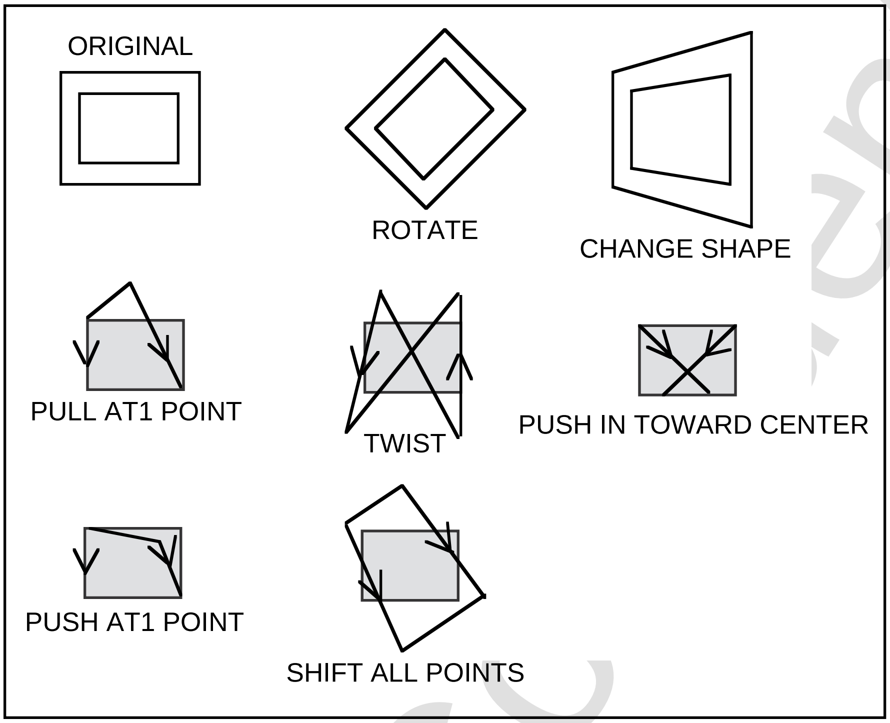


Figure 3.5 Distorted Sprites

Non-Texture Parts

Polygon

This is a four-vertex polygon. It is different with a sprite in that the flat surface encompassed by the four points is painted over by one color. Sprites have an original picture whereas polygons do not.

Polyline

This is a quadrilateral connected by four lines.

Line

This is a line of one color drawn between two points.

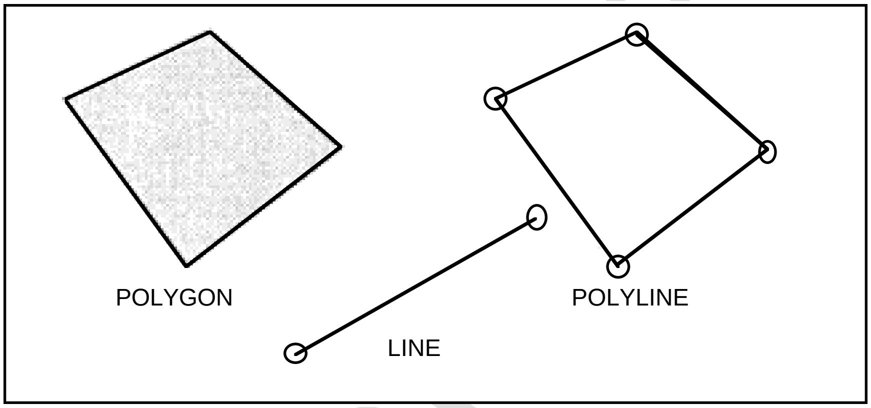


Figure 3.6 Polygon, Polyline, Line

Display

A common TV is used as a display apparatus. NTSC format is the TV standard of both Japan and the U.S. Europe uses the PAL format.

TV display is done by reading data from lead of the frame buffer for each frame (1 frame per 1/60 sec.).

Normally, one frame is equal to one field, but one frame that is interlaced is treated as two fields, allowing the vertical resolution to be doubled (one frame per 1/30 sec.). There is single and double interlace, as shown in Table 3.5.

Table 3.5 Interlace

Double Interlace	Odd numbered line, a different image is shown by even numbered lines
Single Interlace	Odd numbered line, the same image is shown by even numbered lines

Color Mode Designation

There are three methods of designating color modes for textured parts: the color bank, RGB code, and color look-up. Non-textured parts have pixel data for color designation.

Color Bank Method

- Combining color bank with 16, 64, 128, and 256 color palette codes, references colors stored in the VDP2 color RAM.
- VDP2 color palette is selected by the color bank. Color from the color palette is selected by the palette code.
- 16, 64, 128, 256 colors can be expressed by 1 character.
- Data written by the color bank method is divided and processed by the VDP2 color operation, priority, color bank, and function bits of the palette code.

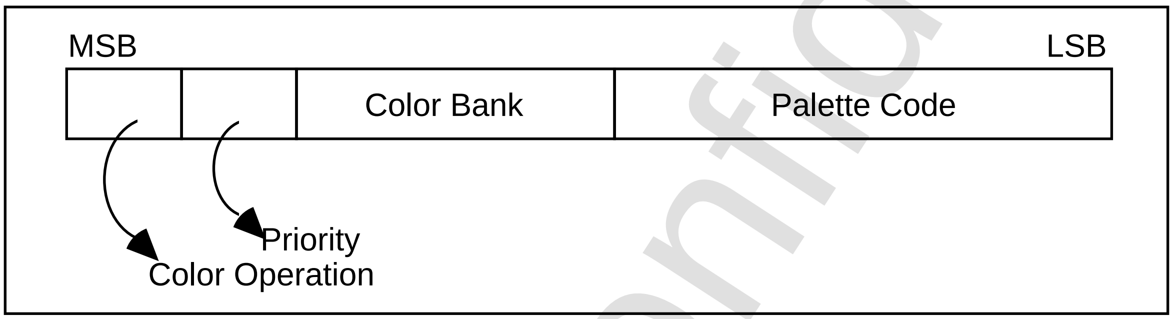


Figure 3.7 Configuration of the Color Bank Method

RGB Code Generation

Color is expressed by five bits of respective RGB (red, green, blue) luminance.

Color Look-up Table

Colors are selected from the 16 colors defined in the color look-up table. One color with 16 bits can be of either RGB code or color bank code.

Color Operation

Gouraud Shading, shadow, half-brightness, and semi-transparent color operations can be designated by VDP1. Table 3.6 shows the types of color operations.

Table 3.6 Types of Color Operations

TYPE	DESCRIPTION
Semi-transparent	A foundation at half brightness is added to the original at half brightness. The result is drawn in the frame buffer.
Half-Brightness	An object at half the brightness of the original picture is drawn in the frame buffer. The foundation cannot be seen because i is written over and the brightness of the original is reduced to half.
Shadow	The foundation at half-brightness is re-drawn in the frame buffer. Here, a shadow of the character shape in the original can be created. The character of the original is used only in th shape of the shadow and color data is ignored.
Gouraud Shading	An object in the original picture to which Gouraud shading is applied is drawn in the frame buffer.
Gouraud Shading Semi-transparent	The brightness of an object in the original picture to which Gouraud shading is applied is reduced to half, and foundation at half-brightness is added. The result is drawn in the frame buffer.
Gouraud Shading Half Brightness	The brightness of an object in the original picture to which Gouraud shading is applied is reduced to half, and the object i drawn in the frame buffer.

Gouraud Shading

Gouraud shading can be applied to parts drawn by RGB, and interpolates color between polygon vertices which causes a flat surface to appear curved.

A surface can appear to be curved by giving brightness correction values to the four vertices of a polygon and applying Gouraud shading within these four vertices. Gouraud shading can be applied to polylines and lines as well. Figure 3.6 shows an example of Gouraud shading.

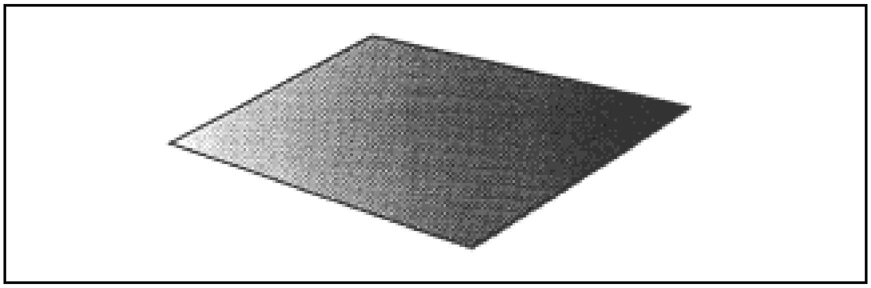


Figure 3.8 Gouraud Shading

Mesh Process

Mesh can be applied to all parts. A checkered pattern (every other dot) is drawn to the part in which the mesh is applied.

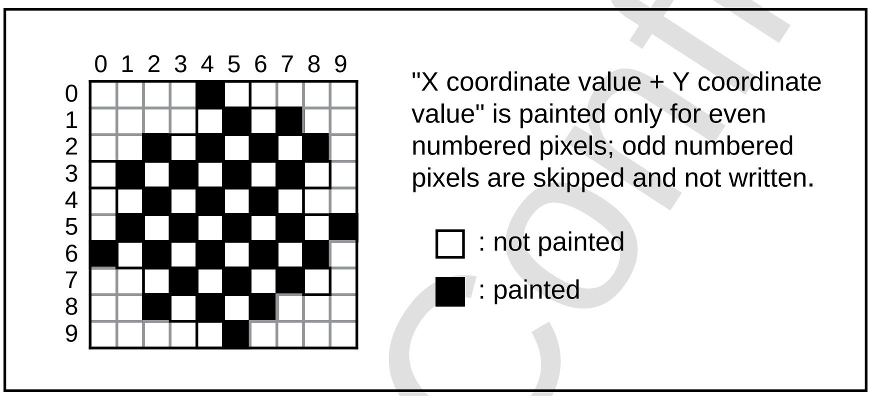
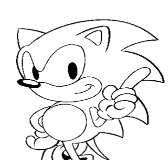


Figure 3.9 Mesh Process



Clipping

Clipping allows only the set display area to be drawn and cuts away any excess. Clipping includes system clipping that sets the system draw area, and user clipping that enables any setting by the software.

System Clipping

System clipping is always in effect while drawing. and the inside of the set area is drawn (see Figure 3.10).

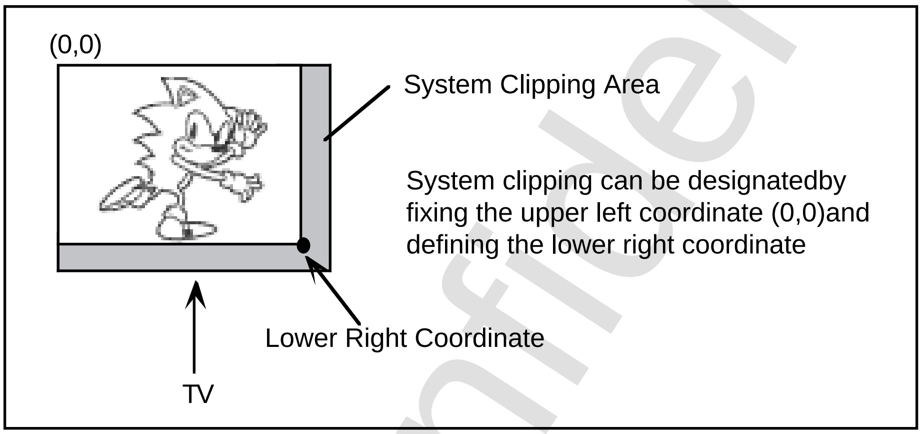


Figure 3.10 System Clipping

User Clipping

User clipping can be selected by the software. Choose whether to make user clipping effective for each part, or the inside or outside of the user clipping set area of the effective area.

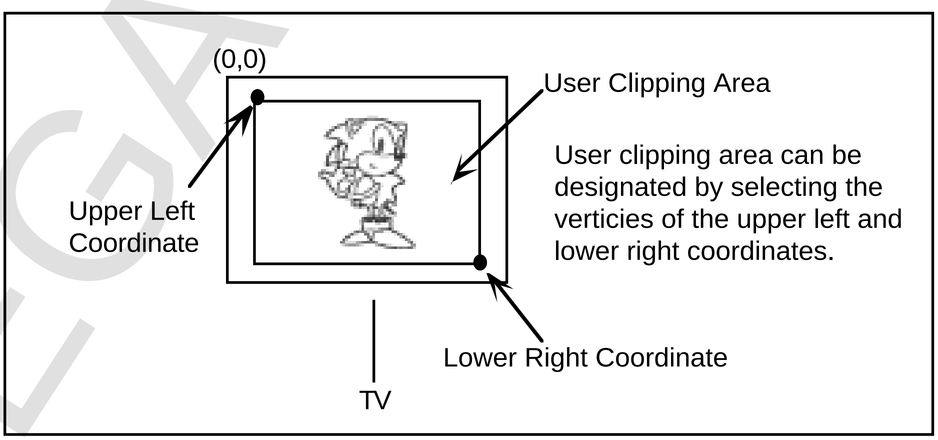
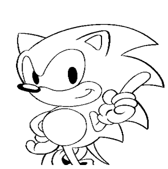


Figure 3.11 User Clipping

Frame Buffer

- The frame buffer is divided into two screens, the display frame buffer and draw frame buffer. Read/Write access from the SCU to the frame buffer is performed only for the draw frame buffer. The display frame buffer becomes a back-end bank and cannot be accessed.

- By reading the frame buffer, the read start coordinate and next dot to be read can enlarge, reduce, and rotate the entire frame buffer surface by giving X and Y direction displacement, which designates the location.



3.4 VDP2

VDP2 determines priority of display of the scroll screens and the entire screen (including sprites). Simultaneous display of scroll screens has been expanded to a maximum of five screens. A screen can be moved up, down, left, and right, and rotated. Priority (display priority order) can be programmably set on each character.

System Configuration

VDP2 has VRAM connected to it and color RAM built-in. Image data is defined from the CPU through the SCU to VRAM and color RAM.

Data defined in VRAM is read according to settings of the register and becomes image data of each scroll screen. This data, VDP1, as well as image data sent from the external image circuits determine the display priority order according to the register setting, then become display image data. Display image data is converted to display color data and output to the TV (Figure 3.12).

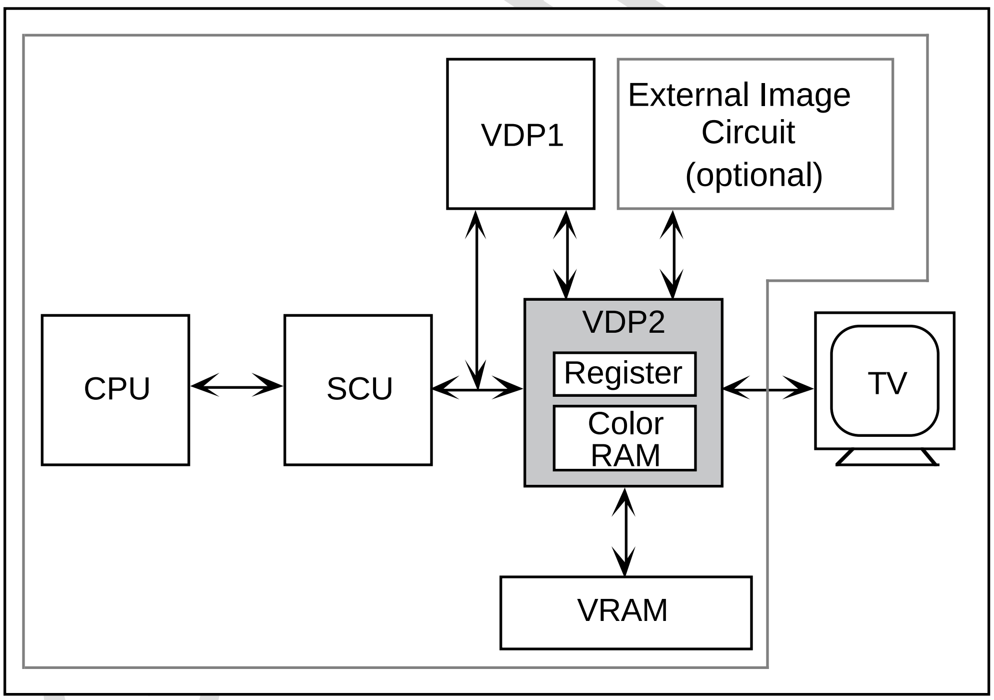
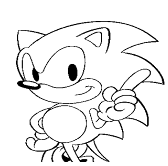


Figure 3.12 VDP2 System Configuration

Table 3.7 VDP2 System Specifications

No	Item	Specification	Remarks
1	TV Screen	• Horizontal Resolution Select from 320, 352, 640, 704 pixels • Vertical Resolution Select from 224, 240, 256 pixels (for non-interlace) Select from 448, 480, 512 pixels (for Interlace)	Vertical resolution of 256 pixels and 512 pixels are for PAL only.
2	Character	• Character Size Select from 1 X 1 cell and 2 X 2 cell • Number of character colors Select from 16, 256, 2048, 32768, and 16,770,000 colors.	Bit map format is also possible.
3	Normal Scroll Screen	• Max. no. of simultaneous screens is 4 • Scrolls horizontally and vertically • Can line scroll • Scrolls vertical cells • Reduces to 1/4, enlarges to 256X • Mosaic function	
4	Rotation Scroll Screen	• Max. no. of simultaneous screens is 2 • Can Enlarge, Reduce, Rotate • Rotation parameter can be switched inside screen • Special Screen processing by coefficient table	Normal scroll screen can not be displayed when 2 screens are displayed
5	Windows	• Normal window 2 screens • Sprite window 1 screen • Line window possible	
6	Priority	• Priority of each screen is programmable • Priority can be switched in character units and dot units	
7	Screen Operation	• Color operation for up to 4 screens is possible • Color operation rate 32 steps • Color offset function • Shadow function	



Functions

VDP2 has a scroll function for controlling the display of the scroll screen, and a priority function for determining the display priority order (Figure 3.13).

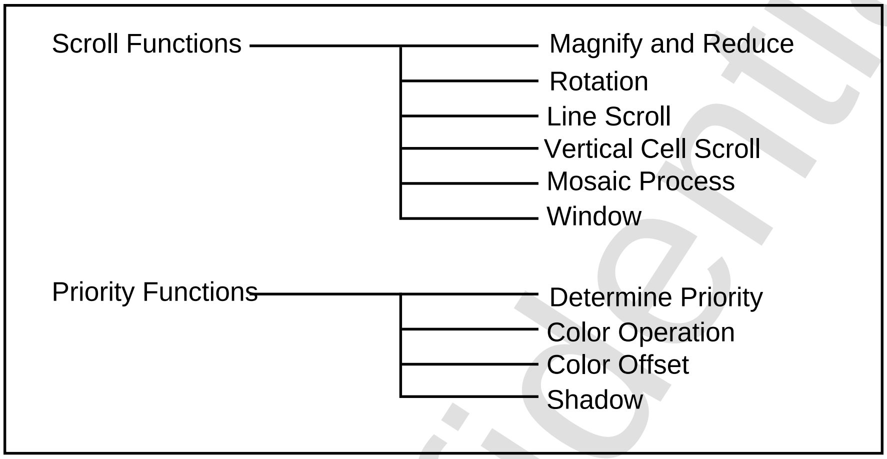


Figure 3.13 Scroll, Priority Functions

Scroll Functions

Scroll has a scroll screen for displaying pictures and windows for display control.

- **Scroll Screen**

Scroll screen includes a normal scroll screen that can change the number of displayable screens, and a rotation scroll screen that can rotate a screen.

Table 3.8 shows the functions of the normal scroll screen and rotation scroll screen, and number of character colors.

Table 3.8 Scroll Screen Functions

Function	Normal Scroll Screen				Rotation Scroll Screen	
	Screen 0	Screen 1	Screen 2	Screen 3	Screen 0	Screen 1
Enlarge/Reduce	1/4 X ~ 256 X		no		any factor	
Rotation	no				yes	
Line Scroll	yes	yes	no	no	no	
Vertical Cell Scroll	yes	yes	no	no	no	
Mosaic Process	yes				yes (only in horizontal)	
Displays Bit Map	yes	yes	no	no	yes	no
Character Color Number	Select from 16 256 2048 32768 16.77 mil.	Select from 16 256 2048 32768	Select from 16 256	Select from 16 256	Select from 16 256 2048 32768 16.77 mil.	Select from 16 256 2048 32768 16.77 mil.

• Enlarge/Reduce Function

Enlarge and reduce the entire screen horizontally and vertically. Reduced display horizontally limits the number of screens.

• Line Scroll Function

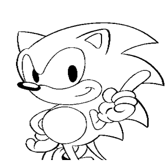
Scroll up, down, right, and left each line as well as enlarge and reduce horizontally. This creates the feeling of distance, such as the road of a driving game.

• Vertical Scroll Function

Scroll up and down in units of horizontal cells. It can create depth as in a vertical scroll game.

• Mosaic Function

All scroll screens are divided horizontally and vertically, and the color of upper-left dots in each area are displayed per dots in that area.



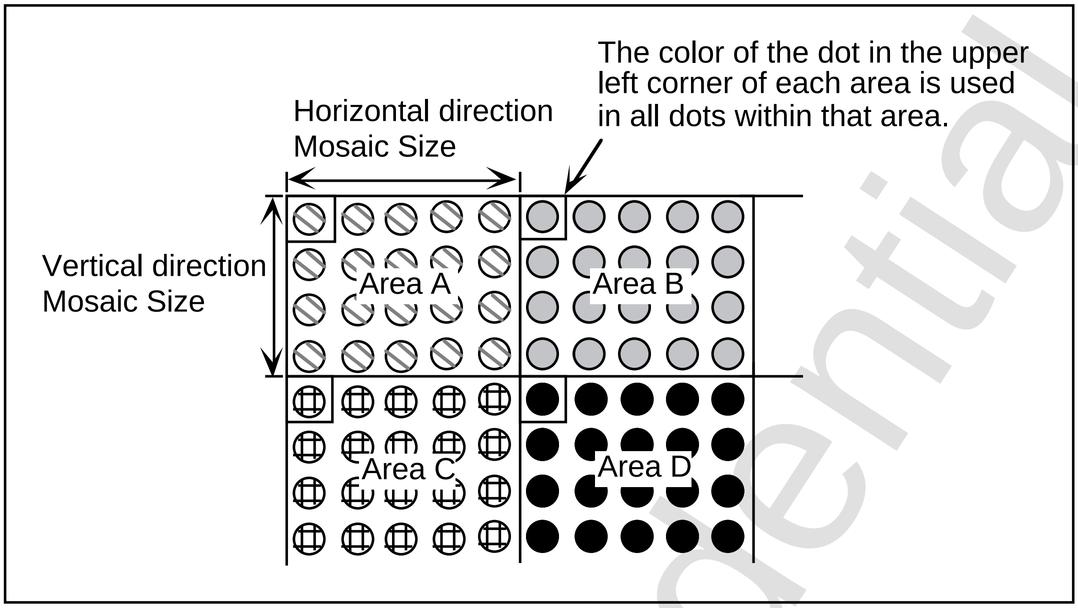


Figure 3.14 Mosaic Pattern

Rotation Function

• Rotation Display

The rotation scroll screen rotates along the coordinate axes (X, Y, Z axes) and the screen axis vertical to the TV screen. Two surfaces can be displayed at the same time.

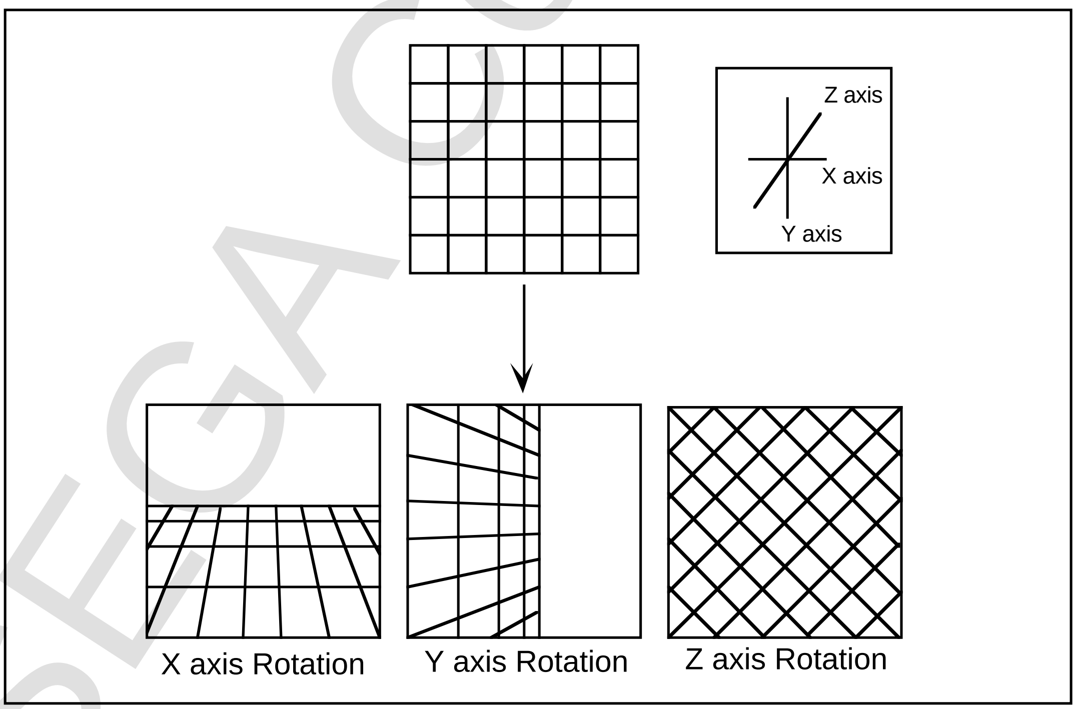


Figure 3.15 Image Modification by Axis Rotation

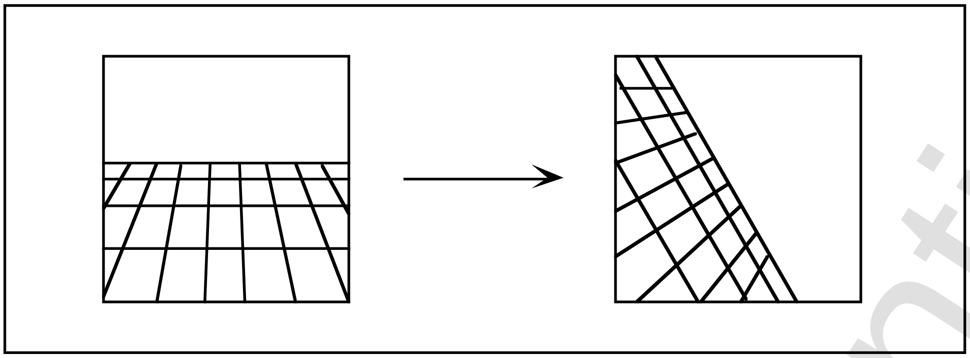


Figure 3.16 Image Modification by Screen Axis

• Rotation

Rotation calculation is done by the hardware according to designated parameters. This means that rotation display can be done without straining the CPU load. Twisted images can be displayed since coordinates can be calculated and different values applied to each dot.

• Simultaneous Display by Screen Division

The image of two screens can be displayed by showing one screen of the rotation scroll screen.

Scroll Screen Structure

The two scroll screen formats are the cell format and the bit map format. The cell format, as in conventional home game devices, displays an arrangement of cells. The bit map format, as with the personal computer, displays a picture that corresponds to each dot on a screen.

• Cell Format

The cell format scroll screen is a picture pattern consisting of cells (eight horizontal dots by eight vertical dots), character patterns (an arrangement of cells), pages (an arrangement of character patterns), planes (an arrangement of pages), and maps (an arrangement of maps). Figure 3.17 shows the structure of a cell format scroll screen.

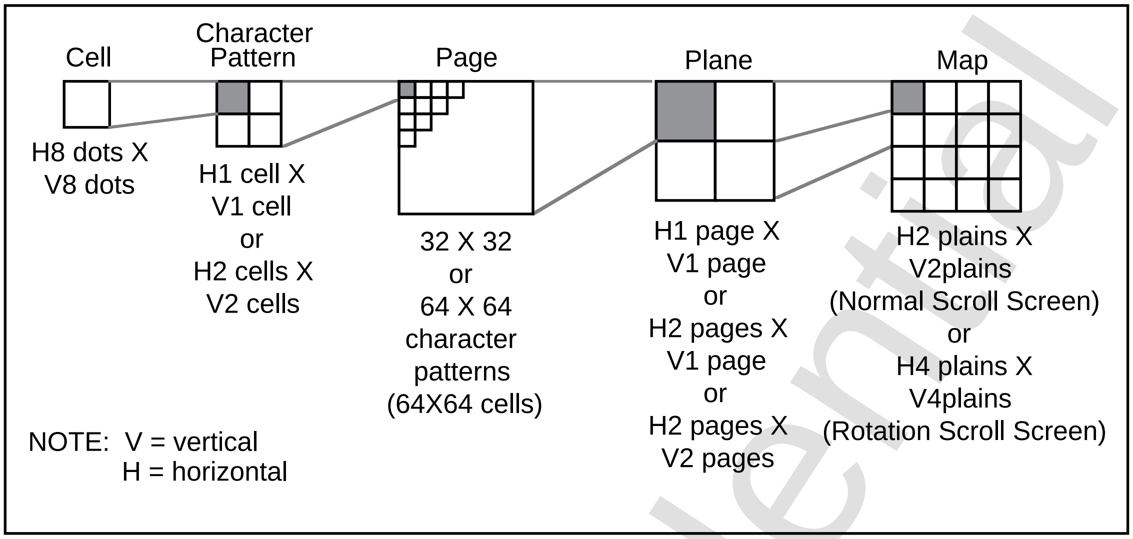


Figure 3.17 Cell Format Scroll Screen

• Bit Map Format

The bit map scroll screen consists of a bit map pattern 512 dots or 1024 dots horizontally and 256 dots or 512 dots vertically in size. Figure 3.18 shows the configuration of the bit map scroll screen.

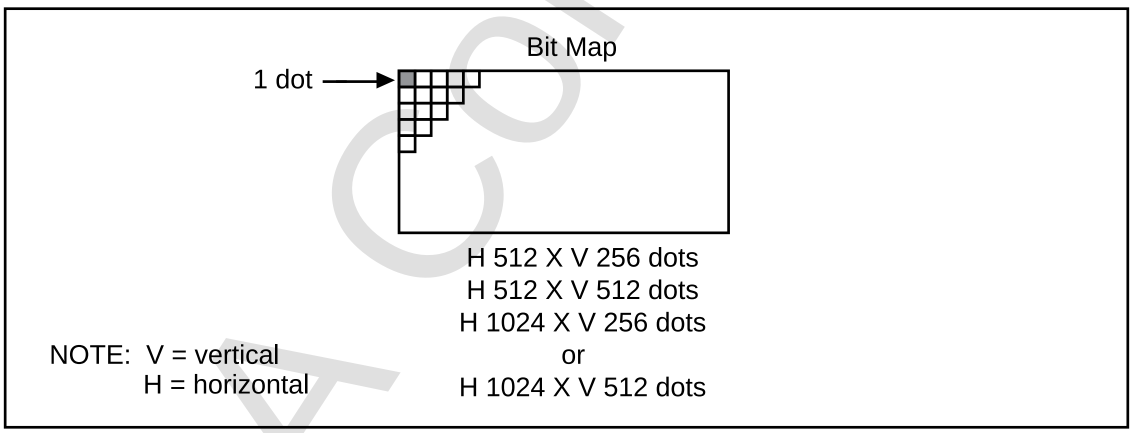


Figure 3.18 Bit Map Scroll Screen and Data Setting Relationship

Windows

Windows are classified into three types depending on the way the area is designated (coordinate designation).

• Normal Rectangular Window

Designated by two coordinate points: start and end.

• Normal Line Window

Designated by the start and end points of each line coordinate.

• Sprite Window

Designated by sprite character patterns.

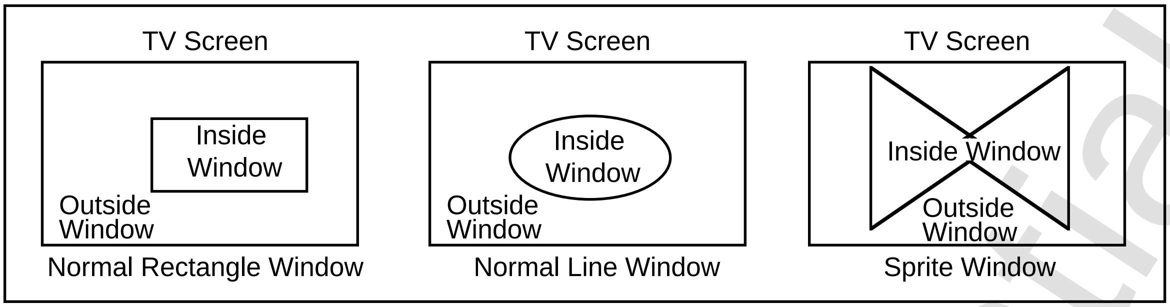


Figure 3.19 Windows

Priority Functions

The display priority order of sprites and scroll screens is determined by a 3-bit priority number. The sprite priority number can set a maximum of eight values; one of which is designated by character units.

Determining Priority

The scroll screen priority number is designated in normal surface units. (This can be changed by character units or dot units using special priority function.)

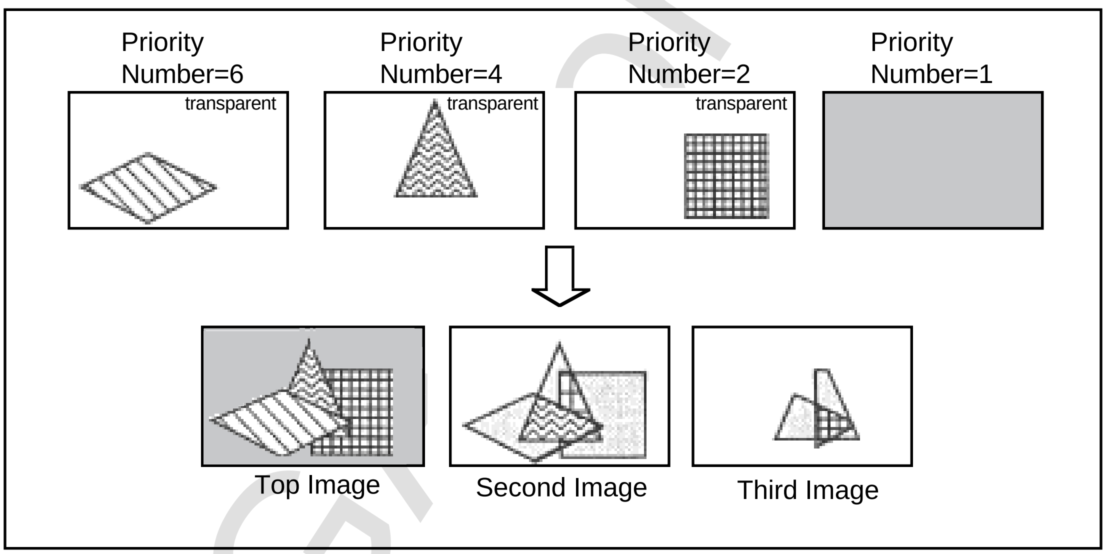
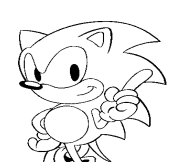


Figure 3.20 Priority Function

• Special Priority Function

Priority numbers that correspond to each scroll screen can be changed by character or dot units. This function the priority of only the area within the scroll screen to be changed, which causes one scroll screen to appear like as more than one screen.



Color Calculation Function

By adding multiple screens of color data, the color calculation function produces an effect that makes the back screen appear to be seen through the front screen. This is normally done by two screens, the top image and the second image, but can be done with up to four screens if the expanded color calculation function is used.

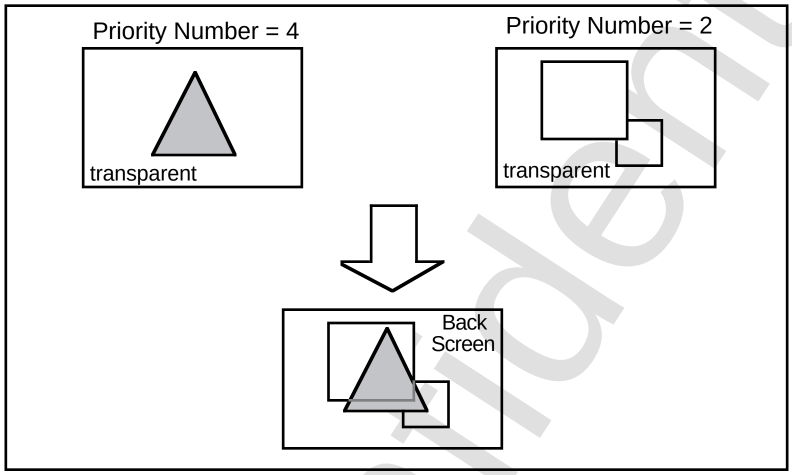


Figure 3.21 Color Calculation Function

• Line Color Screen Insert
The line color screen forces the top image part of the designated screen to be inserted as the second image, and induces color calculation. The pre-inserted second image becomes the third image in the area of the inserted line color screen, and the third images drops one to become the fourth image. Figure 3.22 shows insertion of the line color screen.

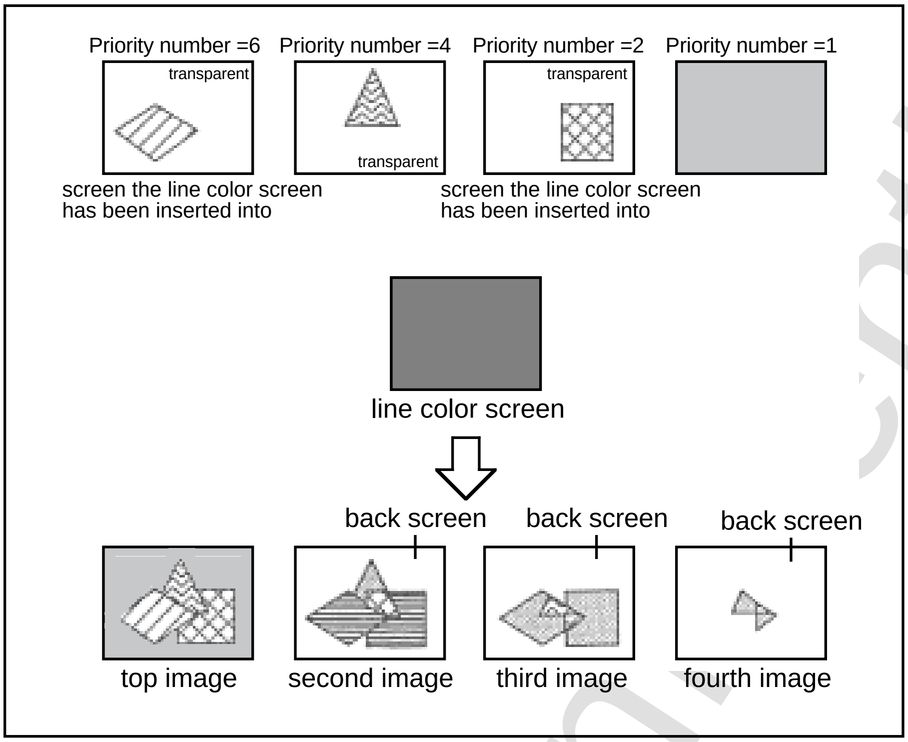


Figure 3.22 Insertion of the Line Color Screen

Shadow Function

The shadow calculation function adds a shadow in the shape of the sprite character on all screens.

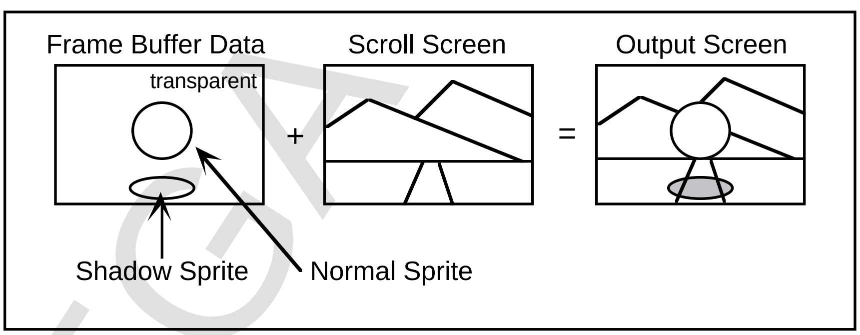
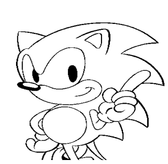


Figure 3.23 Shadow Function

• Blur-Calculation Function

The blur-calculation function adds the horizontal color data of one designated screen at a fixed rate, and is able to create an effect of a blurred distant background.



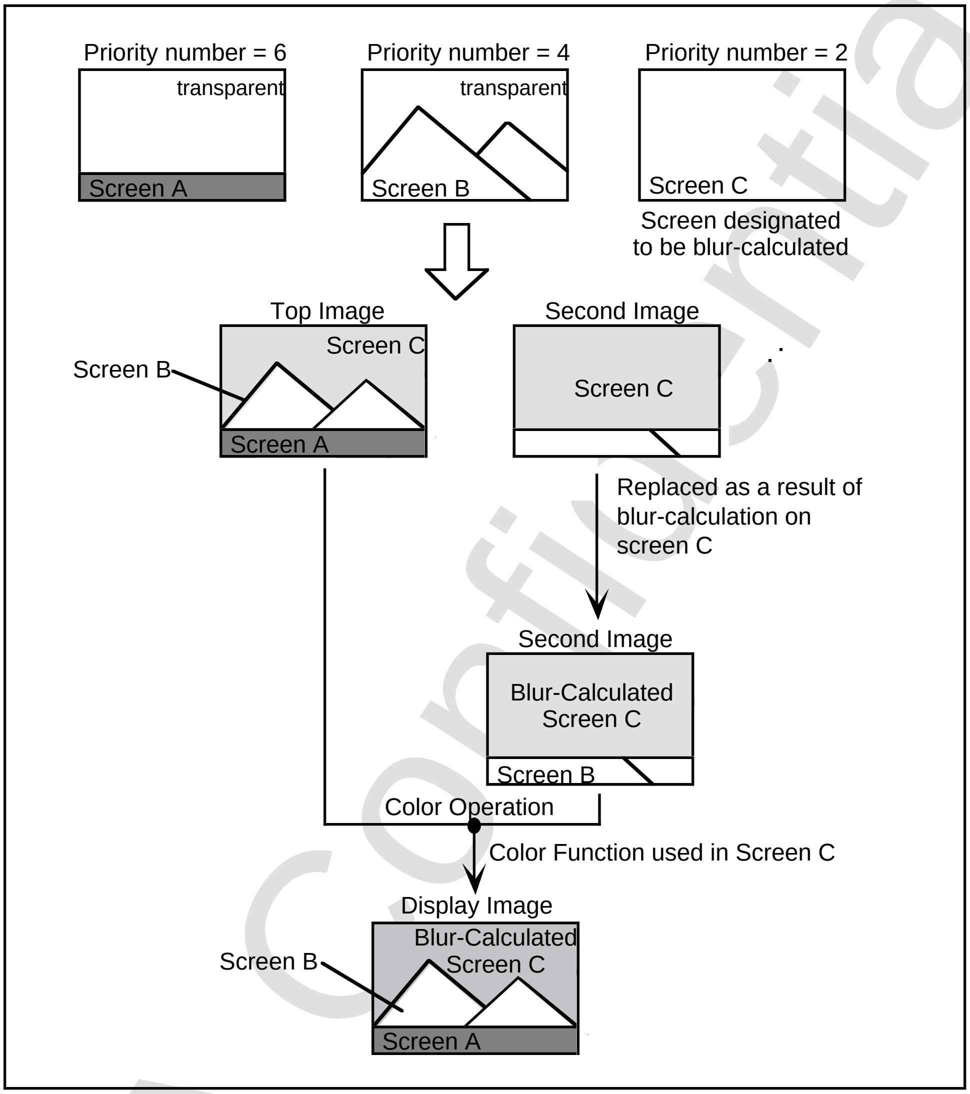


Figure 3.24 Blur-Calculation Function

The sum of color data is forced to be as second image in the area where the top or second image is the designated screen. The blur-calculated picture can be displayed by performing color calculation on the second and top images.

Color Offset Function

The color offset function displays and adds (or subtracts) the offset value for the screen color data, and is used in fade-in and fade-out. Designate whether to use the color offset function in each screen.

3.5 SCSP

SCSP is custom sound LSI that unites PCM (FM) sound generation with a sound only DSP. The goal of the audio function is to provide higher tone quality with all interfaces for increasing expandability. Capable of creating many sounds, the operation part provides a performance that rivals that of a synthesizer. The DSP can create multiple sound fields, such as each type of sound field play as well as the special effects of 3D sound positioning.

System Configuration

The main CPU, sound CPU, sound memory, and D/A converter are all connected to the SCSP. In the sound system, these can operate independent of the main processor.

The main CPU transfers the sound (CPU, DSP) program and wave form data to the SCSP sound memory through the SCU. The sound CPU transfers wave form data to the register inside the SCSP. SCSP reads delayed data for producing sound memory wave form data as well as the effect. The audio is mixed and output as sound through a D/A converter.

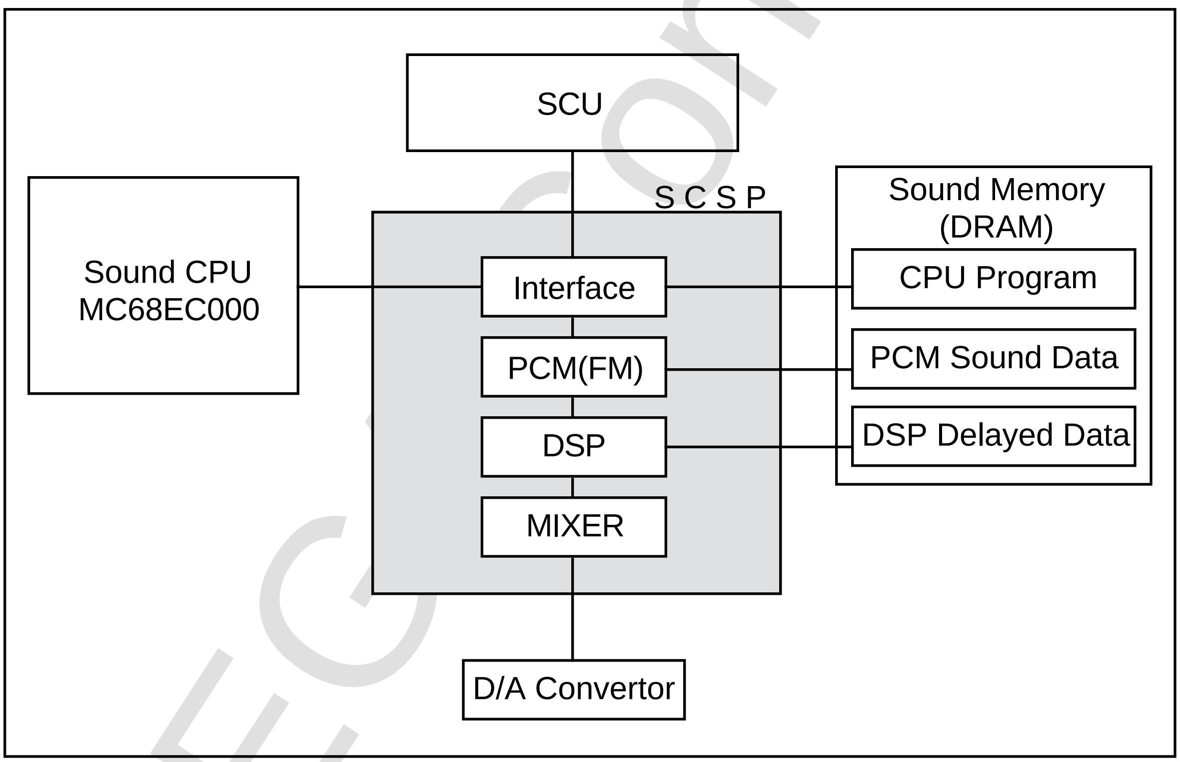


Figure 3.25 SCSP System Configuration

System Specifications

Table 3.9 shows the SCSP system specifications.

Table 3.9 SCSP System Specifications

No	Item	Specifications	Remarks
1	Sampling Frequency	• 44.1 KHz	
2	Audio Synthesis System	• PCM, FM Format	
3	Audio Process Slot Number	• 32 slots	
4	Wave Form Data Format	• 8-bit, 16-bit formats 2'S complement	
5	Each function type	• Envelope • Loop Process • LFO	
6	Effect from internal DSP	• Reverb, Chorus, etc.	
7	Other functions	• DMAC .... 1ch • Timer .... 3ch • MIDI .... IN/OUT each 1 • External D/A Input .... Stereo1 system	

Functions

The main functions of the SCSP are listed below.

- Frequency control
- Volume control
- FM operation
- LFO (Low Frequency Oscillator) modulation function
- Digital / Audio mixing
- Effect from DSP (reverb)

Effect
Because the SCSP DSP can create multiple sound fields, it is possible to have different settings for BMG sound and game sound.

For example, in a racing game, reverb would be applied to the concert grounds as BGM while reverb could be applied at the same time in producing an atmosphere inside a tunnel for the game.

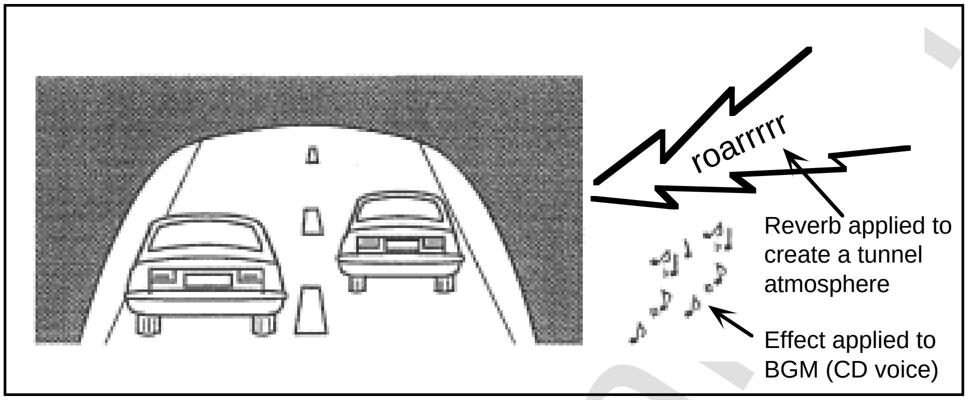


Figure 3.26 Tunnel and BGM Reverb

In the DSP, the effect can be applied to CD audio because the audio signals from the sound generator, and sound signals from the CD are input. Because the CD output level can be controlled through the SCSP, the sound signal from the sound generator and CD can be balanced and therefore the sound from the sound source will still be audible without being "hidden" by the CD sound. Thus, concealing the CD sound will not conceal the sound of the sound generator.

Sound Position

With a high performance digital mixer, the SCSP can control the positions of all sounds in real time. As a result, effective sounds can be produced on the screen with character positions. This process can be done by the DSP as well. In this case, when the character moves slowly, the sound orientation will move smoothly because more intricate settings can be made. A sense of depth (distance) can be created by adding reverb to this positioning.

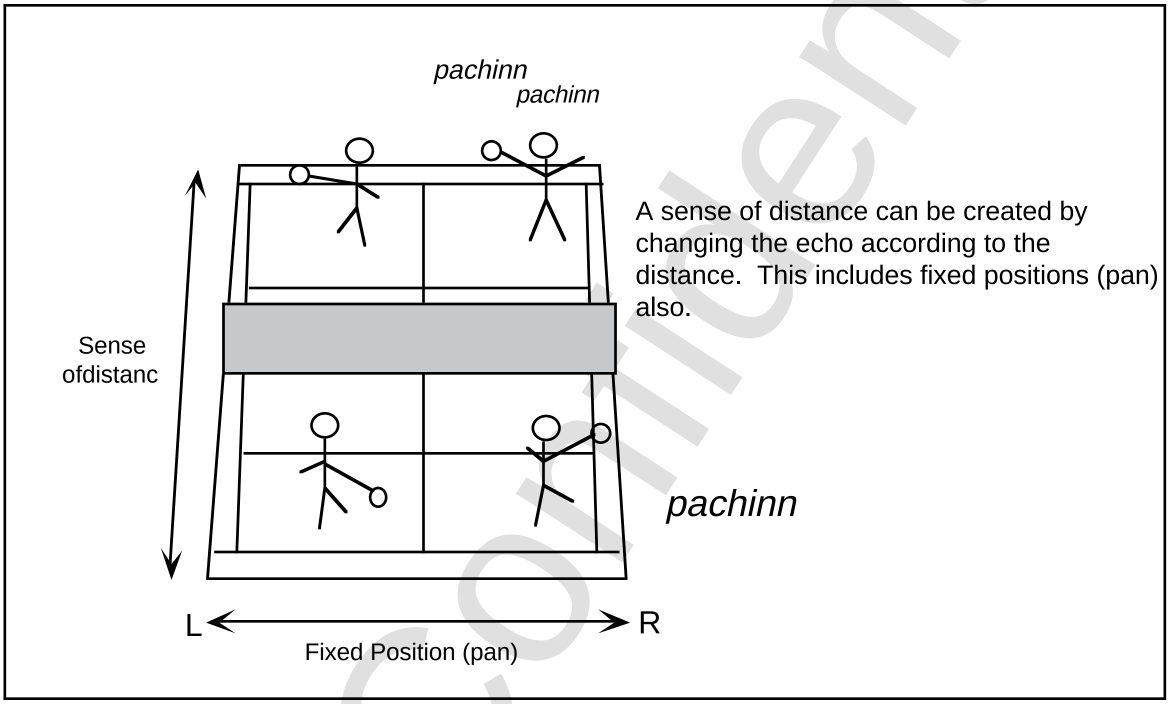


Figure 2.27 Tennis Game Example

Besides this, indoors, outdoors, and wide open spaces can be expressed depending on the type of reverb. Also, the type of reverb can also be set for all conditions, such as a hall, stage room, steel plate, etc.

3.6 CD-ROM

The CD-ROM system has its own CPU and buffer RAM, and can operate independently of the main system. By setting in advance conditions from the main system, flexible buffer management that suits the application configuration is attained.

System Configuration

The CD-ROM system operates only by giving commands through CD I/F from the main system. The sub-CPU interprets commands from the main system, controls the CD-ROM drive and CD buffer, reads data, and plays video and audio. Audio and video playing employs the MPEG international video compression standard, and uses the exclusive "MPEG/Video LSI" as well as "MPEG / Audio LSI." The system configuration is shown in Figure 3.28.

The sub-CPU, CD buffer, frame buffer, C/D I/F are connected to the MPEG / Video. Compressed image data is received from the CD buffer and regeneration image data is written (drawn) to the frame buffer. Drawn frame buffer data carries out the effect according to register settings and displays in the display device through VDP2 the controls screen display; or it is transferred to VDP1 and VDP2 VRAM through CD I/F and SCU.

MPEG / Audio receive compressed audio data from the CD buffer and outputs stereo 1ch audio data. This audio data is output through the SCSP as sound.

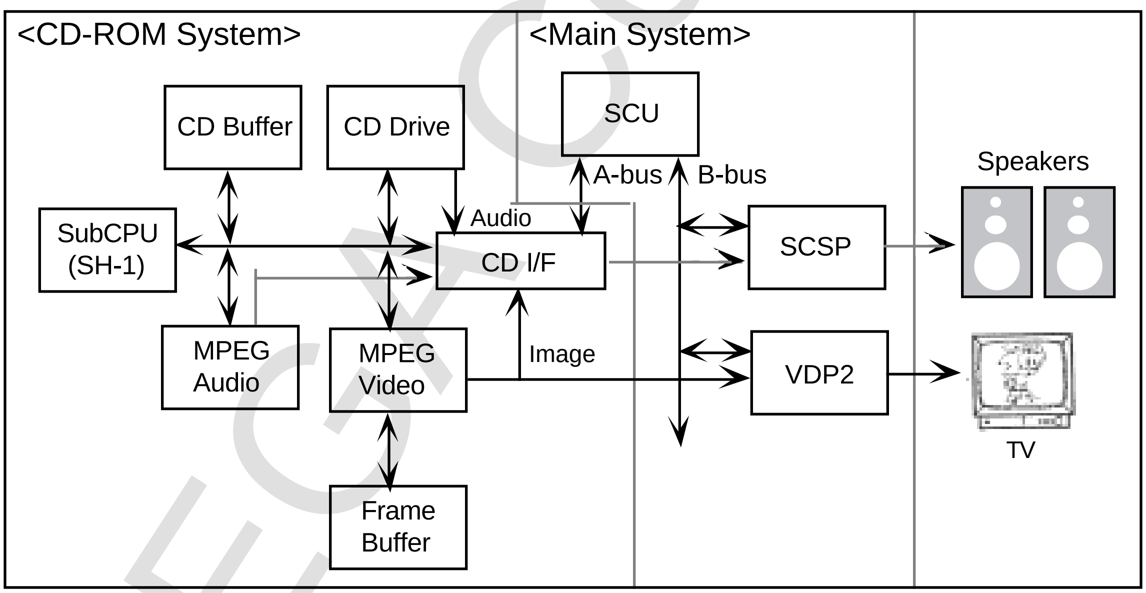


Figure 3.28 CD-ROM System Configuration

CD-ROM system specifications are shown in Table 3.10, and CD drive specifications are shown in Table 3.11.

Table 3.10 CD-ROM System Specifications

No	Item	Specifications	Remarks
1	G/A Register width	16 bit	
2	Seek Time	400 msec (1/3 access time, double speed rotation time)	
3	Rotation Speed	Normal time: 620~1680 rpm 2X speed: 1240~3360 rpm	
4	CD Read Speed	Normal speed: 75 sectors/sec = 150KB/sec 2X speed: 150 sectors/sec = 300KB/sec	
5	Tray Open & Close Method	Top loading	
6	Memory Capacity	RAM 512KB (for CD buffer) ROM 64KB (for BIOS) RAM 512KB (for MPEG)	
7	Data Transfer Speed	Max. 8MB/sec, max. 4MB/sec while MPEG is in operation	
8	LED	Flashes according to CD operation status	

Table 3.11 CD Drive Specifications

No	Item	Specifications	Remarks
1	CD Play	Track/Index designation play Frame address (in absolute time) designation play Play restarts (Cancels pause, controls pick-up movement) Repeat play able to control CD-DA and CD-ROM by commands of identical format Scan regeneration Retrieve subcode	
2	Other	Corresponds to Multi-session Corresponds to Emphasis Decode and error correction corresponding to CD-ROM XA (Subheader recognition, ECC process, Read retry process)	

Functions

The main functions of the CD-ROM system are shown below.

- Stream select
- Parallel processing
- MPEG functions
  - -Video play
  - -Pause screen play (high detail, JPEG)
  - -Window function
  - -Visual effect function
    (mosaic, shading, Chroma key, fade in / fade out)
  - - play function
  - -Pause, freeze, frame feed, slow motion
  - -MPEG buffer function

CD-ROM system first stores data read from the CD-ROM to the CD buffer. The stored data reads/writes to the main system or MPEG in response to commands from the main system. Figure 3.29 shows the data flow of the CD-ROM system.

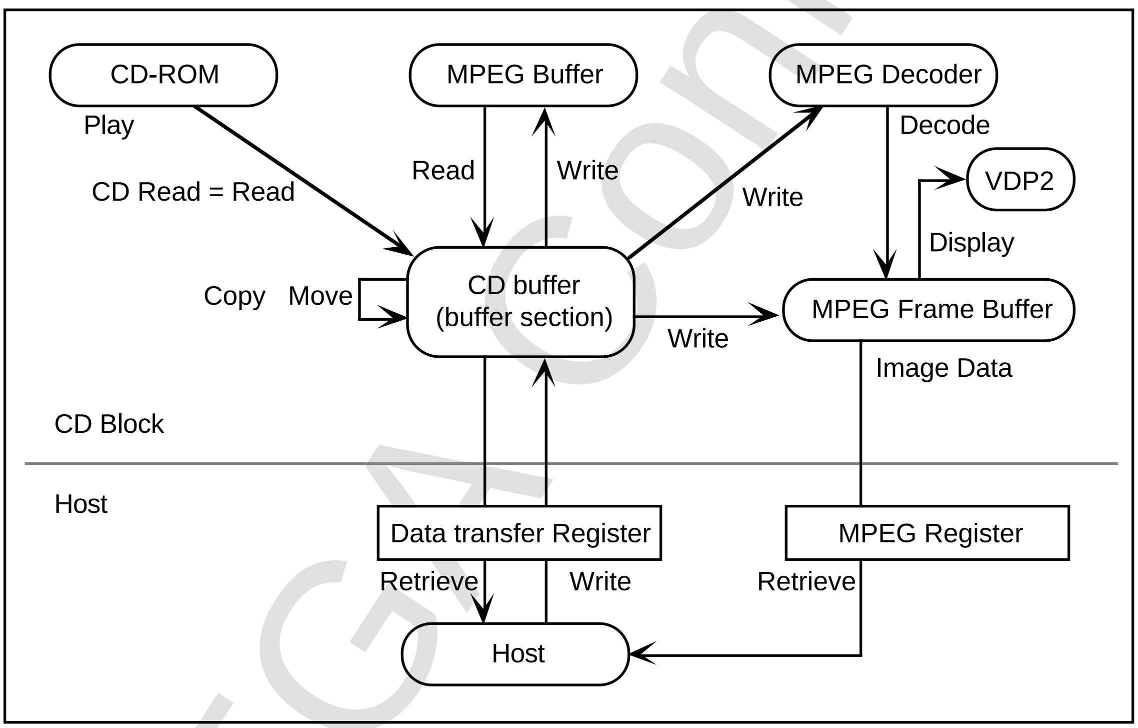
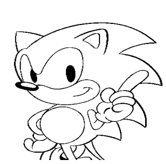


Figure 3.29 CD-ROM System Data Flow



Stream Select

Data flow from the CD-ROM is called a stream. A stream has audio data, image data, and program data. The stream select function selects the classification of data and sends it to the main system and MPEG (Figure 3.30). Control content of the stream select function is shown below.

- Stream data accumulates in the CD buffer and is selected in response to the data classification.
- Data from devices such as a CD-ROM and MPEG decoder are controlled uniformly.
- Stream select conditions are set by command.

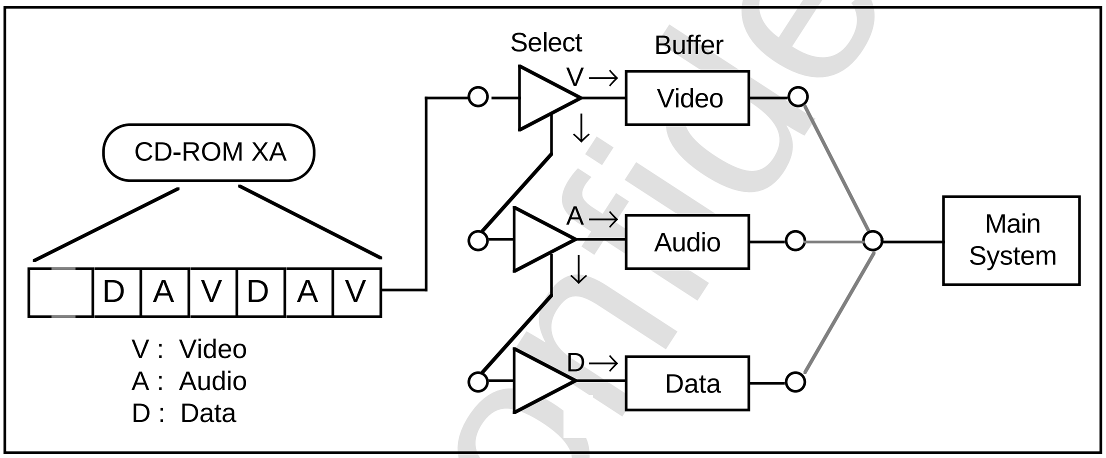


Figure 3.30 Stream Select Function

Parallel Processing

The CD-ROM system reads streams, it also selects streams and controls the CD drive independently of the main system. Further, parallel processing can be done since more than one stream selection mechanism is set.

MPEG Function

MPEG plays animation with sound added.
Image data is compressed to 1/50 and audio data is compressed to 1/10 before being played. Therefore, 74 minutes can be recorded on a CD. An exclusive LSI allows a game with animation (movie) of high image quality to be played without overloading the CPU.

MPEG / Video Function

Saturn's MPEG/Video has various special functions that are exclusively customized for Saturn.

Window Function

As shown in Figure 3.31, this function cuts out part of the image played and displays it at any size on the TV screen. This function allows the display position of the MPEG play image and display size to be changed, to select and display one of several screens, and zoom in, and zoom out.

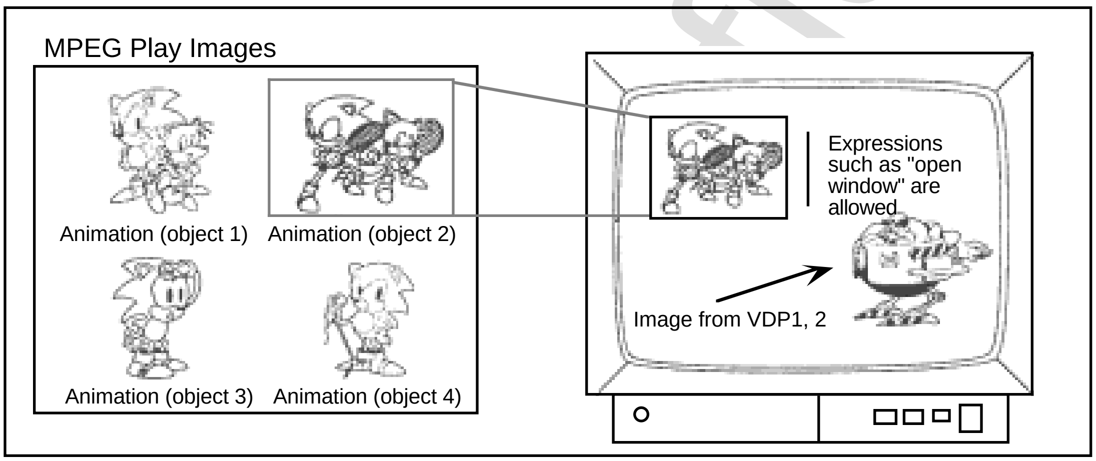
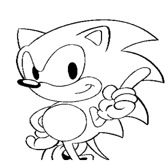


Figure 3.31 Window Function



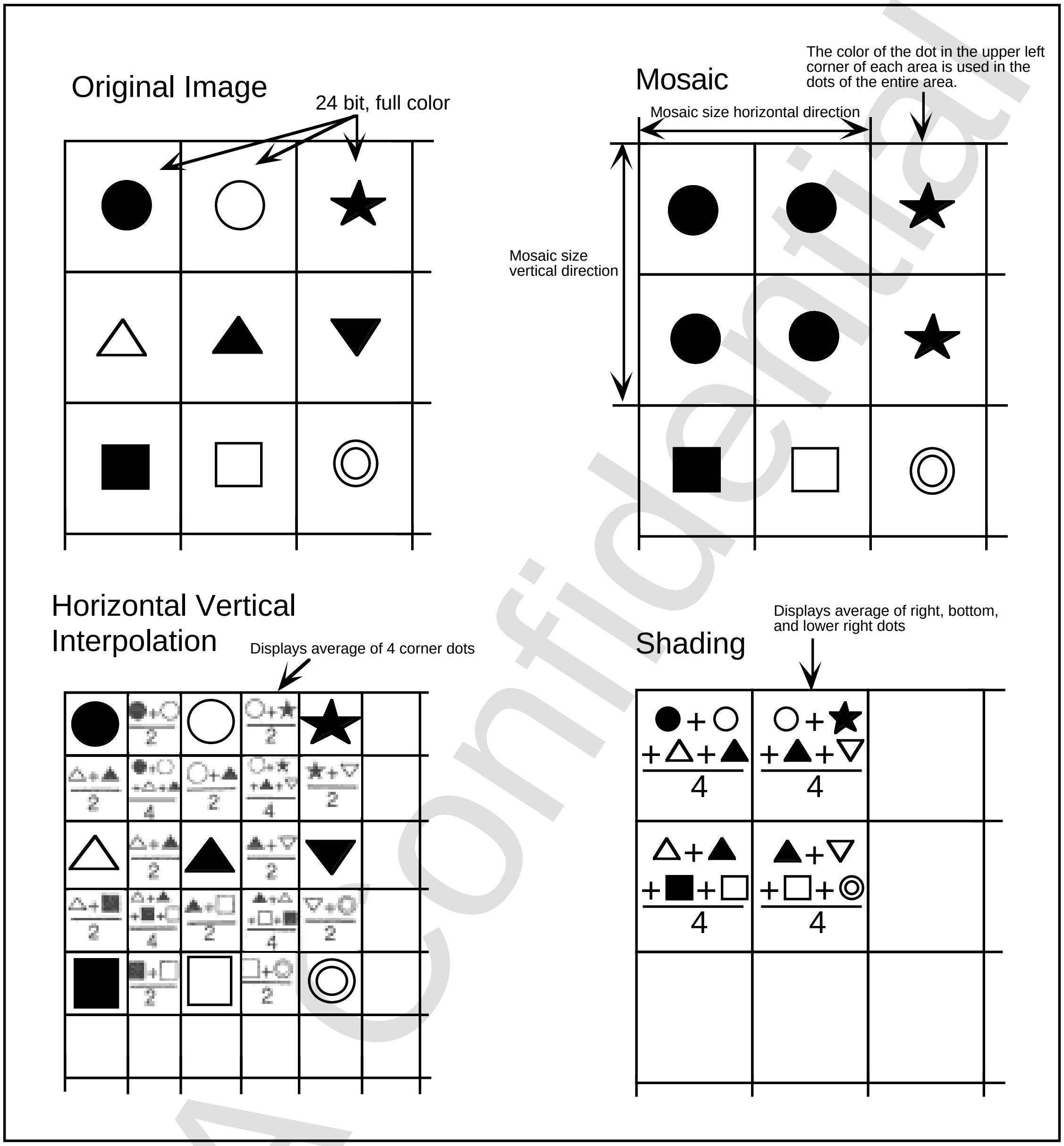


Figure 3.32 Interpolation, Shading, Mosaic Functions

Interpolation Function

The MPEG play image is a maximum 352 X 240 dots horizontally, while vertical interpolation can be displayed at a resolution of a maximum 704 X 480 dots to provide a smooth display with less flickering.

Shading Function

Displays a color data average of four dots that adjoin horizontally and vertically, and can produce a distant background shading effect.

Mosaic Function

The MPEG play image is divided horizontally, vertically, and at a designated size. The color of the dot in the upper left of each area indicates the color of all dots in that area. Horizontal and vertical can be independently designated up to a full screen size.

Fade Function

This is a display function that gives magnification to the coloring signal and screen brightness, and is used for fade-in and fade-out. Because this isn't a method of adding and subtracting offset values, only the brightness can be correctly changed. Further, by changing the coloring signal, the monochrome display or displayed color can be deepened.

Chroma Key

As shown in Figure 3.33, this function plays animation that has transparent dots. The chroma key is a technique of filming an object in front of a blue background, taking out all parts that are not blue, then placing those parts in a separate picture. MPEG animated images can be used only on background with the existing MPEG LSI, but the chroma key function lets Saturn superimpose and display MPEG animated images on sprite and scrolls.

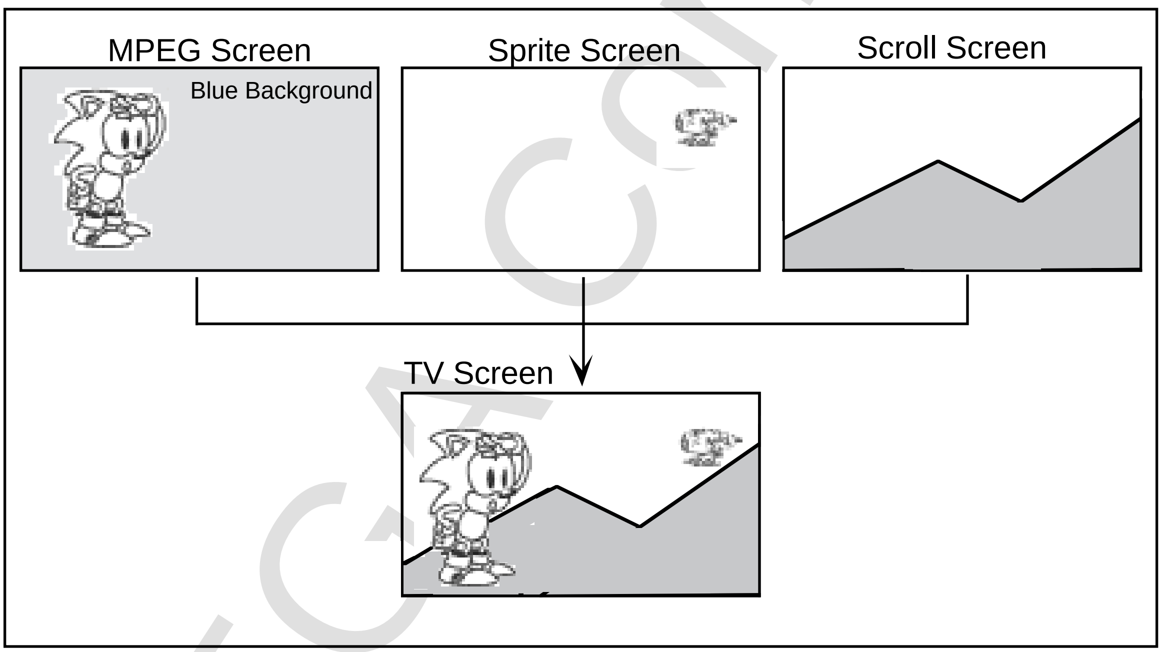


Figure 3.33 Chroma Key Function

Screen Retrieve Function

Animated images played by MPEG are retrieved to the main system by this function, and are handled as sprites, used as texture data, and displayed using the VDP1 and VDP2 functions. Furthermore, this function playing of multiple animations.

The amount of MPEG animated data is 50 times the amount of data from a CD, and because the transfer speed is faster than the transfer speed from a CD buffer, this function can be used to rewrite texture data at high-speeds.

High Detail Pause Function

This function displays a 704 x 480 dot high detail pause screen. Full color high detail images cannot be displayed by the main system (full color is up to 352 x 240 dots), but if the high detail pause function is used, an image with Saturn's maximum number of color can be displayed.

Pause Function, Freeze Function

The pause function can pause the animation at any frame, and can run in slow motion as well as frame by frame.

The freeze function memorizes animation at any frame (image memory) and allows strobe playback.

Branch Play Function

MPEG accumulates compressed image data in the CD buffer memory and plays animation during CD seek (track search). As a result, animation will continue playing even when jumping to another animation track. The screen will not pause as with LD.

In MPEG, the branch playback where branch point cannot be determined is achieved. Furthermore, loop play, which repeats the same animation, can be done.

MPEG / Audio Function

Audio data played by MPEG/Audio is sent to the SCSP by the same path as a CD-DA (Music CD), and can perform various effects.

Variable Compression Rate

The compression rate can be selected in response to the use; you can choose from a compression of 1/3.5 ~ 1/21. If the 1/21 compression is used, 50 hours of audio can be recorded on a CD. Even with huge RPG and ADV, all dialogue and narration can be performed with audio.

On Memory Play Function

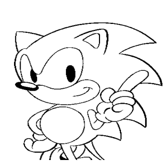
MPEG / Audio can compress to 1/3.5 ~ 1/21. When using half of the 4 Mbit of CD buffer memory for MPEG/Audio by using a compression of 1/21, 64 seconds of audio can be played without accessing the CD. As a result, audio play can be done without waiting. Furthermore, several short dialogues can be connected for long conversations.

Corresponding Standards

Table 3.12 shows the standards that correspond to the CD-ROM system.

Table 3.12 Corresponding Standards

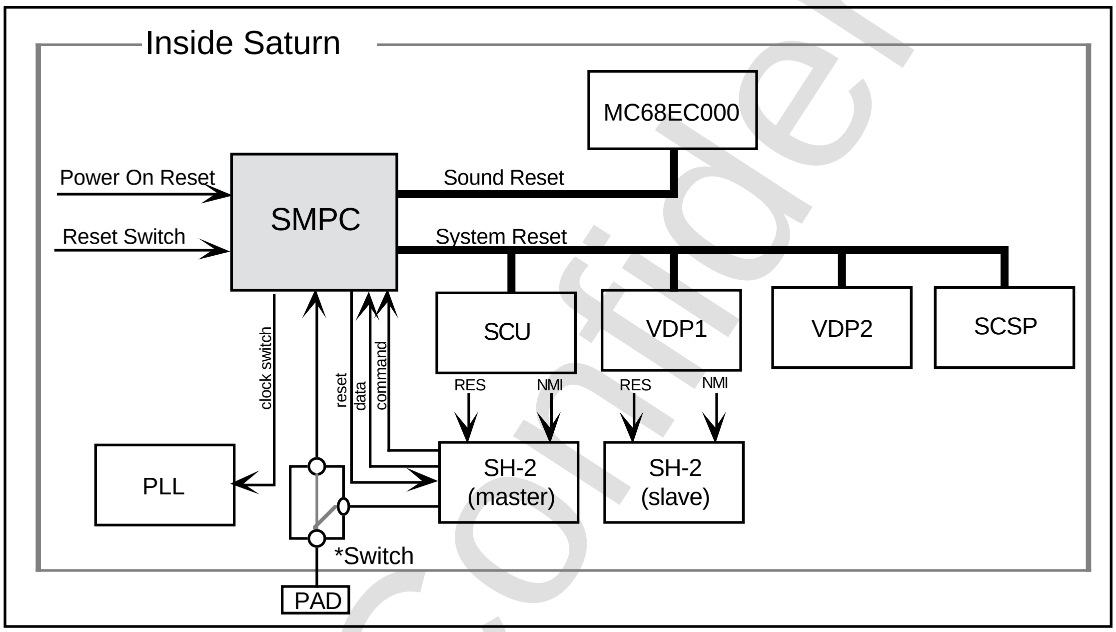
Standard	Description
CD-DA	The standard name of sound entered on a CD is base on the REDBOOK international standard. Sampling frequency 44.1 KHz, quantumization bit 16-bit stereo.
CD-G, CDEG	Records data such as graphics data in the music CD format area. Employs 16 color display and CD-DA sound quality.
CD-ROM	The standard has been established to enable recording of computer data with the same physical format as a music CD (CD-DA). Based on YELLOW BOOK international standard.
CD-ROM XA	This is an expanded CD format with a record format that makes possible interleave recording for concurrent playing of video and audio.
EB (electronic book)	CD-ROM software record format that is employed by the Sony Data Discma (electronic book player).
Photo-CD	System that displays photographs through a monitor such as a television. Up to 100 photographs can be recorded on a CD; the same photograph ca be enlarged and reduced.
Video CD (Karaoke CD)	Records video that has been compressed by MPEG. A maximum of 74 minutes can be recorded on a CD, and a maximum of 2000 high detail pa pictures can be played.



3.7 Other Items

SMPC

SMPC resets the entire Saturn system when the reset button is pressed or the power turned on. The command from SH-2 turns on or off the peripheral LSI inside of Saturn, sets and retrieves the calendar and time, and collects data from peripherals. The clock change command switches between a horizontal resolution of 320 or 352 dots.



(* Peripheral I/O terminal can be directly controlled from the SH-2 side.)

Figure 3.34 SMPC System Configuration

Functions

The main functions of SMPC are shown in Table 3.13.

Table 3.13 SMPC Functions

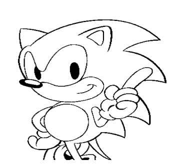
RTC (Real Time Clock)	• Sets and retrieves time and date form SH-2 • Battery back-up function • Automatically revises the date, day of the week, hour/minutes/seconds.
SM (System Management)	• ON/OFF of Sound CPU • ON/OFF of master SH-2 and slave SH-2 • Controls system reset • Switches clocks (PLL switch) • Power ON reset • When Saturn is ON, Saturn system is reset bypressing the reset switch.
PC (Peripheral Control)	• Automatically collects peripheral data such ascontrol pad and mouse. • Supports Megadrive and Genesis peripherals (3 button, 6 button, 4 player adapter, mouse).

PAD

Table 3.14 shows the digital PAD specifications for Saturn.

Table 3.14 Saturn Digital PAD Specifications

PAD Type	Specifications
Saturn Standard PAD	Buttons: up, down, left, right, A, B, C, X, Y, Z, L, R, start.



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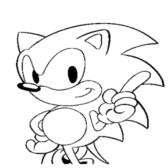

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