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(11/2/94- 002)

SGL Developer's Manual

Tutorial

SEGA SATURN

Development Environment

This manual describes the hardware and software development environment required for SEGA Saturn software development. The recommended environments for programmers, designers, sound designers, and the network are each described individually. Read each section and procure the materials and tools needed in order to create each environment.

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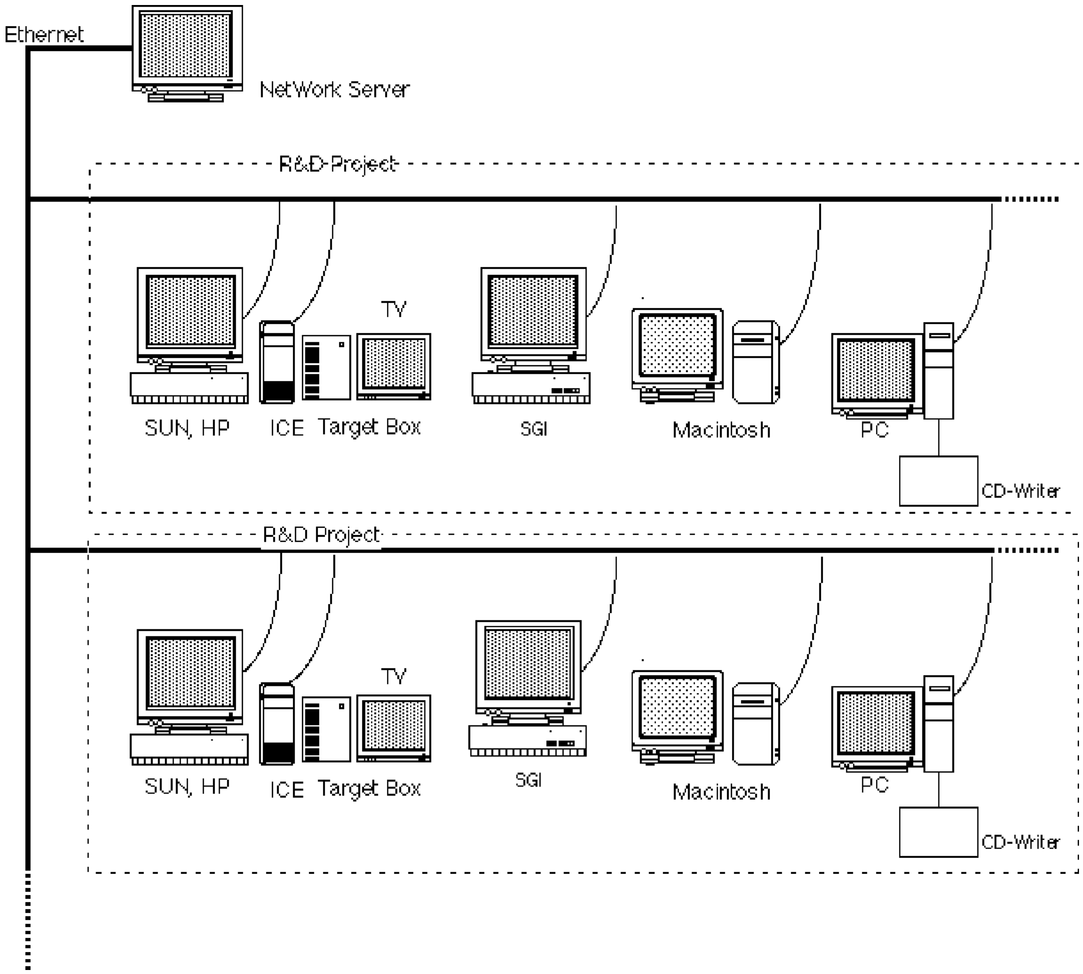
SEGA’s Recommended Development Environment

Fig 1 SEGA’s Recommended Development Environment



SEGA recommends a development environment similar to the one shown in the figure.

In this integrated environment linked together by a network, a Sun or Hewlett-Packard workstation serves as the development host, while a Silicon Graphics, Macintosh, or other system is used by the designers, with an additional Macintosh for the sound design work.

Development Environment for Programmers

The following tables give suggestions and recommendations for the hardware and software systems needed for development work.

Table 1 Hardware Configuration

Tool	Model	Remarks
Development host	☆ Sun Sparc	32MB or more of RAM, 500MB or more of hard disk storage, SUN-OS 4.1.1 or later, X11R4 OPEN Window
	HP9000/700	32MB or more of RAM, 500MB or more of hard disk storage, HP-UX 8.0.5 or later, OSF Motif
	IBM-PC compatible	486 CPU (66 MHz), 8MB or more of RAM, 300MB or more of hard disk storage, MS-DOS 5.0 or later, MS-Windows 3.1
Debugger	☆ E7000 + LAN board	Ethernet type
Development target	☆ Target Box	Connect TV monitor to target in order to check video.

☆: Product recommended by SEGA

Table 2 List of Language Tools for Development Work

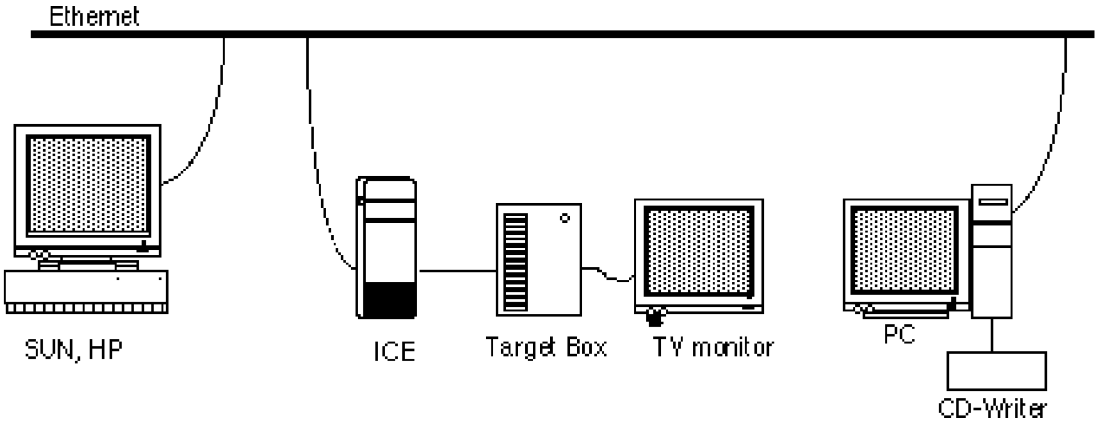
Tool	☆ Hitachi Revised C	Remarks
Compiler	SH-2C compiler	Used by the SEGA Graphics Library
Assembler	SH-2 cross assembler	
Linker	Linkage editor	Used by the SEGA Graphics Library
Debugger	GUI debugger	Used by the SEGA Graphics Library
DSP tool	Assembler, simulator	Provides a DSP library for matrix operation DMA transfers

☆: Product recommended by SEGA

Based on the products marked with stars in the previous charts, SEGA's recommended development environment is as follows.

Hitachi's Revised C compiler is used for the development language. A Sun, Hewlett-Packard, or equivalent UNIX workstation serves as the development host in the network environment, and is connected via an ICE to a target box with TV monitor. A configuration diagram follows.

Fig 2 SEGA's Recommended Hardware Environment for Programmers



The explanations provided subsequently in this manual will assume that the above configuration is being used.

Development Environment for Designers

There are a number of conceivable hardware configurations for designers to do development work. However, for design work, the specific software used is much more important than the hardware. Therefore, the following table indicates representative products for each of the different essential tools, and also indicates the type of system on which that software can run.

Table 3 List of Representative Tools for Designers

Tool	Compatible System		Product Name	Remarks
	SGI	Mac		
3D tool	✓		☆ Softimage Creative env.	Product recommended by SEGA
2D tool	✓	✓	☆ Adobe Photoshop	Product recommended by SEGA
	✓	✓	Adobe Illustrator	
		✓	Pixel Paint Professional	
	✓	✓	☆ Degitaizer	Tool provided by SEGA
Data filter		✓	☆ DeBebelizer	Product recommended by SEGA
	✓	✓	Adobe Photoshop	

☆: Product recommended by SEGA

In addition to the above, SEGA also provides SMAP, which is software that adds texture to 3D models.

SEGA recommends the following development environment.

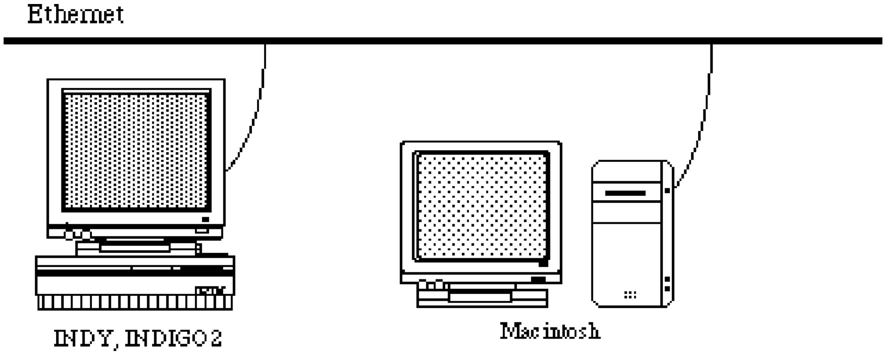
In terms of hardware, a Silicon Graphics machine, such as INDY or INDIGO2, could be used for the 3D tool, and a Macintosh could be used for the 2D tool, all running under one network. The hardware configuration diagram and specifications are shown below for reference purposes.

Table 4 List of SEGA's Recommended Hardware for Designers

Tool	Model	Remarks
Development host	☆ INDY, INDIGO2	R4400SC CPU recommended, 64MB or more of RAM, 1GB or more of hard disk storage, 24-bit full color (and equipped with a geometry engine, if possible)
	☆ Macintosh	68040 CPU recommended, 16MB or more of RAM, 100MB or more of hard disk storage, 24-bit full-color video card (not needed if host provides a full-color environment)

☆: Product recommended by SEGA

Fig 3 SEGA’s Recommended Hardware Environment for Designers



For software, the products marked with a star in the previous chart are recommended by SEGA.

The explanations provided subsequently in this manual will assume that the above configuration is being used.

Development Environment for Sound Designers

Although names of typical software products that are representative of basic minimum of required tools are listed later, because there are a countless number of models for the different hardware devices needed for sound design work, the following table lists categories of devices and the essential functions required in each category.

Table 5 List of Hardware for Sound Designers

Category	Remarks
Macintosh	Centris 650 or higher, 16MB of RAM or more, and 500MB or more of hard disk storage recommended
MIDI instrument	Music keyboard, etc., with a MIDI-OUT jack
MIDI sound source	A device that can be connected to a Macintosh in order to listen to music created with sequencer software (a device that can not be connected to a Macintosh but which can connect to a MIDI interface is also possible)
Sampling source	A CD player or DAT is required. (If using SEGA's Wave editor, a unit with an optical output is required.)
Development target	An amp and headphones, etc., so that it is possible to listen to the sounds. (It is also probably necessary to hook up a TV so that the sound of the game through the TV speaker can also be checked.)

The target box connects to the Macintosh system, MIDI sound source, amp, etc., as well as to the DAT deck or CD player to be used for voice and music sampling. (If the Audio Media 2 board is to be connected, it connects to the Macintosh.)

Fig 4 SEGA's Recommended Hardware Environment for Sound Designers

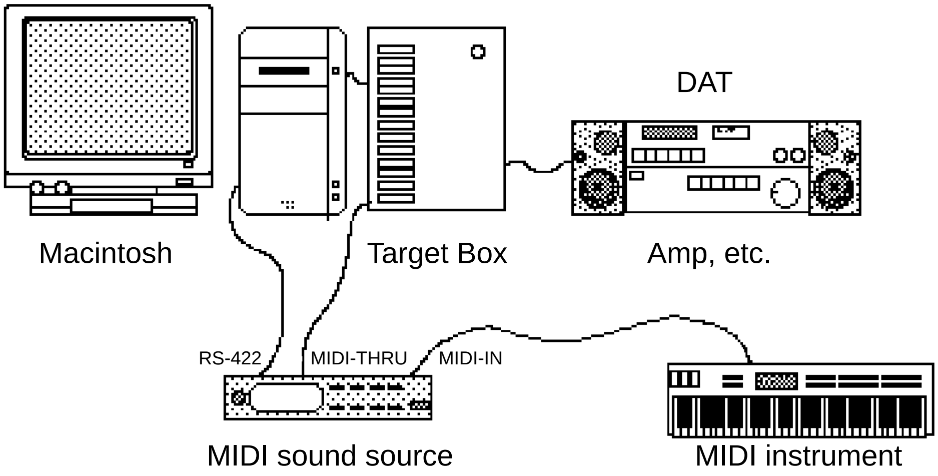


Table 6 List of Software for Sound Designers

Tool	Product	Remarks
Waveform editor	☆ SOUND DESIGNER 2	Also handles sounds sampled from an Audio Media 2 board in a Macintosh
	Alchemy	
	Wave Editor	Tool provided by SEGA (can output sound directly from the target)
Tone editor	Tone Editor	Tool provided by SEGA
Sequencer	☆ Vision	
	Cubase	
	Performer	
Effector	Linker	Tool provided by SEGA
Simulator	SATURN SndSim	Tool provided by SEGA

☆: Product recommended by SEGA

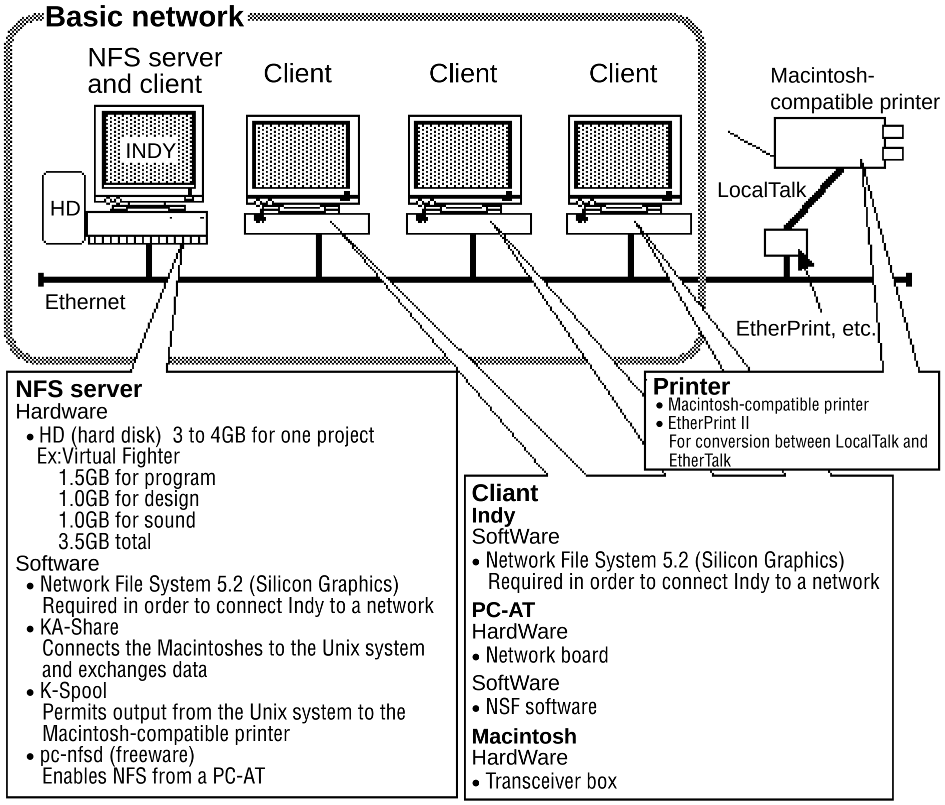
Network Environment

Once the development systems described up to this point for the programmers, designers, and sound designers are linked by a network, software development can begin. The network environment depends on the number of people working on the project (i.e., the number of machines on the network). The details of the network configuration (server and clients) and the costs of constructing the network are described below separately for each case, according to the number of people involved.

NFSH server/client network environment (for 3 to 6 people)

In the following environment, an Indy system functions as both a server and a client.

Fig 5 NFSH Server/Client Network Environment (for 3 to 6 people)



NFS server
Hardware
- HD (hard disk) 3 to 4GB for one project
  Ex:Virtual Fighter
  1.5GB for program
  1.0GB for design
  1.0GB for sound
  3.5GB total

Software
- Network File System 5.2 (Silicon Graphics)
  Required in order to connect Indy to a network
- KA-Share
  Connects the Macintoshes to the Unix system and exchanges data
- K-Spool
  Permits output from the Unix system to the Macintosh-compatible printer
- pc-nfsd (freeware)
  Enables NFS from a PC-AT

Printer
- Macintosh-compatible printer
- EtherPrint II
  For conversion between LocalTalk and EtherTalk

Cliant
Indy
SoftWare
- Network File System 5.2 (Silicon Graphics)
  Required in order to connect Indy to a network

PC-AT
HardWare
- Network board

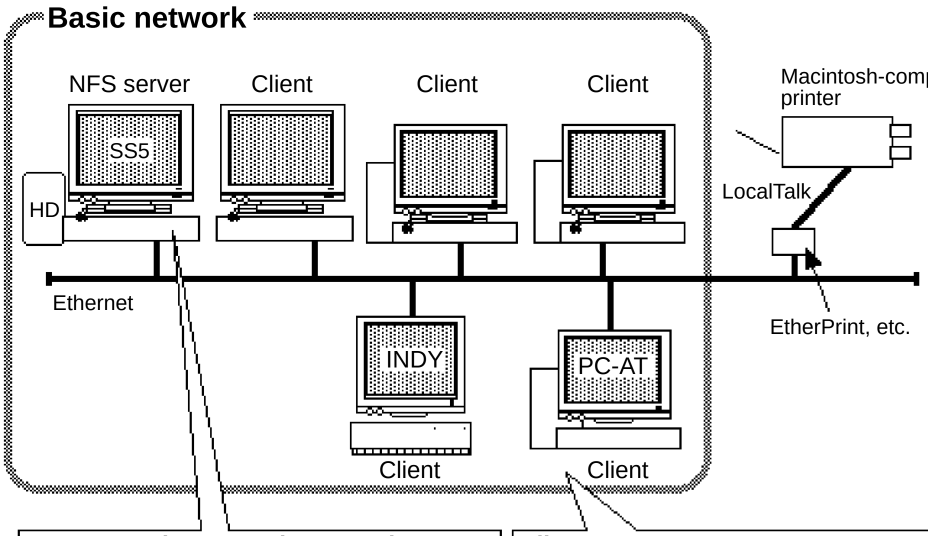
SoftWare
- NSF software

Macintosh
HardWare
- Transceiver box

Dedicated server network (for 7 or more people)

In this network, a SparcStation 5 or similar workstation functions as a dedicated server, and the performance of the server is enhanced by using an Ether/SCSI board.

Fig 6 Dedicated Server Network (for 7 or More People)



NFS server (SparcStation 5, etc.)

Hardware

- Memory
  64MB or more
- PrestoServ (NFS board)
  Uses hard disk cache to improve NFS performance
- SCSI/Ether board (*)
  Extends capabilities of Ethernet and SCSI bus
  Ethernet: Improves Ethernet performance through segment partitioning
  SCSI: Improves hard disk performance through connection to multiple SCSI buses
- HD (hard disk)
  3 to 4GB for one project
  Ex: Virtual Fighter
  1.5GB for program
  1.0GB for design
  1.0GB for sound
  3.5GB total

Software

- KA-Share
  Connects the Macintoshes to the Unix system and exchanges data
- K-Spool
  Permits output from the Unix system to the Macintosh-compatible printer

(*) Not really needed if network is configured for only 7 to 15 people.

Client

Indy

Software

- Network File System 5.2 (Silicon Graphics)
  Required in order to connect Indy to a network

PC-AT

Hardware

- Network board

Software

- NSF software

Macintosh

Hardware

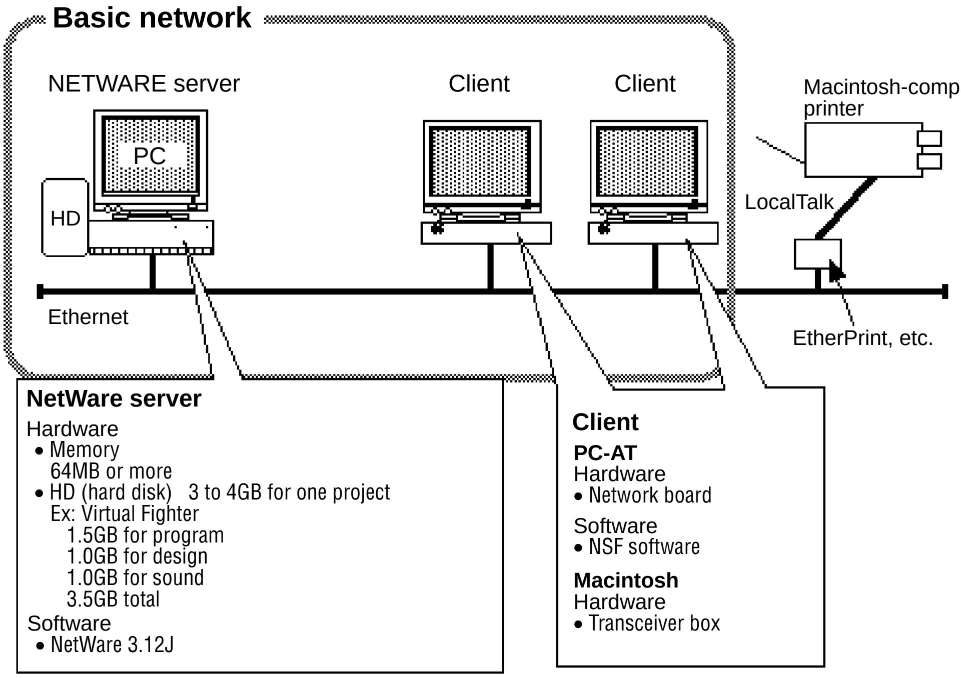
- Transceiver box

PC-AT and Macintosh network environment

An efficient network environment can be constructed using a NetWare server.

***NetWare is well-suited to both the Mac and to the PC-AT (Windows, etc.).**

Fig 7 PC-AT and Macintosh Network Environment



NetWare server

Hardware
- Memory
  64MB or more
- HD (hard disk) 3 to 4GB for one project
  Ex: Virtual Fighter
  1.5GB for program
  1.0GB for design
  1.0GB for sound
  3.5GB total

Software
- NetWare 3.12J

Client

PC-AT

Hardware
- Network board

Software
- NSF software

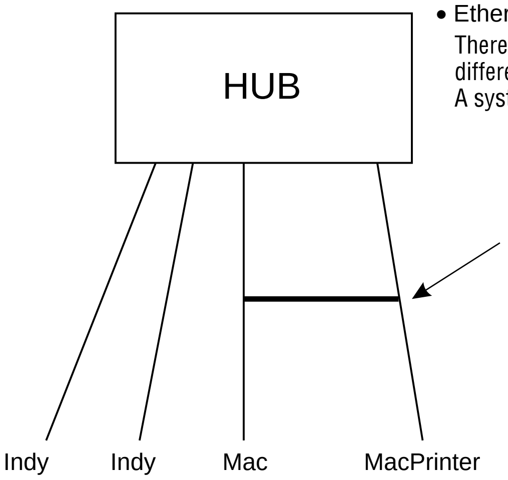
Macintosh

Hardware
- Transceiver box

Connection methods

The network connection methods differ as shown below, depending on the number of machines in the network.

Fig 8 Connection Using One Hub (8 to 16 Machines)



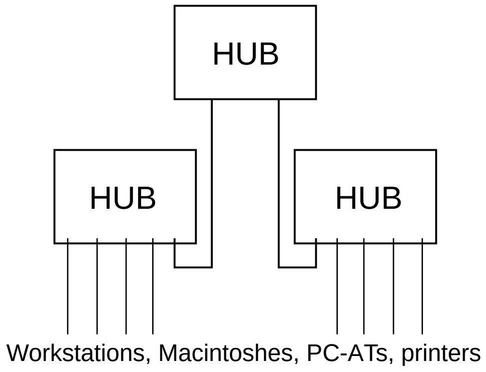
- Ethernet hub

  There are a variety of different types available from different manufacturers (8 ports, 16 ports, etc.).
  A system costing ¥60,000 to ¥90,000 should be sufficient.

- 10BASE-T (twisted-pair cable)

  Currently the most widely used type of Ethernet cable.
  Can be used with most workstations.
  Indy: Standard
  SS5: Standard
  PC-AT: Requires 10BASE-T Ethernet board
  Macintosh: Requires 10BASE-T transceiver box

Fig 9 Connection Using Two or More Hubs (for More Than 16 Machines)



Appendix: Hardware Costs

Hardware Costs

[Servers]

Indy (IRIX5.2)

Software

• KA-Share (dit Co.)	233,000 (2 users) ~
• K-Spool (dit Co.)	220,000
• pc-nfsd (freeware)	0

SparcStation 5 (Solaris 2.3), etc.

Hardware

• Main unit (memory: 64MB)	2,012,000
• PrestoServe	630,000
• SCSI/Ether board	230,000

Software

• KA-Share (dit Co.)	233,000 (2 users) ~
• K-Spool (dit Co.)	220,000

NetWare server

Hardware

• Main unit	300,000

Software

• NetWare 3.12J (Novell)	190,000 (5 users)
	390,000 (10 users)
	630,000 (25 users)
	950,000 (50 users)

[Clients]

Macintosh

Hardware

• Transceiver box	?

PC-AT

Hardware

• Network board NE2000 (Novell)	4

Software

• NFS software PC/TCP2.3 (Allied Telesys)	5

[Hubs]

• 8 ports to 16 ports	6~

[Printers]

Hardware

• Main unit MICROLINE-803PSII	648,000
• EtherPrint EtherPrintII	128,000

NFSH server/client network environment (for 3 to 6 people)

Indy (IRIX5.2)

Software

〈 KA-Share (dit Co.)	233,000 (2 users) ~
• pc-nfsd (freeware)	0
Total:	233,000 ~

Printer

Software (required if the server is a UNIX server)

• K-Spool (dit Co.)	220,000

Hardware

• Main unit MICROLINE-803PSII	648,000
• EtherPrint EtherPrintII	128,000
Total:	986,000

PC-AT and Macintosh network environment

NetWare server

Hardware

• Main unit (486DX4-99MHz)	500,000

Software

• NetWare 3.12J (Novell)	190,000 (5 users) 390,000 (10 users) 630,000 (25 users) 950,000 (50 users)
Total:	690,000 (5 users)

Printer

Software (required if the server is a UNIX server)	
• K-Spool (dit Co.)	220,000
Hardware	
• Main unit MICROLINE-803PSII	648,000
• EtherPrint EtherPrintII	128,000
Total:	986,000

SEGA SATURN

Programmer's Tutorial

The SEGA Saturn Programmer's Tutorial is designed to teach programmer's all that they need to know in order to develop 3D software for the SEGA Saturn system.

This manual assumes that the SEGA Graphics Library (SGL) will be used for programming, and explains the necessary steps involved in 3D software development by using sample programs. This manual also provides a basic overview of 3D software, and is designed to be understood even by programmers with no experience in programming 3D software.

Although this manual is written with 3D software programming in mind, much of the information contained within can also be applied to conventional 2D games.

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Flow Charts

1

Programmer’s Tutorial

SEGA 3D Game Library

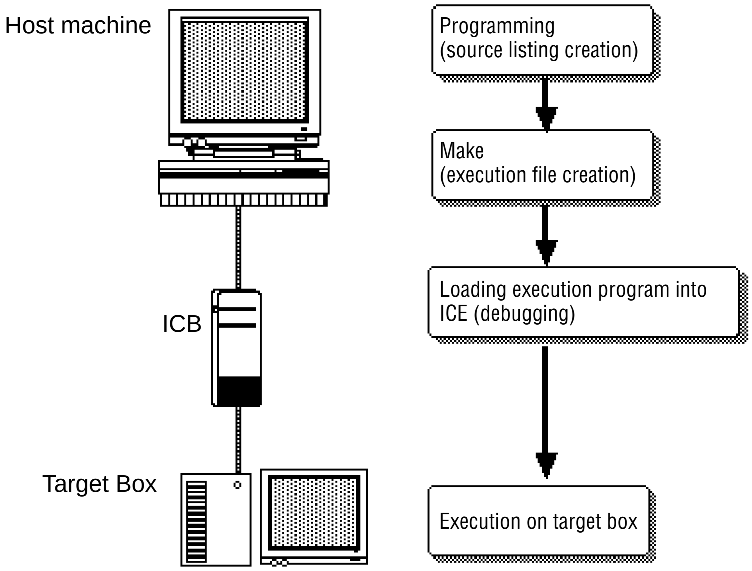
The SEGA 3D Game Library (SGL) is a function library capable of 3D graphics control that is provided for developers of software for the SEGA Saturn system. Each function in the library (especially the functions in the operation library), makes fast processing possible, since they are based on algorithms designed by programmers who are experts in the processing capabilities of the Saturn system.

This chapter explains the procedure for software development using the SEGA 3D Game Library, and also describes points that need to be observed when using the SGL.

Flow of Programming Work

The following diagram illustrates the flow of programming work in SEGA Saturn software development using the SGL.

Fig 1-1 Flow of Programming Work


Host machine
ICB
Target Box
Programming
(source listing creation)
Make
(execution file creation)
Loading execution program into
ICE (debugging)
Execution on target box

Host machine

The host machine is used for the programming work, compiling, debugging, etc.

Make

This step entails the creation of the execution format file, including the compiling work.

ICE

This device emulates the SH2, the main CPU in the SEGA Saturn system. The operation of the program that was created can be checked by loading the execution program into the ICE.

Debugging

The debugger can be used during program loading, during execution, and at the source level.

Target box

This device can be connected to the ICE, and is functionally equivalent to the SEGA Saturn system.

*** For details on the use of the ICE or the debugger, refer to their respective manuals:**

- **HITACHI E7000 SH7604 Emulator**
- **SEGA SH7604 E7000 Graphical User Interface Software**

Host machine settings

The following two points are essential for the host machine environment settings. These settings either must be made in the “.cshrc” or “.tcshrc” scripts, or must be made in scripts of your own creation.

1) Add a path for the debugger in the path environment variables.

   Example:

   ```
   set path=($path /usr/local/lib/sh2/GUI)
   ```

2) Set three environment variables for the SHC library path, the debugger help path, and the ICE address.

Fig. 1-2 Environment Variable Settings

● Environment variables ●

```
setenv   SHC_LIB       <library path>
setenv   SH76GIHOST    <IP address>
setenv   HELPPATH      <help path>
```

ICE settings

A number of initial settings are required in order to connect the ICE and the host machine, such as the network ID and registering the host machine. This process is described below.

1) Connecting the ICE with a terminal

- Eject the ICE floppy disk.
- Set DIP switch S8 on the rear of the unit to “OFF.” (Facing the rear of the unit, flipping the switch to the left turns it off.)
- Connect a notebook computer, etc., to the ICE via the RS-232C interface. (A CRT must be connected to the E7000 side.)
- Start up the terminal software on the personal computer.

*** When using Wterm:**
After making the various settings, press the [Control] + [GRAPH] + [S] keys simultaneously to complete the connection process. If the various settings have not been made, it is necessary to coordinate the ICE and Wterm settings. For details on the ICE settings, refer to page 29 of the ICE Emulator User’s Manual.

2) Setting the IP address (network ID)

- Once connection is successfully completed, the following message is displayed:

```
START ICE
S: START ICE
R: RELOAD & START ICE
B: BACK UP FD
F: FORMAT FD
L: SET LAN PARAMETER
T: START DIAGNOSTIC TEST
(S/R/B/F/L/T)?
```

- After the message is displayed, inputting “L” causes the following message to appear:

```
IP ADDRESS = X.X.X.X
```

- Input the address to be set. for example:

```
IP ADDRESS = X.X.X.X .123.456.78.987
```

After input is complete, turn off the power. The address setting process is now complete.

3) Registering the host machine

- Connect the network.
- Set DIP switch S8 on the rear of the unit to “ON.” (Facing the rear of the unit, flipping the switch to the right turns it on.)
- Turn on the power for the ICE.
- Execute the “telnet” command on the workstation. For example:

```
telnet 157.109.50.120
```

or,

```
telnet [host name|IP address]
```

- When the message “(file name/return)?” is displayed, press [Return].
- Input the following at the “:” prompt. A list of registered workstations will appear.

```
LAN_HOST;S
```

(It is also possible to input just “lh;s”; this will appear on the screen as “llhh;;ss”.)

- When “PLEASE SELECT NO?” is displayed, select the number (01 to 09) that you either want to register a new host under or that you want to make a change to.”
- Input the host name (the name of the workstation that will control the ICE).
  Ex.:

```
01 HOST NAME SUN214 ?SUNXXX
```

Host name of host machine to be used

- Input the IP address of the host.

  Ex.:

```
01 IP ADDRESS 157.109.50.14 ? 157.109.50.47
```

Host IP address

- After all input is complete the following message appears:

```
PLEASE SELECT NO? . [RET]
```

- Press the [ctrl] + []] (right square bracket) keys to terminate the “telnet” command.
- When the “telnet>” prompt appears, input “quit”.
- Turn off the ICE power.
- Insert the floppy disk in the ICE and restart the ICE.

The ICE setting process is now complete.

Setting up and executing the Make file

Make generates a series of commands to be executed by the Unix shell according to a file (called a “Make file”) that describes a series of procedures and rules. Because the Make command permits effective control of the relationships among related files, it eliminates, for example, the need to recompile all of the source files if a change is made in just one of several source files.

SGL uses its own special Make file. When the Make command is executed, the source program groups specified in this file are compiled, so that the execution file is generated automatically.

*** These Make files must be located in the same level of the directory hierarchy as the source files.**

When a user creates a new application, it is necessary to modify the Make file accordingly. For details on the Make function and its format, consult one of the references available from other sources.

Reference: make (Keigaku Shuppan; Andrew Olam and Steve Talbot)

Debugger startup and initial settings

The Hitachi E7000 ICE is controlled by software with a special graphical user interface (GUI). This software is called “the debugger” in this manual. This section explains the procedure for starting up the debugger and making the initial settings.

1) Turn on the power, first for the ICE, and then for the target box. (Reverse this sequence when turning off the power.)
2) Creating the files needed for automation

   Create the two files “gish” and “PRESET” in the current directory.

   gish

   ```
   gish76 PRESET
   ```

   PRESET

   ```
   HOST <machine host name> <log-in name> <password>
   RS
   G
   ```

Setting up these files makes it possible to automate the following tasks:

- Setting the HOST NAME, USER NAME, and PASSWORD in the HOST dialog box.
- Resetting the target
- Because “gish” is executed as a shell script, first use the “chmed tx gish” to set the execution authority.

3) Debugger startup

   Input “gish” on the host machine and press [Return] to start up the debugger. During the startup process, when the following message appears and the system waits for input, click inside the window to enable key input and then press the [Return] key.

   ```
   (file name/return)?
   ```

   Once the target is reset and the initial screen is displayed, click on “STOP”.
4) Loading the initial program

   Type in “g400”; when the screen disappears, click “STOP”.
5) Settings for development work (disabling interrupts)

   From the VIEW menu, select REGISTER; the Register dialog box appears.

   Input “000000f0” in the Status Register (SR), and click “ENTER”.

   *** This setting is for development purposes, and is required only in order to use the ICE; it is not required in the software to be actually released.**

Loading and executing a program

This section describes how to load an execution program into the ICE by using the debugger and then how to execute the program.

*** If an initialization file like “PRESET” as described in the preceding section is not to be used, select “HOST” from the FILE menu and enter the HOST NAME, USER NAME, and PASSWORD in the HOST dialog box. It is also necessary to input “rs [Return] g [Return]” in the debugger command area in order to reset the target box.**

1) Select “PROGRAM FILE” from the LOAD submenu under the FILE menu, and input the file path for the file name.
2) Click “LOAD”.

The execution program is now loaded.

*** If “tcsh” is used in the user log-in shell but “tcsh” is not registered in the “/etc/shells” file in the host machine, FTP will not operate and the execution program will not be loaded. For details, refer to a reference on FTP.**

3) Select “GO” from the EXECUTION menu.
4) Clock in the START ADDRESS input field in the GO dialog box, input “6004000”, select “order” from the pull-down menu for the START MODE button, and then click “Done”.

The execution program now begins executing.

Debugging

Displaying the source program

1) When “SOURCE DISPLAY” is selected from the VIEW menu, the SOURCE DISPLAY dialog box appears.
2) Click on the name of the program that you wish to display; the program name is then highlighted.

*** Each time the mouse button is clicked, the highlighted display area becomes larger; continue until the desired lines, including the path name, are highlighted.**

3) Click “DISPLAY”. (Doing so while the source program is loading or executing will generate an error. Either wait until the program finishes loading or stop the execution of the program so that the ICE is waiting for command input before clicking “DISPLAY”.)

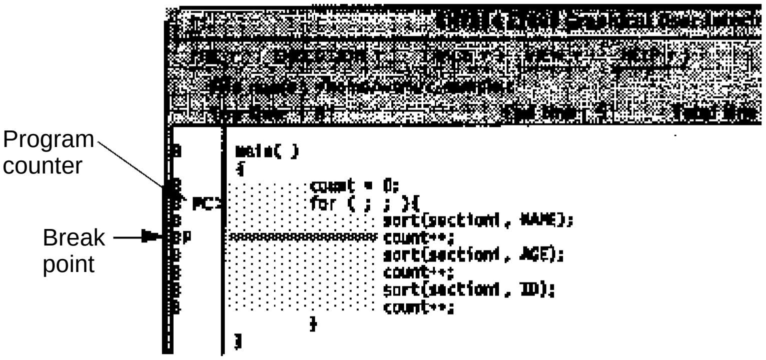
*** To close the dialog box, click “CANCEL”.**

Trace

The trace function can be used to trace the execution of the source program one step at a time.

1) After program execution, either after having clicked “STOP” or with the source program displayed as described above, double-clicking on the portion of the listing enclosed in the border in the diagram below causes the first part of those lines to be highlighted.

Fig 1-3 Trace from the Source Program



```
main( )
{
        count = 0;
        for ( ; ; ){
                sort(section1, NAME);
                count++;
                sort(section1, AGE);
                count++;
                sort(section1, ID);
                count++;
        }
}
```

2) Clicking “SET” here creates a break point [P].

   *** A break point cannot be established on a line that does not have a “B” at the head of the line.**

3) When “GO” is selected from the EXECUTION menu, the program counter [PC>] advances to the break point [P] and stops.

At this point, there are two methods for tracing execution of the program one step at a time.

- STEP: When execution jumps to a subroutine, execution of each step of the subroutine is also traced one step at a time.
- STEP_OVER: When execution jumps to a subroutine, execution of the entire subroutine is traced as a single step.

Notes on Using the Library

Values used in the library

Floating-point decimals are not supported in the SGL.

There are three variable types, each based on fixed-point decimals.

*** Because conversion from floating-point decimals to fixed-point decimals in the form of macro definition is supported, separate conversion by each individual is not required. (Refer to Table 1-1, "Examples of Numeric Type Conversion Macros.")**

Fixed-point decimals: Used for values for coordinate positions and trigonometric functions

Type name: FIXED

The high-order 16 bits are the integer portion, and low-order 16 bits are the decimal portion, for a total of 32 bits (signed)

Example: 16.5 is expressed as follows:

```
16.5 = 0x0010 8000
```

Decimal portion

Integer portion

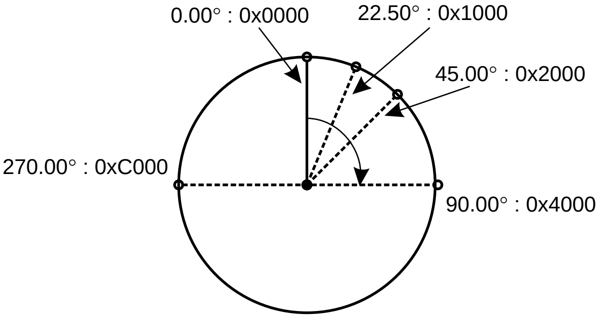
Note: The “0x” at the head of the FIXED format indicates hexadecimal notation.

Angles: Used in all angular expressions, such as angle of rotation.

Type name: ANGLE

360° are represented by 16 bits.

Fig 1-4 Angles as Represented in ANGLE Format



Matrices: Used for all matrix variables, such as conversion matrixes.

Type name: MATRIX

A 4-row x 3-column matrix in which the values are given in FIXED format (Refer to the following diagram for allocation in memory.)

Fig 1-5 Arrangement of Matrix Values in Memory

$$\begin{bmatrix} 1 , 0 , 0 \\ 0 , 1 , 0 \\ 0 , 0 , 1 \\ 0 , 0 , 0 \end{bmatrix} = \begin{bmatrix} \text{0x0001\_0000 , 0x0000\_0000 , 0x0000\_0000} \\ \text{0x0000\_0000 , 0x0001\_0000 , 0x0000\_0000} \\ \text{0x0000\_0000 , 0x0000\_0000 , 0x0001\_0000} \\ \text{0x0000\_0000 , 0x0000\_0000 , 0x0000\_0000} \end{bmatrix} \underset{\text{Store}}{=} \begin{bmatrix} M00 , M01 , M02 \\ M10 , M11 , M12 \\ M20 , M21 , M22 \\ M30 , M31 , M32 \end{bmatrix}$$

a) Original matrix

b) Matrix when converted to FIXED format

c) Arrangement of matrix values in memory

The table below lists the value conversion macros supported by SGL. SGL also supports a number of additional macros for specific purposes. The macros supported by SGL are defined in the header files "sgl.h" and "sl_def.h". (For details, refer to the "Structure Reference" in the Reference Manual.)

Table 1-1 Examples of Numeric Type Conversion Macros

Variable type	Macro name	Macro contents	Usage
FIXED	toFIXED(p)	((FIXED)((p) * 65536.0))	Converts values to FIXED format
ANGLE	DEGtoANG(d)	((ANGLE)(8d) * 65536.0 / 360.0))	Converts DEG-type angular values to ANGLE format
FIXED	POStoFIXED(X,Y,Z)	{toFIXED(x) , toFIXED(y) , toFIXED(z) }	Converts XYZ coordinates to FIXED format

Note: The macros are defined in the include files "sgl.h" and "sl_def.h".

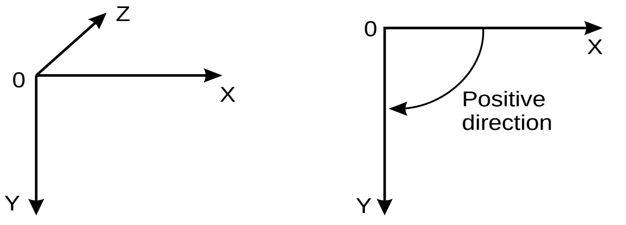
Note: The appropriate macros are used without notice in the sample programs included in these manuals.

Coordinate system

The "right-hand" coordinate system is used in the SEGA Saturn system.

In addition, angles in the positive direction when a rotation matrix is used rotate to the right from the axis.

Fig 1-6 Coordinate System Used in the SEGA Saturn System



a) Coordinate system used in the Sega Saturn system

b) Positive direction of rotation versus the Z axis

- When the positive direction on the Z axis points into the screen, the positive direction on the Y axis points to the obttom of the screen, and the positive direction on the X axis points to the right side of the screen.
- The positive direction of rotation around an axis is to the right.

2

Programmer's Tutorial

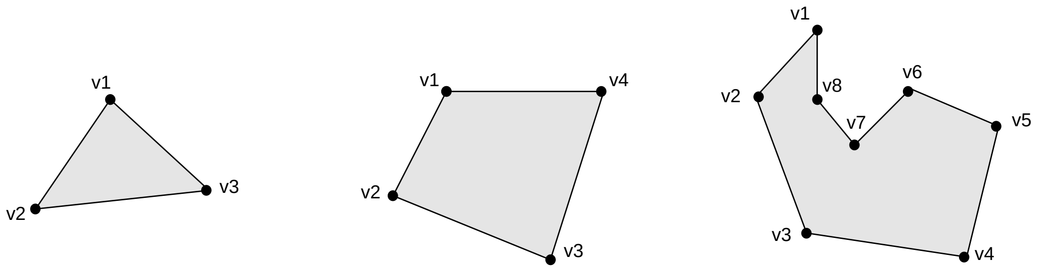
Graphics

This chapter describes the approach to polygons, a fundamental concept in 3D graphics, and the method for setting up polygons in SGL.

Polygons

A polygon is defined by three or more vertices ("v1, v2, v3, v4, ... vn") on a single plane. The polygon is the enclosed region that is obtained when v1 is connected to v2, v2 is connected to v3, v3 is connected to v4, and so on, until at the end vn is connected to v1. In general, the straight lines connecting the vertices are called "edges."

Fig 2-1 Examples of General Polygons



a) Polygon with three vertices a) Polygon with four vertices c) Polygon with 8 vertices

Note: The "•" are vertices, and the straight lines connecting them are edges.

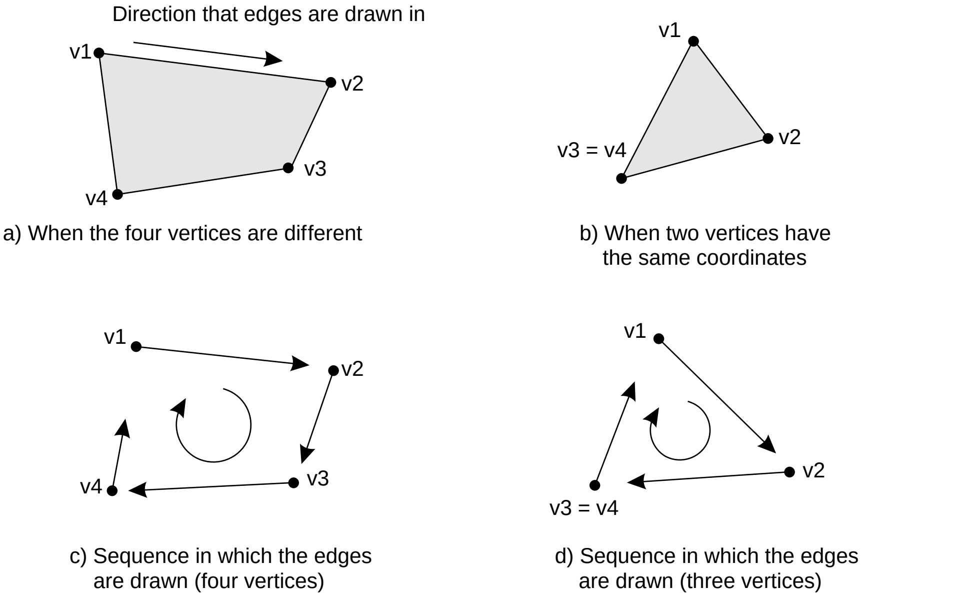
Although any shape with three or more vertices is a polygon, in general, polygons with three or four vertices are considered optimal. (SGL supports only polygons with four vertices.)

Polygons in SGL

SGL supports only polygons with four vertices. As a result, it is not possible to express polygons with three vertices or with five or more vertices. However, with SGL it is possible to draw a polygon that appears to only have three vertices by defining a polygon in which two of the four vertices have the same coordinates.

Edges are always drawn in the clockwise direction, without regard to the numbering of the vertices.

Fig 2-2 Examples of Polygons in the SEGA Saturn System


Direction that edges are drawn in
v1
v2
v3
v4
a) When the four vertices are different
v1
v2
v3 = v4
b) When two vertices have the same coordinates
v1
v2
v3
v4
c) Sequence in which the edges are drawn (four vertices)
v1
v2
v3 = v4
d) Sequence in which the edges are drawn (three vertices)

Note: The "•" are vertices, and the straight lines connecting them are edges.

In the SEGA Saturn system, polygons are drawn as painted regions on the screen. The procedure for drawing polygons is as follows:

1) Create list of coordinates for vertices.

2) Create list of faces of polygon.

3) Determine surface attributes for each polygon face.

4) Draw polygon on screen.

Using an actual drawing subroutine as a reference, the related functions and function parameters are explained next.

Polygon drawing subroutine

The library function “slPutPolygon” is used to actually draw a polygon with SGL. Although the function draws the polygon using the specified parameters, the display position and various transformation operations (rotation, parallel shift, and enlargement/reduction) conform with the current matrix.

[void slPutPolygon(PDATA*pat);]

This function draws the polygon defined by the data.

For the parameters, insert the start address of the region where the polygon data table (containing the polygon vertex data list, the number of vertices, the face list, the number of faces, and the face attribute data) is stored.

For details on the parameters, refer to “Parameters required for drawing a polygon” in the next section.

The following explanation is based on the sample program below.

In this sample program, after completing the preparations for drawing the polygon (initialization, setting of the coordinates and display angle, etc.), the hierarchical matrix concept (refer to chapter 5, "Matrices") is used to determine the polygon’s display position, display angle, enlargement/reduction ratio (not used here), and other attributes; the polygon is then actually drawn on the basis of that data.

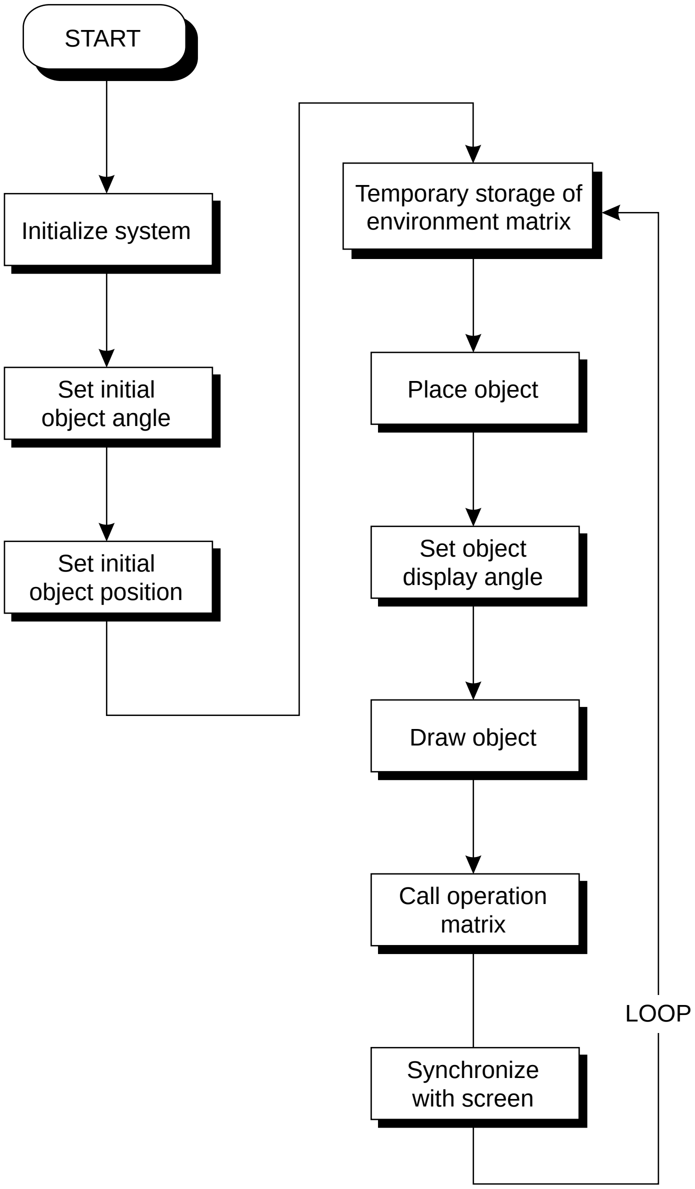
The library function “slPutPolygon(&PD_DATA);” is used to draw the polygon. The “&PD_DATA” within the parentheses is a variable that groups together all of the parameters required in order to display the polygon, and is defined within the data file “polygon.c” (refer to List 2-2, "polygon.c: Polygon Parameters").

List 2-1 for sample_2_2: Polygon Drawing Subroutine

```
/*-----------------------------------------------------*/
/*      Draw1Polygon
/*-----------------------------------------------------*/
#include        "sgl.h"                                        /* include file containing various settings */

exterm PDATA PD_PLANE1;

void main()
{
        static ANGLE ang[XYZ];
        static FIXED pos[XYZ];

        slInitSystem(TV_320x224,NULL, 1);                      /* system initialization */

        ang[X]=ang[Y]=ang[Z]=DEGtoANG(0,0);                    /* initial angle substitution */
        pos[X]=toFIXED( 0.0);                                  /* initial position substitution */
        pos[Y]=toFIXED( 0.0);
        pos[Z]=toFIXED(220.0);

        slPrint("Sample program2.2",slLocate(9.2));            /* title display */

        while(-1){
                slPushMatrix();
                {
                        slTranslate(pos[X],pos[Y],pos[Z]);     /* initial position setting */
                        slRotX(ang[X]);
                        slRotY(ang[Y]);                        /* initial angle setting */
                        slRotZ(ang[Z]);
                        slPutPolygon(&PD_PLATE1);              /* polygon drawing function */
                }
                slPopMatrix();

                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "polygon.c".

Flow Chart 2-1 sample_2_2: Polygon Drawing Flow Chart



Parameters required for drawing a polygon

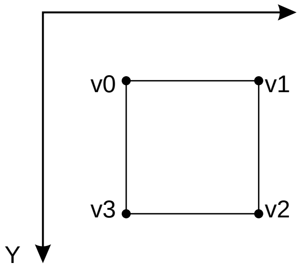
The following listing is the parameter group used for drawing the polygon that is read by the program as “polygon.c”. By changing the data here, it is possible to change the shape of the polygon, its size, the number of faces, its surface attributes, etc.

List 2-2 for polygon.c: Polygon Parameters

```
#include             "sgl.h"                                    /* include file containing various settings */

POINT point_PLANE1[]={                                          /* creation of vertex list */
        POStoFIXED(-10.0,-10.0,0.0),                            /* vertex coordinates (XYZ array) */
        POStoFIXED( 10.0,-10.0,0.0),
        POStoFIXED( 10.0, 10.0,0.0),
        POStoFIXED(-10.0, 10.0,0.0),
};
POLYGON polygon_PLANE1[]={                                      /* creation of face list */
        NORMAL(0.0,1.0,0.0),VERTICES(0,1,2,3),                  /* setting of normal vector (determines orientation of face */
};                                                              /* vertex number list selected for one face */

ATTRattribute_PLANE1[]={                                        /* creation of face attributes list */
        ATTRIBUTE(Dual_Plane,SORT_CEN,No_Texture,C_RGB(31,31,31),NO_Gouraud,MESHoff,sprPolygon,No_Option),
};

PDATAPD_PLANE1={                                                /* creation of data string for drawing function */
        point_PLANE1,sizeof(point_PLANE1)/sizeof(POINT),        /* vertex list, number of vertices */
        polygon_PLANE1,sizeof(polygon_PLANE1)/sizeof(POLYGON),  /* face list, number of faces */
        attribute_PLANE1                                        /* face attribute list */
};
```

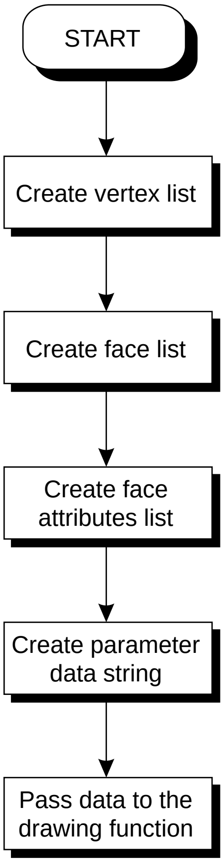
Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".

Fig 2-3 Drawing Model Based on “polygon.c”



Note: Because the right-handed coordinate system is used,
the positive direction of the Z axis points into the screen.

Fig 2-4 Parameter Data String Creation Procedure


START
Create vertex list
Create face list
Create face attributes list
Create parameter data string
Pass data to the drawing function

- Vertex ID numbers, "0, 1, 2, 3, 4,...n", are automatically assigned to the vertices in the sequence in the vertex list, starting from the top.
- For each face of the polygon, four points are selected by their vertex numbers from the vertex list and are then used to create the polygon face list. In addition, when using light sources, etc., the normal vector for each face is also set.
- The attributes for each polygon face are determined in the order of the face list, starting from the top. The attributes include not only the polygon color, but also other settings such as the surface processing method.
- The number of vertices is calculated on the basis of the vertex list, and the number of faces is calculated on the basis of the face list, and the results are added to a new list. This list is passed to the drawing function as the polygon parameters.

The polygon data creation procedure is explained below, based on the data string that is created.

[Vertex list creation: POINT point_<label name>[]]

This is the list of initial coordinates for the polygon vertices. An ID number, “0, 1, 2, 3, 4,...n”, is automatically assigned to each vertex in the order they appear in the list, starting from the top.

Variable name: POStoFIXED(vertex_x,vertex_y,vertex_z),
This variable shows the coordinates of each vertex. Floating-point decimals can be substituted for the coordinates by using the macro “POStoFIXED”. (“POStoFIXED” is an SGL-supported macro.)

[Face list creation: POLYGON polygon_<label name>[]]

This creates a list of the polygon faces and normal vectors on the basis of the vertex list.

Variable name: NORMAL (vector_x,vector_y,vector_z),
This variable defines the normal vector for each face. The normal vectors are used to indicate the orientation of the polygon face, and consists of a unit vector that is perpendicular to the polygon face.

The parameters consist of the XYZ values that express the orientation of the respective normal vector, and the normal vector must always be specified as a unit vector.

Variable name: VERTICES (v1,v2,v3)
This is a list of which vertices in the polygon list are to be used to form the polygon face. The number of selected vertices is always four. However, a three-sided polygon (a triangle) can be displayed, but only if the third and fourth vertex numbers are the same.

The vertex numbers have no relation to the sequence in which the vertices are connected by the edges. The edges are always connected in the clockwise direction, starting from the first vertex in the list.

[Face attribute list creation: ATTR attribute_<label name>[]]

This sets the polygon face attributes for each face in the sequence of the face list. For details on the contents of the settings, refer to Chapter 7, “Polygon Face Attributes.”

Variable name: ATTRIBUTE (plane, sort, texture, color, gouraud, mode, dir, option),
This variable sets the polygon face attributes. There are eight parameters: front/back determination, Z sorting, texture, color, gouraud processing, drawing mode, sprite reversal processing, and options. (For details, refer to Chapter 7, “Polygon Face Attributes.”)

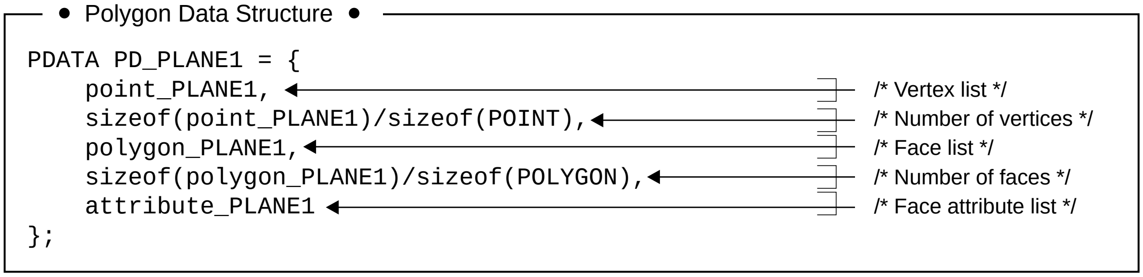
[Drawing function data string parameter creation: PDATA PD_<label name>]

This creates the data structure used to pass the polygon data settings as parameters to the library function “slPutPolygon”.

Variable names: vertex list, number of vertices, face list, number of faces, and face attribute list
These create the data string that is actually passed to “slPutPolygon”.

Here, the number of vertices and the number of polygon faces are newly calculated on the basis of information such as the vertex list, and are added to the parameter data string.

Fig 2-5 “PDATA PD_<label name>” Parameters



● Polygon Data Structure ●

```
PDATA PD_PLANE1 = {
    point_PLANE1,                                   /* Vertex list */
    sizeof(point_PLANE1)/sizeof(POINT),             /* Number of vertices */
    polygon_PLANE1,                                 /* Face list */
    sizeof(polygon_PLANE1)/sizeof(POLYGON),         /* Number of faces */
    attribute_PLANE1                                /* Face attribute list */
};
```

Combining Multiple Polygons

It is impossible to use just one polygon to express most shapes. This section explains the method for creating data for objects consisting of multiple polygons.

Creating cubes: Sample _3_2

To create a cube, it is necessary to set up an object with eight vertices and six polygon faces as the parameter values.

This can be expressed in SGL by changing the contents of the parameter setting data file “polygon.c” (described earlier) in the manner shown below.

In the listing, first a list of the eight vertices of the cube is created, and then a list of the six faces defined by these vertices is created. After determining the face attributes of each surface, all of the data is stored in the parameter data string “PD_PLANE”. When this data string is passed to the drawing function “slPutPolygon” as the polygon parameters, a cube is drawn on the screen.

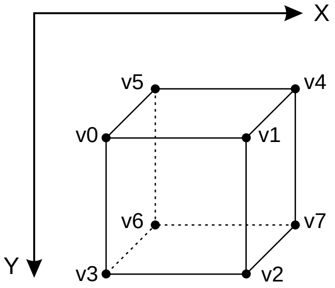
List 2-3 shows an example of creating data from a cubic polygon.

List 2-3 for polygon.c: Cubic Polygon Parameters

```
#include "sgl.h"

POINT point_plane[]={                                          /* creation of vertex list */
        POStoFIXED(-15.0,-15.0,-15.0),                         /* vertex coordinates (XYZ array) */
        POStoFIXED( 15.0,-15.0,-15.0),
        POStoFIXED( 15.0, 15.0,-15.0),
        POStoFIXED(-15.0, 15.0,-15.0),
        POStoFIXED(-15.0,-15.0, 15.0),
        POStoFIXED(-15.0, 15.0, 15.0),
        POStoFIXED( 15.0, 15.0, 15.0),
};
POLYGONpolygon_plane[]={                                       /* creation of face list */
        NORMAL(0.0,0.0,-1.0),                                  /* setting of normal vector (determines orientation of face */
        VERTICES(0,1,2,3),                                     /* vertex number list selected for one face */
        NORMAL(1.0, 0.0, 0.0)
        VERTICES(1, 4, 7, 2),
        NORMAL(0.0, 0.0, 1.0),
        VERTICES(4,5,6,7),
        NORMAL(-1.0, 0.0, 0.0),
        VERTICES(5,0,3,6),
        NORMAL(0.0, -1.0, 0.0),
        VERTICES(4,1,0,5),
        NORMAL(0.0,1.0,0.0),
        VERTICES(2,7,6,3),
};
ATTR attribute_plane[]={                                       /* creation of face attributes list */
        ATTRIBUTE(Dual_Plane,SORT_MAX,No_Texture,C_RGB(31,31,31),No_Gouraud,MESHoff,sprPolygon,No_Option),
        ATTRIBUTE(Dual_Plane,SORT_MAX,No_Texture,C_RGB(31,00,00),No_Gouraud,MESHoff,sprPolygon,No_Option),
        ATTRIBUTE(Dual_Plane,SORT_MAX,No_Texture,C_RGB(00,31,00),No_Gouraud,MESHoff,sprPolygon,No_Option),
        ATTRIBUTE(Dual_Plane,SORT_MAX,No_Texture,C_RGB(00,00,31),No_Gouraud,MESHoff,sprPolygon,No_Option),
        ATTRIBUTE(Dual_Plane,SORT_MAX,No_Texture,C_RGB(31,31,00),No_Gouraud,MESHoff,sprPolygon,No_Option),
        ATTRIBUTE(Dual_Plane,SORT_MAX,No_Texture,C_RGB(00,31,31),No_Gouraud,MESHoff,sprPolygon,No_Option),
};
PDATACUBE={                                                    /* creation of data string for drawing function */
        point_plane,
        sizeof(point_plane)/sizeof(POINT),                     /* calculation of number of vertices */
        polygon_plane,
        sizeof(polygon_plane)/sizeof(POLYGON),                 /* calculation of number of polygon faces */
        attribute_plane
};
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".

Fig 2-6 Drawing Model Based on Parameters in List 2-3



Note: Because the right-handed coordinate system is used, the positive direction of the Z axis points into the screen.

The Polygon Distortion Problem

Sometimes a polygon may appear to be distorted. The distortion is frequently caused by calculation errors.

The fact that the polygon is originally specified as a three-dimensional object and is then subjected to transformation operations and projected on a two-dimensional screen is also sometimes a factor.

One type of distortion in which a true polygon (a polygon in which all of the vertices are in the same plane) can no longer be recognized occurs when a polygon is viewed “edge on,” in which case the polygon appears as a straight line.

Supplement. SGL Library Functions Covered in this Chapter

The functions listed in the following table were explained in this chapter.

Table 2-1 SGL Library Functions Covered in this Chapter

Function type	Function name	Parameters	Function
void	slPutPolygon	PDATA*pat	Drawing polygons (according to parameter settings)

3

Programmer’s Tutorial

Light Sources

This chapter describes the method for setting up light sources in SGL. Light sources can be used to create shadows for object groups displayed with 3D graphics, making it possible to increase the realism of images.

Light Sources

A description of a light source generally includes the following information:

1) Position of the light source

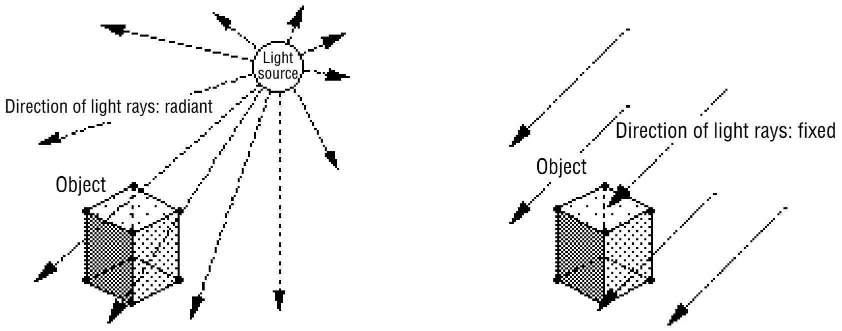
2) Intensity of the light

3) Color of the light

However, calculating all of this light source information and then using it accurately in drawing an object requires a tremendous amount of time. Therefore, in SGL, out of all of the light source information, only the effect of the direction of the light source is reflected in the drawing of images.

Furthermore, the direction of the light is normally defined as being radiated from a single point, but implementing this would also consume too much computing time. Therefore, in SGL, the position of the light source is assumed to be infinitely far away, so that the light is treated as always shining on an object from the same direction, regardless of the coordinates of the object.

Fig 3-1 Light Source Models


Light source
Direction of light rays: radiant
Object
Direction of light rays: fixed
Object

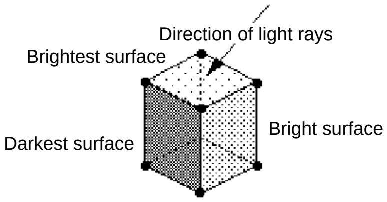
a) Normal light source modeling

b) Light source modeling in SEGA Saturn

Note: The intensity of the color of the polygon faces exhibits the ef fect of shadows

Changes in object surfaces due to light sources are determined by the direction of the light rays and the orientation of the normal vectors of each polygon surface. This modeling concept is illustrated below.

Fig 3-2 Shadow Modeling



Shadowing on polygon faces due to light source

- The color of the polygon faces changes according to the angle of incidence of the light.
- Colors are brighter the closer the angle of incidence is to perpendicular, and are darker the closer the angle of incidence is to horizontal.
- The color is darkest when the angle of incidence is negative and perpendicular

Setting up a Light Source

Use “slLight” to set up a light source with the SGL. The light source function only includes the direction vector (light source vector) that indicates the direction of the light rays, and does not include light intensity or color information.

[void slLight (VECTOR light);]

This function sets up the light source for the SGL.

For the parameters, substitute the VECTOR-type variable (light source vector) that indicates the direction of the light rays. Light source intensity and color information is not included in the parameters. In the SGL, light rays are defined as always coming from the direction specified by the direction vector. In addition, if light source calculations are not turned on in the object surface attributes, the shadows from the light source are not reflected in the image even if a light source is set up. (For details, refer to Chapter 7, “Polygon Face Attributes.”)

The color of polygon faces is determined by the angle of incidence of the light shining on the surface. Colors are brighter the closer the angle of incidence is to perpendicular, and are darker the closer the angle of incidence is to horizontal. The color is darkest when the angle of incidence is negative and perpendicular.

Note: Cautions concerning the establishment of light sources
When a polygon has been subjected to several transformation operations, such as scaling to the current matrix, the light source calculations may not be performed properly.
This happens because the user uses matrix operations for calculating the light source vector specified by the function “slLight”. Therefore, when setting up the light source, it is necessary to first initialize the current matrix.
Use either the “slPushUnitMatrix” function or the “slUnitMatrix” function to initialize the current matrix.

[Bool slPushUnitMatrix (void)]

Allocates space for a user matrix in the stack and makes it the current matrix. The previous current matrix is temporarily stored at the top of the stack.

[Bool slUnitMatrix (MATRIX mtptr)]

Makes the matrix specified by the parameter a unit matrix. Substitute the MATRIX-type variable to be specified for the parameter.

If “CURRENT” is specified for the parameter, the matrix that is the target of conversion becomes the current matrix, making it possible to initialize the current matrix.

For details on the current matrix and the matrix functions, refer to Chapter 5, “Matrices.”

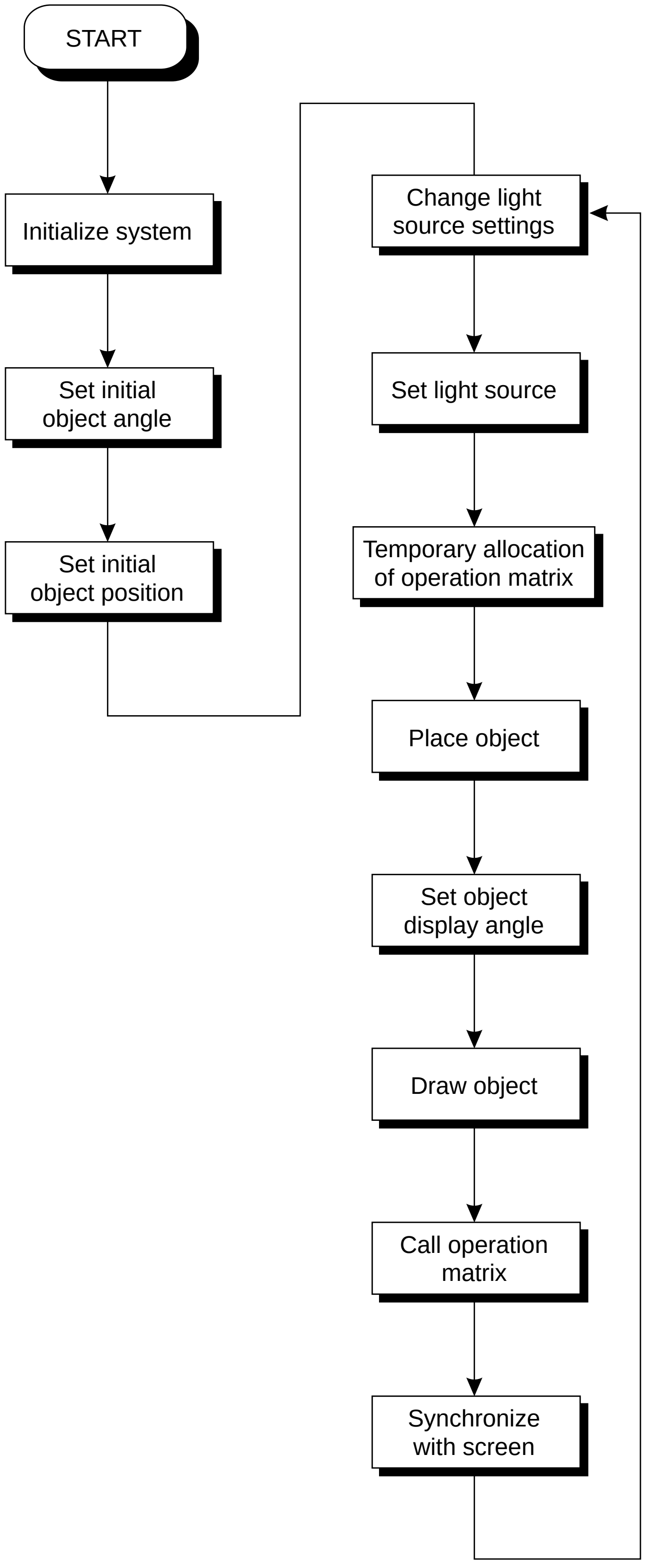
The following program “sample_3_2” demonstrates the changes in shadowing on the surfaces of a cube suspended in space when the light source direction vector is changed.

List 3-1 sample_3_2: Changes in Object Faces due to Movement of Light Source

```
/*-----------------------------------------------------*/
/*      Cube & A Light Source                           */
/*-----------------------------------------------------*/
#include        "sgl.h"                                     /* include file containing various settings */

exterm PDATAPD_PLANE1;

void main()
{
        static ANGLE ang[XYZ];
        static FIXED pos[XYZ];
        static FIXED light[XYZ];
        static ANGLE tmp=DEGtoANG(0.0);

        slInitSystem(TV_320x224,NULL,1);                    /* screen mode and other settings */

        ang[X]=DEGtoANG(30.0);                              /* initial setting of object angle */
        ang[Y]=DEGtoANG(45.0);
        ang[Z]=DEGtoANG(0.0);
        pos[X]=toFIXED( 0.0);                               /* initial setting of object position */
        pos[Y]=toFIXED( 0.0);
        pos[Z]=toFIXED(190.0);

        light[X]=toFIXED(-1.0);                             /* light source parameter setting */
        light[Y]=toFIXED(0.0);
        light[Z]=toFIXED(0.0);

        slPrint("Sample program3.2",slLocate(9.2);          /* title display */
        while(-1){
                slPushUnitMatrix();
                {
                        slRotY(tmp);                        /* light source parameter substitution */
                        slRotX(DEGtoANG(15.0));             /* Calculation of light source vector in terms of angles to each axis */
                        slRotZ(DEGtoANG(15.0));
                        slCalcPoint(toFIXED(0.0),toFIXED(0.0),toFIXED(1.0),light);
                }
                slPopMatrix();                              /* light source parameter substitution */
                slLight(light);                             /* light source setup */
                tmp+=DEGtoANG(1.0);                         /* changing light source setting variables */

                slPushMatrix();
                {
                        slTranslate(pos[X],pos[Y],pos[Z]);
                        slRotX(ang[X]);
                        slRotY(ang[Y]);
                        slRotZ(ang[Z]);
                        slPutPolygon(&PD_PLATE);            /* polygon drawing function */
                }
                slPopMatrix();

                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "polygon.c".

Flow Chart 3-1 sample_3_2: Flow Chart for Light Source Movement



Supplement. SGL Library Functions Covered in this Chapter

The functions listed in the following table were explained in this chapter.

Table 3-1 SGL Library Functions Covered in this Chapter

Function type	Function name	Parameters	Function
void	slLight	VECTOR light	Light source vector setting
Bool	slPushUnitMatrix	void	Store unit matrix in stack
void	slUnitMatrix	MATRIX mtptr	Convert specified matrix to unit matrix

4

Programmer’s Tutorial

Coordinate Transformation

This chapter explains the basic concepts of 3D graphics and the subroutines used to implement those concepts. In addition, this chapter will primarily cover the mathematical tool called “coordinate transformation.” Although the material in this chapter may be complex, since it will make frequent use of unusual tools such as matrix operations, it is important to study and understand this material thoroughly, since it covers the foundation of 3D graphics.

Objects displayed through 3D graphics are generally defined by the following four items:

Coordinate system: Determines the positioning and orientation of the object and the viewpoint.

Projection transformation: Defines how an image will appear when projected onto a surface.

Modeling transformation: Defines movement, rotation, and enlargement/ reduction within the coordinate system.

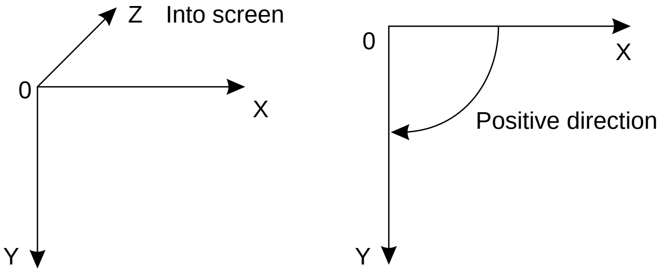
Viewing transformation: Defines the viewpoint and its movement. (For details, refer to Chapter 6, “The Camera.”)

In combination, these four elements make it possible to display an image in 3D on the monitor. In this chapter, the first three elements (but not viewing transformation) will be explained in sequence, followed by a more detailed explanation.

Coordinate System

In the SEGA Saturn system, a 3D coordinate system generally called the “right-handed coordinate system” is used. In this system, the positive direction on the Z axis points into the screen, the positive direction on the Y axis points to the bottom of the screen, and the positive direction on the X axis points to the right side of the screen. The positive direction of rotation is clockwise around an axis.

Fig 4-1 Coordinate System Used in the SEGA Saturn System



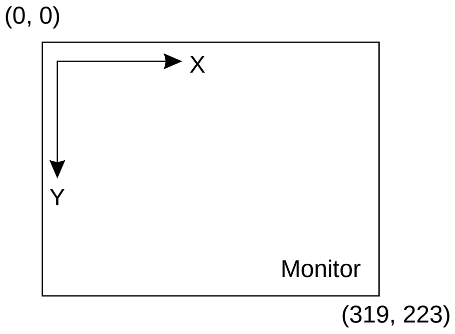
- When the positive direction on the Z axis points into the screen, the positive direction on the Y axis points to the bottom of the screen, and the positive direction on the X axis points to the right side of the screen
- The positive direction of rotation around an axis is to the right.

a) Coordinate system used in the SEGA Saturn system (right-hand system)

b) Positive direction of rotation versus the Z axis

In addition, SGL also has a 2D coordinate system called the “screen coordinate system” that corresponds with the resolution of the TV monitor and screen mode. Although this is primarily used for scrolling and for handling 2D graphics, such as sprites, it is also used to set up windows, as described "Windows."

Fig 4-2 Screen Coordinate System



Note: Although there are other resolutions this coordinate system is usually used in 320 × 224 (horizontal × vertical) mode

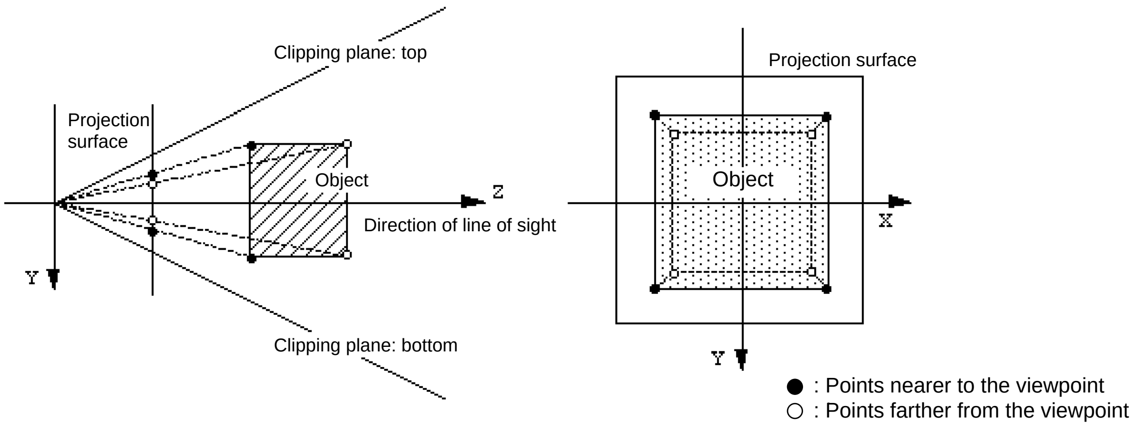
Projection Transformation

This section explains how the coordinates are expressed on the screen and also explains the projection setting method.

Projection with perspective

This section explains projection with perspective. After first establishing the viewpoint, the illustrations below depict the results of projection when there is a cube placed perpendicular to the line of sight on a line extending from that viewpoint.

Fig 4-3 Projection Concepts


Clipping plane: top
Projection surface
Object
Z
Direction of line of sight
Y
Clipping plane: bottom
Projection surface
Object
X
Y
● : Points nearer to the viewpoint
○ : Points farther from the viewpoint

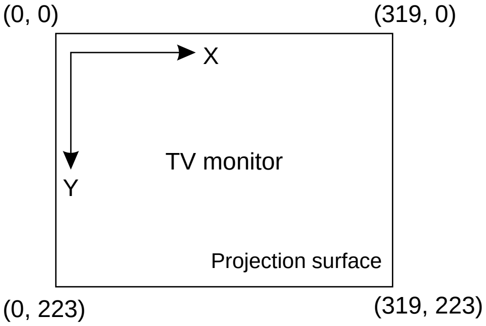
a) Projection with perspective (side view)

b) Projection with perspective (front view)

In projection with perspective, the image is defined as the image mapped onto a flat surface called the “projection surface.” The projection surface can be thought of as being similar to a movie screen.

The points where the line segments connecting the viewpoint with the points of the object intersect with the projection surface are where the points of the object are drawn. By performing this operation for all of the points of an object in a space, the space is drawn on the projection surface.

Fig 4-4 Projection Surface in SGL



- The monitor is represented as a collection of dots extending 320 pixels in the horizontal direction by 224 pixels in the vertical direction.
- Images are represented by changing the colors of these dots.
- Aside from its virtual 3D space coordinate system, SGL also has a 2D coordinate system that corresponds with the monitor screen.

Note: In the diagram, 320 × 224 screen mode is depicted

The projection surface in the SGL is the TV monitor screen. After an object group located in a virtual 3D space is projected with perspective, the image is mapped onto the screen coordinate system and is then drawn on the TV monitor.

Viewing volume

The range of space projected onto the projection surface is called the “viewing volume.”

In the case of the SGL, the parameters used to control the viewing volume are the perspective angle and the display level.

These two parameters are described below.

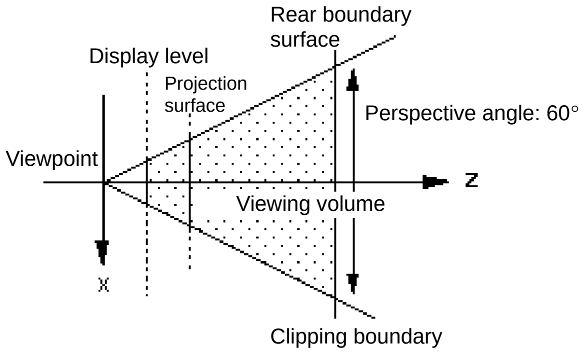
1) Perspective angle

The perspective angle is the parameter that describes the spread in the horizontal direction of the image to be projected on the projection surface.

If this volume is large, the density of the object projected on the projection surface becomes high, and the image appears as if viewed through a fish-eye lens.

Note that the spread of the image in the vertical direction is determined not only by the perspective angle but also by the resolution as defined by the screen mode.

Fig 4-5 Perspective Angle Concept

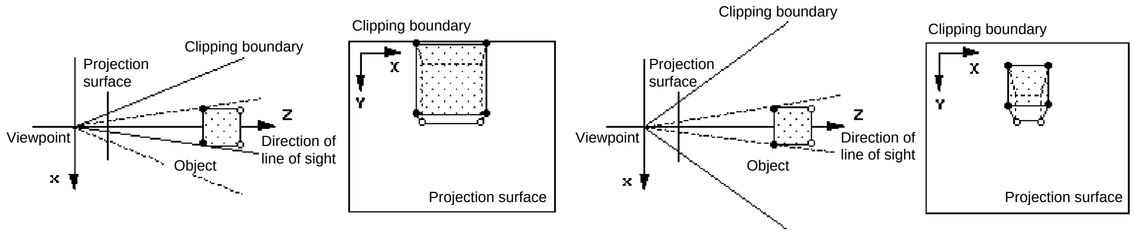


In the SGL, use the function “slPerspective” to change the projection with perspective settings.

[void slPerspective (ANGLE perspective_angle);]

By changing the function parameter, it is possible to control the volume of space that is projected on the projection surface. Substitute the angle that determines the volume of space to be projected (20 < angle < 160). If a value outside of the permitted range is inserted, an overflow error will occur.

Fig 4-6 Differences in the Image Caused by Perspective Angle



a) When perspective angle is small

b) When perspective angle is large

● Vertices that are closer to the viewpoint.

○ Vertices that are farther from the viewpoint.

2) Display level

The display level parameter determines the level to which the area behind the projection surface is to be projected onto the projection surface.

Objects with the projection surface behind them are projected on the projection surface by the same means as images far behind the projection surface.

The display level is set by using the function “slZdspLevel”.

The display level is determined by the position of the dividing point between the viewpoint to the projection surface beyond which objects are to be projected.

[void slZdspLevel (Uint16 level);]

Determines the display level of the viewing volume.

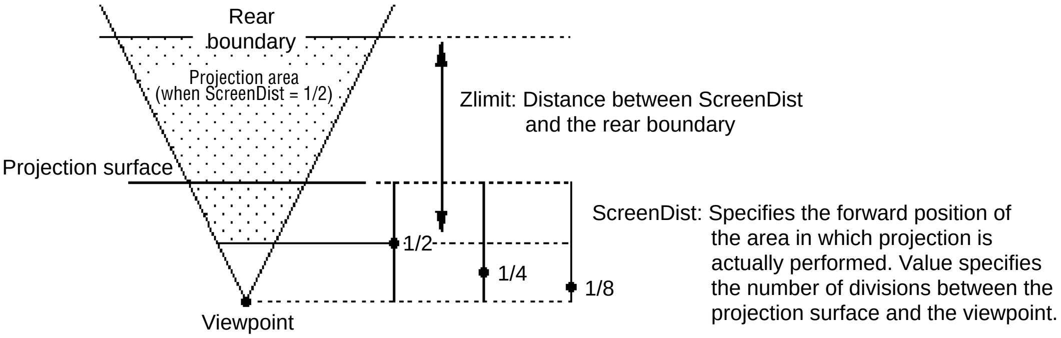
Substitute in the parameter the appropriate value from the following chart according to the display level.

Table 4-1 Display Level Substitution Values (level)

	Display level		
	1/2	**1/4**	**1/8**
Substitution value	1	2	3

The following diagram illustrates the display level concept.

Fig 4-7 Display Level


Rear boundary
Projection area (when ScreenDist = 1/2)
Projection surface
Viewpoint
Zlimit: Distance between ScreenDist and the rear boundary
ScreenDist: Specifies the forward position of the area in which projection is actually performed. Value specifies the number of divisions between the projection surface and the viewpoint.
1/2
1/4
1/8

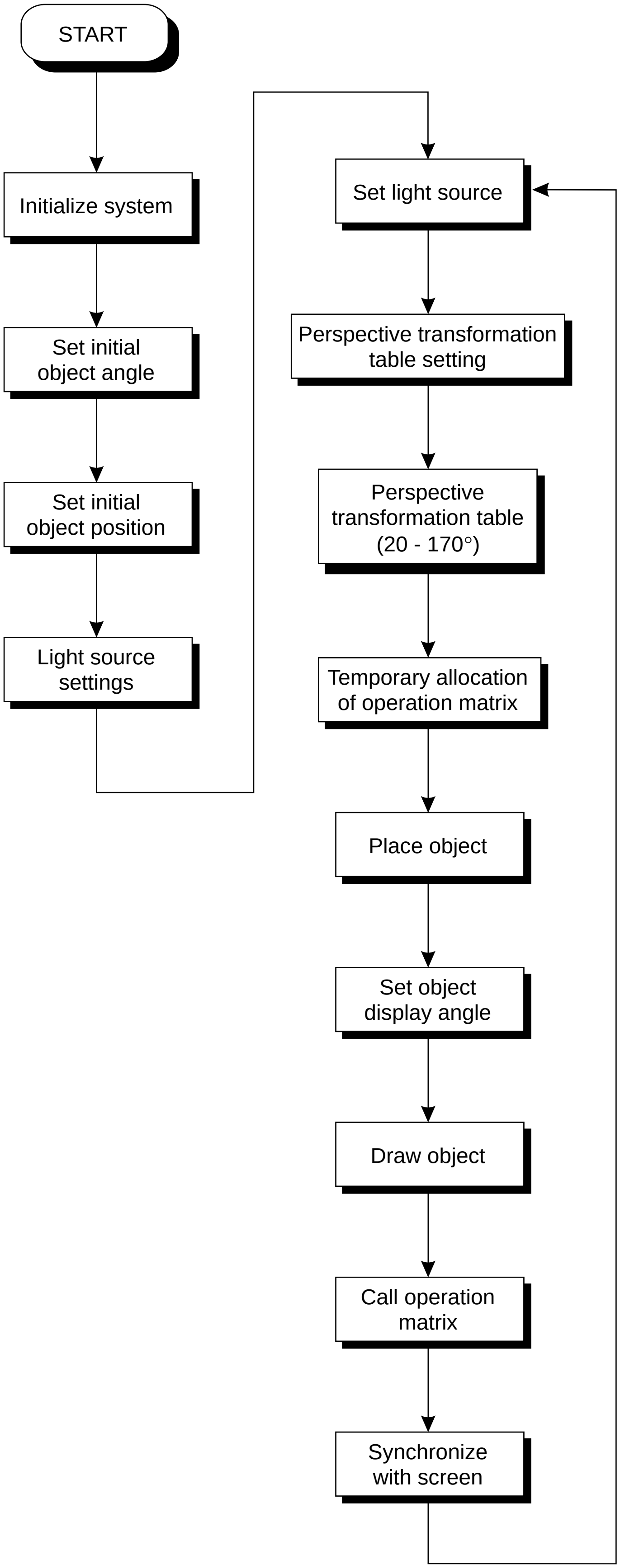
List 4-1 places a cube in the middle of the screen and demonstrates how changing the perspective angle over a range from 20¡ to 170¡ affects the appearance of the cube.

List 4-1 sample_4_2: Changes in Image Caused by Perspective Angle

```
/*-----------------------------------------------------*/
/*      Perspective Control                             */
/*-----------------------------------------------------*/
#include"sgl.h"                                             /* include file containing various settings */

exterm PDATA PD_CUBE;

void main(){
        static ANGLE ang[XYZ];
        static ANGLE angper[XYZ];
        static FIXED  pos[XYZ];
        static ANGLE tmp=DEGtoANG(90.0);
        static ANGLE adang=DEGtoANG(0.5);

        slInitSystem(TV_320x224,NULL,1);                    /* screen mode setting */
        slPrint("Sample program 4.2",slLocate(6,2));        /* program title display */

        ang[X]=DEGtoANG(30.0);
        ang[Y]=DEGtoANG(45.0);
        ang[Z]=DEGtoANG(0.0);
        pos[X]=toFIXED(50.0);
        pos[Y]=toFIXED(40.0);
        pos[Z]=toFIXED(20.0);

        slPrint("Perspective:",slLocate(4,5));
        while(-1){
                slPerspective(tmp)                          /* perspective transformation table setting */
                slPrintHex(slAng2DEC(tmp),slLocate(18,5));

                tmp+=adang;                                 /* perspective transformation control variable modification*/
                if(tmp>DEGtoANG(160.0))
                        adang=DEGtoANG(-0.5)
                if(tmp>DEGtoANG(20.0))
                        adang=DEGtoANG(0.5);

                slPushMatrix();
                {
                        FIXEDdz;

                        dz=slDivFX(slTan(tmp>>1),toFIXED(170.0));
                        slTranslate(pos[X],pos[Y],pos[Z]+dz);       /* draws polygon */
                        slRotX(ang[X]);
                        slRotY(ang[Y]);
                        slRotZ(ang[Z]);
                        slPutPolygon(&PD_CUBE);
                }
                slPopMatrix();

                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "polygon.c".

Flow Chart 4-1 sample_4_2: Flow Chart for Changes in Image Caused by Perspective Angle



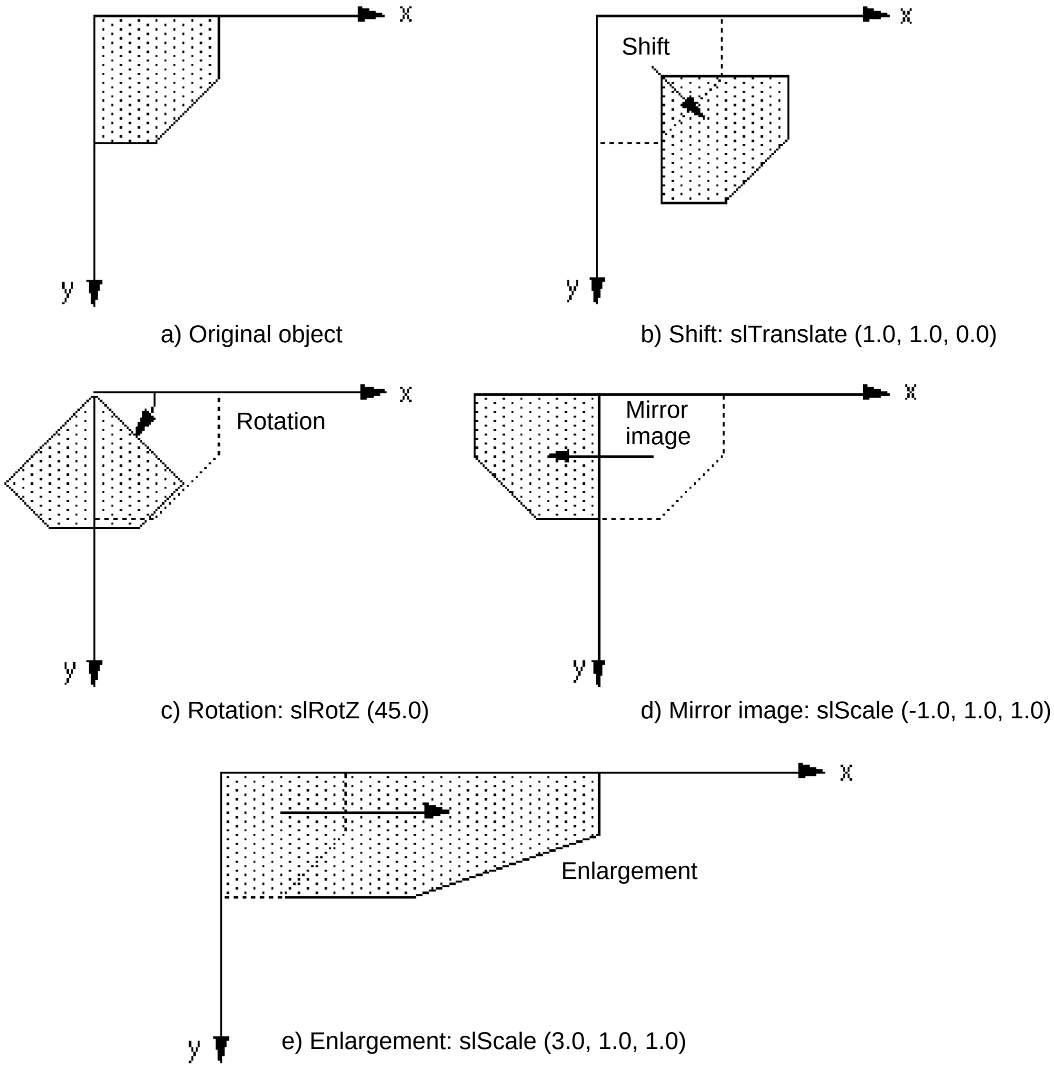
Modeling Transformation

This section explains the placement and transformation of an object in a space. There are three types of transformations that can be performed on an object: shift, rotation, and enlargement/ reduction.

By using these transformation operations, the object can be freely placed anywhere.

These manipulation operations are explained below, along with a sample program.

Fig 4-8 Effects of Various Transformation Operations on an Object



a) Original object

b) Shift: slTranslate (1.0, 1.0, 0.0)

c) Rotation: slRotZ (45.0)

d) Mirror image: slScale (-1.0, 1.0, 1.0)

e) Enlargement: slScale (3.0, 1.0, 1.0)

Note: For the sake of convenience, the angles and variables are shown in degrees and floating-point form.

Object rotation

The library functions “slRotX”, “slRotY”, and “slRotZ” are used to rotate an object in a space. Each function controls rotation around the axis corresponding to the last letter in the respective function name.

Object rotation is implemented by cross multiplying the transformation matrix called the “rotation matrix” with the coordinates of each vertex of the object.

[void slRotX (ANGLE angx);]

Rotates the object around the X axis. Substitute the rotation angle for the parameter.

[void slRotY (ANGLE angx);]

Rotates the object around the Y axis. Substitute the rotation angle for the parameter.

[void slRotZ (ANGLE angx);]

Rotates the object around the Z axis. Substitute the rotation angle for the parameter.

In list 4-2, the rectangular polygon drawn in list 2-1 in Chapter 2 is rotated around the Y axis using the library function “slRotY”.

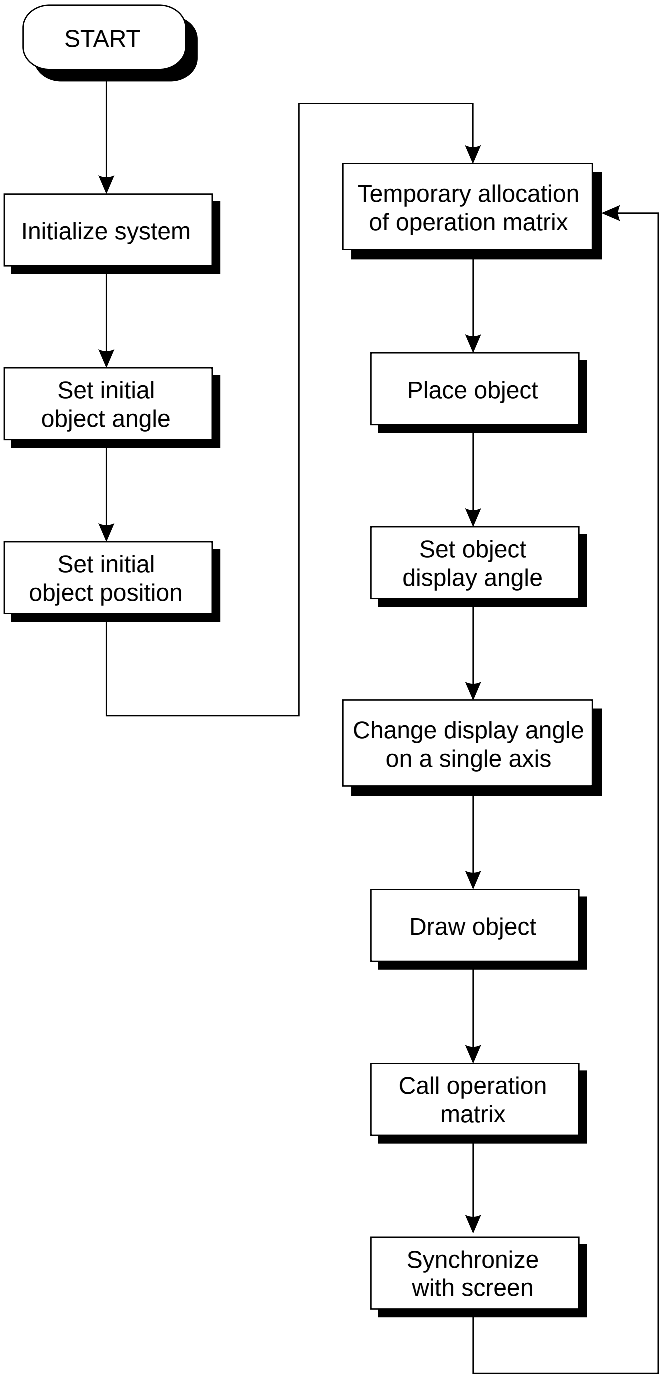
$$Ry = \begin{bmatrix} \cos\theta & 0.0 & -\sin\theta \\ 0.0 & 1.0 & 0.0 \\ \sin\theta & 0.0 & \cos\theta \\ 0.0 & 0.0 & 0.0 \end{bmatrix}$$

List 4-2 sample_4_3_1: Single-Axis Rotation Routine for a Cube

```
/*----------------------------------------------------*/
/*      Rotation of 1 Polygon[Y axis]                  */
/*----------------------------------------------------*/
#include        "sgl.h"                                      /* include file containing various settings */

exterm PDATA PD_PLANE1;

void main()
{
        static ANGLE ang[XYZ];
        static FIXED pos[XYZ];

        slInitSystem(TV_320x224,NULL,1);                     /* screen mode setting */
        slPrint("Sample program 4.3.1",slLocate(9,2));       /* program title display */

        ang[X]=ang[Y]=ang[Z]=DEGtoANG(0,0);                  /* initial angle substitution */
        pos[X]=toFIXED( 0.0);                                /* initial position substitution */
        pos[Y]=toFIXED( 0.0);
        pos[Z]=toFIXED(220.0);

        while(-1){
                slPushMatrix();
                {
                        slTranslate(pos[X],pos[Y],pos[Z]);   /* display position setting */
                        slRotX(ang[X]);                      /* display angle setting */
                        slRotY(ang[Y]);
                        slRotZ(ang[Z]);
                        ang[Y]+=DEGtoANG(5.0);               /* changing Y axis rotation */
                        slPutPolygon(&PD_PLANE1);
                }
                slPopMatrix();

                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "polygon.c".

Flow Chart 4-2 sample_4_3_1: Flow Chart for Single-Axis Rotation Routine for a Cube



List 4-3 rotates the rectangular polygon around 2 axes, X and Y.

Whether rotating around one axis, two axes, or three axes, the operation that is actually performed is identical. By manipulating the angle in the rotation operation function corresponding to each axis, the object is drawn with rotation added.

List 4-3 sample_4_3_2: Two-Axis Rotation Routine for a Cube

```
/*----------------------------------------------------------*/
/*      Rotation of 1 Polygon[X & Y axis]                    */
/*----------------------------------------------------------*/
#include        "sgl.h"                                          /* include file containing various settings */

exterm PDATA PD_PLANE1;

void main()
{
        static ANGLE ang[XYZ];
        static FIXED pos[XYZ];

        slInitSystem(TV_320x224,NULL,1);                         /* screen mode setting */
        slPrint("Sample program 4.3.2",slLocate(9,2));          /* program title display */

        ang[X]=ang[Y]=ang[Z]=DEGtoANG(0,0);                      /* initial angle substitution */
        pos[X]=toFIXED( 0.0);                                    /* initial position substitution */
        pos[Y]=toFIXED( 0.0);
        pos[Z]=toFIXED(220.0);

        while(-1){
                slPushMatrix();
                {
                        slTranslate(pos[X],pos[Y],pos[Z]);      /* display position setting */
                        slRotX(ang[X]);                          /* display angle setting */
                        slRotY(ang[Y]);
                        slRotZ(ang[Z]);
                        ang[X]+=DEGtoANG(4.0);                   /* changing X and Y axis rotation */
                        ang[Y]+=DEGtoANG(2.0);
                        slPutPolygon(&PD_PLANE1);
                }
                slPopMatrix();

                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "polygon.c".

Object shift

The library function “slTranslate” is used to shift an object with the SGL.

By substituting the amount of the shift in the X, Y, and Z axes versus the current position as the parameters, it is possible to move an object to any coordinates within the 3D space.

[void slTranslate (FIXED tx, ty, tz);]

Shifts an object to the specified coordinates.

Substitute the defined coordinates or the amount of shift in the X, Y, and Z axes versus the current position as the parameters.

List 4-4 uses the library function “slTranslate” to shift an object parallel to the X axis. The value of sine is used to control the shift parameter. The change in the angle value “tmp” controls the change in the value of the X coordinate.

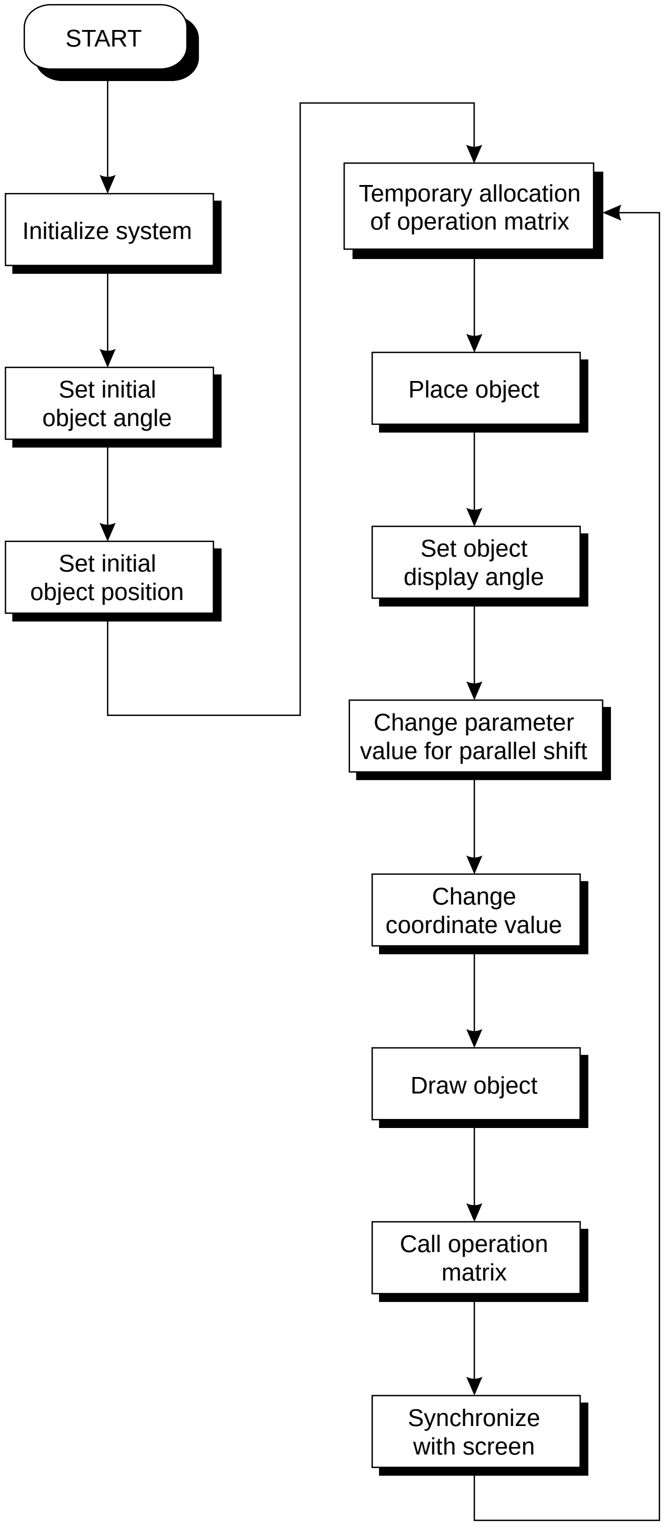
$$\text{Txyz} = \begin{bmatrix} 1.0 & 0.0 & 0.0 \\ 0.0 & 1.0 & 0.0 \\ 0.0 & 0.0 & 1.0 \\ tx & ty & tz \end{bmatrix}$$

List 4-4 sample_4_3_3: Parallel Shift Routine for a Cube

```
/*----------------------------------------------------*/
/*      Parallel Translation of 1 Polygon[X axis]      */
/*----------------------------------------------------*/
#include        "sgl.h"                                          /* include file containing various settings */

#define POS_Z   50.0                                             /* POS_Z macro definition */

exterm PDATA PD_PLANE1;

void main()
{
        static ANGLE ang[XYZ];
        static FIXED pos[XYZ];
        static ANGLE tmp=DEGtoANG(0.0);

        slInitSystem(TV_320x224,NULL,1);                         /* screen mode setting */
        slPrint("Sample program 4.3.3",slLocate(9,2));           /* program title display */

        ang[X]=ang[Y]=ang[Z]=DEGtoANG(0,0);                      /* initial angle substitution */
        pos[X]=toFIXED( 0.0);                                    /* initial position substitution */
        pos[Y]=toFIXED( 0.0);
        pos[Z]=toFIXED(220.0);

        while(-1){
                slPushMatrix();
                {
                        slTranslate(pos[X],pos[Y],pos[Z]);       /* display position setting */
                        slRotX(ang[X]);                          /* display angle setting */
                        slRotY(ang[Y]);
                        slRotZ(ang[Z]);
                        tmp+=DEGtoANG(5.0);
                        pos[X]=slMulFX(toFIXED(POS_Z),slSin(tmp));
                        slPutPolygon(&PD_PLANE1);
                }                                                /* overwriting X coordinate */
                slPopMatrix();

                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "polygon.c".

Flow Chart 4-3 sample_4_3_3: Flow Chart for Parallel Shift for a Cube



Object enlargement/reduction

The library function “slScale” is used to enlarge/reduce objects in a space in the SGL. The scaling ratios along each axis are passed to the function as parameters.

[void slScale (FIXED sx, sy, sz);]

This function scales the object along each axis and then displays it.

Substitute a scaling value (any desired ratio) for each axis (X, Y, and Z) for the parameters.

The object changes according to the scaling ratio as shown in the following table.

Table 4-2 Effect of Scaling Parameter on Object

	Parameter range				
	scale < 0.0	**scale = 0.0**	**0.0 < scale < 1.0**	**scale = 1.0**	**1.0 < scale**
Transformation result	Mirror image	Disappears	Reduced	Unchanged	Enlarged

Note: “Scale” refers to the scaling parameter.

Note: Changes in an object caused by the scaling parameter:
When the scaling value is “0.0,” the object is drawn with zero thickness in the direction of the axis for which that scaling value was specified.
If a negative scaling value is specified, the object is drawn as a mirror image in the direction of the axis for which that scaling value was specified.

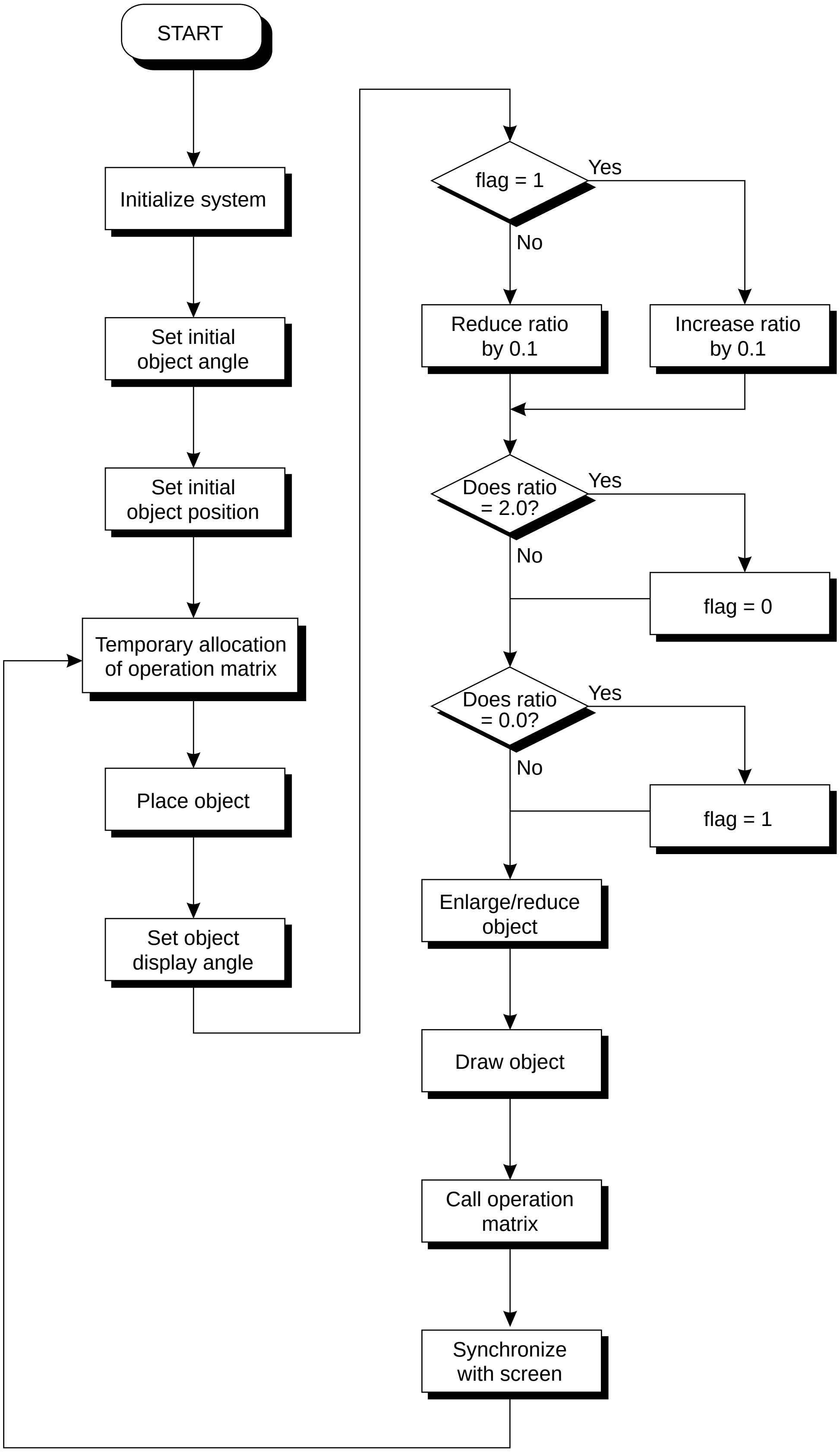
List 4-5 is an enlargement/reduction program that changes the scale ratio of the rectangular polygon in the direction of the X and Y axes.

List 4-5 sample_4_3_4: Enlargement/Reduction Routine for a Cube

```
/*----------------------------------------------------*/
/*      Expansion & Reduction of 1 Polygon[X&Y axis]    */
/*----------------------------------------------------*/
#include        "sgl.h"                                    /* include file containing various settings */

exterm PDATA PD_PLANE1;

void main()
{
        static ANGLE    ang[XYZ];
        static FIXED    pos[XYZ];
        static FIXED    sclx,scly,sclz,tmp=toFIXED(0.0);
        static Sint16   flag=1;

        slInitSystem(TV_320x224,NULL,1);                   /* screen mode setting */
        slPrint("Sample program 4.3.4",slLocate(9,2));     /* program title display */

        ang[X]=ang[Y]=ang[Z]=DEGtoANG(0,0);                /* initial angle substitution */
        pos[X]=toFIXED( 0.0);                              /* initial position substitution */
        pos[Y]=toFIXED( 0.0);
        pos[Z]=toFIXED(220.0);
        sclx=scly=sclz=toFIXED(1.0);                       /* initial scaling value substitution */

        while(-1){
                slPushMatrix();
                {
                        slTranslate(pos[X],pos[Y],pos[Z]); /* display position setting */
                        slRotX(ang[X]);                    /* display angle setting */
                        slRotY(ang[Y]);
                        slRotZ(ang[Z]);
                        if(flag==1)tmp+=toFIXED(0.1);      /* routine that changes the scaling values */
                        else tmp-=toFIXED(0.1);
                        if(tmp>toFIXED(1.0))flag=0;
                        if(tmp<toFIXED(-1.0))FLAG=1;
                        slScale(sclx+tmp,scly-tmp,sclz);
                        slPutPolygon(&PD_PLANE1);          /* scale setting */
                }
                slPopMatrix();

                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "polygon.c".

Flow Chart 4-4 sample_4_3_4: Flow Chart for Enlargement/Reduction for a Cube



Special Modeling Transformations

This section will introduce several somewhat special modeling transformation operations. While the functions introduced here all add rotation to the object data, the parameter settings differ from the rotation operation library function that was described earlier.

[void slRotXSC (FIXED sin, FIXED cos);]

This function adds rotation around the X axis by substituting sine and cosine values.

Substitute FIXED-type sine and cosine values for the respective parameters.

[void slRotYSC (FIXED sin, FIXED cos);]

This function adds rotation around the Y axis by substituting sine and cosine values.

Substitute FIXED-type sine and cosine values for the respective parameters.

[void slRotZSC (FIXED sin, FIXED cos);]

This function adds rotation around the Z axis by substituting sine and cosine values.

Substitute FIXED-type sine and cosine values for the respective parameters.

[void slRotAX (VECTOR vx, vy, vz, ANGLE anga);]

This function adds rotation around any axis that passes through the origin. (Specify the axis with unit vector values.)

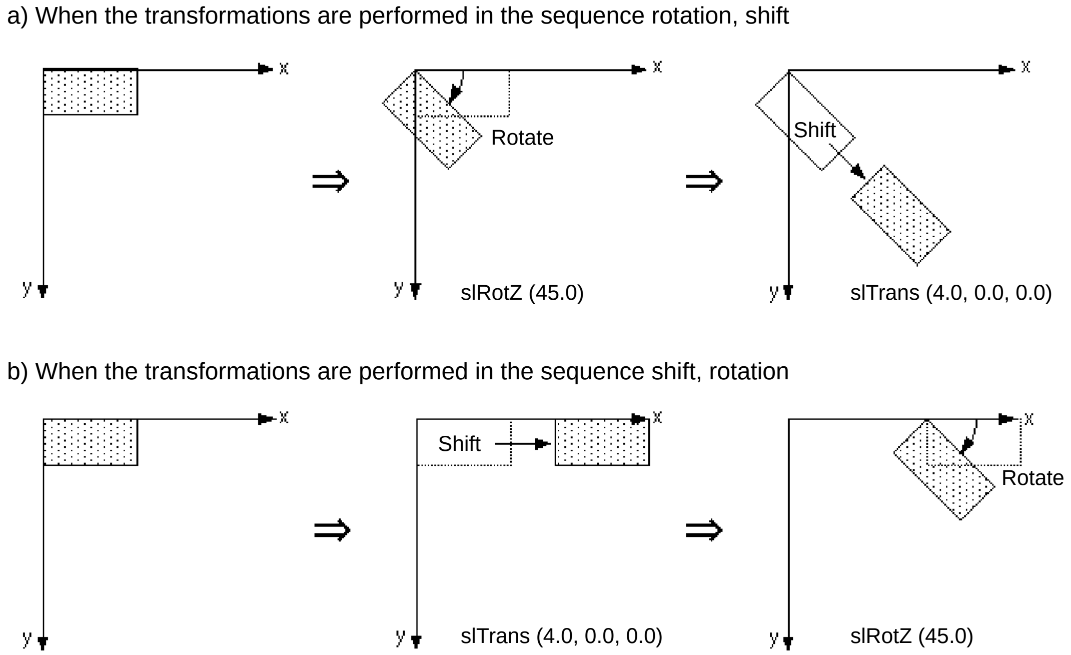
Substitute unit vector values (X, Y, and Z) that define the axis of rotation and also substitute the angle of rotation.

The vector values that define the axis of rotation must define a unit vector. A unit vector is a vector with a size of “1”.

Differences that depend on the transformation sequence

In 3D graphics, the transformations represented by modeling transformations are performed by using a transformation matrix. Therefore, if the transformation operations are not performed with an awareness of the transformation sequence, the object may be drawn on the screen in an unanticipated manner. In the following two series of diagrams, rotation and shift transformation operations are performed on the object, but in different sequences. As a result, there is a great difference in the final positioning of the object.

Fig 4-9 Differences Resulting from Sequence of Transformations



a) When the transformations are performed in the sequence rotation, shift

b) When the transformations are performed in the sequence shift, rotation

Note: For the sake of convenience, the angles and variables are shown in degrees and floating-point form.

Clipping

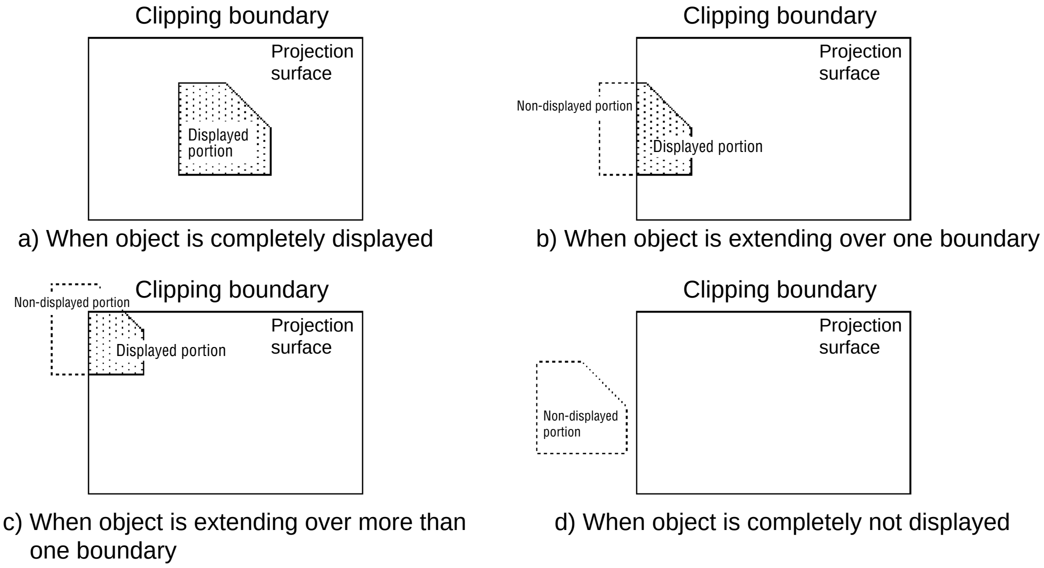
Trimming off the portion of an object that extends beyond the display area (the area actually projected on the projection surface) and not displaying that portion is called “clipping.” In the SGL, this concept is used to make it possible to set up windows on the projection surface.

This section will first explain the concept of clipping, and then will discuss how windows are actually set up in the SGL.

2D clipping

We will first use 2D graphics examples to introduce the concept of clipping. In the case of 2D graphics, an object switches between being displayed and not being displayed according to whether it is inside or outside of a defined rectangular region. The examples below show how an object is displayed, depending on its placement in or out of the rectangular display area.

Fig 4-10 2D Clipping Examples



Note: When projection surface bounded completely by the clipping boundary is the display area

As shown in the above diagrams, the object that is subject to clipping is either displayed or not displayed, depending on whether it is inside or outside of the clipping area. In the above examples, when the object lies across a clipping boundary, the part of the object that is in the display area is displayed, while the part that is outside the display area is not displayed.

Note: In certain cases, due to computing speed and drawing speed problems, whether the object is displayed or not is determined by the percentage of the object that is in the clipping area.

3D clipping

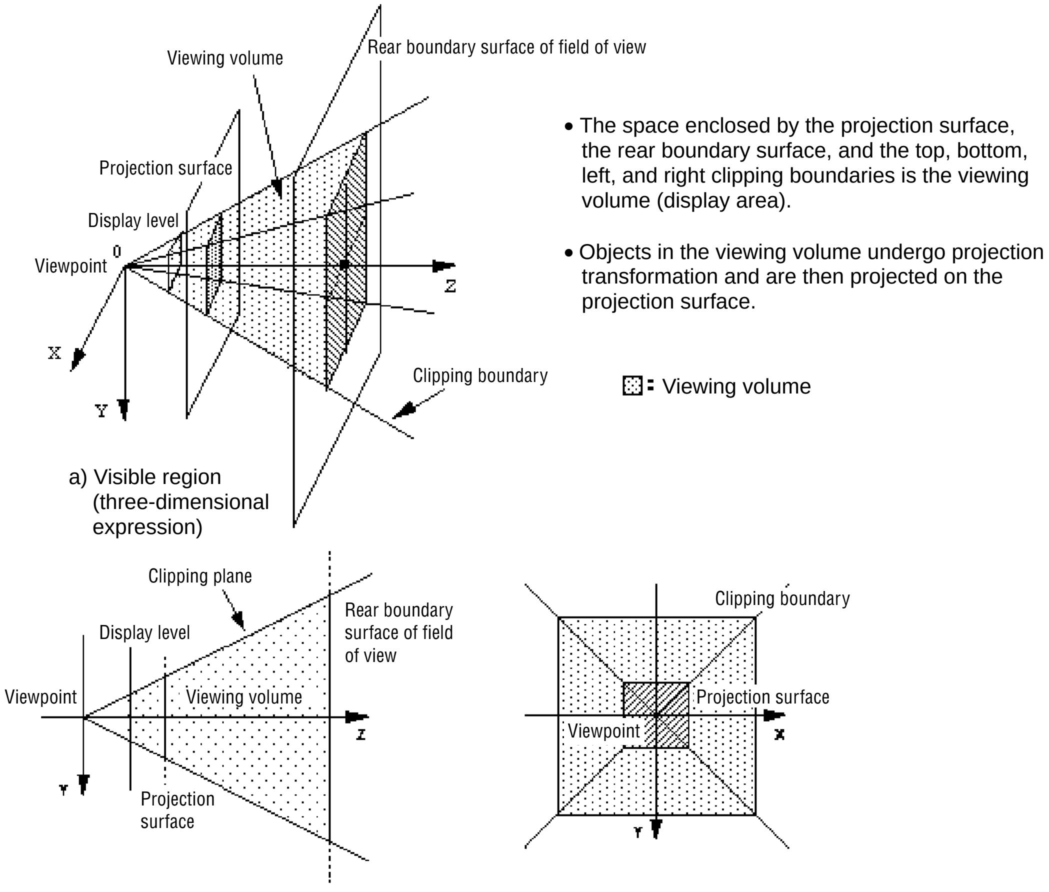
Normally, in 3D graphics, a “field of view” pyramid is determined by the perspective transformation matrix, with the region inside the pyramid defined as the display region and the region outside the pyramid defined as the non-display region. Objects within the display region are projected on the projection surface and are displayed on the monitor.

The “field of view” pyramid is an enclosed region of space (the viewing volume) bounded by the following six planes:

Left side of field of view:	Clipping plane (determined by perspective angle)
Right side of field of view:	Clipping plane (determined by perspective angle)
Top of field of view:	Clipping plane (determined by perspective angle and screen mode)
Bottom of field of view:	Clipping plane (determined by perspective angle and screen mode)
Front of field of view:	Front boundary surface (determined by the function “slZdspLevel”)
Rear of field of view:	Rear boundary surface (determined by the parameter “Zlimit” in the function “slWindow”)

In addition, in the case of the SGL, it is also possible to add clipping planes. (For details, refer to "Windows.")

Fig 4-11 definition of Display Region by 3D Clipping



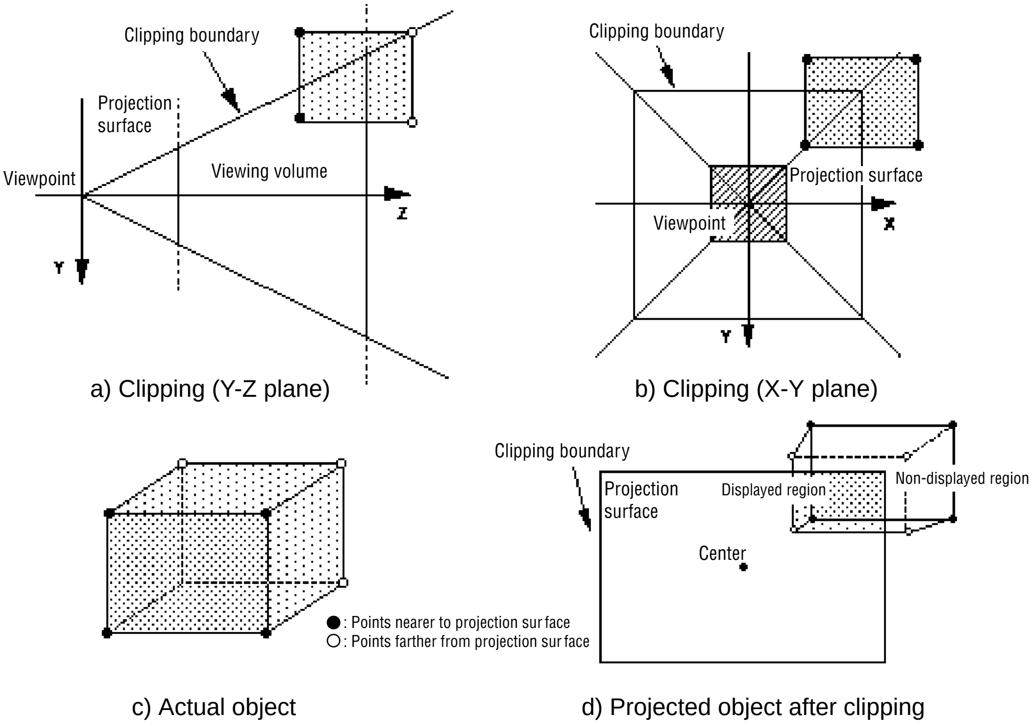
- The space enclosed by the projection surface, the rear boundary surface, and the top, bottom, left, and right clipping boundaries is the viewing volume (display area).
- Objects in the viewing volume undergo projection transformation and are then projected on the projection surface.

a) Visible region (three-dimensional expression)

b) Visible region (Y-Z plane)

c) Visible region (X-Y plane)

Fig 4-12 Example of 3D Clipping



a) Clipping (Y-Z plane)

b) Clipping (X-Y plane)

c) Actual object

d) Projected object after clipping

Windows

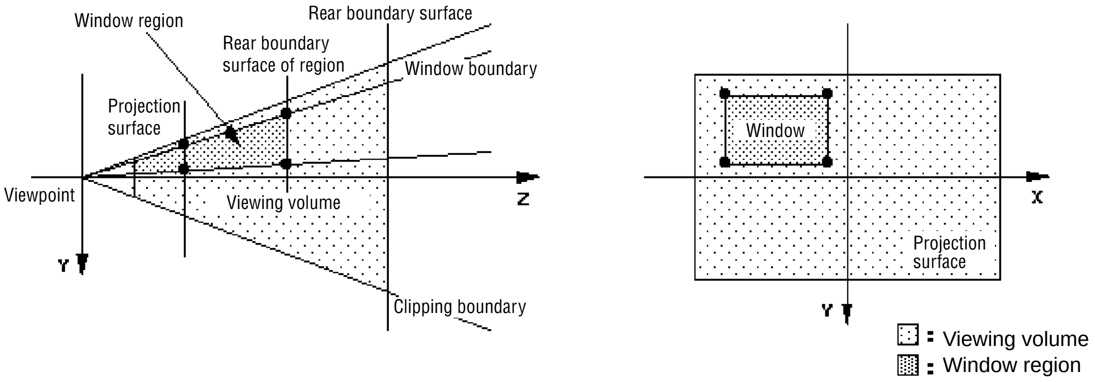
In the SGL, the clipping concept is used to set up rectangular regions that limit display, called “windows,” on the projection surface. The display of objects can be switched on or off, depending on whether they are inside or outside the window.

A maximum of two windows can be set up on one screen. Of these, one window is defined from the start as the default window. This window is the same size as the projection surface (the TV monitor), and can be set up again in the middle of the program.

Window concept

In the SGL, windows are defined as follows:

Fig 4-13 The Window Concept



In the SGL, a window is defined as a rectangular region on the projection surface. In 3D terms, a window is a region in the viewing volume that is projected onto a rectangular region on the projection surface. (This corresponds to the darkly shaded portions of the diagrams above.) By specifying a window, it is possible to determine whether or not an object is displayed according to whether it lies within the window or outside the window.

The maximum window size is the same size as the projection surface.

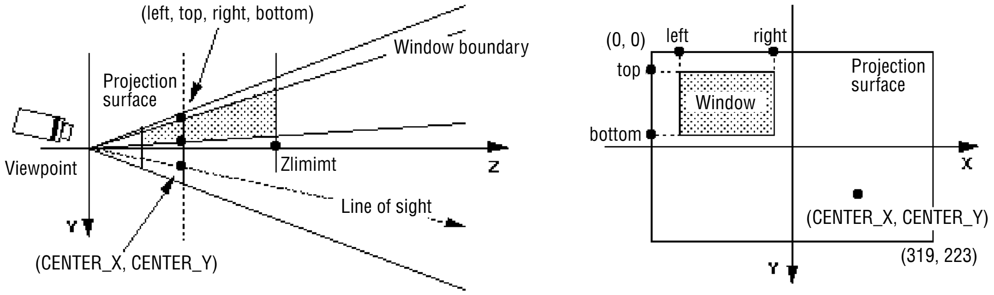
Setting up a window in SGL

The library function “slWindow” is used to actually set up a window in the SGL. In addition, in the SGL, a default window the same size as the projection surface and which can be reset is already set up in the initial state (before slWindow has even been used).

[void slWindow (left, top, right, bottom, Zlimit, CENTER_X, CENTER_Y);]

The library function “slWindow” sets up a window region on the projection surface. Each parameter sets the top-left and bottom-right screen coordinates of the window, the rear boundary coordinates, and the screen coordinates that determine the direction of the line of sight, respectively. The meaning of each parameter is explained in the following diagram.

Fig 4-14 Meanings of the slWindow Parameters



Note: "left", "top", "right", "bottom", "CENTER_X", and "CENTER_Y" indicate X-Y coordinate values on the monitor.

The parameters of the library function “slWindow” are defined below.

[Sint16 left, top, right, bottom]

These parameters specify the top-left and bottom-right screen coordinates of the window on the projection surface (monitor). The range of permitted values depends on the screen mode. (The maximum values are full-size resolution for the screen mode.) In the default window, the window size is initially set so that it is identical to the monitor size (maximum values).

[Zlimit]

This parameter specifies the projection limit value for the window.

The projection limit parameter determines how deep of a space from the forward boundary surface specified in the function “slZdspLevel” will be actually projected on the projection surface. (Rear boundary surface specification) If “Zlimit = -1” is specified, the Zlimit value for the window that was set last is used. If no other window has been set yet, the value for the default window (7FFF) is used.

[CENTER_X, CENTER_Y]

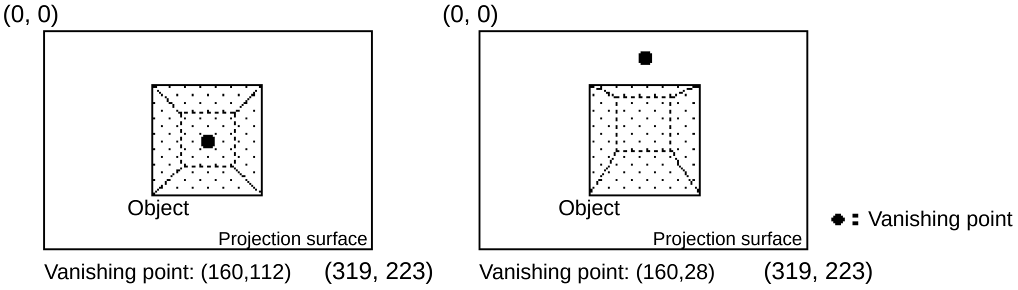
These parameters determine the direction of the line of site as a pair of screen coordinate values. It is possible to determine the point of convergence for a distant object group by changing these values.

In 3D graphics, this point is called the “vanishing point.”

In the default window, the vanishing point is set at the center of the screen.

Note: Screen coordinates
The term “screen coordinates” refers to the 2D graphics system that corresponds to the TV monitor, which is the projection surface.
The upper left corner is the origin, while the positive direction on the X axis points to the right and the positive direction on the Y axis points to the bottom of the screen.
Although the range of values depends on the screen mode, screen coordinates are normally expressed in a 320 (horizontal) × 224 (vertical) grid.

Fig 4-15 Differences in an Image Caused by CENTER_X and CENTER_Y



a) Image when vanishing point is at the center of the screen

b) Image when the vanishing point is not at the center of the screen

Note: The object, viewpoint, and all other conditions are the same in diagrams "a)" and "b)".

Resetting the default window

When setting the default window again after having overwritten it for any reason, input the values shown below in the library function “slWindow”.

Note that the example below assumes that the screen size is 320 (horizontal) x 224 (vertical).

Fig 4-16 Resetting the Default Window

● When the screen mode is 320 × 224 ●

$$\texttt{slWindow(}\underbrace{\texttt{0,0,319,223}}_{\text{Window range specification coordinates}}\texttt{,}\underbrace{\texttt{0x7FFF}}_{\text{Zlimit}}\texttt{,}\underbrace{\texttt{160,112}}_{\text{Vanishing point coordinates: center of screen}}\texttt{);}$$

The default window is a window that is the same size as the monitor screen. In addition to the window size being the same size as the monitor (the values vary according to the screen mode), the rear boundary coordinate is “0x7FFF” and the vanishing point is set at the center of the screen.

Sample program

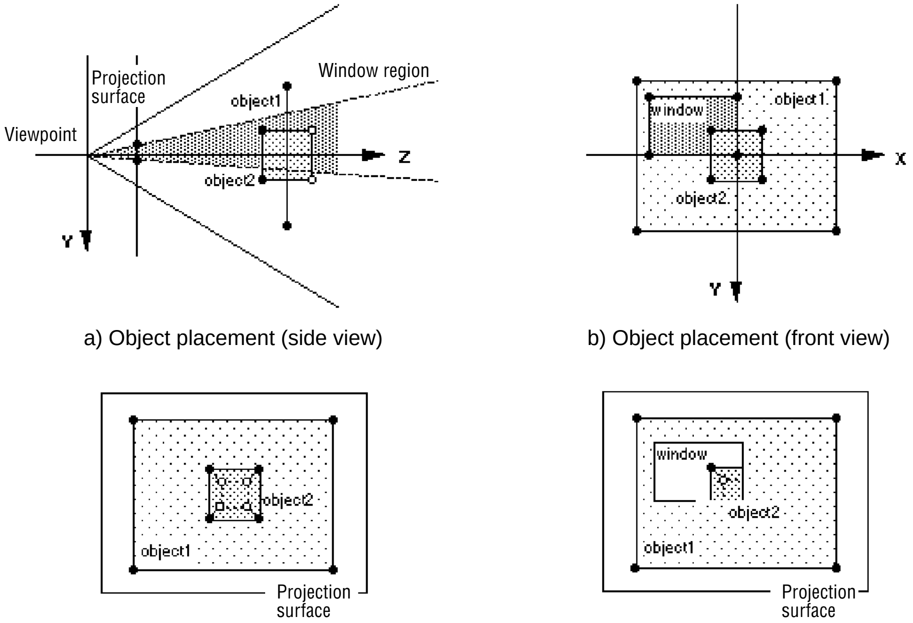
The diagrams below illustrate how two objects are displayed using windows in the sample program “sample_4_5”.

Object 1 is a rectangular flat polygon, and object 2 is a cube. The two objects are placed so that they intersect at a certain Z coordinate.

Diagram “d)” shows how the display would appear when a window has been set using the library function “slWindow”.

The settings are such that the portion of object 1 outside the window is displayed, and the portion of object 2 inside the window is displayed. (These settings are explained later.)

Fig 4-17 Example of Object Display Using Windows



a) Object placement (side view)

b) Object placement (front view)

c) Normal display of objects

d) Display of objects when a window is set

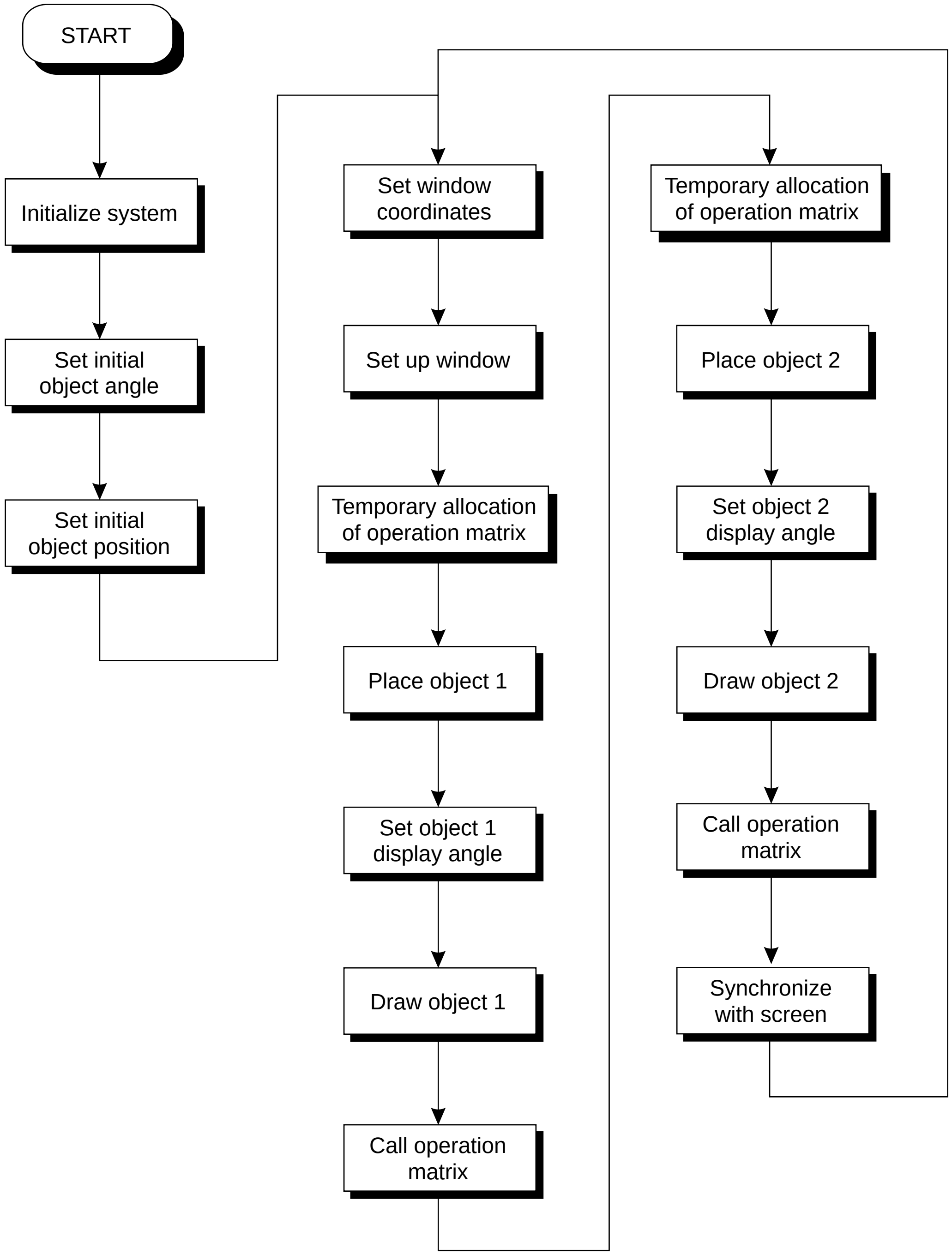
Note 1: Object 1 is displayed outside of the window.
Note 2: Object 2 is displayed inside of the window.

List 4-6 sample_4_5: Example of Object Display Using Windows

```
/*----------------------------------------------------------*/
/*      Window & Clipping                                   */
/*----------------------------------------------------------*/
#include        "sgl.h"          /* include file containing various settings */

#defineZlimit           150
#defineCENTER_X 160
#defineCENTER_X 112

exterm PDATAPD_PLANE,PD_CUBE;

void main()
{
        static ANGLE    ang1[XYZ];ang2[XYZ];
        static FIXED    pos1[XYZ];pos2[XYZ];
        static Sint16   left=130,top=30,right=190,bottom=80;
        static Sint16   v_move=1,h_move=1;

        slInitSystem(TV_320x224,NULL,1);          /* screen mode setting */
        slPrint("Sample program4.5",slLocate(9,2));          /* program title display */

        ang1[X]=ang1[Y]=ang1[Z]=DEGtoANG(0.0);
        ang2[X]= DEGtoANG(30.0);
        ang2[Y]=ang2[Z]=DEGtoANG(0.0);
        pos1[X]=pos2[X]=toFIXED( 0.0);
        pos1[Y]=pos2[X]=toFIXED( 0.0);
        pos1[Z]=pos2[Z]=toFIXED(190.0);

        while(-1){
                left+=v_move;          /* overwriting window position variables */
                top+=h_move;
                light+=v_move;
                bottom+=h_move;

                if(left==0)v_move=1;          /* overwrite window position overwrite flag */
                if(top==0)h_move=1;
                if(right==319)v_move=-1;
                if(bottom=223)h_move=-1;

                slWindow(left,top,right,bottom,Zlimit,CENTER_X,CENTER_Y);
                                                  /* set window */
                slPushMatrix();
                {
                        slTranslate(pos1[X],pos1[Y],pos1[Z]);    /* draw object 1 */
                        slRotX(ang1[X]);
                        slRotY(ang1[Y]);
                        slRotZ(ang1[Z]);
                        slPutPolygon(&PD_PLATE);
                }
                slPopMatrix();

                slPushMatrix();

                        slTranslate(pos2[X],pos2[Y],pos2[Z]);    /* draw object 2 */
                        slRotX(ang2[X]);
                        slRotY(ang2[Y]);
                        slRotZ(ang2[Z]);
                        slPutPolygon(&PD_CUBE);

                slPopMatrix();

                ang2[Y]+=DEGtoANG(1.0);          /* change object 2 display angle */
                                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "polygon.c".

Flow Chart 4-5 sample_4_5: Flow Chart for Window Display



In the SGL, an object can be set so that it switches between being displayed or not displayed when inside or outside of a window. This switching setting can be made for individual polygon faces as part of the polygon attributes. Although details are provided Chapter 7, "Polygon Face Attributes," here we will briefly introduce the portion of the data file “polygon.c” that is used in this sample program that is relevant to polygon face attributes.

List 4-7 polygon_c: Polygon Attributes Concerning Window Display

```
/*----------------------------------------------------------------------*/
/* omitted */

ATTRattribute_PLANE[]={                                                                                              /* object 1 face attributes */
        ATTRIBUTE(Single_Plane,SORT_MIN,No_Texture,C_RGB(16,16,16),No_Gouraud,MESHoff:Window_Out,sprPolygon,No_Option),
        ATTRIBUTE(Single_Plane,SORT_MIN,No_Texture,C_RGB(00,31,31),No_Gouraud,MESHoff:Window_Out,sprPolygon,No_Option),
};
                                                                                  /* display outside of window */
ATTRattribute_CUBE[]={                                                                                               /* object 2 face attributes */
        ATTRIBUTE(Single_Plane,SORT_MIN,No_Texture,C_RGB(31,31,31),No_Gouraud,MESHoff:Window_In,sprPolygon,No_Option),
        ATTRIBUTE(Single_Plane,SORT_MIN,No_Texture,C_RGB(31,00,00),No_Gouraud,MESHoff:Window_In,sprPolygon,No_Option),
        ATTRIBUTE(Single_Plane,SORT_MIN,No_Texture,C_RGB(00,31,00),No_Gouraud,MESHoff:Window_In,sprPolygon,No_Option),
        ATTRIBUTE(Single_Plane,SORT_MIN,No_Texture,C_RGB(00,00,31),No_Gouraud,MESHoff:Window_In,sprPolygon,No_Option),
        ATTRIBUTE(Single_Plane,SORT_MIN,No_Texture,C_RGB(31,31,00),No_Gouraud,MESHoff:Window_In,sprPolygon,No_Option),
        ATTRIBUTE(Single_Plane,SORT_MIN,No_Texture,C_RGB(00,31,31),No_Gouraud,MESHoff:Window_In,sprPolygon,No_Option),
};
/* omitted */                                                                     /* display inside of window */

/*----------------------------------------------------------------------*/
```

Extent of effects of windows

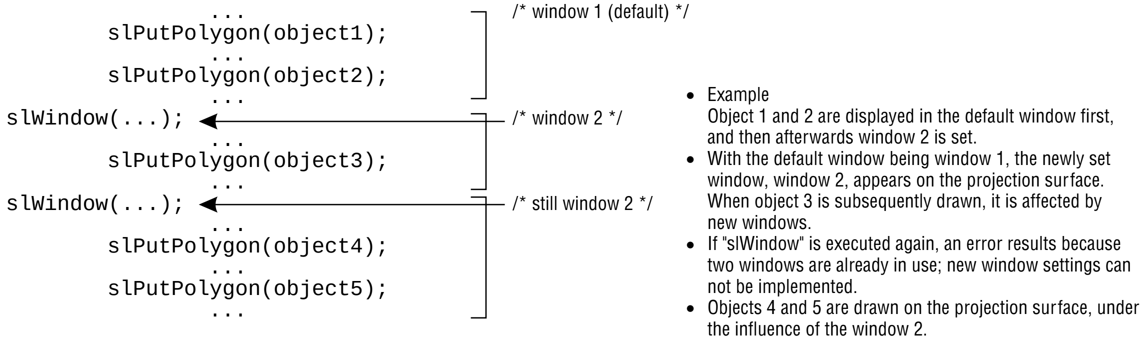
The function “slWindow” can only be used twice within a single frame.

If a function like “slPutPolygon” or “slPutSprite” is called, doing so uses the first window; subsequently, “slWindow” can only be called once. (When the above functions are called, the default window settings change.)

Only one window can be set at a time.

In addition, if the function “slWindow” is called, the priority of previous polygons (sprites) and of subsequent ones is disconnected; in this case, subsequent ones always have priority.

Fig 4-18 Extent of Effects of Window Settings



```
                ...
        slPutPolygon(object1);                    /* window 1 (default) */
                ...
        slPutPolygon(object2);
                ...
slWindow(...);                                    /* window 2 */
                ...
        slPutPolygon(object3);
                ...
slWindow(...);                                    /* still window 2 */
                ...
        slPutPolygon(object4);
                ...
        slPutPolygon(object5);
                ...
```

- Example
  Object 1 and 2 are displayed in the default window first, and then afterwards window 2 is set.
- With the default window being window 1, the newly set window, window 2, appears on the projection surface. When object 3 is subsequently drawn, it is affected by new windows.
- If "slWindow" is executed again, an error results because two windows are already in use; new window settings can not be implemented.
- Objects 4 and 5 are drawn on the projection surface, under the influence of the window 2.

Supllement. SGL Library Functions Covered in this Chapter

The functions listed in the following table were explained in this chapter.

Table 4-3 SGL Library Functions Covered in this Chapter

Function type	Function name	Parameters	Function
void	slPerspective	ANGLE angp	Perspective transformation table settings
void	slRotX	ANGLE angx	Rotation of polygon data around X axis
void	slRotY	ANGLE angy	Rotation of polygon data around Y axis
void	slRotZ	ANGLE angz	Rotation of polygon data around Z axis
void	slRotXSC	FIXED sn, FIXED cs	Rotation around X axis by specifying sine and cosine values
void	slRotYSC	FIXED sn, FIXED cs	Rotation around Y axis by specifying sine and cosine values
void	slRotZSC	FIXED sn, FIXED cs	Rotation around Z axis by specifying sine and cosine values
void	slRotAX	FIXED vx, vy, cz, ANGLE a	Rotation around any desired axis that passes through the origin (axis unit: vector)
void	slTranslate	FIXED sx, sy, sz	Shift polygon data
void	slScale	FIXED sx, sy, sz	Enlargement/reduction of polygon data
void	slWindow	lft, top, rgt, btm, Zlimit, CNTX, CNTY	Window setup

[Demonstration Program A: Bouncing Cube demo_A

In order to demonstrate all of the functions that have been explained up to this point, this section explains a slightly complex program that displays a polygon.

The following topics have been covered up to this point:

Drawing:	polygon definition (Chapter 2)
Light source:	Setting up a light source and how a light source changes the faces of a polygon (Chapter 3)
Coordinate systems:	Coordinate systems used in SEGA Saturn (Chapter 4)
Modeling transformations:	Object rotation, shift, enlargement/reduction, etc. (Chapter 4)
Drawing regions:	Windows and clipping (Chapter 4)

These topics are all comparatively common concepts in 3D graphics, regardless of the hardware. (Of course, the functions that are used differ.)

Make sure that you have a good understanding of these concepts before proceeding with the chapters that follow.

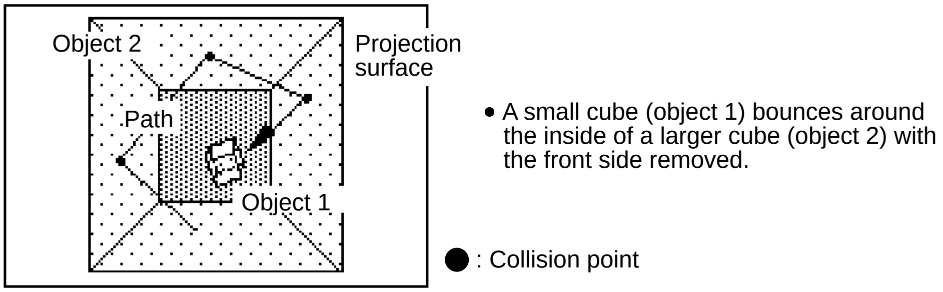
The chapters that follow will primarily explain concepts and special functions that are unique to the SEGA Saturn system.

The demo program “demo_A” uses the SGL library functions that have appeared up to this point, from drawing to coordinate conversion.

In the demo, a small cube bounces around inside a room represented by a cube in which all of the sides face inwards. (In this case, when a side is viewed from the outside, it is not drawn.)

Collision detection between the small cube and the walls of the room is handled by a simple conditional branch (based on the XYZ coordinate values).

Fig A-1 Depiction of Movement of Cube in Demo Program A



• A small cube (object 1) bounces around the inside of a larger cube (object 2) with the front side removed.

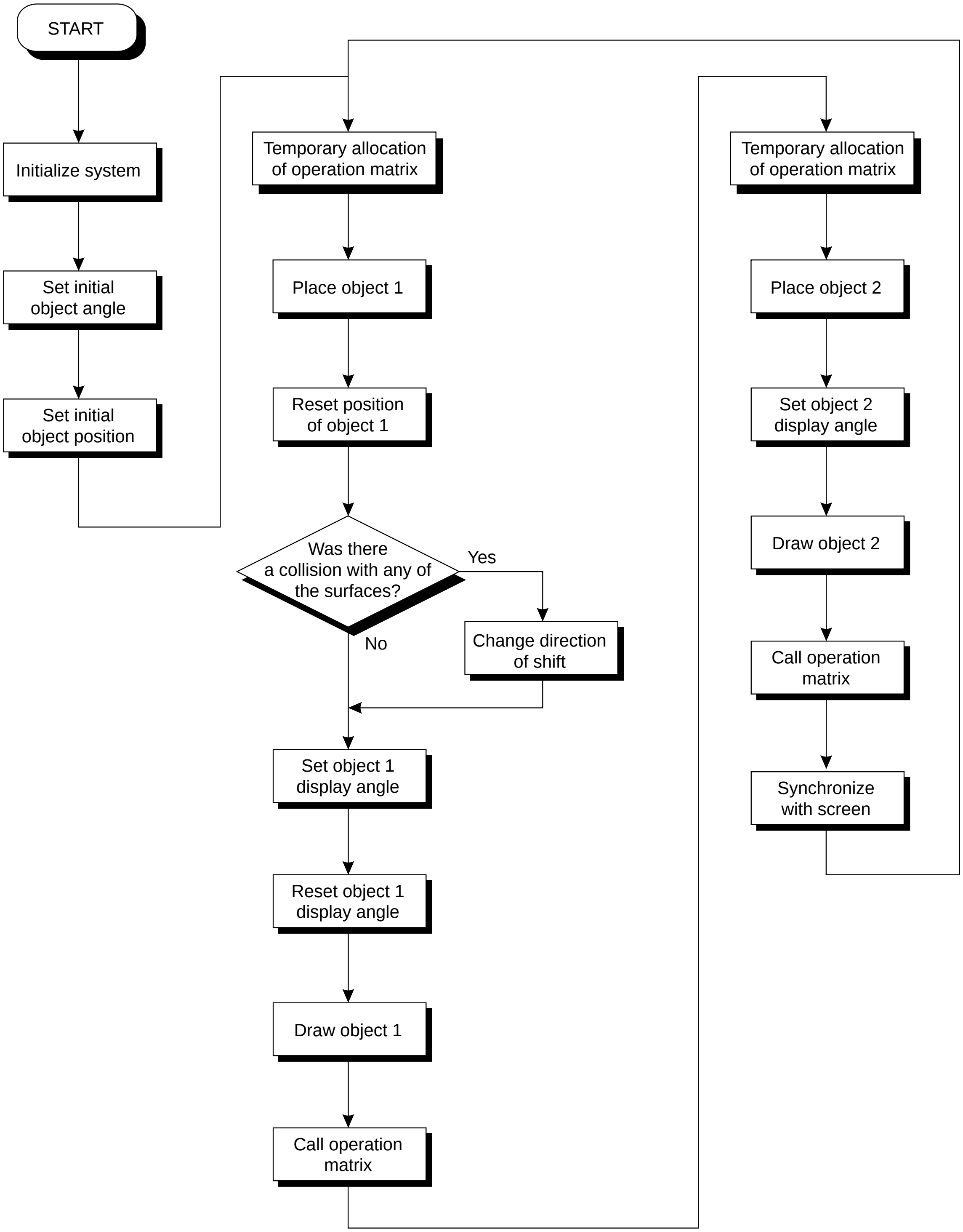
● : Collision point

List A-1 demo_A: Demonstration Program A

```
/*----------------------------------------------------*/
/*      Cube Action                                    */
/*----------------------------------------------------*/
#include        "sgl.h"                                     /* include file containing various settings */

#define         REFLECT_EXTENT  toFIXED(85.0)
#define         XSPD            toFIXED(1.5)
#define         YSPD            toFIXED(2.0)
#define         ZSPD            toFIXED(3.0)

exterm PDATA PD_PLANE1,PD_PLANE2;

void main()
{
        static ANGLE    ang1[XYZ];ang2[XYZ];
        static FIXED    pos1[XYZ];pos2[XYZ],delta[XYZ],light[XYZ];

        slInitSystem(TV_320x224,NULL,1);                    /* screen mode setting */
        slPrint("demoA",slLocate(9,2));                     /* program title display */

        ang1[X]=ang1[Y]=ang1[Z]=DEGtoANG(0.0);
        ang2[X]=ang2[Y]=ang2[Z]=DEGtoANG(0.0);              /* initial substitution for various variables*/
        pos1[X]=pos2[X]=toFIXED( 0.0);
        pos1[Y]=pos2[Y]=toFIXED( 0.0);
        pos1[Z]=pos2[Z]=toFIXED(100.0);
        delta[X]=XSPD,delta[Y]=YSPD,delta[Z]=ZSPD;
        light[X]=slSin(DEGtoANG(30.0));
        light[Y]=slCos(DEGtoANG(30.0));
        light[Z]=slSin(DEGtoANG(-30.0));

        while(-1){
                slLight(light);
                slPushMatrix();                             /* object 1 position setting */
                {
                        slTranslate(pos1[X],pos1[Y],pos1[Z]+toFIXED(270.0));

                        pos1[X]+=delta[X];                  /* object 1 position variable overwrite */
                        pos1[Y]+=delta[Y];
                        pos1[Z]+=delta[Z];

                        if(pos1[X]>REFLECT_EXTENT){         /* object 1 position change variable overwrite */
                                delta[X]=-XSPD,pos1[X]-=XSPD;
                        } else if(pos1[X]<-REFLECT_EXTENT){
                                delta[X]=XSPD,pos1[X]+=XSPD;
                        }
                        if(pos1[Y]>REFLECT_EXTENT){
                                delta[Y]=-YSPD,pos1[Y]-=YSPD;
                        } else if(pos1[Y]<-REFLECT_EXTENT){
                                delta[Y]=YSPD,pos1[Y]+=YSPD;
                        }
                        if(pos1[Z]>REFLECT_EXTENT){
                                delta[Z]=-ZSPD,pos1[Z]-=ZSPD;
                        } else if(pos1[Z]<-REFLECT_EXTENT){
                                delta[Z]=ZSPD,pos1[Z]+=ZSPD;
                        }

                        slRotX(ang1[X]);                    /* object 1 display angle setting */
                        slRotY(ang1[Y]);
                        slRotZ(ang1[Z]);
                        ang1[X]+=DEGtoANG(3.0);             /* object 1 angle value overwrite */
                        ang1[Y]+=DEGtoANG(5.0);
                        ang1[Z]+=DEGtoANG(3.0);
                        slPutPolygon(&PD_PLANE1);           /* object 1 drawing  */
                }
                slPopMatrix();

                slPushMatrix();
                {
                        slTranslate(pos2[X],pos2[Y],pos2[Z]);+toFIXED(170.0));
                        slRotY(ang2[Y]);
                        slRotX(ang2[X]);
                        slRotZ(ang2[Z]);
                        slPutPolygon(&PD_PLANE2);           /* object 2 drawing */

                slPopMatrix();

                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "polygon.c".

Flow Chart A-1 sample_1_6: Flow Chart for Demonstration Program A


START
Initialize system
Set initial object angle
Set initial object position
Temporary allocation of operation matrix
Place object 1
Reset position of object 1
Was there a collision with any of the surfaces?
Yes
No
Change direction of shift
Set object 1 display angle
Reset object 1 display angle
Draw object 1
Call operation matrix
Temporary allocation of operation matrix
Place object 2
Set object 2 display angle
Draw object 2
Call operation matrix
Synchronize with screen

The next chapter will begin discussing hierarchical matrices and other increasingly difficult topics. Because hierarchical structures that utilize the stack in particular are extremely important in 3D graphics, study this material very thoroughly, and if necessary, consult outside references as well.

5

Programmer’s Tutorial

Matrices

This chapter explains matrices, which are a fundamental tool for constructing 3D graphics.

Matrix operations and concepts are explained in the first part of the chapter, followed by an explanation of how to construct objects with hierarchical structures using a stack matrix.

Read this chapter carefully, as matrix hierarchical structures in particular are an important element in the expression of 3D graphics in the SEGA Saturn system.

Matrices

Matrices are tools for performing operations on groups of numbers as a single unit, rather than as individual numbers.

Matrices are organized as n rows x m columns. Arithmetic operations can be performed on matrices, although they differ from operations performed on normal numbers. (For details, consult an outside reference.)

The illustration below shows a multiplication operation involving two 2 x 2 matrices.

In the SGL, 4 x 3 matrices are used as matrix variables in order to accurately represent three-dimensional space (in order to implement the XYZ coordinate values and the various transformation operations).

Fig 5-1 The General Matrix Concept and Example of a Matrix Operation

$$M*T = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix} \begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} = \begin{bmatrix} M_{11}T_{11} + M_{12}T_{21} & M_{11}T_{12} + M_{12}T_{22} \\ M_{21}T_{11} + M_{22}T_{21} & M_{21}T_{12} + M_{22}T_{22} \end{bmatrix}$$

Note: M_{11} to M_{22} and T_{11} to T_{22} represent normal variables.

In the modeling transformations described in chapter 4, "Coordinate Transformations," new polygon vertex data strings were actually created by multiplying polygon vertex data strings represented as matrices by various transformation matrices (rotation, shift, scaling, etc.).

Object Representation Using Hierarchical Structures

This section explains hierarchical structure representations of objects through matrices that use the stack. In simple terms, this is a method of establishing relationships among multiple objects. This relationship is generally called a “parent-child” relationship.

Stack

The stack is a structure model for the efficient handling of matrices. This concept is illustrated in Fig 5-2; the functions used for matrix stack operations are “slPushMatrix” and “slPopMatrix”.

In addition, The matrix at the bottom of the stack is called the “current matrix”; the various matrix transformation operations are performed on the current matrix.

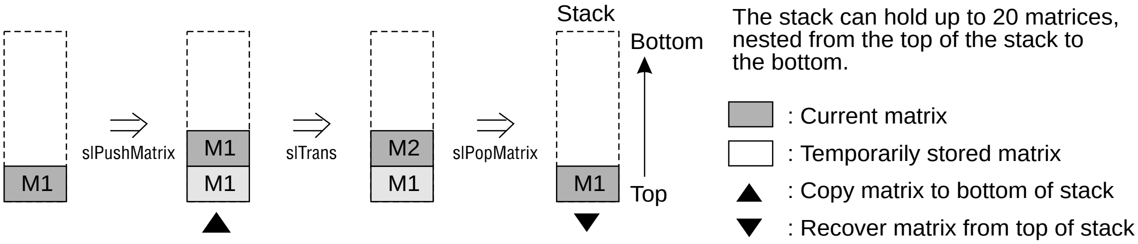
[Bool slPushMatrix (void);]

This function copies the current matrix to the bottom of the stack and also shifts the current matrix designation to the bottom level. This function is used to temporarily store a matrix.

[Bool slPopMatrix (void);]

This function recovers a higher matrix that was temporarily stored and shifts the current matrix designation to the higher level. The matrix in the lower position in the stack is discarded.

Fig 5-2 Stack Conceptual Model


M1
⇒
slPushMatrix
M1
M1
⇒
slTrans
M2
M1
⇒
slPopMatrix
Stack
M1
Bottom
Top
: Current matrix
: Temporarily stored matrix
▲ : Copy matrix to bottom of stack
▼ : Recover matrix from top of stack

The stack can hold up to 20 matrices, nested from the top of the stack to the bottom.

When the matrix environment has been initialized, the SGL stores a matrix, called the “environment matrix,” as the current matrix.

This matrix defines the foundation for the SGL 3D matrix environment; if it is overwritten, it is possible that the transformation operations will not be performed correctly.

The SGL supports the library function “slInitMatrix”, which is used to initialize the stack and various matrix variables.

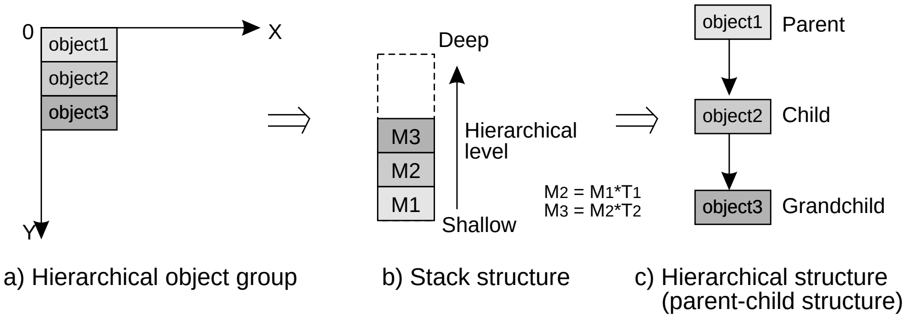
[void slInitMatrix (void)]

This function initializes the stack and matrix variables. After initialization, the environment matrix is stored in the stack as the current matrix.

Overview of hierarchical structures

The following diagram is a conceptual model of an object group with a hierarchical structure. Object 1 is set to the shallowest level of the structure, and object 2 and object 3 are defined at consecutively deeper levels of the structure.

Fig 5-3 Conceptual Model of Hierarchical Structures



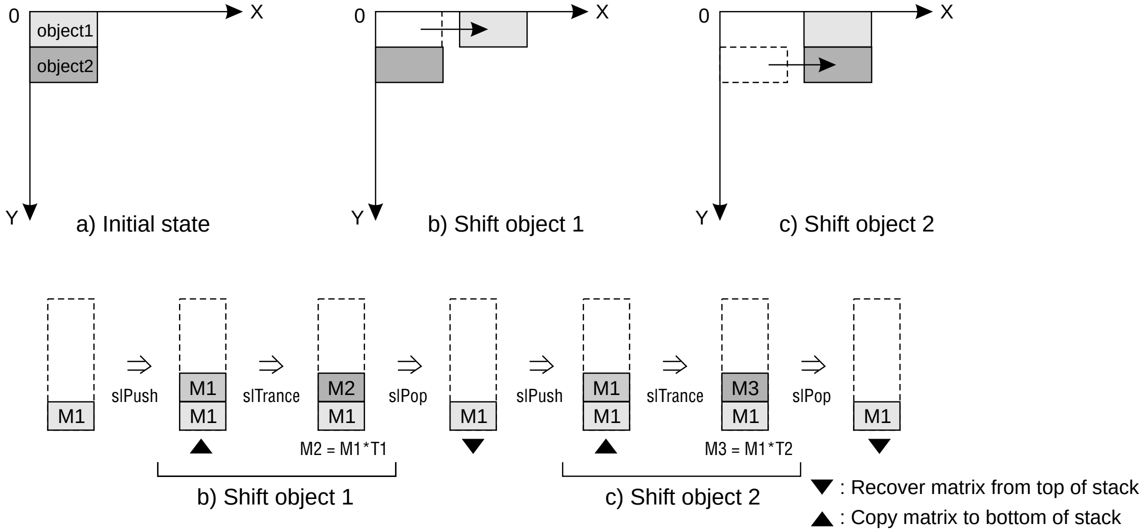
a) Hierarchical object group

b) Stack structure

c) Hierarchical structure (parent-child structure)

When the hierarchical structure is used, the object moves as shown in Fig 5-3. Fig 5-4 and 5-5 show the results when the same transformations are applied to an object group without a hierarchical structure and an object group with one. (Each object is being shifted in the X direction.)

Fig 5-4 Example of Shifting Objects without a Hierarchical Structure



a) Initial state

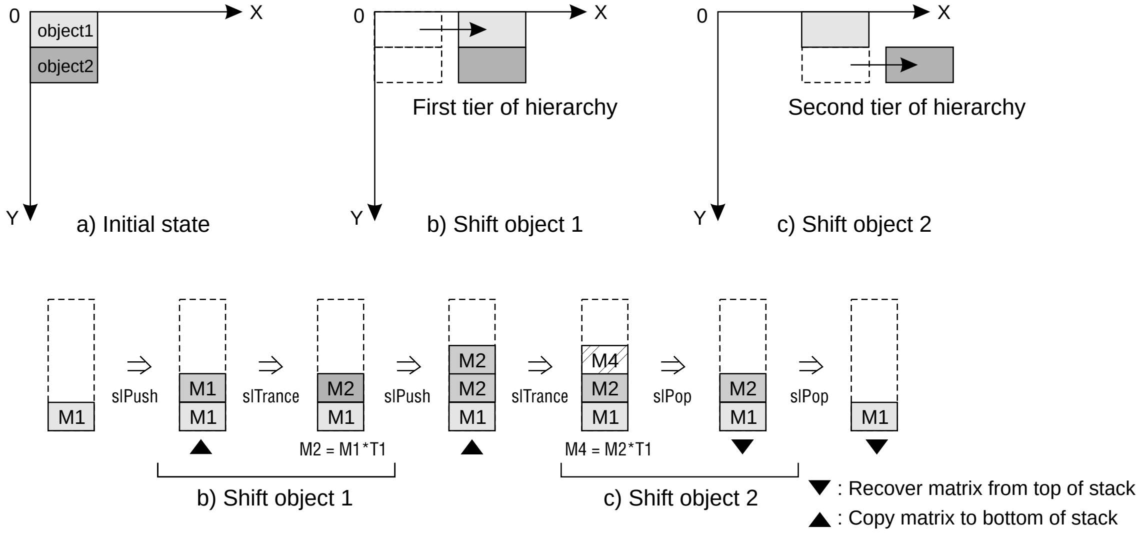
b) Shift object 1

c) Shift object 2

b) Shift object 1

c) Shift object 2

Fig 5-5 Example of Shifting Objects with a Hierarchical Structure



Definition of hierarchical structures in the SEGA Saturn system

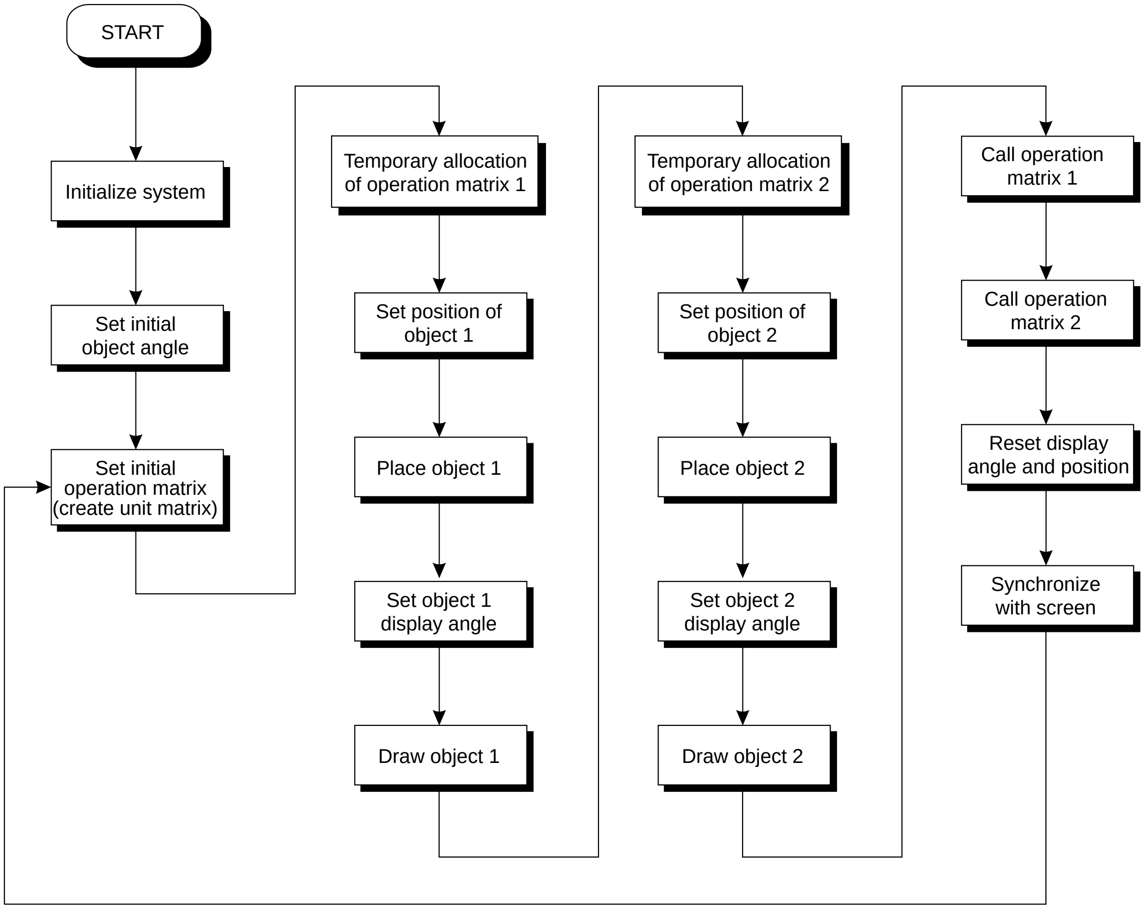
The method for implementing hierarchical structures in the SEGA Saturn system is described below, using a sample program as a reference.

List 5-1 sample_5_2: Hierarchical Matrix Definition

```
/*----------------------------------------------------*/
/*      Double Cube Circle Action                      */
/*----------------------------------------------------*/
#include        "sgl.h"                                  /* include file containing various settings */

#define         DISTANCE_R1     40
#define         DISTANCE_R2     40

exterm PDATA PD_CUBE;

static void set_star(ANGLE ang[XYZ],FIXED pos[XYZ])
{
        slTranslate(pos[X],pos[Y],pos[Z]);
        slRotX(ang[X]);
        slRotY(ang[Y]);
        slRotZ(ang[Z]);
}
void main()
{
        static ANGLE    ang1[XYZ];ang2[XYZ];
        static FIXED    pos1[XYZ];pos2[XYZ];
        static ANGLE tmp=DEGtoANG(0.0);

        slInitSystem(TV_320x224,NULL,1);                 /* screen mode setting */
        slPrint("Sample program 5.2",slLocate(6,2));     /* program title display */

        ang1[X]=ang2[X]=DEGtoANG(30.0);
        ang1[Y]=ang2[Y]=DEGtoANG(45.0);
        ang1[Z]=ang2[Z]=DEGtoANG(0.0);

        pos2[X]=toFIXED(DISTANCE_R2);
        pos2[Y]=toFIXED(0.0);
        pos2[Z]=toFIXED(0.0);
        while(-1){
                slUnitMatrix(CURRENT);                   /* make specified matrix a unit matrix */

                slPushMatrix();                          /* move to bottom of stack */
                {
                        pos1[X]=DISTANCE_R1*slSin(tmp);
                        pos1[Y]=toFIXED(30.0);
                        pos1[Z]=toFIXED(220.0)+DISTANCE_R1*slCos(tmp);
                        set_star(ang1,pos1);
                        slPutPolygon(&PD_CUBE);

                        slPushMatrix();                  /* move to bottom of stack */
                        {
                                set_star(ang2,pos2);
                                slPutPolygon(&PD_CUBE);
                        }
                        slPopMatrix();                   /* move to top of stack */
                }
                slPopMatrix();                           /* move to top of stack */

                ang1[Y]+=DEGtoANG(1.0);                  /* overwrite angle */
                ang2[Y]-=DEGtoANG(1.0);
                tmp+=DEGtoANG(1.0);

                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "polygon.c".

Flow Chart 5-1 sample_5_2: Flow Chart for Hierarchical Matrix Definition


START
Initialize system
Set initial object angle
Set initial operation matrix (create unit matrix)
Temporary allocation of operation matrix 1
Set position of object 1
Place object 1
Set object 1 display angle
Draw object 1
Temporary allocation of operation matrix 2
Set position of object 2
Place object 2
Set object 2 display angle
Draw object 2
Call operation matrix 1
Call operation matrix 2
Reset display angle and position
Synchronize with screen

Matrix Functions

In addition to those described previously, the SGL also supports the following matrix-related library functions:

[void slLoadMatrix (MATRIX mtptr)]

This function copies the matrix specified as the parameter to the current matrix. Substitute a MATRIX-type variable for the matrix being specified as the parameter.

[void slGetMatrix (MATRIX mtptr)]

This function copies the current matrix to the matrix specified as the parameter. Substitute a MATRIX-type variable for the matrix being specified as the parameter.

[void slMultiMatrix (MATRIX mtrx)]

This function multiplies the current matrix with the matrix specified as the parameter. Substitute a MATRIX-type variable for the matrix being specified as the parameter.

[Bool slPushUnitMatrix (void)]

This function allocates a unit matrix in the stack and makes it the current matrix. The previous current matrix is temporarily stored at a high level in the stack.

[void slUnitMatrix (MATRIX mtptr)]

This function makes the matrix specified as the parameter into a unit matrix. Substitute a MATRIX-type variable for the matrix being specified as the parameter.

If “CURRENT” is substituted for the parameter, the target matrix in this case is the current matrix; this can be used to initialize the current matrix.

Supplement. SGL Library Functions Covered in this Chapter

The functions listed in the following table were explained in this chapter.

Table 5-1 SGL Library Functions Covered in this Chapter

Function type	Function name	Parameters	Function
void	slLoadMatrix	MATRIX mtptr	Copy the specified matrix to the current matrix
Bool	slPushMatrix	void	Temporarily store a matrix
Bool	slPushUnitMatrix	void	Temporarily store a unit matrix in the stack
void	slGetMatrix	MATRIX mtptr	Copy the current matrix to the specified matrix
void	slInitMatrix	void	Initialize the matrix variables and buffer
void	slMultiMatrix	MATRIX mtrx	Multiply the specified matrix by the current matrix
Bool	slPopMatrix	void	Recover a temporarily stored matrix
void	slUnitMatrix	MATRIX mtptr	Make the specified matrix into a unit matrix

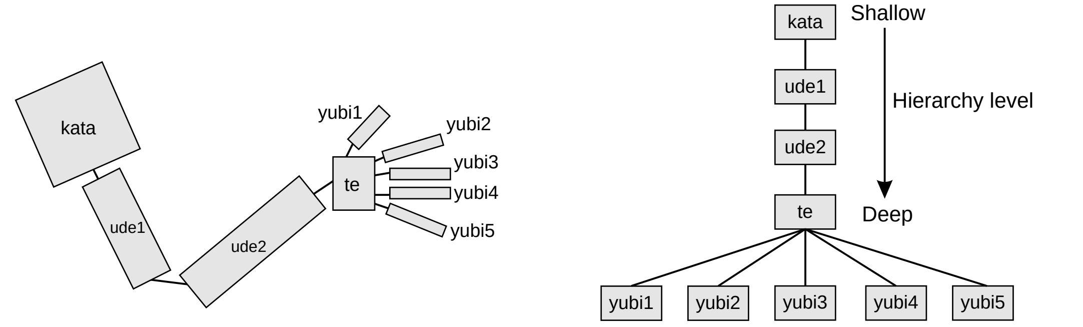
[Demonstration Program B: Matrix Animation]
demo_B

This is a somewhat complex program that uses hierarchical structures.

Hierarchical structures are a concept that is unique to 3D graphics. This is because 3D graphics, which involves handling a large volume of three-dimensional space, requires the ability to handle a large volume of parameters at one time. Especially when maintaining relationships among multiple objects as they move through a 3D space, it is necessary to handle fairly simple yet highly intricate parameter groups at one time. As a result, the concept of the hierarchical structure came into being.

The hierarchical structure is also called a “parent-child” structure. Hierarchical structures are primarily used to represent joints (in modeling humans, etc.) and in representing object groups.

Fig B-1 Representation of Joints Using a Hierarchical Structure

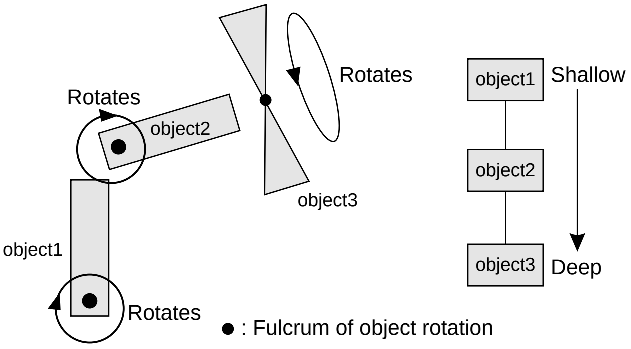


a) Example of joints using a hierarchical structure

b) Conceptual model of a hierarchical structure (parent-child structure)

Demo program B is a sample program that shows animation using a hierarchical structure. In the demonstration, complex motion (animation of an object group with a jointed structure) is realized by creating and maintaining a relationship (parent-child structure) between three objects. If the concept of hierarchical structures was not used, the resulting program would be very complex and intricate.

Fig B-2 Conceptual Model of Demo Program B



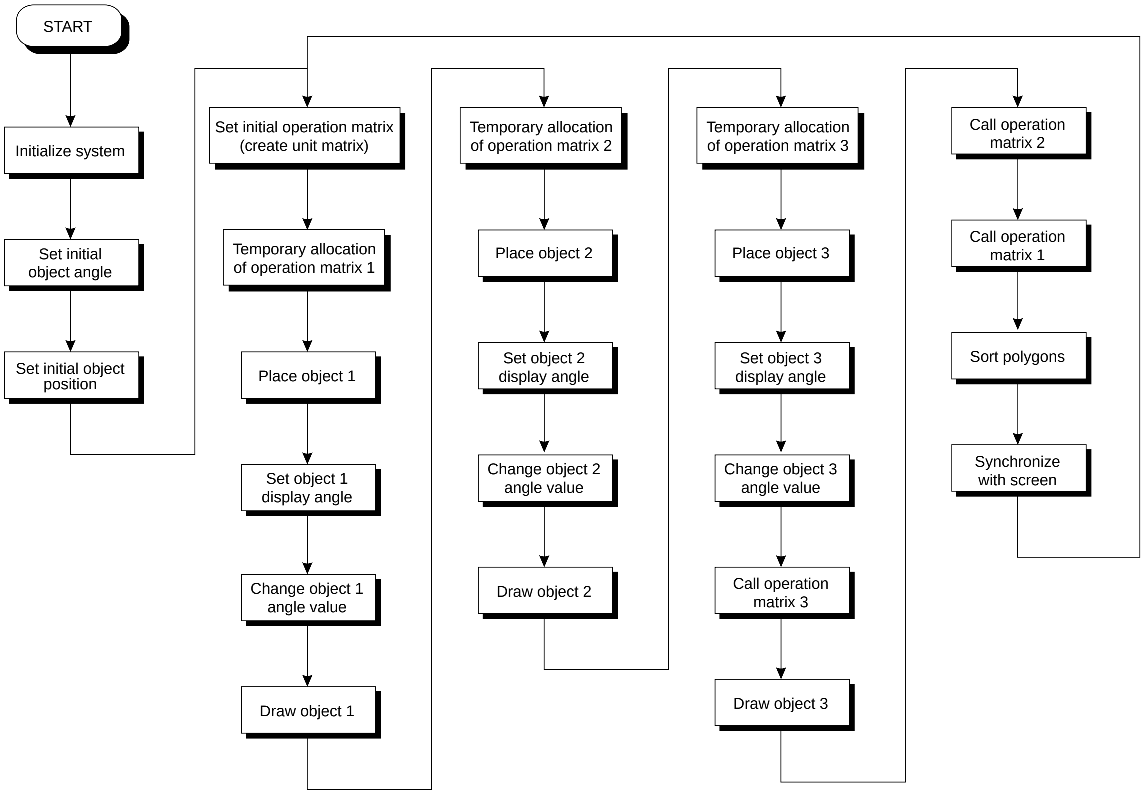
1) Object 1 rotates around its fulcrum
2) Object 2 receives matrix from object 1
3) Object 2 rotates around its fulcrum
4) Object 3 receives matrix
5) Object 3 rotates around its fulcrum

List B-1 demo_B: Animation Using Hierarchical Structures

```
/*------------------------------------------------------*/
/*      Matrix Animation                                 */
/*------------------------------------------------------*/
#include        "sgl.h"        /* include file containing various settings */

exterm PDATA PD_PLANE1,PD_PLANE2,PD_PLA NE3;

static void set_poly(ANGLE ang[XYZ],FIXED pos[XYZ])
{
        slTranslate(pos[X],pos[Y],pos[Z]);
        slRotX(ang[X]);
        slRotY(ang[Y]);
        slRotZ(ang[Z]);
}
void main()
{
        static ANGLE ang1[XYZ],ang2[XYZ],ang3[XYZ];
        static FIXED pos1[XYZ],pos2[XYZ],pos3[XYZ];
        static ANGLE tang,aang;

        slInitSystem(TV_320x224,NULL,1);        /* screen mode setting */
        slPrint("demo B",slLocate(6,2));        /* program title display */

        ang1[X]=ang1[Y]=ang1[Z]=DEGtoANG(0.0);        /* substitution of initial angles for objects */
        ang2[X]=ang2[Y]=ang2[Z]=DEGtoANG(0.0);
        ang3[X]=ang3[Y]=ang3[Z]=DEGtoANG(0.0);
        pos1[X]=toFIXED(0.0);        /* substitution of initial positions for objects */
        pos1[Y]=toFIXED(40.0);
        pos1[Z]=toFIXED(170.0);
        pos2[X]=toFIXED(0.0);
        pos2[Y]=toFIXED(-40.0);
        pos2[Z]=toFIXED(0.0);
        pos3[X]=toFIXED(0.0);
        pos3[Y]=toFIXED(-40.0);
        pos3[Z]=toFIXED(0.0);
        tang=DEGtoANG(0.0);
        aang=DEGtoANG(2.0);

        while(-1){
                slUnitMatrix(CURRENT);
                ang1[Z]=ang2[Z]=tang;
                tang+=aang;
                if(tang<DEGtoANG(-90.0)){
                        aang=DEGtoANG(2.0);
                } else if(tang>DEGtoANG(90.0)){
                        aang=-DEGtoANG(2.0);
                }
                slPushMatrix();        /* move to bottom of stack (second tier of hierarchy) */
                {
                        set_poly(ang1,pos1);
                        slPutPolygon(&PD_PLANE1);        /* draw object 1 */

                        slPushMatrix();        /* move to bottom of stack (third tier of hierarchy) */
                        {
                                set_poly(ang2,pos2);
                                slPutPolygon(&PD_PLANE2);        /* draw object 2 */

                                slPopMatrix();        /* move to bottom of stack (fourth tier of hierarchy) */
                                {
                                        set_poly(ang3,pos3);
                                        ang3[Y]+=DEGtoANG(5.0);
                                        slPutPolygon(&PD_PLANE3);/* draw object 3 */
                                }
                                slPopMatrix();        /* move to top of stack (third tier of hierarchy) */
                        }
                        slPopMatrix();        /* move to top of stack (second tier of hierarchy) */
                }
                slPopMatrix();        /* move to top of stack (first tier of hierarchy) */

                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "polygon.c".

Flow Chart B-1 demo_B: Flow Chart for Hierarchical Structures


START
Initialize system
Set initial object angle
Set initial object position
Set initial operation matrix (create unit matrix)
Temporary allocation of operation matrix 1
Place object 1
Set object 1 display angle
Change object 1 angle value
Draw object 1
Temporary allocation of operation matrix 2
Place object 2
Set object 2 display angle
Change object 2 angle value
Draw object 2
Temporary allocation of operation matrix 3
Place object 3
Set object 3 display angle
Change object 3 angle value
Call operation matrix 3
Draw object 3
Call operation matrix 2
Call operation matrix 1
Sort polygons
Synchronize with screen

The following chapters will explain polygon surface attributes (including priority, color, and texture), background scrolling (which is indispensable for game development), drawing alphanumerics, and input/output control.

SEGA SATURN

6

Programmer’s Tutorial

The Camera

This chapter explains the definition of the “camera” and its operation method.

The camera defines the vantage point from which the 3D space is being viewed, and is also called the “viewing transformation.” The camera consists of the viewpoint, the line of sight, and the angle; by changing these three elements, it is possible to draw anywhere within the space on the projection surface.

Camera Definition and Setup

There are two methods of camera definition and setup in the SGL.

1) Fix the viewpoint at the origin and the line of sight on the Z axis and move the objects to obtain the desired image

2) Fix the objects in place, and move the viewpoint and line of sight to obtain the desired image

In order to implement “1”, it is necessary to apply modeling transformations to all of the objects residing in the space.

To implement “2”, use the library function “slLookAt”.

However, even in the case of “2”, method “1” is used internally, and it only appears that the camera is moving freely within the space.

For more precise camera setup (which will not be covered here), use method “1”. From the standpoint of processing speed, method “1” is more efficient, and it is possible to add changes to the viewpoint and line of sight.

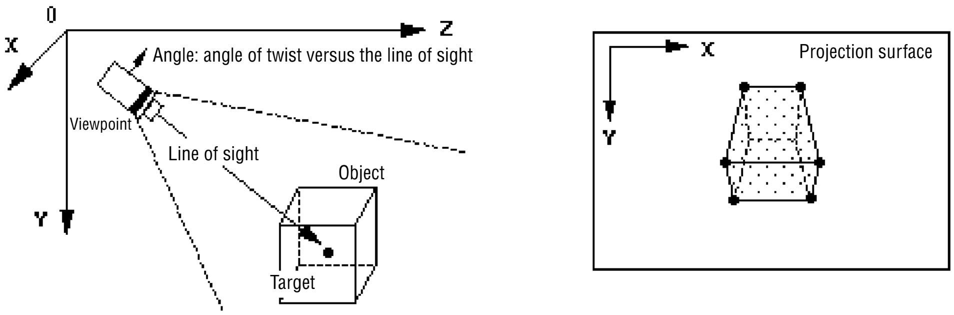
Camera Setup Using “slLookAt”

The SGL supports the library function “slLookAt”, which simplifies camera setup.

[void slLookAt (FIXED *camera, FIXED *target, ANGLE angz);]

This function controls the 3D graphics camera (the direction of the field of view). There are three parameters: the X, Y, and Z coordinates (three-dimensional matrix) of the camera, the X, Y, and Z coordinates (three-dimensional matrix) of the target that determines the direction of the line of sight, and the angle of rotation of the camera versus the direction of the line of sight. When used in conjunction with the functions “slPerspective” and “slWindow”, these three functions can completely determine the 3D graphics drawing region.

Fig 6-1 Conceptual Model of the Camera

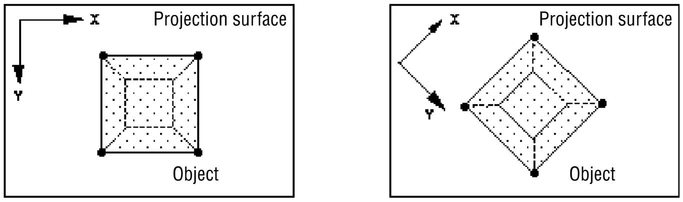


a) Conceptual model of camera

b) Image seen by camera

We will explain the angle parameter in a little more detail here. Put simply, the angle parameter determines the angle of the camera versus the line of sight. By changing the angle parameter, a different image can be drawn on the same line of sight.

Fig 6-2 Differences in an Image Due to the Angle Parameter



a) When top of camera is aligned with the Y axis

b) When the top of the camera is at a 45° angle to the Y axis

Note: The camera position, target coordinates, and the object are exactly the same in diagrams "a" and "b."

Actual Camera Operation

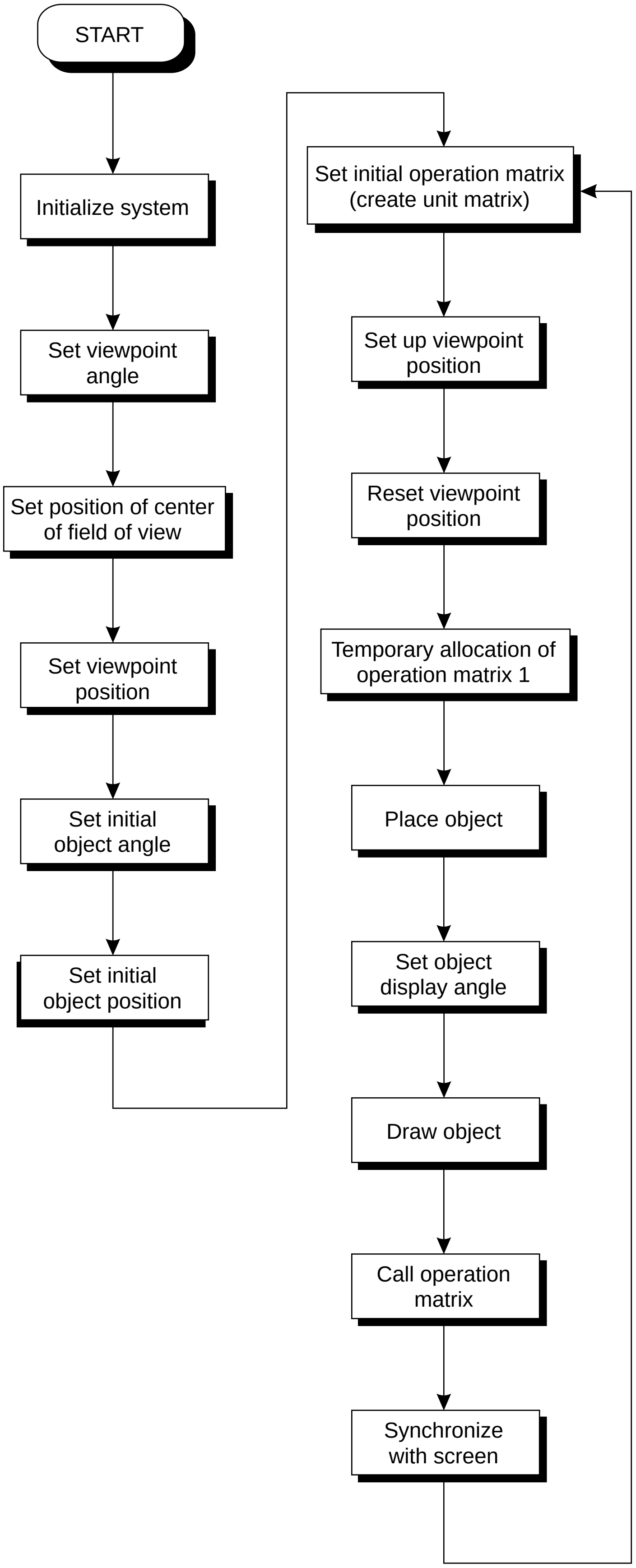
The following listing is for a program that shows the changes in an image that result when the camera parameters are changed so that the camera moves through a 3D space. A cubic polygon with different colors on each side is placed in a 3D space away from the target coordinates.

List 6-1 sample_6_3: Camera Movement

```
/*----------------------------------------------------*/
/*      Camera Action                                  */
/*----------------------------------------------------*/
#include        "sgl.h"                                              /* include file containing various settings */

#define POS_Z   100.0

typedef struct cam{
        FIXEDpos[XYZ]
        FIXEDtarget[XYZ]
        ANGLE   ang[XYZ]
}CAMERA;

extern PDATAPD_CUBE;

static FIXED cubepos[][3]={
        POStoFIXED(20,0,270),
        POStoFIXED(-70,0,270),
        POStoFIXED(40,0,350),
        POStoFIXED(-60,0,370),
};

void dispCube(FIXED pos[XYZ])
{
        slPushMatrix();
        {
                slTranslate(pos[X],pos[Y],pos[Z]);
                slPutPolygon(&PD_CUBE);
        }
        slPopMatrix();
}

void main()
{
        static ANGLE ang[XYZ];
        static CAMERA   cmbuf;
        static ANGLE tmp=DEGtoANG(0,0);

        slInitSystem(TV_320x224,NULL,1);                             /* screen mode setting */
        slPrint("Sample program6.3",slLocate(9,2));                  /* program title display */

        cmbuf.ang[X]=cmbuf.ang[Y]= cmbuf.ang[Z]= DEGtoANG(0,0);
        cmbuf.target[X]=cmbuf.target[Y]= toFIXED(0,0);               /* initial setting of camera variables */
        cmbuf. target [Z]=toFIXED(320,0);
        cmbuf.pos[X]=toFIXED( 0.0);
        cmbuf.pos[Y]=toFIXED(-20.0);
        cmbuf.pos[Z]=toFIXED( 0.0);

        while(-1){
                slUnitMatrix(CURRENT);                               /* initialization of operation matrix */
                slLookAt(cmbuf.pos, cmbuf.target, cmbuf.ang[Z]);     /* camera setup */
                tmp+=DEGtoANG(2.0);                                  /* change camera setting variables */
                cmbuf.pos[X]=POS_Z*slCos(tmp);
                cmbuf.pos[Z]=POS_Z*slSin(tmp);

                dispCube(cubepos[0]);
                dispCube(cubepos[1]);                                /* draw object */
                dispCube(cubepos[2]);
                dispCube(cubepos[3]);

                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "polygon.c".

Flow Chart 6-1 sample_6_3: Flow Chart for Camera Movement



Supplement. SGL Library Functions Covered in this Chapter

The functions listed in the following table were explained in this chapter.

Table 6-1 SGL Library Functions Covered in this Chapter

Function type	Function name	Parameters	Function
void	slLookAt	FIXED *camera, *target, ANGLE angz	Multiplies line of sight matrix with the current matrix

7

Programmer’s Tutorial

Polygon Face Attributes

This chapter explains polygon face attributes in the SEGA Saturn system. The polygon attributes include: “Sort”, which shows the reference position that determines the display order; the “front-back attribute”, which specifies whether one or both sides of a polygon is to be displayed; and “texture”, a 2D picture (bit-mapped data) that is applied to the polygon.

By specifying the polygon attributes, it is possible to add a variety of representations to polygons that were simply pictures before.

Attributes

In the SEGA 3D Game Library (SGL), polygon attributes are specified by the ATTRIBUTE macro.

In the sample programs used in this manual up to this point, these attributes have been set tacitly without a detailed explanation of their contents.

However, the attributes are a collection of very important elements for the handling of polygons. Therefore, this section will explain each of the parameters of the ATTRIBUTE macro in detail.

List 7-1 Attribute Data

● Attribute data ●

```
ATTR attribute_label [ ] = {
     ATTRIBUTE ( plane, sort, texture, color, ground, mode, dir, option),
     .....................
};
```

Note: The ATTRIBUTE macro is defined in "sl_def.h".

The meaning of each parameter is as follows:

plane: Indicates whether the polygon is a one-sided polygon or a double-sided polygon (front-back attribute).

sort: Indicates the representative point for the polygon’s positional relationships (Zsort).

texture: Indicates the texture name (No.).

color: Indicates the color data.

gouraud: Indicates the gouraud shading table address.

mode: Indicates the polygon drawing mode (various mode settings).

dir: Indicates the status of the polygon and the texture.

option: Indicates other functions (optional settings).

Plane

The first attribute parameter, “plane”, indicates the front-back attribute of the polygon. The front-back attribute is the attribute that indicates whether the polygon is single-sided or double-sided.

A double-sided polygon can be seen from both the front and the back, but a single-sided polygon disappears if viewed from the back.

The macros that can be specified for this parameter are introduced below.

Table 7-1 Plane (Front-Back Attribute)

Macro	Description
Single_Plane	Single-sided display of polygon
Dual_Plane	Double-sided display of polygon

Now let’s examine the sample program (List 7-2). In this program, a single-sided yellow polygon is rotating around the Y axis. Because it is a single-sided polygon, the back of the polygon is not displayed.

List 7-2 sample_7_2: main.c

```
/*----------------------------------------------------*/
/*      Rotation of Single Plane Polygon               */
/*----------------------------------------------------*/
#include        "sgl.h"

exterm PDATA PD_PLANE;

void main()
{
        static ANGLE ang[XYZ];
        static FIXED pos[XYZ];

        slInitSystem(TV_320x224,NULL, 1);        /* initialization */
        slPrint("Sample program 7.2",slLocate(6,2));

        ang[X]=ang[Y]=ang[Z]=DEGtoANG(0,0);       /* initial angle substitution */
        pos[X]=toFIXED( 0.0);                     /* initial position substitution */
        pos[Y]=toFIXED( 0.0);
        pos[Z]=toFIXED(170.0);

        while(-1){
                slPushMatrix();                   /* save matrix */
                {
                        slTranslate(pos[X],pos[Y],pos[Z]);   /* set position */
                        slRotX(ang[X]);                      /* set angle */
                        slRotY(ang[Y]);
                        slRotZ(ang[Z]);
                        ang[Y]+=DEGtoANG(2.0);               /* addition of Y axis rotation angle */
                        slPutPolygon(&PD_PLANE);             /* polygon drawing function */
                }
                slPopMatrix();                    /* recover matrix */

                slSynch();
        }
}
```

Look again at line 27. This line calls the polygon drawing routine “slPutPolygon”, and passes the pointer to the polygon data “PD_PLANE”.

“PD_PLANE” is defined in the source file “polygon.c” as shown below.

List 7-3 sample_7_2: Polygon.c

```
#include                "sgl.h"

POINTpoint_PLANE1[]={
        POStoFIXED(-20.0,-20.0,0.0),
        POStoFIXED( 20.0,-20.0,0.0),
        POStoFIXED( 20.0, 20.0,0.0),
        POStoFIXED(-20.0, 20.0,0.0),
};
POLYGONpolygon_PLANE1[]={
        NORMAL(0.0,0.0,1.0),VERTICES(0,1,2,3),
};
ATTRattribute_PLANE1[]={
        ATTRIBUTE(Single_Plane,SORT_CEN,No_Texture,C_RGB(31,31,0),NO_Gouraud,MESHoff,sprPolygon,No_Option),
};

PDATAPD_PLANE1={                                                     /* polygon data */
        point_PLANE,sizeof(point_PLANE)/sizeof(POINT),
        polygon_PLANE,sizeof(polygon_PLANE)/sizeof(POLYGON),
        attribute_PLANE
};
```

The polygon data starts in line 18. Because line 21 is the pointer for the attribute data, the data actually starts in line 14.

As you can see, the first parameter is “Single_Plane”. change this to “Dual_Plane” and execute the program again. Whereas only one side of the polygon was displayed before, now both sides of the polygon should be displayed.

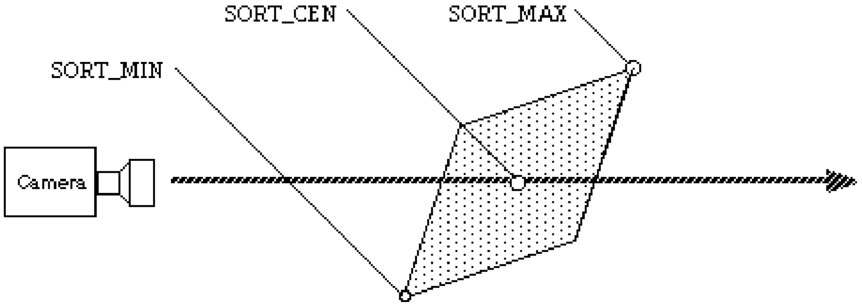
The second parameter, “Sort”. specifies the Z sort position on the polygon. The Z sort method uses a representative point on each polygon to determine its position in 3D space and its interrelationships with other polygons. This method offers the advantage of faster computing and drawing than the Z buffer method (in which the position is determined for each pixel in the polygon). The macros that can be specified for this parameter are introduced below.

Table 7-2 Z Sort Specification

Macro	Description
SORT_MIN	Makes the point (on the polygon) closest to the camera the representative point.
SORT_CEN	Makes the center point of the polygon the representative point.
SORT_MAX	Makes the point (on the polygon) farthest from the camera the representative point.
SORT_BFR	Displays the polygon in front of the last polygon that was registered.

The following diagram illustrates each of these specifications.

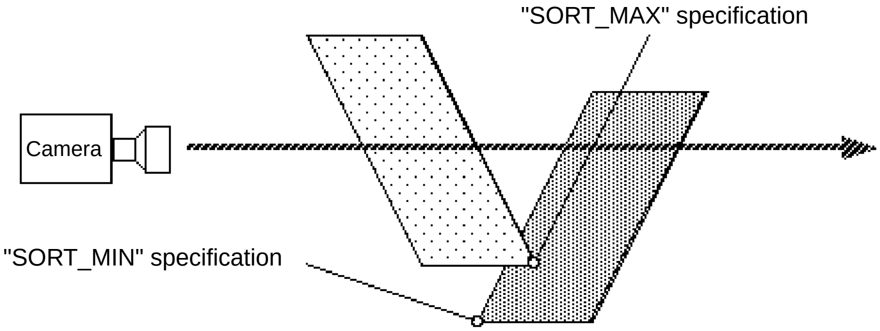
Fig 7-1 Z Sort Representative Points



“SORT_BFR” is a special specification that is used to display a certain polygon on top of (in front of) another polygon. To be specific, the display position of the polygon for which “SORT_BFR” is specified is right in front of the polygon that was registered last. This specification is not used often, since it has meaning only in cases where you wish to group two polygons together and use them as a unit.

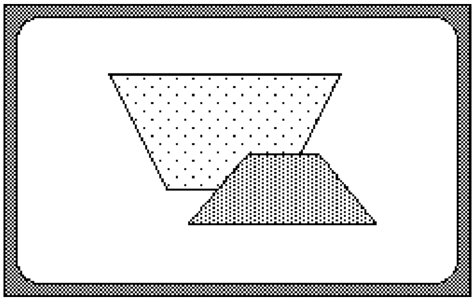
Due to the nature of the Z sort method, the manner in which the representative point is determined may cause unusual interrelationships. The following illustration is an example of such as case.

Fig. 7-2 Differences in Interrelationships Due to the Representative Points



If the representative points are specified as shown in the above diagram, the actual screen image will appear as shown below.

Fig. 7-3 Actual Screen Image



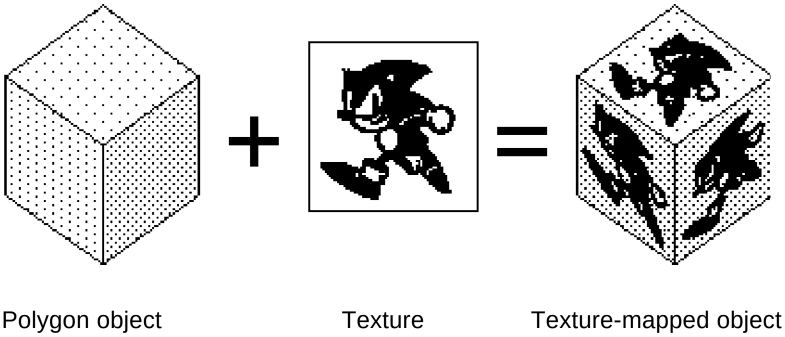
Texture

The third parameter is required when using texture mapping. Specify the texture number to be actually used from the texture table that was registered using the function “slInitSystem”.

If texture is not to be used, specify the macro “No_Texture”.

“Texture mapping” is the name of a function in which 2D graphics are applied to the surface of a polygon. Polygons by themselves can only display colors, and it goes without saying that this limits the realism of the objects. By using the texture mapping function, however, it is possible to replicate 3D objects with a higher degree of realism by depicting textures and surface patterns that could not be represented solely with polygons.

Fig 7-4 Texture Mapping



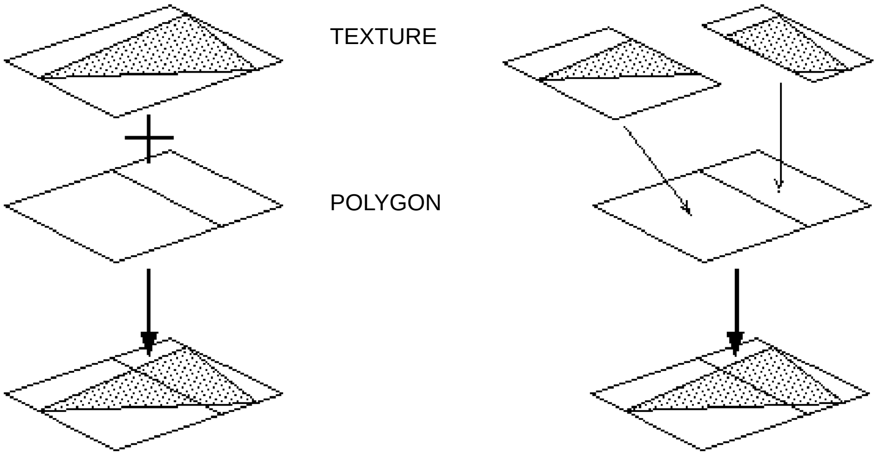
As shown in Table 7-3, there are two major differences between texture mapping in the SEGA Saturn system and texture mapping in computer graphics in general.

Table 7-3 Differences between Texture Mapping in the SEGA Saturn System and Texture Mapping in General Computer Graphics

	SEGA Saturn Texture Mapping	**General Computer Graphics Texture Mapping**
Texture application	Only one texture can be applied to one polygon	One texture can be applied across multiple polygons
Texture shape	Texture changes shape according to shape of polygon	Texture is clipped according to shape of polygon

Texture application

Fig 7-5 Special Texture Characteristic 1



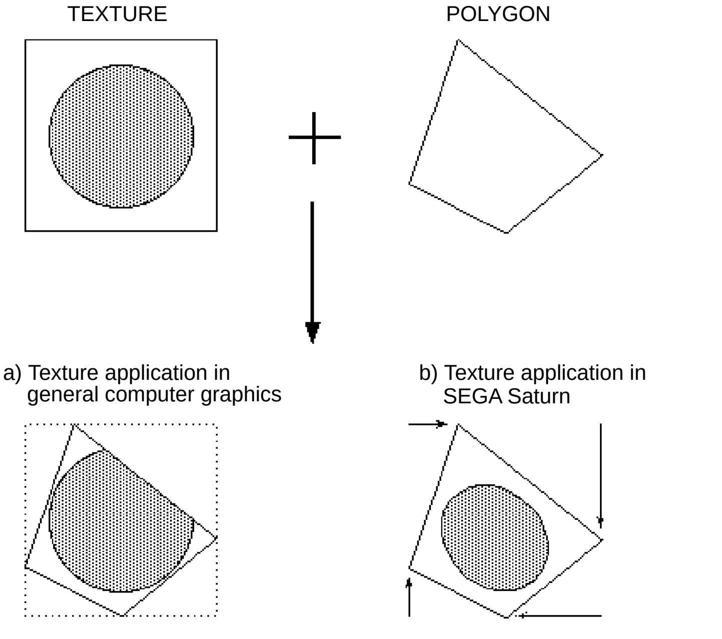
a) Texture application in general computer graphics

b) Texture application in SEGA Saturn

While in general computer graphics it is possible to apply one texture across multiple polygons, in the SEGA Saturn system, one texture is applied to only one polygon. To apply texture across two or more polygons, it is necessary to divide the texture for each polygon as shown in Fig 7-5.

Texture Shaping

In general computer graphics, if the polygon is not rectangular (or square), the texture is clipped according to the shape of the polygon. However, in the SEGA Saturn system, the texture is not clipped, and instead changes shape to conform to the polygon. Even if the polygon is a triangle, the texture changes to a triangular shape.



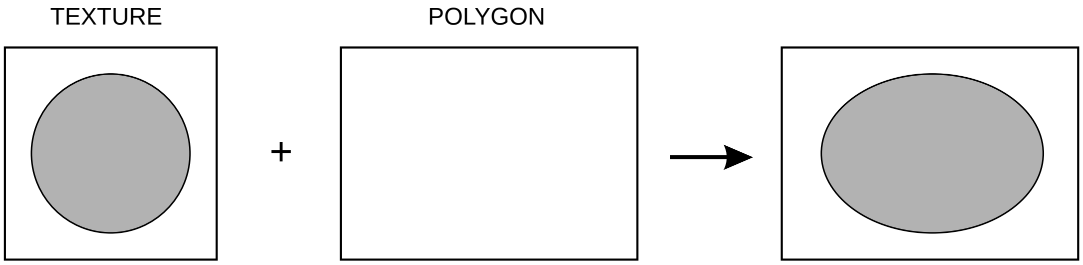
a) Texture application in general computer graphics

b) Texture application in SEGA Saturn

The texture changes shape to conform with the shape of the polygon.

Note: Texture distortion
When a polygon is rectangular and the texture is square, the texture will change to a rectangular shape in order to match the aspect ratio of the polygon.
Therefore, is best to try to remember to keep the aspect ratio of the texture as close as possible to the aspect ratio of the polygon in order to minimize texture distortion.

Fig 7-7 Texture Distortion



Let’s now examine another sample program (List 7-4).

In this program, a single polygon with texture applied rotates around the Y axis. In this program, two textures are registered. One is a 4 × 4 matrix-type picture (size: 64 × 64 pixels), and the other is the “AM2” mark (size: 64 × 64 pixels).

List 7-4 sample_7_4: main.c

```
/*-----------------------------------------------------*/
/*      Polygon & Texture                               */
/*-----------------------------------------------------*/
#include        "sgl.h"

exterm PDATA            PD_PLANE;
exterm TEXTURE  tex_sample[];
exterm PICTURE          pic_sample[];

#define         max_texture     2                        /* number of texture registrations */

void set_texture(PICTURE*pcptr,Uint32 NbPicture)         /* store texture data in VRAM */
{
        TEXTURE*txptr;

        for(;NbPicture-->0;pcptr++){
                txptr=tex_sample+pcptr->texno;
                slDMACopy(void*)pcptr->pcsrc,
                        (void*)(SpriteVRAM+((txptr->CGadr)<<3)),
                        (Uint32)((txptr->Hsize*txptr->Vsize*4)>>(pcptr->cmode)));
        }
}

void main()
{
        static ANGLE ang[XYZ];
        static FIXED pos[XYZ];

        slInitSystem(TV_320x224,tex_sample,1);           /* initialization */
        set_texture(pic_sample,max_texture);             /* store texture data */
        slPrint("Sample program7.4",slLocate(9,2));

        ang[X]=ang[Y]=ang[Z]=DEGtoANG(0.0);              /* initial angle substitution */
        pos[X]=toFIXED( 0.0);
        pos[Y]=toFIXED( 0.0);                            /* initial position substitution */
        pos[Z]=toFIXED(170.0);

        while(-1){
                slPushMatrix();                          /* save matrix */
                {
                        slTranslate(pos[X],pos[Y],pos[Z]);   /* set position */
                        slRotX(ang[X]);
                        slRotY(ang[Y]);                  /* set angle */
                        slRotZ(ang[Z]);
                        ang[Y]+=DEGtoANG(2.0);           /* addition of Y axis rotation angle */
                        slPutPolygon(&PD_PLANE);         /* polygon drawing function */
                }
                slPopMatrix();                           /* recover matrix */

                slSynch();
        }
}
```

The flow of the program is basically the same as that of List 7-2.

Look closely at line 29.

Although this is the initialization routine that has been tacitly used up to this point, the specification of the second parameter is different this time. Here the parameter specifies the pointer for the texture table to be passed to SGL. (The actual table is defined by “texture.c”; refer to List 7-5.) Because texture has not been used up to this point, previously “NULL” was specified.

In line 30, the texture data is transferred to VRAM.

Because this texture data transfer can be executed at any point after initialization, it is easy to draw over the previous texture in the middle of a game, for example.

The actual texture data transfer routine starts in line 12.

The starting address of the texture table and the number of texture registrations are accepted here. In line 18, the function “slDMACopy” executes a high-speed DMA data transfer. The first parameter of this function is the transfer source address, the second parameter is the transfer destination address, and the third parameter indicates the size of the transfer.

[void slDMACopy (void *src, void *dst, Uint16 cnt);]

This function executes a block transfer of data using the DMA built into the CPU.

For the parameters, substitute the start address of the area in memory that is the source of the transfer, the start address of the area in memory that is the destination of the transfer, and the number of bytes in the transfer block.

The function in question completes the transfer soon after DMA is activated.

Use the function “slDMAWait” if you want to know when the transfer is completed.

Next, let’s examine the texture data.

List 7-5 sample_7_4: texture.c

```
#include              "sgl.h"                   /* include file containing various settings */

/******************************/
/*      Texture Data          */
/*****************************/

TEXDAT sonic_64x64[]={                          /* texture data 1 */
        0xffff,0xffff,0xffff,0xffff,0xffff,0xffff,0xffff,0xffff,
        ... omitted ...

        };

TEXDAT am2_64x32[]={                            /* texture data 2 */
        0xffff,0xffff,0xffff,0xffff,0xffff,0xffff,0xffff,0xffff,
        ... omitted ...

        };

/*******************************/
/*      Texture Table          */
/*******************************/

TEXTURE tex_sample[]={                          /* table to be passed to SGL */
        TEXDEF(64,64,0),
        TEXDEF (64,32,64*64*1),
};

/******************************/
/*      Picture Table         */
/*****************************/

PICTURE pic_sample[]={                          /* table for transfer to VRAM */
        PICDEF(0,COL_32K,sonic_64x64),
        PICDEF(1,COL_32K,am2_64x32),
};
```

The TEXDAT macro describes the actual texture data. Although omitted from the above listing, all of the data is included in the source listing. Finally, the texture data format is beyond the scope of this manual. Refer to the "Function Reference" of the Reference Manual.

The TEXTURE macro describes the texture table to be passed to SGL. This macro sets the size (horizontal × vertical) and the offset from the start address of the actual texture data for each texture.

Finally, the PICTURE macro describes the VRAM transfer table. This macro sets each texture number, color mode, and texture data pointer.

Lastly, we will examine the polygon data attributes.

List 7-6 sample_7_4: polygon.c

```
#include        "sgl.h"

#define         PN_SONIC        0
#define         PN_AM2          1

POINT point_plane[]={
        POStoFIXED(-40.0,-40.0, 0.0),
        POStoFIXED( 40.0,-40.0,0.0),
        POStoFIXED( 40.0, 40.0,0.0),
        POStoFIXED(-40.0, 40.0,0.0),
};

POLYGON polygon_plane[]={
        NORMAL(0.0,0.01.0),     VERTICES(0,1,2,3),
};
ATTR attribute_plane[]={
        ATTRIBUTE(Single_Plane,SORT_CEN, PN_SONIC, No_Palet, No_Gouraud, CL32KRGB|MESHoff,
sprNoflip, No_Option),
};                                                                             /* attribute settings */
PDATAPD_PLANE={                                                                /* polygon data */
        point_plane, sizeof(point_plane)/sizeof(POINT),
        polygon_plane, sizeof(polygon_plane)/sizeof(POLYGON),
        attribute_plane
};
```

The third “ATTRIBUTE” parameter is “PN_SONIC”. In short, the “4 × 4 matrix” with the texture number registered as “0” is applied to the polygon.

Next, change this parameter to “PN_AM2” and observe the result.

The texture changes to texture number 1, the “AM2” mark.

It is also possible to view the texture from the back by changing the first parameter, “Single_Plane”, to “Dual_Plane”.

Color

The fourth parameter “Color” specifies the polygon color and the offset address for the texture color palette.

In the case of a polygon, the color data specification method is limited to RGB direct, and the format is “C_RGB(r,g,b)”. “r,g,b” refer to the three primary colors of light (red, green, and blue), and can be specified with decimal numbers in the range from 0 to +31.

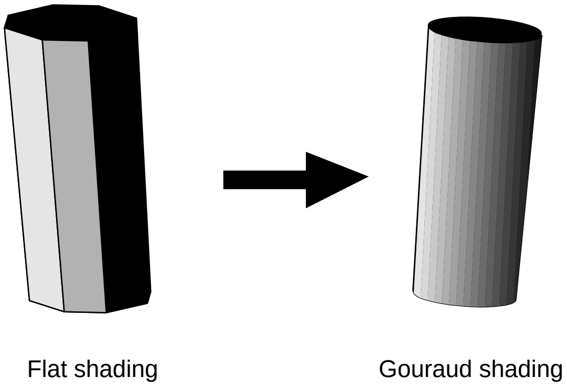
In the case of texture, the color data specification method depends on the “Mode” specification (the sixth attribute parameter; refer to "Mode"). Specify either the macro “No_Palet” in the case of 32,768-color RGB mode, or else the offset address for the color palette in the case of another index mode.

Gouraud

The fifth parameter, “Gouraud”, specifies the gouraud table used for gouraud shading.

“Gouraud shading” is a technique that, as opposed to the flat shading which clearly delineates the boundaries between polygons, applies shadow processing to the surfaces of polygons in order to eliminate the boundary line between polygons and create the impression of a curved surface. In the SEGA Saturn system, gouraud shading is implemented by using the color gradations between polygon vertices.

Fig 7-8 Gouraud Shading



The sample program (List 7-7) shows a cube with gouraud shading rotating around the Y axis.

List 7-7 sample_7_6: main.c

```
/*----------------------------------------------------*/
/*      Gouraud Shading                                */
/*----------------------------------------------------*/
#include        "sgl.h"

exterm PDATA PD_CUBE;

#idefine        GroffsetTBL(r,g,b)      (((b & 0x1f)<<10) | ((g & 0x1f)<<5) | (r & 0x1f))
#define         VRAMaddr        (SpriteVRAM+0x70000)

static Uint16 GRdata[6][4]={
        { GRoffsetTBL( 0,-16,-16) , GRoffsetTBL( 0,-16,-16) ,     /* gouraud table */
        GRoffsetTBL( 0,-16,-16) , GRoffsetTBL(-16, 15, 0) } ,
        { GRoffsetTBL( 0,-16,-16) , GRoffsetTBL( 0,-16,-16) ,
        GRoffsetTBL(-16, 15, 0) , GRoffsetTBL( 0,-16,-16) ,
        { GRoffsetTBL(-16, 15, 0) , GRoffsetTBL( 0,-16,-16) ,
        GRoffsetTBL( 0,-16,-16) , GRoffsetTBL( 0,-16,-16) ,
        { GRoffsetTBL( 0,-16,-16) , GRoffsetTBL(-16, 15, 0) ,
        GRoffsetTBL( 0,-16,-16) , GRoffsetTBL( 0,-16,-16) ,
        { GRoffsetTBL( 0,-16,-16) , GRoffsetTBL(-16, 15, 0) ,
        GRoffsetTBL( 0,-16,-16) , GRoffsetTBL( 0,-16,-16) ,
        { GRoffsetTBL(-16, 15, 0) , GRoffsetTBL( 0,-16,-16) ,
        GRoffsetTBL( 0,-16,-16) , GRoffsetTBL( 0,-16,-16) ,
};

void main()
{
        static ANGLE    ang[XYZ];
        static FIXED    pos[XYZ];

        slInitSystem(TV_320x224,NULL,1);                          /* initialization */
        slPrint("Sample program 7.6", slLocate(9,2));

        ang[X]=DEGtoANG(30.0);
        ang[Y]=DEGtoANG(0.0);                                     /* initial angle substitution */
        ang[Z]=DEGtoANG(0.0);
        pos[X]=toFIXED(0.0);
        pos[Y]=toFIXED(0.0);                                      /* initial position substitution */
        pos[Z]=toFIXED(200.0);

slDMACopy(GRdate,(void*)VRAMaddr,sizeof(GRdata));                 /* store gouraud table */

        while(-1){
                slPushMatrix();                                   /* save matrix */
                {
                        slTranslate(pos[X] , pos[Y] , pos[Z]);
                        slRotX(ang[X]);
                        slRotY(ang[Y]);                           /* set position */
                        slRotZ(ang[Z]);
                        slPutPolygon(&PD_CUBE);                   /* polygon drawing function */
                }
                slPopMatrix();                                    /* recover matrix */

                ang[Y] += DEGtoANG(1.0);                          /* addition of Y axis rotation angle */

                slSynch();
        }
}
```

The routine that draws the cube and rotates it is not very different from what has been used before, so its explanation is omitted here. What is different from previous programs is line 41, where the gouraud table is sent to VRAM. The approach is the same as for the texture data transfer; all of the required tables are first stored in VRAM.

Now let’s proceed to the next attribute.

List 7-8 sample_7_6: polygon.c

```
#include        "sgl.h"

#define GRaddr  0xe000

static POINT point_CUBE[]={
        POStoFIXED(-20.0,-20.0,20.0),
        POStoFIXED( 20.0,-20.0,20.0),
        POStoFIXED( 20.0,20.0,20.0),
        POStoFIXED(-20.0,20.0,20.0),
        POStoFIXED(-20.0,-20.0,-20.0),
        POStoFIXED( 20.0,-20.0,-20.0),
        POStoFIXED( 20.0,20.0,-20.0),
        POStoFIXED(-20.0,20.0,-20.0),
};

static POLYGON polygon_CUBE[]={
        NORMAL( 0.0,0.0,1.0),VERTICES(0,1,2,3),
        NORMAL(-1.0,0.0,0.0),VERTICES(4,0,3,7),
        NORMAL( 0.0,0.0,-1.0),VERTICES(5,4,7,6),
        NORMAL( 1.0,0.0,0.0),VERTICES(1,5,6,2),
        NORMAL( 0.0,-1.0,0.0),VERTICES(4,5,1,0),
        NORMAL( 0.0,1.0,0.0),VERTICES(3,2,6,7),
};

static ATTR attribute_CUBE[]={ ◄──────────────────────────────── /* attribute settings */
        ATTRIBUTE(Single_Plane,SORT_MIN, No_Texture,C_RGB(31,16,31),GRaddr, MESHoffiCL_Gourand,sprPolygon,No_Option),
        ATTRIBUTE(Single_Plane,SORT_MIN, No_Texture,C_RGB(31,16,31),GRaddr,+1,MESHoffiCL_Gourand,sprPolygon,No_Option),
        ATTRIBUTE(Single_Plane,SORT_MIN, No_Texture,C_RGB(31,16,31),GRaddr,+2,MESHoffiCL_Gourand,sprPolygon,No_Option),
        ATTRIBUTE(Single_Plane,SORT_MIN, No_Texture,C_RGB(31,16,31),GRaddr,+3,MESHoffiCL_Gourand,sprPolygon,No_Option),
        ATTRIBUTE(Single_Plane,SORT_MIN, No_Texture,C_RGB(31,16,31),GRaddr,+4,MESHoffiCL_Gourand,sprPolygon,No_Option),
        ATTRIBUTE(Single_Plane,SORT_MIN, No_Texture,C_RGB(31,16,31),GRaddr,+5,MESHoffiCL_Gourand,sprPolygon,No_Option),
};

PDATA PD_CUBE={ ◄─────────────────────────────────────────┐─ /* polygon data */
        point_CUBE, sizeof(point_CUBE)/sizeof(POINT),        │
        polygon_CUBE,sizeof(polygon_CUBE)/sizeof(POLYGON),   │
        attribute_CUBE                                       ┘
};
```

Examine the attributes closely.

The VRAM address where the gouraud data was stored earlier is specified for the fifth parameter. The VRAM address specified here is relative address divided by eight.

Now look at the sixth parameter.

When using gouraud shading, this parameter must be specified as “CL_Gouraud”. This specification will be explained later.

Note that the macro “No_gouraud” should be specified for “Gouraud” when not using gouraud shading.

Mode

The sixth parameter is “Mode”.

This parameter is used to add a variety of conditions and settings to the polygon. The macros that can be specified for this parameter are shown in the following table.

Table 7-4 Modes

Group	Macro	Description
[1]	No_Window	Accept no window restrictions (default)
	Window_In	Display inside window
	Window_Out	Display outside window
[2]	MESHoff	Normal display (default)
	MESHon	Display with mesh
[3]	ECdis	Disable EndCode
	ECenb	Enable EndCode (default)
[4]	SPdis	Display clear pixels (default)
	SPenb	Do not display clear pixels
[5]	CL16Bnk	16-color color bank mode (default)
	CL16Look	16-color look-up table mode
	CL64Bnk	64-color color bank mode
	CL128Bnk	128-color color bank mode
	CL256Bnk	256-color color bank mode
	CL32KRGB	32,768-color RGB mode
[6]	CL_Rdplace	Overwrite (standard) mode (default)
	CL_Shadow	Shadow mode
	CL_Half	Half-bright mode
	CL_Trans	Semi-transparent mode
	CL_Gouraud	Gouraud shading mode

One option from each group can be specified. Use consecutive description, delimiting the options with the “or” (“|”) operator.

> **Note: If a group is omitted, the default option is assumed. However, it is not permissible to omit specifications for all of the options. To use the default options for all groups, specify “No_Window” as dummy data.**

Because group [5] is used to specify the texture color mode, you must set the default option (either specify “CL_16Bnk” or make no specification for this group) if texture is not to be used. If any other mode is specified in this case, the polygon will not be displayed.

As an exception, in group [6] it is possible to specify “CL_Gouraud | CL_Half” and “CL_Gouraud | CL_Trans” if you wish to use half-bright gouraud shading or semi-transparent gouraud shading.

Note that when using gouraud shading it is necessary to both set the fifth parameter and to specify “CL_Gouraud” here.

When using half-bright mode, semi-transparent mode, or gouraud shading, polygons support only RGB direct mode and textures support only 32,768-color RGB mode. Objects will not be displayed properly with any other settings.

The seventh parameter is “Dir”. This parameter specifies whether the object is a polygon or a texture, and if it is a texture, how it should be flipped.

Table 7-5 Dir

Macro	Description
sprNoflip	Display texture normally
sprHflip	Flip texture horizontally
sprVflip	Flip texture vertically
sprHVflip	Flip texture vertically and horizontally
sprPolygon	Display polygon
sprPolyLine	Display polyline
sprLine	Display a straight Line using the first two points

Note: If texture is not being applied to an object, do not specify “sprHflip” or “sprVflip”. Specify sprLine with four points, just as with a polygon. (Repeat the specifications of the first two points.)

Option

The last parameter is “Option”. Other settings concerning polygons and textures are made here. At present, the SGL only supports the following two options:

Table 7-6 Options

Macro	Description
UseLight	Perform light source calculations
UseClip	Do not display vertices outside of the display area
UsePalette	Indicates that the palette format is used for the polygon color

More than one option can be specified by using the “or” (“|”) operator.

> **Note: If no options are to be used, specify the “No_Option” macro. To perform light source calculations when the polygon color is in palette format, use both "UsePalette" and "UseLight".**

Supplement. SGL Library Functions Covered in this Chapter

The functions listed in the following table were explained in this chapter.

Table 7-7 SGL Library Functions Covered in this Chapter

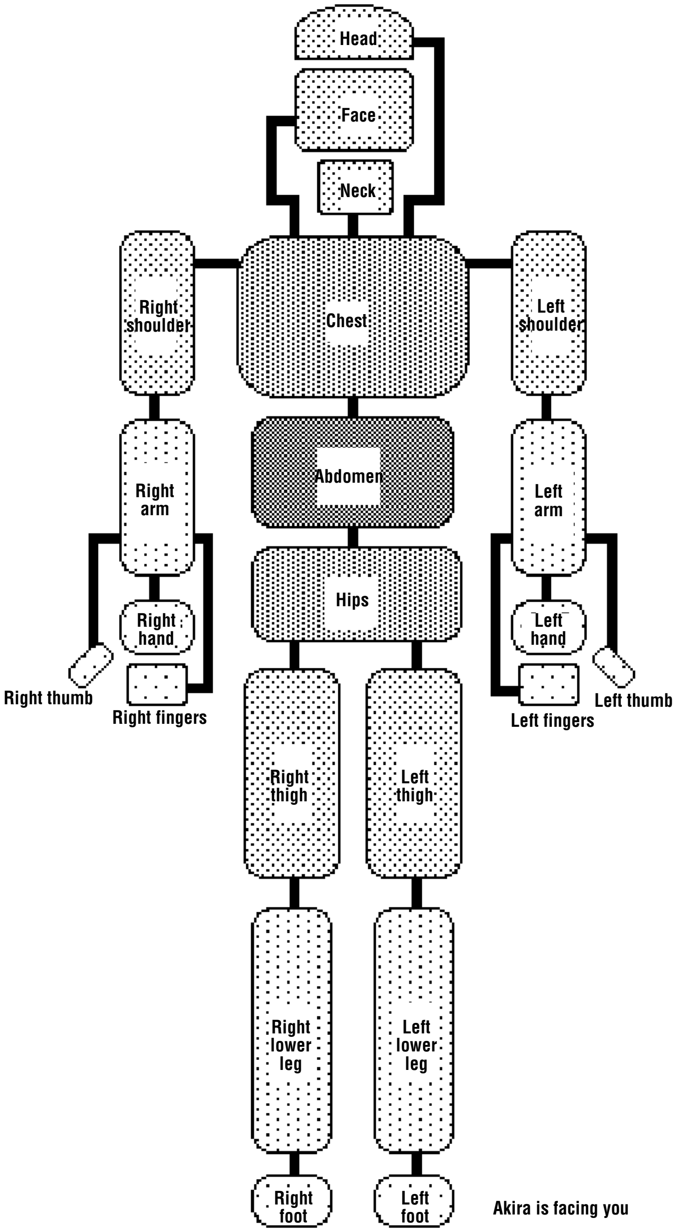
Function type	Function name	Parameters	Function
void	slDMACopy	src, dst, cnt	CPU DMA blook transfer

[Demonstration Program C: Walking Akira]
demo_C

Demonstration program C depicts animation of a walking human model. The model is the virtual fighter Akira.

Akira consists of 22 polygon objects, each part of a hierarchical structure as shown in the following diagram.

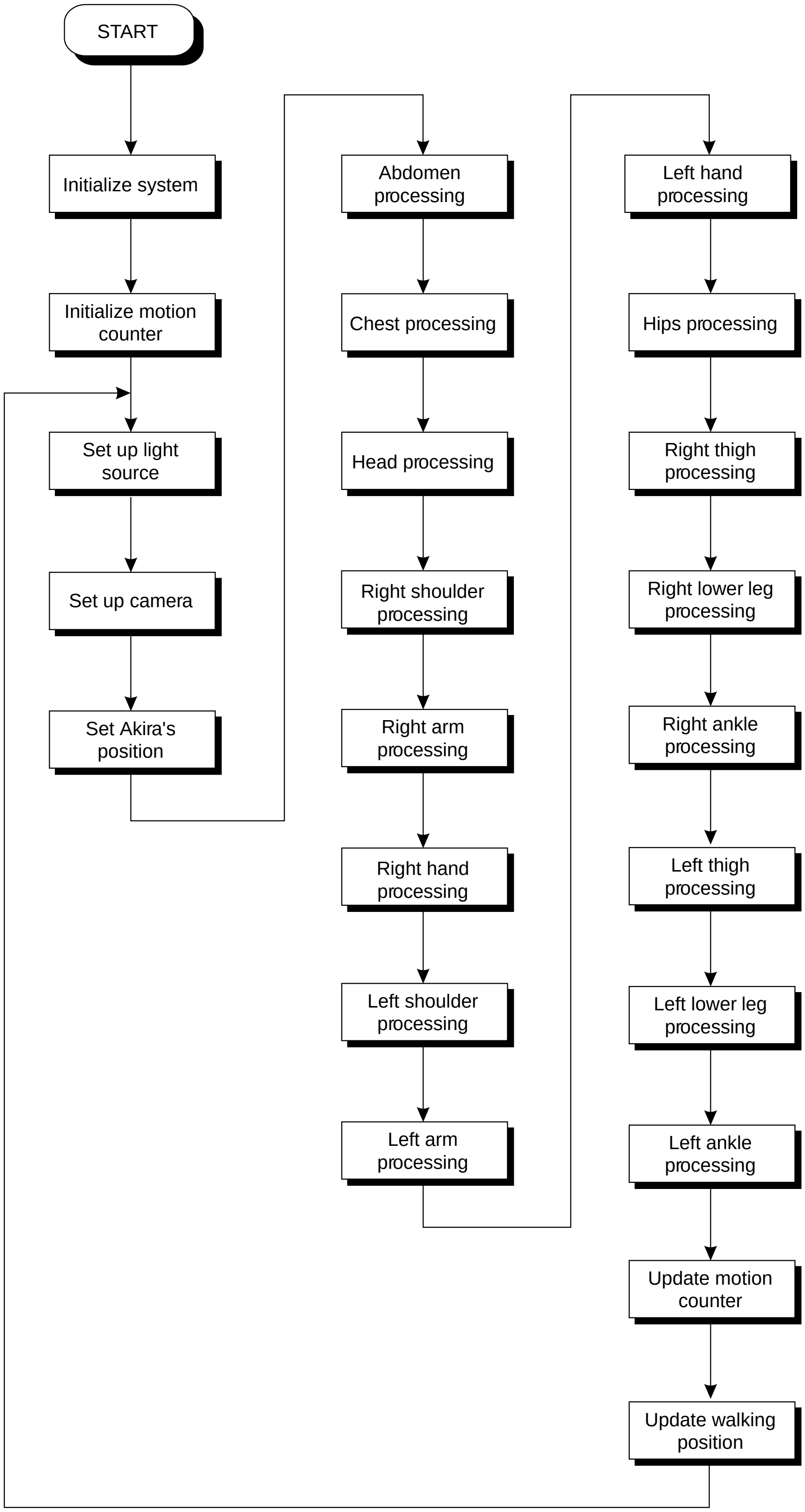
Fig C-1 Akira's Hierarchical Structure



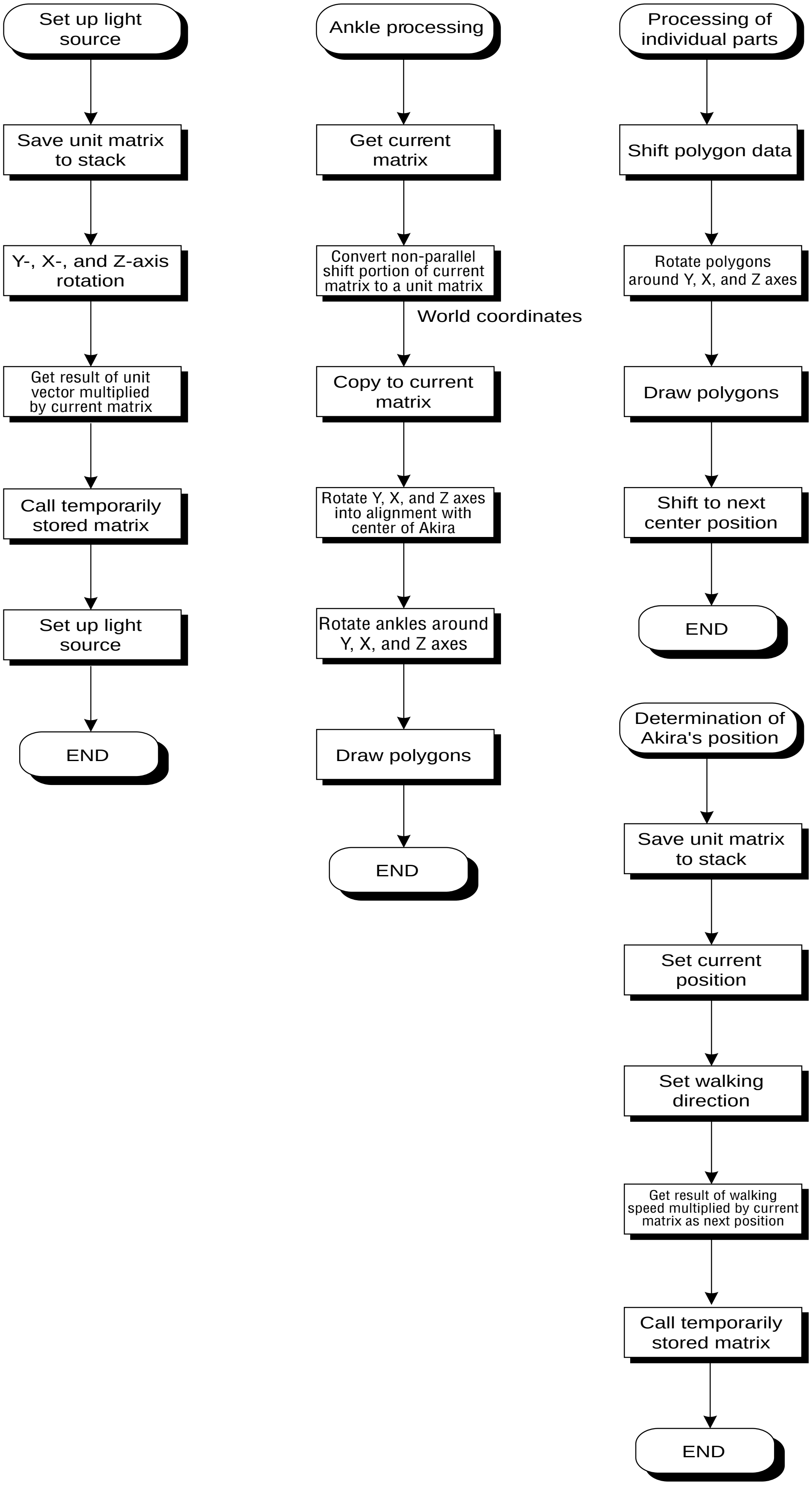
By supplying angle data between each set of parent-child objects, it is possible to create "joints." By changing this angle data, it is possible to make Akira move. The angle data between each set of parent-child objects is called "motion data."

This program uses normal 3D animation tools to create the complex motion data needed to model human movement.

Flow Chart C-1 Main Process



Flow Chart C-2 Main Processing


Set up light source
Save unit matrix to stack
Y-, X-, and Z-axis rotation
Get result of unit vector multiplied by current matrix
Call temporarily stored matrix
Set up light source
END
Ankle processing
Get current matrix
Convert non-parallel shift portion of current matrix to a unit matrix
World coordinates
Copy to current matrix
Rotate Y, X, and Z axes into alignment with center of Akira
Rotate ankles around Y, X, and Z axes
Draw polygons
END
Processing of individual parts
Shift polygon data
Rotate polygons around Y, X, and Z axes
Draw polygons
Shift to next center position
END
Determination of Akira's position
Save unit matrix to stack
Set current position
Set walking direction
Get result of walking speed multiplied by current matrix as next position
Call temporarily stored matrix
END

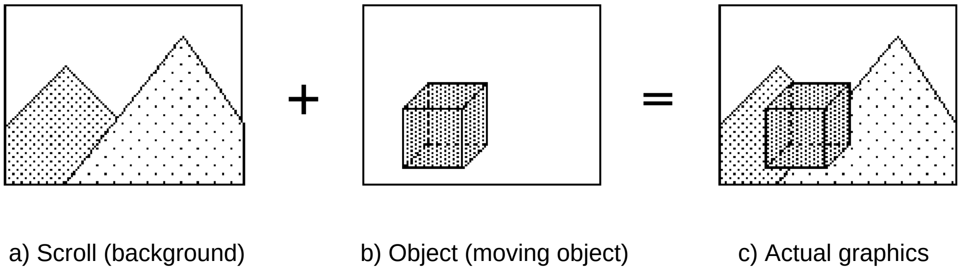
8

Programmer's Tutorial

Scrolls

“Scrolls” are 2D graphics used for game backgrounds and text display. In addition to scrolls, the SGL also has “sprites,” which also use 2D graphics. Sprites, however, are primarily used to represent moving objects, while scrolls are used to express stationary objects.

Fig 8-1 Example of Using a Scroll



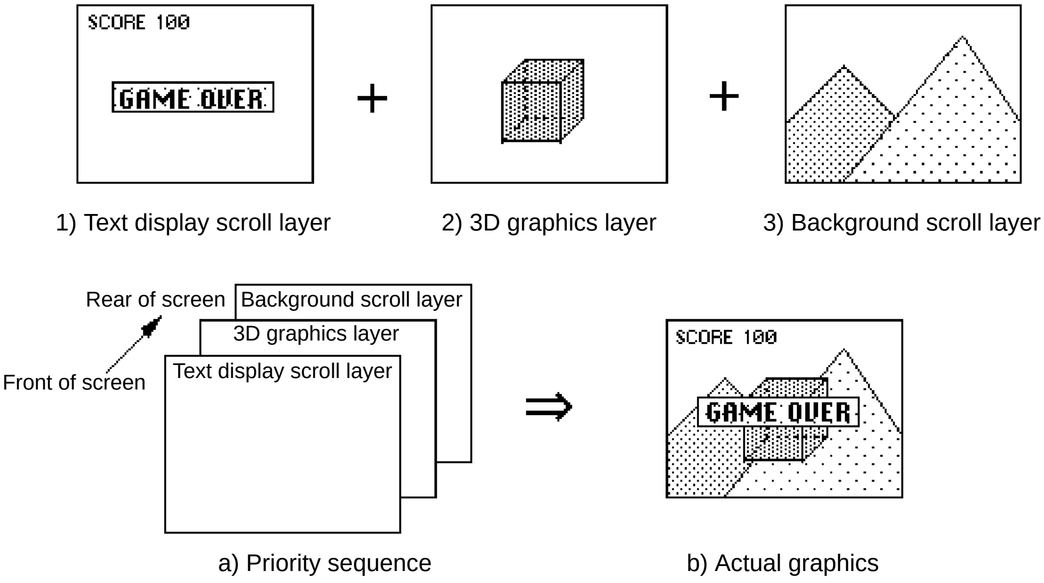
Note: In this example, the scroll is displayed behind the polygon.

Scrolls in SGL

The SGL permits the overlapping display of multiple scroll layers on a single screen. For example, it is possible to display a text display scroll layer in front, a polygon layer in the middle, and a background scroll layer in the rear.

The stacked drawing of graphics elements in this manner is controlled through “priority,” and it is possible to specify a priority for individual scroll, sprite, and polygon display layers. (For details on priority, refer to “Priority.”)

Fig 8-2 Screen Configuration Example



1) Text display scroll layer

2) 3D graphics layer

3) Background scroll layer

a) Priority sequence

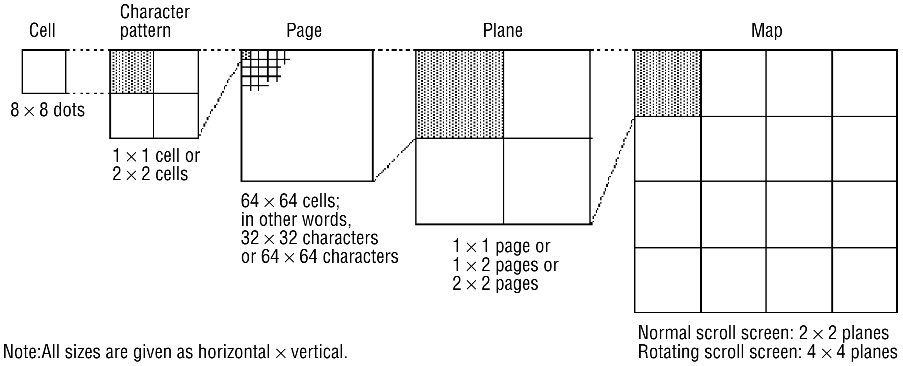
b) Actual graphics

Scroll Configuration Units

Scrolls are collections of the very fine dots that make up the monitor screen. In order to use these dots efficiently, the scroll unit system illustrated below has been adopted in the SGL.

An 8 × 8 group of dots is called a "cell;" in our discussion of the handling of scrolls, the cell will be the minimum unit of dots. Groups of cells form character patterns, groups of character patterns form pages, groups of pages form planes, and groups of planes form a map.

Fig 8-3 Scroll Screen Configuration Units



Note:All sizes are given as horizontal × vertical.

Note: Scroll Configuration Units

Although the Sega Saturn hardware includes functions for handling scrolls not in cell units, but in dot units (called bit-mapping), these functions are not discussed in this manual.

However, the SGL library does include several functions that support scroll functions that include bit-mapping, and a simple explanation of this group of functions has been added to the function reference that comes with the Reference Manual.

For details on the several functions that include a bit-map mode, refer to "HARDWARE MANUAL vol. 2" and to the "Function Reference" of the Reference Manual.

Screen Modes

The screen mode determines settings such as the screen resolution, the screen size, and the display device. Although the Sega Saturn system supports a large number of screen modes, of these, the SGL supports the following 16 screen modes.

Table 8-1 Screen Modes

Display device	TV screen mode	Graphics mode	Interlace mode	Resolution: horizontal × vertical (pixels)
NTSC system	Normal	Graphics A	Non-interlaced	320×224
				320×240
			Interlaced	320×448
				320×480
		Graphics B	Non-interlaced	352×224
				352×240
			Non-interlaced	352×448
				352×480
	Interlaced	Graphics A	Non-interlaced	640×224
				640×240
			Interlaced	640×448
				640×480
		Graphics B	Non-interlaced	704×224
				704×240
			Interlaced	704×448
				704×480

Note: The default screen mode is 320 × 224 (horizontal × vertical)

For details on screen modes, refer to “HARDWARE MANUAL vol. 2: VDP2,” page 12.

In the SGL, the library function “slInitSystem” is to initialize scrolls, set the screen mode, etc.

The function “slInitSystem” also initializes and makes the initial settings for elements other than scrolls at the same time. For details, refer to the default list at the end of the “Function Reference” of the Reference Manual.

[void slInitSystem (Uint16 type, TEXTURE *texptr, Uint16 cnt);]

This function initializes settings, including those for scrolls, sets the screen mode, and sets the graphics processing units. For the parameters, substitute the “#define” value indicating the screen mode, the starting address in memory where texture data is stored (“NULL” if textures are not to be used), and an integer value (from 1 to 127) that indicates the screen processing unit. The default screen mode is the mode with a resolution of 320 × 224 (horizontal × vertical) pixels.

In addition, TV monitors are not able to completely display 352 × 240 mode because they do not offer adequate resolution; 352 × 240 mode can only be fully displayed on monitors that accept RGB input.

Table 8-2 "slInitSystem" Parameter Substitution Example (TV_MODE)

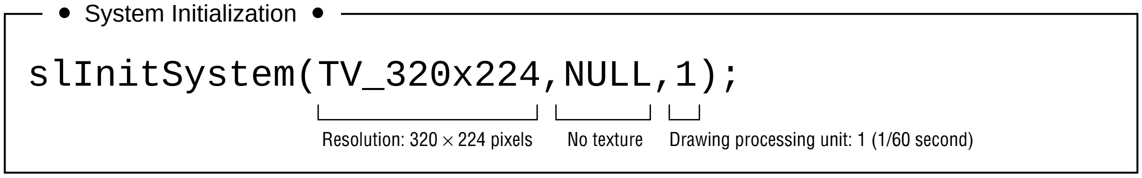
	Resolution (pixels)	
	320 (hor.) × 224 (ver.)	352 (hor.) × 240 (ver.)
Substitution value	TV_320 × 224	TV_352 × 240

Note: The values in the above table are defined by “sl_def.h”.

As shown by the examples in the table at left, the screen mode can be specified by using a macro in the form “TV_(horizontal pixels) x (vertical pixels)” in accordance with the desired resolution mode.

To specify resolution of 320 × 224 pixels, no texture, and a drawing processing unit of 1 (1/60 second), the function “slInitSystem” would appear as follows:

Fig 8-4 Example of Using the Function “slInitSystem”



● System Initialization ●

```
slInitSystem(TV_320x224,NULL,1);
```

Resolution: 320 × 224 pixels
No texture
Drawing processing unit: 1 (1/60 second)

Note: Drawing processing unit

The drawing processing unit parameter specifies the interval for updating (rewriting) the image.

In the SGL, the range of values that can be set is from 1 to 127, with 1 drawing processing unit equaling 1/60 of a second in non-interlaced mode and 1/30 of a second in double interlaced mode.

The longer the update interval is, the more operations that can be processed, but because the interval is long moving images will appear jerky.

On the other hand, the shorter the interval is, smooth image movement can be obtained, but the amount of processing that can be performed at one time decreases.

Scroll Screens

In the Sega Saturn system, up to five scroll screens can be displayed simultaneously on one screen. There are two types of scroll screens: normal scroll screens and rotating scroll screens; in addition, there are four types of normal scroll screens. The SGL permits these five types of scroll screens to be output to the monitor at the same time.

The following table summarizes the scroll screen types and summarizes their primary functions. (For details on the scroll functions and how to set them, refer to "Scroll Function settings.")

Table 8-3 Scroll Screens

Scroll screen name		Abbre-viation	Function				Remarks
			Movement	Enlarge-ment/ reduction	Rotation	Number of colors that can be dis-played	
Normal scroll screen	Normal scroll 0	NBG0	●	●		16.77 million colors	Enlargement setting ranges from 1/4 to 256x
	Normal scroll 1	NBG1	●	●		32.768 colors	
	Normal scroll 2	NBG2	●			256 colors	
	Normal scroll 3	NBG3	●			256 colors	
Rotating scroll screen	Rotating scroll 0	RGB0	●	●	●	16.77 million colors	Enlargement setting can be as desired

Note: For details on the scroll functions, refer to the section on scroll functions.

The maximum number of colors that can be set and the enlargement/reduction functions differ among the normal scroll screens “NBG0 to 3”. (For details, refer to "Scroll Functions.")

In the default state, the scroll screens permit 256 colors.

Note: Limitation on the number of scroll screens

Although the maximum number of scroll screens that can be output simultaneously is five, that does not mean that it is always possible to output five screens. Because there is a limit on the maximum number of accesses that can be made during one processing interval to VRAM, where the scroll data is stored, there are a number of limitations placed on scroll drawing.

For details, refer to the “HARDWARE MANUAL vol. 2:VDP2,” pp. 31 to 42.

Storing Scroll Data in Memory

This section explains the different types of scroll data and the methods for storing each type of scroll data in memory.

Scroll data types

In the SGL, there are three major types of scroll data that differ according to the information that they contain.

1) **Character pattern data**: Character pattern dot information
(This type of data is sometimes abbreviated as “CG” within the text.)

2) **Pattern name data**: Character pattern identification and placement information
(This type of data is sometimes abbreviated as “PN” within the text.)

3) **Color palette data**: Color data when using a color palette

In terms of the scroll screen configuration units described in "Scroll Configuration Units", the type 1 information contains information in dot units for the character pattern level, while type 2 contains the placement information for character patterns at the page level and beyond. Data of type 1 and 2 is stored in an area in memory called VRAM and the actual image is drawn by accessing the area and reading data in.

The type 3 information is palette-format color information used in scrolls. “Palette format” is a color setting system that uses 16, 256, or 2048 (or, for some settings, 1024) colors as a single palette for character pattern units. A color palette consists of three types of data:

Individual color RGB data:	stored in color RAM
Identification numbers for colors within the palette:	used within the character pattern data
Identification numbers for individual palettes:	Used within the pattern name data

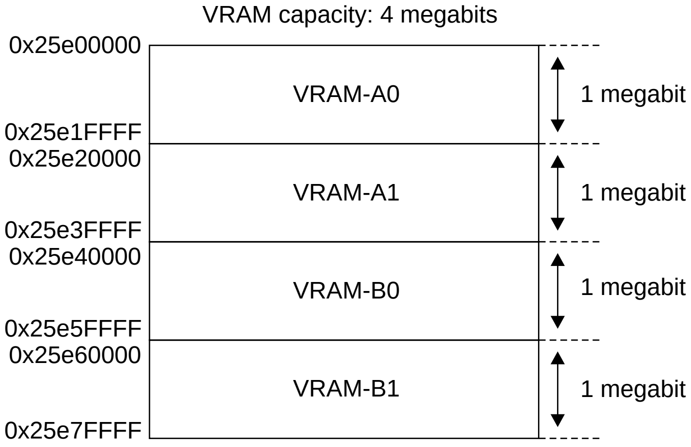
The color palette data is stored in an area of memory called color RAM, and the actual image is drawn by accessing the area and reading data in.

Storing scroll data in VRAM

VRAM is the general name for the data storage area used to store graphic data, such as scrolls. In the SGL, VRAM is divided into four partitions. Each area is named VRAM-A0, -A1, -B0, and -B1, and the various types of scroll data are stored in these four data areas called "banks." Because the Sega Saturn system has a VRAM capacity of 4 megabits, the VRAM capacity of each bank is 1 megabit.

Drawing of actual images is accomplished by accessing these four data banks and reading in data. The following diagram shows the VRAM addresses.

Fig 8-5 VRAM Address Map



In the SGL, scroll information is stored in these four banks, and scroll screens are drawn on the actual screen by calling the data from these banks.

In the sample program, the data storage operation is performed by two functions, "Cel2VRAM" and "Map2VRAM" (registered in the program).

These functions are not supported as library functions; use them as a reference.

[void Cel2VRAM (cel_adr, VRAM_adr, chara_size);]

This function stores character pattern data in VRAM.

For the parameters, substitute the starting address in memory where the character pattern is currently stored, the starting address in VRAM where the character pattern data is to be stored, and the amount of character pattern data.

[void Map2VRAM (pat_adr, VRAM_adr, mapY, mapX, pal_off, map_off);]

This function stores the pattern name data in VRAM.

For the parameters, substitute the starting address in memory where the pattern name table is currently stored, the starting address in VRAM where the pattern name data is to be stored, the vertical and horizontal size of the map in cells, the offset for the color palette to be used next, and the map data offset.

Notes on storing data in VRAM (1)

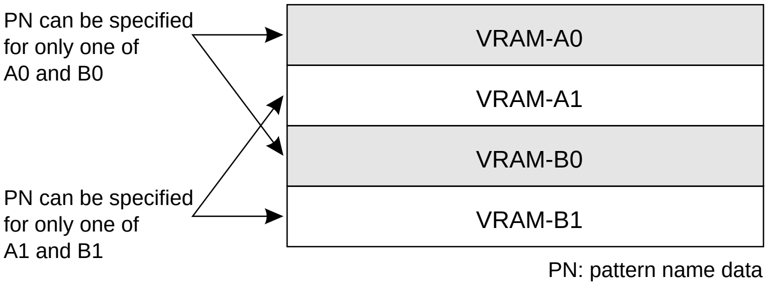
Due to hardware limitations, there are a number of restrictions that apply to the storing of scroll data in VRAM banks as described above.

Although the details of these restrictions will not be discussed here, the following two points should be observed:

1) **Priority of VRAM bank usage according to scroll type:**
   Do not store scroll data for normal scroll screens and rotating scroll screens in the same VRAM bank.

2) **Restriction on storing pattern name data in VRAM banks:**
   All of the pattern name data can only be stored in two of the four VRAM banks, in one of either VRAM_A0 and B0, and one of either VRAM_A1 and B1.

Fig 8-6 Restriction on Storage of Pattern Name Data in VRAM Banks


PN can be specified for only one of A0 and B0
VRAM-A0
VRAM-A1
VRAM-B0
PN can be specified for only one of A1 and B1
VRAM-B1
PN: pattern name data

If these restrictions are not observed, the drawing of scrolls will be affected in the following ways:

If restriction 1 is not observed:

Due to the priority of usage of the VRAM banks, the normal scroll screen data will be ignored, and only the rotating scroll screen data will be valid.

If restriction 2 is not observed:

If the pattern name data is stored in VRAM banks with the same digit at the ends of their names, the scrolls will either not be drawn properly or will not be drawn at all.

Note: PN storage restrictions

For details on PN storage, restrictions, refer to “SEGA SATURN HARDWARE MANUAL vol. 2.” (VDP2 User’s Manual: p. 35)

Notes on storing data in VRAM (2)

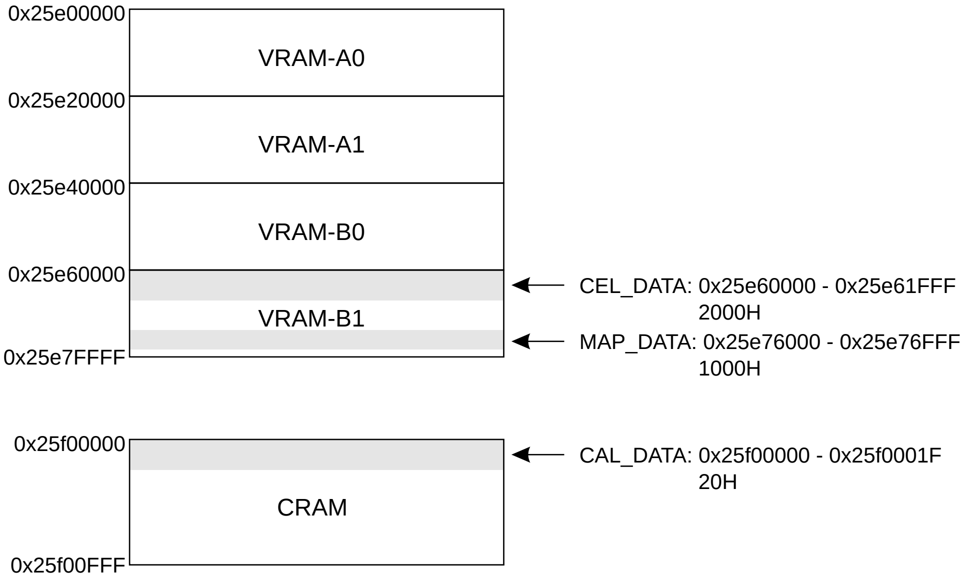
The following notes on data storage concern the SGL initial settings.

In the default state of the SGL, the ASCII cells, which are the scroll data (including color data) used for displaying letters and numerals, are already stored in memory.
If the ASCII scroll data stored in the default state is overwritten by other scroll data, the SGL functions that display letters and numerals can no longer be used properly.

The ASCII scroll consists of 128 cells and 256 colors, and uses the normal scroll “NBG0”.

The ASCII scroll data is stored in RAM as follows:

Fig 8-7 ASCII Scroll Data Storage Area



Character data:	For 2000H, starting from address 0x25e60000
Map data:	For 1000H, starting from address 0x25e76000
Palette data:	For 20H, starting from address 0x25ef0000

If the ASCII scrolls are to be used, specify offsets when storing scroll data so that the scroll data is not written to the above regions.

Color RAM

Color RAM is used to control color for all palette-type sprites and scroll screens. Depending on the color RAM, the color data consists of either five bits or eight bits for each of red, green, and blue.

The following table shows the three color RAM modes:

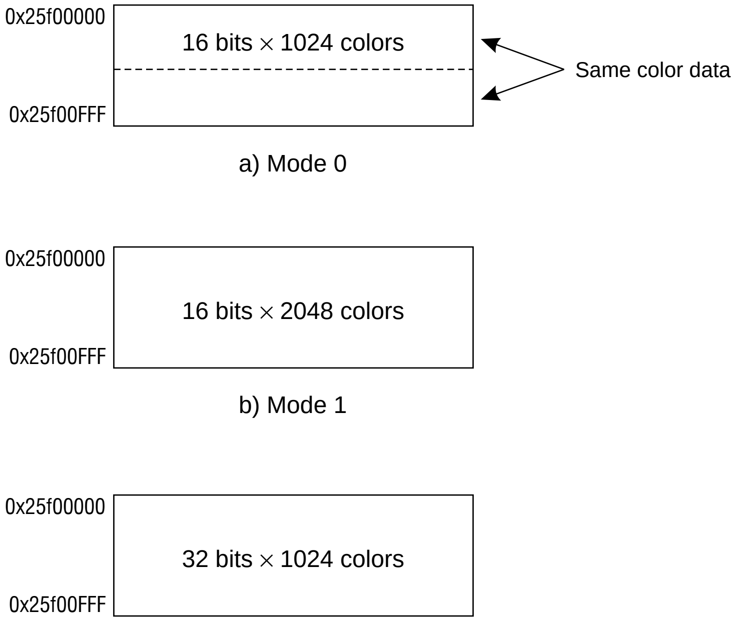
Table 8-4 Color RAM Mode

Color mode	Color bits	Data size	Number of colors
Mode 0	15 bits; 5 bits each for R, G, and B	1 word	1024 colors out of 32,768
Mode 1	15 bits; 5 bits each for R, G, and B	1 word	2048 colors out of 32,768
Mode 2	24 bits; 8 bits each for R, G, and B	2 words	1024 colors out of 16.77 million

Note: In color mode 0, color RAM is partitioned into two banks, each storing the same color data.

The color RAM modes utilize color RAM as shown in the following diagram:

Fig 8-8 Color RAM Address Map



a) Mode 0

b) Mode 1

b) Mode 2

The color RAM modes are selected and used in the following circumstances:

Color RAM mode 0: Used when using extended color operation functions

Color RAM mode 1: Used when 2048 colors out of 32,768 colors are desired

Color RAM mode 2: Used when 1024 colors out of 16,77 million colors are desired

As Fig 8-8 makes clear, in color RAM mode 0, the color RAM area is partitioned into two banks, each containing the same color data. As a result, while the number of colors that can be used is only half that of color RAM mode 1, this configuration does permit the use of extended color operation functions.

Note: However, extended color operation mode is not supported in the current version of the SGL. To use the extended color operation mode, refer to the "HARDWARE MANUAL vol. 2."

The difference between modes 1 and 2 is the number of colors that can be used.

Mode 1 permits 2048 colors to be selected from among 32,768; mode 2 permits 1024 colors to be selected from among 16.77 million colors. As a result, while mode 1 permits the use of more colors, because the data length is shorter than in mode 2, the gradations between colors in mode 1 are coarser than in mode 2.

On the other hand, while only half as many colors can be used in mode 2 as in mode 1, the longer data length in mode 2 permits the choice of finer gradations.

The library function "slColRam" is used to set the color RAM mode.

[void slColRAMMode (Uint16 mode)]

This function sets the color RAM mode.

For the parameter, substitute a #define value from the following table corresponding to the desired color RAM mode.

Table 8-5 slColRAMMode Parameter Substitution Values

	Color RAM mode		
	Mode 0	**Mode 1**	**Mode 2**
Substitution value	CRM16_1024	CRM16_2048	CRM32_1024

Note: 2048 colors can be used only when color RAM mode 1 is selected.

Initial color RAM setting:
When the system is initialized, color RAM mode 1 is set.

Storing data in color RAM

In the SGL, color information (color palette information) is stored in color RAM, and scroll screens can be drawn by calling out the data when needed.

In the sample program, the color data storage operation is performed by the "Pal2CRAM" function (registered in the program). This function is not supported as a library function; use it as a reference.

[void Pal2CRAM (col_adr, CRAM_adr, col_no.);]

This function stores the color information (color palette information) in the color RAM.

For the parameters, substitute the starting address in memory where the color palette to be registered is currently stored, the starting address in color RAM where the palette is to be stored, and the size of the color palette.

Scroll Function Settings

This section explains the method for setting up scrolls, starting from character units and continuing on up to map settings. In the SGL, the scroll functions (number of character colors, character size, etc.) are set at each stage of scroll setup.

The following table lists the scroll functions.

Table 8-6 Scroll Functions List

colors

Function		Normal scrolls		Rotating scrolls	
	NBG0	NBG1	NBG2	NBG3	RBG0
Number of character	Select 16, 256, 2048*, 32,768, or 16.77 million colors	Select 16, 256, 2048*, or 32,768 colors	Select either 16 or 256 colors	Select either 16 or 256 colors	Select 16, 256, 2048*, 32,768, or 16.77 milion colors
Character size	Select either 1 (hor.) × 1 (ver.) cell, or 2 (hor.) × 2 (ver.) cells				
Pattern name data size	Select either 1 word or 2 words				
Plane size	Select either 1 (hor.) × 1 (ver.) page, 2 (hor.) × 1 (ver.) pages, or 2 (hor.) × 2 (ver.) pages				
Number of planes	4	4	4	4	16
Enlargement/ reduction function	1/4 to 256x		No		Any ratio
Rotation function	No				Yes

Note: 2048 (marked by an asterisk) is available as a choice when color RAM mode 1 is in effect. If mode 0 or mode 2 is in effect, 1024 is available as a choice instead.

VRAM access restrictions

The list of functions shown in Table 4-6 above is a list of possible functions for each scroll screen. This does not mean that when actually using these scroll screens in a program all of these functions will be available for use with every scroll screen. There is also no guarantee that it will be possible to draw all scroll screens at the same time.

This results from limitations on VRAM access that restrict the number of scroll screens that can be used at one time and the setting of the functions.

For details on the access limitations, refer to the “HARDWARE MANUAL vol. 2” (VDP2 User’s Manual: pp. 31 to 42).

In addition to the VRAM access specification limitations, there are also scroll drawing restrictions that are founded in the setting of the number of characters for normal scroll screens NBG0 to 3. (Refer to the section on character patterns.)

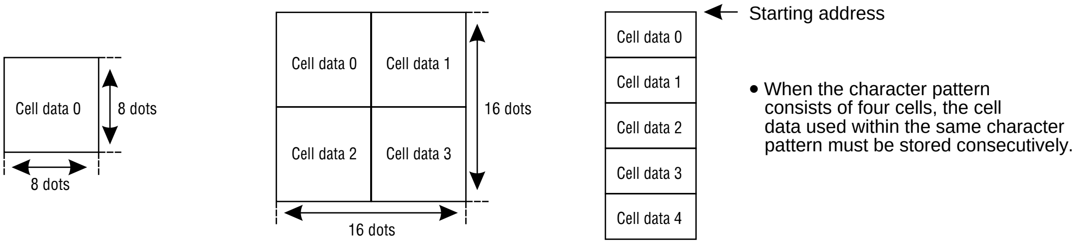
Therefore, the number of scroll screens that can be drawn simultaneously and their functions are limited and determined by the two types of restrictions indicated above.

Character patterns

Character patterns are square patterns consisting of 1 × 1 cell or 2 × 2 cells, and are used to store information (such as the dot drawing color) for individual dots. In the SGL, units of character pattern information called "data tables" are stored and accessed as needed in VRAM.

This is also the level at which the number of colors for each character in the scroll screen is specified. In addition, when one character consists of four cells, it is necessary to store the cell data used within one character pattern so that the cell data is continuous within the character pattern table.

Fig 8-9 Character Patterns



a) 1 × 1 cell　　b) 2 × 2 cell　　c) Character pattern table

Table 8-7 Number of Character Colors

Number of character colors

Color format	**Number of**	**Number of bits per dot character colors**	**Number of colors that can be used on each screen**				
			NBG0	**NBG1**	**NBG2**	**NBG3**	**RBG0**
Palette format	16 colors	4 bits	●	●	●	●	●
	256 colors	8 bits	●	●	●	●	●
	2048 colors	16 bits (only low-order 11 bits are used)	●	●	×	×	●
RGB format	32,768 colors	16 bits	●	●	×	×	●
	16.77 million colors	32 bits (only MSB and low-order 24 bits are used)	●	×	×	×	●

Note: For color RAM modes 0 and 1, "2048 colors" changes to "1024 colors."

In the SGL, use the library functions "slCharNbg0 to 3" and "slCharRbg0".

[void slCharNbg0 to 3 (Uint16 color_type, Uint16 char_size);]
[void slCharRbg0 (Uint16 color_type, Uint16 char_size);]

These functions specify the number of character colors and character size for each scroll screen (indicated by the scroll screen name that follows "slChar"). For the parameters, substitute the "#define" value that corresponds with the number of colors and character size according to the following chart. Note, however, that on some scroll screens there are limits on the number of colors that can be used. (Refer to "Scroll Function List.")

Table 8-8 Parameter Substitution Values for slCharNbg0 to 3 and slCharRbg0

	Number of character colors					Character size	
	Palette format			RGB format			
	16 colors	256 colors	2048 colors	32,768 colors	16.77 million colors	1×1	2×2
Substitution value	COL_TYPE_16	COL_TYPE_256	COL_TYPE_2048	COL_TYPE_32768	COL_TYPE_1M	CHAR_SIZE_1×1	CHAR_SIZE_2×2

Note 1: For color RAM modes 0 and 1, “2048 colors” changes to “1024 colors.”
Note 2: The values in the above table are defined in “sl_def.h”, which is included with the system.

Scroll limitations due to the number of character colors

A restriction may be placed on the number of scroll screens that can be output, depending on the number of colors set for normal scroll screens NBG0 and NBG1.

These restrictions are summarized in the following table:

Table 8-9 Scroll Screen Restrictions Due to Number of Character Colors

Number of colors for NBG0 and NBG1		Effective scroll screens			
NBG0	NBG1	NBG0	NBG1	NBG2	NBG3
16.77 million colors	*	●	×	×	×
2048 or 32,768 colors	*	●	●	×	●
*	2048 or 32,768 colors	●	●	●	×
2048 or 32,768 colors	2048 or 32,768 colors	●	●	×	×

Note: An asterisk represents selection of 256 colors or less

- If the NBG0 setting is 16.77 million colors, NBG1 to 3 cannot be displayed.
- If the NBG0 setting is 2048 colors or 32,768 colors, then NBG2 cannot be displayed.
- If the NBG1 setting is 2048 colors or 32,768 colors, then NBG3 cannot be displayed.

Scroll restrictions due to VRAM access

In the Sega Saturn system, there are other restrictions on scroll screens due to VRAM access as a result of hardware performance.

These restriction apply in addition to the restrictions arising from the number of character colors on the normal scroll screen. In particular, when the reduction setting is made for a normal scroll screen and when the rotating scroll screen is used, the number of scroll screens that can be drawn is markedly restricted on top of the restrictions due to the number of character colors.

For details on access restrictions, refer to the “HARDWARE MANUAL vol. 2” (VDP2 User’s Manual: pp. 31 to 42).

Pattern name data

Pattern name data is data generated from dot unit data created as a character pattern, particularly by extracting the two kinds of information indicated below.

Character number: The starting address of the character pattern (VRAM); 20H is stored for the character pattern as one unit.

Palette number: Palette number of the color palette to be used (color RAM).

In addition to the above two types of information, the pattern name data in its final form also consists of the following two types of function control bits concerning the character pattern.

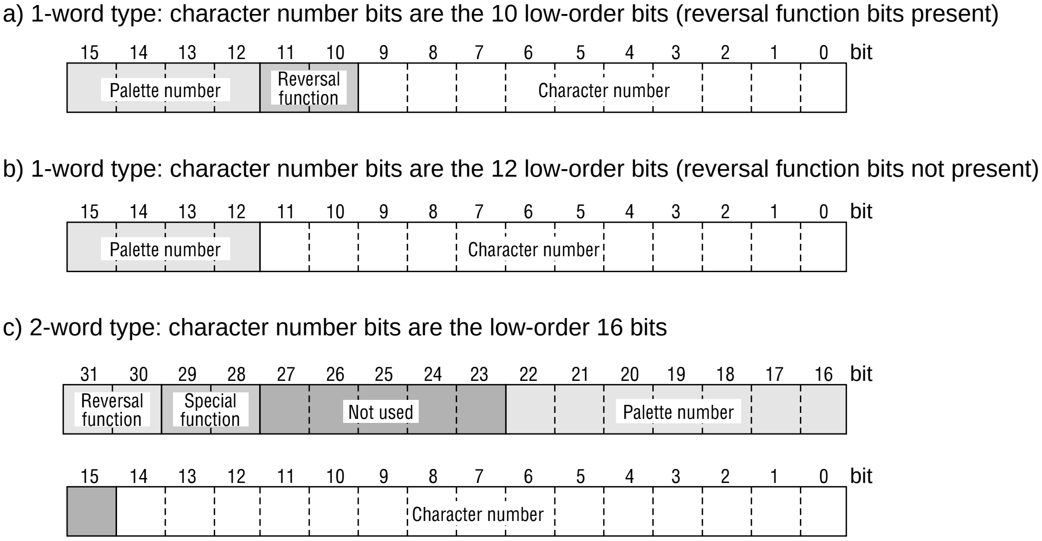
Special function bits (two bits): Control special function operations and special priorities.

Reverse function bits (two bits): Control top-bottom, left-right reversal of the character pattern.

However, there are some instances where the special function bits and reverse function bits are not added to the pattern name data. This is because, depending on the pattern name data type (described later), the number of bits used in the pattern name data changes.

The following figure is a conceptual model of the pattern name data. The details of the pattern name data types are described in the next section.

Fig 8-10 Pattern Name Data Concept


a) 1-word type: character number bits are the 10 low-order bits (reversal function bits present)

b) 1-word type: character number bits are the 12 low-order bits (reversal function bits not present)

c) 2-word type: character number bits are the low-order 16 bits

15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 bit
Palette number
Reversal function
Character number
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 bit
Palette number
Character number
31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 bit
Reversal function
Special function
Not used
Palette number
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 bit
Character number

Pattern name data is used when setting up pages; pattern name data tables are created as a group of 64 × 64 continuous pattern name data entries, and are then passed to the plane and map placement information.

Pattern name data types

There are two types of pattern name data: 1-word and 2-word.

The 1-word type is further broken down into two types, according to the number of information bits used for character identification. (There are either 10 or 12 pattern identification bits.)

Each data type has its advantages and disadvantages; in the SGL, one of these three data types must be selected and used.

Table 8-10 Pattern Name Data Sizes

*Word size	Number of character number bits	Remarks
1-word	10 low-order bits	The reversal function can be specified for individual characters
	12 low-order bits	The reversal function cannot be used
2-word	15 low-order bits	The reversal function can be specified for individual characters

*: The 1-word size is recommended for the SGL.

1-word pattern name data is divided into two types, depending on whether or not two reverse function bits are inserted into the pattern name data.

As its name indicates, the character pattern reversal function is used to control and execute top-bottom and left right reversal of the corresponding character pattern. This control requires the allocation of two reversal function bits in the pattern name data.

In the case of 1-word pattern name data, the reversal function bits are always allocated, but in 1-word pattern name data, because there are only a limited number of bits available for use, if the reversal function bits are allocated then the number of character patterns that can be identified is reduced by an amount corresponding to the two bits. As a result, there are two types of 1-word pattern name data distinguished by whether the reversal function bits are used or not, or by the difference in the number of character patterns that can be identified.

The difference between the 2-word type and the 2-word type is simply the number of character patterns that can be processed. However, the amount of memory used by the 2-word type is double that used by the 1-word type; in addition, while offsets can be specified with the 1-word type, the absolute address must be specified with the 2-word type. Therefore, from the standpoint of ease of use, in the SGL the use of the 1-word type is recommended.

Supplemental data

When using 1-word pattern name data, not all of the pattern name data can be specified. Therefore, the system provides the 10 low-order bits of the pattern name data control register to supplement the pattern name data. This is called “supplemental data.”

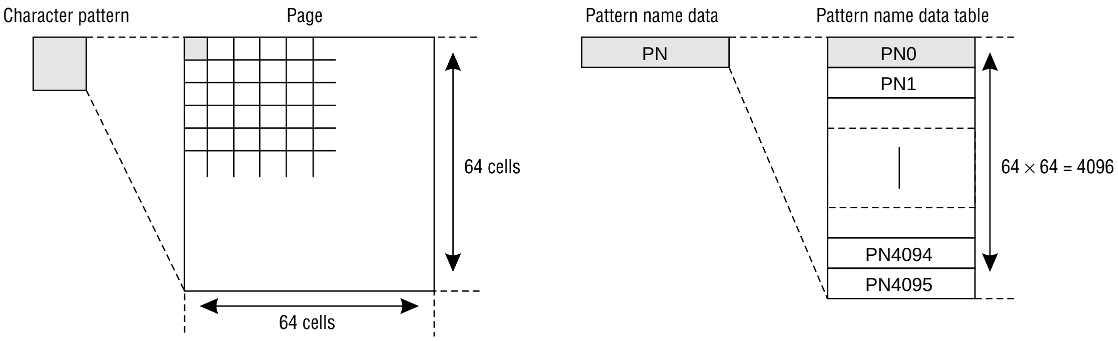
For details, refer to the “HARDWARE MANUAL vol. 2: VDP2,” pp. 69 to 78.

Pages

A page is a square covered with 64 × 64 character pattern cells. The actual data format consists of a table of the pattern name data for each character pattern for all 64 × 64 cells, stored consecutively in memory. This table is called the pattern name data table.

The pattern name data table created when the page is set up is passed to the plane or map that the page belongs to and is then rearranged.

Fig 8-11 Page Image



a) Page image

b) Pattern name data table image

In the SGL, the library functions “slPageNbg0 to 3” and “slPageRbg0” are used for each scroll screen to set up pages.

[void slPageNbg0 to 3 (void *cell_adr, void *col_adr, Uint16 data_type);]
[void slPageRbg0 (void *cell_adr, void *col_adr, Uint16 data_type);]

These functions set up pages (pattern name data tables).

For the parameters, substitute the starting address of the character patterns to be used, the starting address of the color palette to be used (offset specification is possible in the case of 1-word type data), and the pattern name data type specification (refer to the following table for the parameter substitution value).

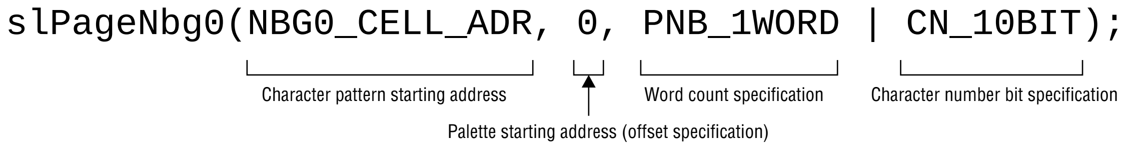
Table 8-11 slPageNbg0 to 3, Rbg0 Parameter Substitution Values (data_type)

Number of words	Character number bits	Substitution value
1-word	10 low-order bits	PNB_1WORD
	12 low-order bits	PNB_1WORD Ω CN_12BIT
2-word	15 low-order bits	PNB_2WORD

Note: The values in the above table are defined by “sl_def.h”.

An example of an actual page setup specification and a list of the #define values used in the page setting parameters are shown below.

Fig 8-12 "slPageNbg0 to 3", "slPageRbg0" Parameter Setting Example



```
slPageNbg0(NBG0_CELL_ADR, 0, PNB_1WORD | CN_10BIT);
```

Character pattern starting address
Palette starting address (offset specification)
Word count specification
Character number bit specification

List 8-1 #define Values for the Page Setting Parameters

● Define values used in the page setting parameters ●

```
/* VRAM_BANK ADDRESS */
#define       VDP2_VRAM_A0        0x25e00000
#define       VDP2_VRAM_A1        0x25e20000
#define       VDP2_VRAM_B0        0x25e40000
#define       VDP2_VRAM_B1        0x25e60000
/* slPage */
#define       PNB_2WORD           0
#define       PNB_1WORD           0x8000
#define       CN_10BIT            0
#define       CN_12BIT            0x4000
/* others */
#define       NBG_CELL_ADR        VDP2_VRAM_B0
```

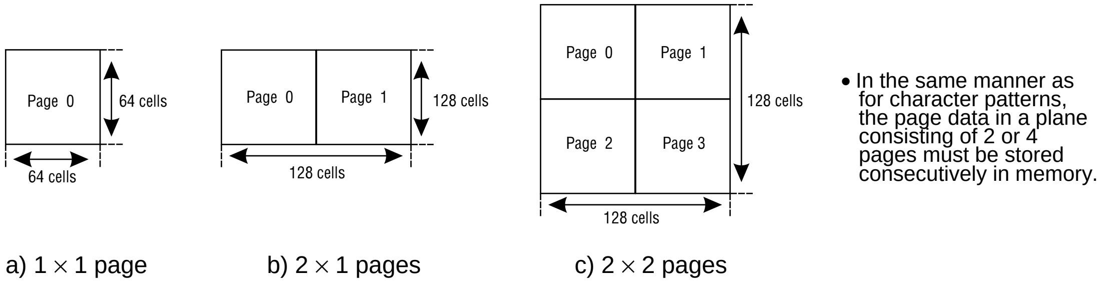
Note: These #define values are defined in "sl_def.h".

Planes

Planes consist of pages in a 1 × 1, 2 × 1, or 2 × 2 (horizontal × vertical) arrangement. When a plane consists of multiple pages, the page data (pattern name data tables) must be stored consecutively in VRAM.

The plane data is passed up to the map and rearranged.

Fig 8-13 Plane Image


Page 0
64 cells
64 cells
Page 0
Page 1
128 cells
128 cells
Page 0
Page 1
Page 2
Page 3
128 cells
128 cells
• In the same manner as for character patterns, the page data in a plane consisting of 2 or 4 pages must be stored consecutively in memory.
a) 1 × 1 page
b) 2 × 1 pages
c) 2 × 2 pages

Note: All matrices are shown in the format horizontal x vertical.

In the SGL, the library functions “slPlaneNbg0 to 3” and “slPlane Rbg0” are used to set the plane size.

[void slPlaneNbg0 to 3 (Uint16 plane_size);]
[void slPlaneRA,RB (Uint16 plane_size);]

These functions set the plane size for each scroll screen.

For the parameters, substitute the value in the table below corresponding to the desired plane size.

Table 8-12 "slPlaneNbg0 to 3" and "slPlaneRA,RB" Parameter Substitution Values (plane_size)

	Plane size		
	1 × 1 (hor. × ver.)	**2 × 1 (hor. × ver.)**	**2 × 2 (hor. × ver.)**
Substitution value	PL_SIZE_1×1	PL_SIZE_2×1	PL_SIZE_2×2

Note: The above values are defined in “sl_def.h” provided with the system.

Plane size specification restriction due to the reduction setting

If the reduction setting down to 1/4 is made on the normal scroll screens NBG0 and NBG1, do not set the plane size for that scroll screen to 2 × 2 pages, because the map size differs from the normal size when the reduction range is set to 1/4.

This problem does not arise if the plane size is 1 × 1 or 2 × 1 pages.

For details on the plane size specification restrictions, refer to the “HARDWARE MANUAL vol. 2.” (VDP2 User’s Manual: pp. 84 to 85)

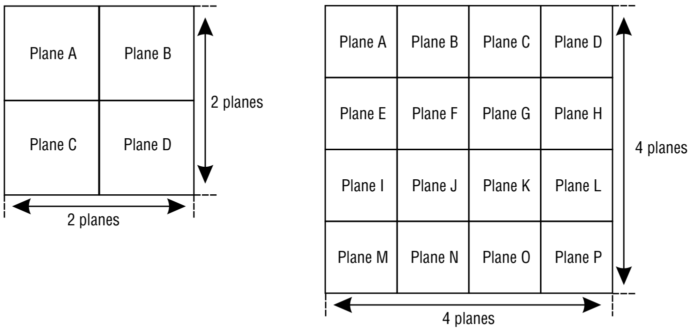
Maps

Maps are the largest scroll unit actually used for scroll drawing in the SGL. For normal scroll screens, a map consists of 2 × 2 planes (vertical × horizontal); for rotating scroll screens, a map consists of 4 × 4 pages (vertical × horizontal).

The planes that make up a map can be freely determined by specifying the starting address of each plane (actually the starting address where the pattern name data table that makes up the plane is stored); in other words, it is not necessary for the planes to be stored consecutively in VRAM. Therefore, it is possible to specify the same plane for all of the planes that make up the map.

In the scroll shift, enlargement/reduction and rotation operations described later, the shift and transformations are all performed in map units.

Fig 8-14 Map Image



- The map register specification is made by specifying the starting address for the pattern name table for each plane.

a) Normal scrolls　　b) Rotating scrolls

The map size is determined by the scroll screen type:

Normal scroll screens:	2 × 2 (horizontal × vertical) planes for a total of 4 planes
Rotating scroll screens:	4 × 4 (horizontal × vertical) planes for a total of 16 planes

In the SGL, the library functions “slMapNbg0 to 3” and sl1MapRA,RB” are used to register each of the planes that make up a map.

[void slMapNbg0 to 3 (void *map_a, void *map_b, void *map_c, void *map_d);]

This function registers the plane data for each of the normal scroll screen maps.

For the parameters, substitute the starting addresses for each of the four planes to be registered. The target scroll screens are those whose normal scroll screen name corresponds with the end of the function name.

[void sl1MapRA (void *map_a);]
[void sl1MapRB (void *map_a);]

These functions register the plane data for the rotating scroll screen map.

For each parameter, substitute the starting address of the plane to be registered. The function registers 16 planes of data for the map, starting from the specified address.

In addition, the function “sl1MapRA” is used for map registration when rotation parameter A was used, and “sl1MapRB” is used for map registration when rotation parameter B was used.

Rotation parameters
For details on the rotation parameters, refer to the section on rotation parameters.

Reduction setting

Of the five types of scroll screens in the Sega Saturn system, it is possible to enlarge or reduce three of the screens: the rotating scroll screen “RGB0” and the normal scroll screens “NBG0” and “NBG1”. Of the three screens that permit enlargement or reduction, the rotating scroll screen RBG0 permits enlargement or reduction at any ratio, while the normal scroll screens “NBG0” and “NBG1” only permit reduction or enlargement by a factor ranging from 1/4 to 256.

In addition, in the case of normal scroll screens, there are three enlargement/reduction modes, depending on the setting of the permitted range of reduction. This mode setting is called the reduction setting, and this setting must be made when using the normal scroll screens “NBG0” and “NBG1”.

Table 8-13 Scroll Screen Enlargement/Reduction Ranges

Scroll type	Name	Enlargement/reduction	Enlargement/reduction
Normal scroll screen	NBG0	●	1/4 to 256x
	NBG1	●	1/4 to 256x
	NBG2	×	
	NBG3	×	
Rotating scroll screen	RBG0	●	Any ratio

Note: For NBG0 and NBG1, the permitted range of reduction varies according to the reduction setting.

In the SGL, use the library function “slZoomModeNbg0,1” to make the reduction setting for the corresponding normal scroll screen.

[void slZoomModeNbg0, 1 (Uint16 zoom_mode);]

This function determines the reduction setting for the normal scroll screens, either NBG0 or NBG1, for which enlargement or reduction are possible.

The target scroll screen is the normal scroll screen with the same name as the end of the function name.

For the parameters, substitute the value from the following chart corresponding to the reduction setting mode.

Table 8-14 slZoomModeNbg0,1 Substitution Values (zoom_mode)

	Reduction setting		
	1x	1/2x	1/4x
Substitution value	ZOOM_1	ZOOM_HALF	ZOOM_QUARTER

Note: The values in the above table are defined by “sl_def.h”.

Rotating scroll screen enlargement/reduction
Because the rotating scroll screen always permits enlargement or reduction at any ratio, the reduction setting is not necessary.

Restriction on the number of scroll screens due to the reduction setting
The reduction setting for the normal scroll screens NBG0 and NBG1 (when set to permit reduction to a smaller value) places restrictions on the number of scroll screens that can be displayed and on their functions. This is because the reduction setting changes the number of VRAM accesses that are made. For details on access restrictions, refer to “HARDWARE MANUAL vol. 2: VDP2 User's Manual,” pp. 31 to 42.

Function settings unique to the rotating scroll screen (1)

In addition to the scroll function settings described up to this point, there are several function settings that are necessary in the case of the rotating scroll screen.

These function settings are required in order to use the unique functions of the rotating scroll.

Rotation parameter setting:

When using the rotating scroll screen, an area for storing and calling the data concerning the rotation is required; collectively, this data is called the “rotation parameters.”

Therefore, when using the rotating scroll screen, it is necessary as part of the scroll function settings to store the rotation parameters in VRAM. (Rotation parameter size: 100H) Use the library function “slRparaInitSet” to specify the rotation parameters.

[void slRparaInitSet (ROTSCROLL *Rpara_adr);]

This function stores the rotation parameters in the VRAM area and simultaneously sets the default values.

For the parameter, substitute the starting address of the area where the rotation parameters are to be stored.

Rotation parameter usage mode:

There are two types of rotation parameters: A and B. These two types of rotation parameters are stored together in an area that is allocated by using the function “slRparaInitSet”. Because there are two types of rotation parameters, two sets of status data are simultaneously retained for rotating scrolls, one of which can be selected to draw the scroll on the monitor.

The user can select one of the following four rotation parameter usage modes in order to determine how the rotation parameters are to be used.

Mode 0: Use rotation parameters A

Mode 1: Use rotation parameters B

Mode 2: Switch the image according to the coefficient data read from the coefficient table in rotation parameters A

Mode 3: Switch according to the rotation parameter window

[void slRparaMode (Uint16 mode);]

This function switches the rotation parameter usage mode.

For the parameter, substitute the flag in the following table that indicates the desired rotation parameter usage mode.

Table 8-15 slRparaMode Parameter Substitution Values

	Mode 0	Mode 1	Mode 2	Mode 3
Substitution value	RA	RB	K_CHANGE	W_CHANGE

Note: The actual values are defined in “sgl_def.h”.

Current Rotation Parameter Switching

Of the functions used for rotating scrolls, those functions whose names end in “R” set their functions for the current rotation parameters; by using the function “slCurRpara” to switch the current rotation parameters, it is possible to make separate function settings for rotation parameters A and B.

If a function name ends in “RA” or “RB”, then that function makes a setting only for the rotation parameters indicated by the end of the function name.

[void slCurRpara (Uint16 flag);]

Switches the current rotation parameters.

For the parameter, substitute the flag shown in the table below indicating the rotation parameters to be switched to.

Table 8-16 slCurRpara Substitution Values

	Rotation parameters A	**Rotation parameters B**
Substitution value	RA	RB

Note: The actual values are defined in “sgl_def.h”.

Note:
For details on the rotation parameters, refer to the “HARDWARE MANUAL vol. 2” (VDP2 User’s Manual: p. 151).

Function settings unique to the rotating scroll screen (1)

Screen overflow processing mode selection:

This function selects the processing to be performed when the drawing of the rotating scroll screen goes beyond the display area. This is called screen overflow processing. There are four screen overflow processing modes:

Mode 0: The image set for the display area is repeated outside of the area.

Mode 1: The character pattern specified in the screen overflow PN register is repeated outside of the display area.

Mode 2: The entire area outside of the display area is clear.

Mode 3: Clipping (0 _ X _ 512, 0 _ Y _ 512) is forcibly performed on the area, and the area outside of the area is entirely clear.

Use the library function “slOverRA,RB” to select the screen overflow processing.

[void slOverRA (Uint16 over_mode);]
[void slOverRB (Uint16 over_mode);]

These functions select the screen overflow processing when the rotating scroll screen exceeds the display area.

For the parameter, substitute the value from the following table that corresponds to the desired screen overflow processing mode.

The function “slOverRA” sets the overflow processing when rotation parameters A are used, and the function “slOverRB” sets the overflow processing when rotation parameters B are used.

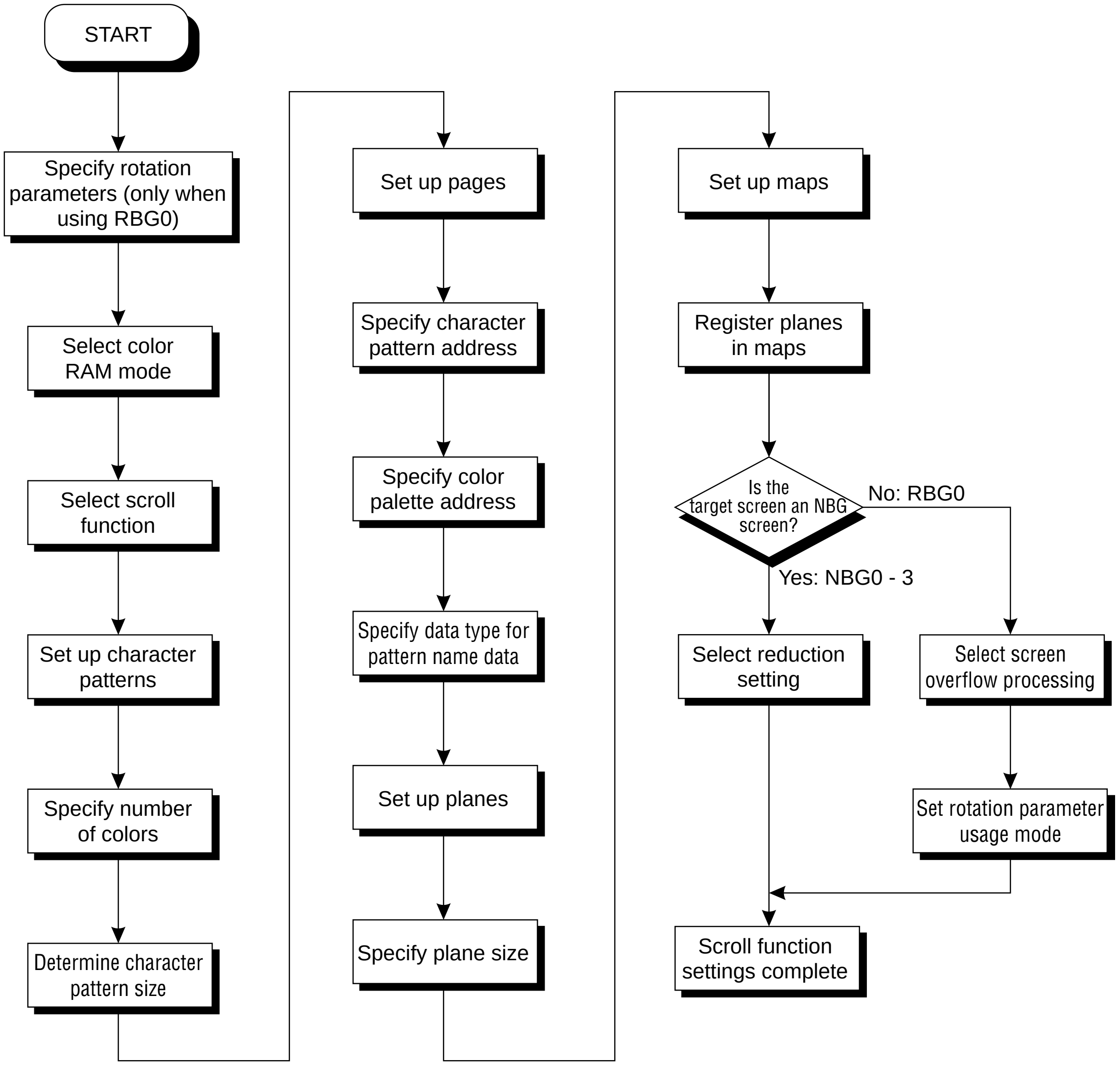
Table 8-17 Screen Overflow Processing Parameter Substitution Values (over_mode)

	Overflow processing mode			
	Mode 0	**Mode 1**	**Mode 2**	**Mode 3**
Parameter substitution value	0	1	2	3

Scroll setting flow chart

The following flow chart summarizes the scroll setting procedure, including the setting of the character patterns, the page -> plane -> map settings, the reduction setting, and scroll registration.

Flow Chart 8-1 Flow of Scroll Function Settings


START
Specify rotation parameters (only when using RBG0)
Select color RAM mode
Select scroll function
Set up character patterns
Specify number of colors
Determine character pattern size
Set up pages
Specify character pattern address
Specify color palette address
Specify data type for pattern name data
Set up planes
Specify plane size
Set up maps
Register planes in maps
Is the target screen an NBG screen?
No: RBG0
Yes: NBG0 - 3
Select reduction setting
Select screen overflow processing
Set rotation parameter usage mode
Scroll function settings complete

Scroll Drawing

This section explains the procedure from the point when the scroll function settings and scroll registration have been completed up to the point where the scroll screen is actually drawn. The explanation will describe the library functions in the sequence in which they are used.

Background screen setup

Background screen setup:

Select the color for the background screen.

The background screen is the single-color screen that is displayed in the background anywhere on the monitor where nothing is displayed.

Use the library function “slBack1ColSet” to set the background screen.

[void slBack1ColSet (void *back_col_adr, Uint16 RGB_col);]

This function sets the background color for the single-color background screen.

For the parameters, set the starting address in VRAM where the background screen color data is stored and a 1-word RGB value (#define value) that shows the background screen color.

The #define value used for RGB color specification is defined in the header file “sl_def.h” as “RGB_Flag”.

Fig 8-15 RGB Color Mode Sample (RGB_Flag)

● RGB mode color sample ●

```
#define    CD_Black        (0<<10) | (0<<5) | (0) | RGB_Flag
#define    CD_DarkRed      (0<<10) | (0<<5) | (8) | RGB_Flag
#define    CD_DarkGreen    (0<<10) | (8<<5) | (0) | RGB_Flag

                  |
                  |
                  |

#define    CD_Purple       (31<<10) | (0<<5) | (31) | RGB_Flag
#define    CD_Magenta      (31<<10) | (31<<5) | (0) | RGB_Flag
#define    CD_White        (31<<10) | (31<<5) | (31) | RGB_Flag
```

Note: The above values are defined in "sl_def.h".

Display position setting

Normal scroll screen:

This function determines the display position of the normal scroll screen for which the function has been set. Use the library function “slScrPosNbg0 to 3” to determine the normal scroll screen display position.

[void slScrPosNbg0 to 3 (FIXED posx, FIXED posy);]

This function sets the normal scroll screen display coordinates.

For the parameters, substitute the values for the XY coordinates (in the scroll coordinate system) that determine where the monitor will be positioned on the scroll map.

The normal scroll screen placement reference point is the upper left corner of the monitor.

Rotating scroll screen:

These functions determine the coordinates for the placement of the rotating scroll screen for which the function has been set, as well as the coordinates for the center of rotation.

The function “slLookR” determines the display position of the rotating scroll screen, and the function “slDispCenterR” determines the coordinates for the center of rotation.

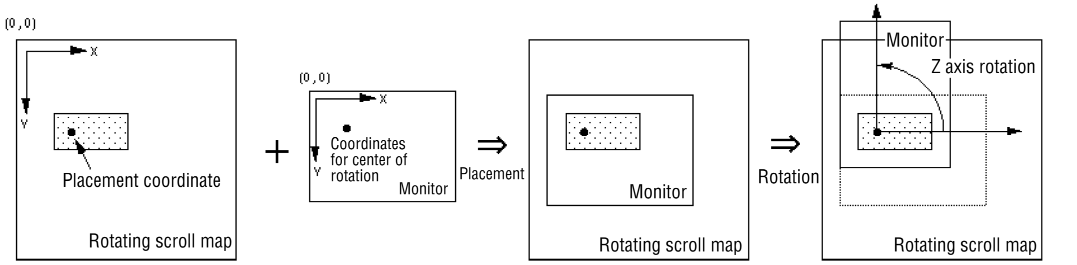
[void slLookR (FIXED posx, FIXED posy);]

This function sets the rotating scroll screen placement coordinates and stores the information in the current rotation parameters. For the parameters, specify the scroll XY coordinates that will be the origin for the upper left corner of the scroll map. The display position of rotating scrolls is determined by the placement coordinates and by the coordinates for the center of rotation.

[void slDispCenterR (FIXED posx, FIXED posy);]

This function sets coordinates for the center of rotation (vanishing point) of the rotating scroll screen and stores the information in the current rotation parameters. For the parameters, specify the screen XY coordinates where the rotating scroll screen is to be placed. The display position of rotating scrolls is determined by the placement coordinates and by the coordinates for the center of rotation.

Fig 8-16 Relationship between the Display Position and the Center of Rotation



Note:The positive direction on the Z axis in the scroll screen is towards the front of the screen.

In addition, the functions “slLookR” and “slDispCenterR” can be used to make settings for the rotation parameters A and B, respectively; use the function “slCurRpara” to switch between the rotation parameters to be set (the rotation parameters currently being used). Of the functions used for the rotating scrolls, all with a function name that ends with an “R” can be used to set their corresponding functions independently for rotation parameters A and B.

Scroll registration

Once all scroll data has been stored and all scroll function settings have been completed, it is necessary to register the scroll by using the SGL library function “slScrAutoDisp”. Scroll registration is the process of setting up the cycle pattern and drawing settings for scroll screens for which the function settings have been completed.

In addition, the scroll registration process may fail in some cases, depending on the scroll function settings to be registered, the number of scroll screens, and the VRAM bank in which the scroll data is stored. This is due to the various restrictions placed on scrolls, including restrictions on scrolls due to the number of colors used in normal scroll screens as described earlier. (These restrictions are discussed in the section that follows.)

[Uint16 slScrAutoDisp (Uint32 disp_bit);]

This function registers scroll screens for which functions have been set.

For the parameter, substitute the value from the following chart that corresponds to the scroll screen to be registered.

The function returns a value of “0” if scroll registration is completed successfully, and of “-1” if scroll registration fails.

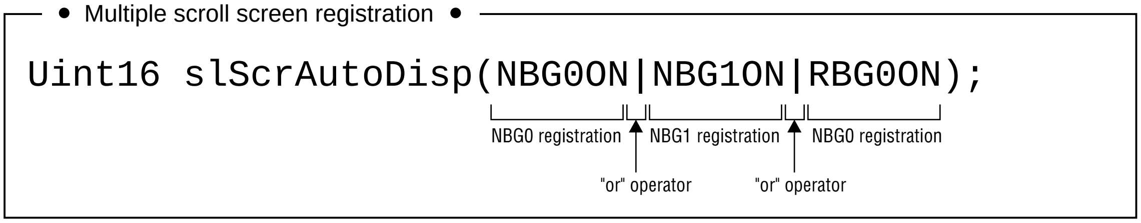
Table 8-18 Scroll Registration Parameter Substitution Values (disp_bit)

	Scroll screen to be registered				
	NBG0	**NBG1**	**NBG2**	**NBG3**	**RBG0**
Substitution value	NBG0ON	NBG1ON	NBG2ON	NBG3ON	RBG0ON

Note: The values in the above table are defined in “sl_def.h”.

When registering more than one scroll screen, it is convenient to link the #define values corresponding to each scroll screen by using the “or” (“|”) operator when substituting for the parameter in the library function “slScrAutoDisp”. (An example is shown in the diagram below.)

Fig 8-17 Multiple Scroll Screen Registration



• Multiple scroll screen registration •

```
Uint16 slScrAutoDisp(NBG0ON|NBG1ON|RBG0ON);
```

Note: The parameter substitution values are defined in "sl_def.h".

Notes on scroll registration

When using the SGL library function “slScrAutoDisp” to perform scroll registration, in certain cases the function may return a value of “-1”. This return value indicates that the function “slScrAutoDisp” failed at scroll registration.

There are four basic causes for scroll registration to fail:

Causes of scroll registration failure

1) Scroll restrictions due to the number of colors used in normal scroll screens

   An attempt was made to register scroll screens which cannot be used due to the setting for the number of colors used in NBG0 and NBG1.

2) Bank occupied by rotating scroll data

   Rotating scroll screen data and normal scroll screen data were both stored in the same VRAM bank.

3) Pattern name data storage bank limitations

   Pattern name data is stored in both VRAM banks with names that end with the same number.

4) Deviation from allowable scroll functions

   The scroll screen to be registered exceeded the number of scroll functions and screens that can be selected at one time.

Measures to resolve each of these problems are described below.

Remedres for scroll registration faiture

Remedy for cause number 1:

Either decrease the number of colors set for NBG0 or NBG1, or else do not try to register NBG2 or NBG3.

Remedy for cause number 2:

Store the scroll data for the rotating scroll screen and the normal scroll screen in separate VRAM banks.

Remedy for cause number 3:

Observe the restrictions on storing pattern name data in VRAM banks.

Remedy for cause number 4:

Try reducing the number of scroll screens being registered, reducing the number of colors in the character patterns in the function settings, increasing the reduction setting value, and reducing the amount of scroll screen data in each VRAM bank.

VRAM access restrictions
The causes underlying number 4 above are ultimately caused by restrictions on accesses to VRAM banks. Explaining and comprehending the VRAM access restrictions is very difficult. Therefore, we are limiting ourselves here to simply suggesting a limitation of the number of scroll functions and screens as a means of solving this problem.

(For details on VRAM access, refer to the “ HARDWARE MANUAL vol. 2: VDP2 User’s Manual.”)

Drawing start

Drawing declaration:

In the SGL, scroll screen drawing processing on the monitor screen begins for the first time when the library function “slTVOn” is executed.

Subsequently, the scroll screens are drawn continuously on the screen in synchronization with the scan lines according to the stored scroll information (position, scale, rotation angle, graphics data, etc.).

In addition, there is also a complementary function to “slTVOn”, called “slTVOff”. This function is used to halt scroll drawing processing.

[void slTVOn (void);]

This function starts drawing processing for scroll screens that have been set up for drawing.

[void slTVOff (void);]

This function halts drawing processing for scroll screens that have been set up for drawing.

Draw setup:

This setting determines whether or not a scroll screen for which the functions have been set is actually drawn on the monitor or not. Scrolls which have been registered as scrolls by using the function “slScrAutoDisp” have the draw setting set to “on” when they are registered, so drawing of those scrolls is executed right away; however, it is possible to turn the draw setting off so that the scrolls are not drawn. In addition, scrolls for which the draw setting has been turned off can have the setting turned back on so that those scrolls are drawn again.

Operations involving scroll screens for which the draw setting has been turned off are not executed.

[void slScrDisp (Uint32 mode);]

This function sets the draw setting for scroll screens for which the function settings have been completed.

For the parameter, substitute the value from the table below corresponding to the draw setting for each scroll screen.

Table 8-19 "slScrDisp" Parameter Substitution Value List (mode)

	NBG0		NBG1		NBG2		NBG3		RBG0	
	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
Substitution value	NBG0ON	NBG0OFF	NBG1ON	NBG1OFF	NBG2ON	NBG2OFF	NBG3ON	NBG3OFF	RBG0ON	RBG0OFF

Note: The values in the above table are defined in “sl_def.h”.
ON: Draw the scroll screen
OFF: Do not draw the scroll screen

Screen synchronization (scroll overwriting)

This function overwrites the scroll drawing data according to the state of the scan lines.

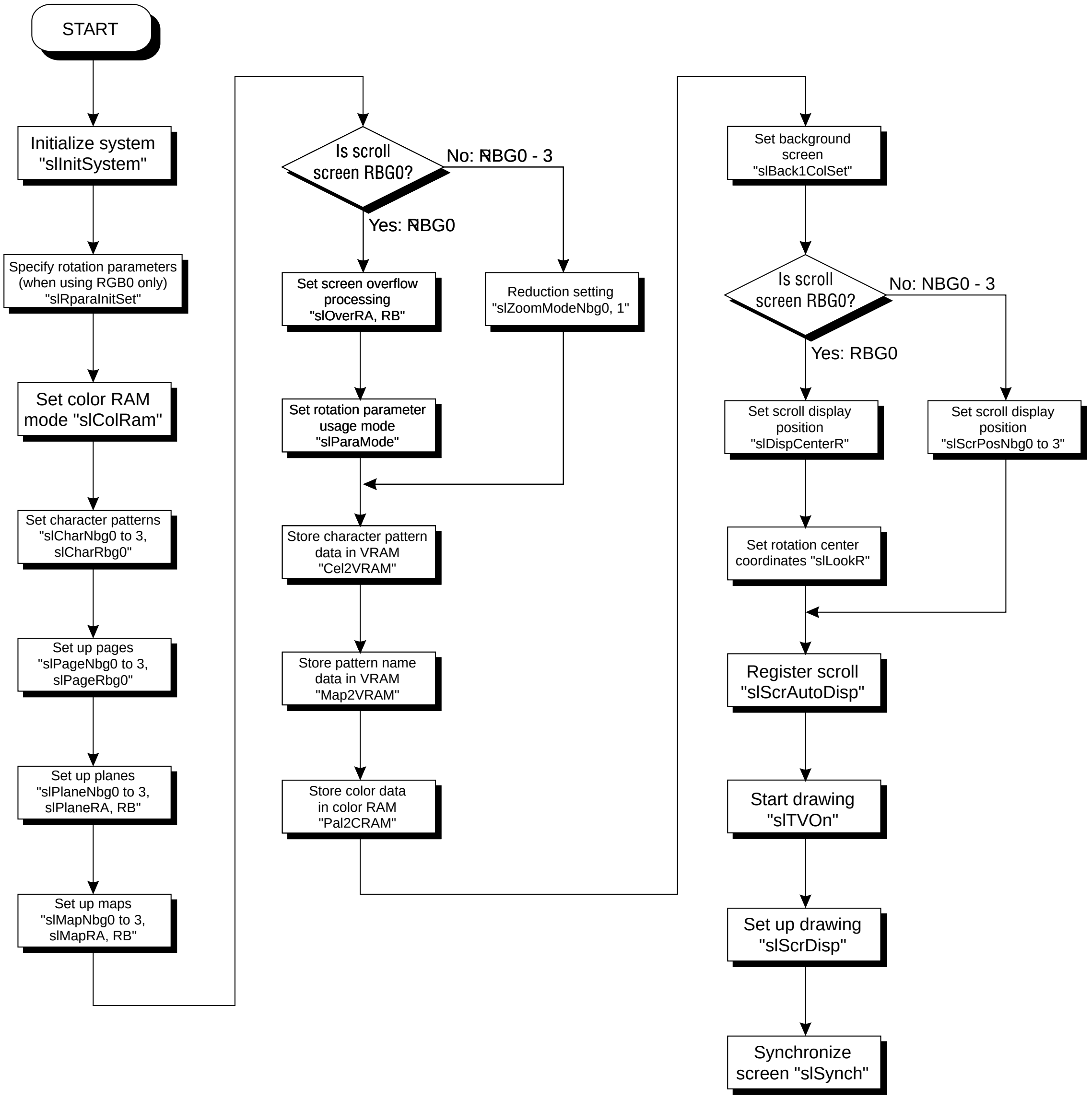
[void slSynch (void);]

This function overwrites the drawing data while the monitor is not overwriting the screen.

Flow of operations up to scroll drawing

The following flow chart shows the flow of operations from the initialization of scroll data up to the actual drawing of the scroll data, and serves as a summary of what has been explained up to this point, from scroll function setup to scroll drawing.

Flow Chart 8-2 Flow of Operations up to Scroll Drawing


START
Initialize system "slInitSystem"
Specify rotation parameters (when using RGB0 only) "slRparaInitSet"
Set color RAM mode "slColRam"
Set character patterns "slCharNbg0 to 3, slCharRbg0"
Set up pages "slPageNbg0 to 3, slPageRbg0"
Set up planes "slPlaneNbg0 to 3, slPlaneRA, RB"
Set up maps "slMapNbg0 to 3, slMapRA, RB"
Is scroll screen RBG0?
No: NBG0 - 3
Yes: RBG0
Set screen overflow processing "slOverRA, RB"
Reduction setting "slZoomModeNbg0, 1"
Set rotation parameter usage mode "slParaMode"
Store character pattern data in VRAM "Cel2VRAM"
Store pattern name data in VRAM "Map2VRAM"
Store color data in color RAM "Pal2CRAM"
Set background screen "slBack1ColSet"
Is scroll screen RBG0?
No: NBG0 - 3
Yes: RBG0
Set scroll display position "slDispCenterR"
Set scroll display position "slScrPosNbg0 to 3"
Set rotation center coordinates "slLookR"
Register scroll "slScrAutoDisp"
Start drawing "slTVOn"
Set up drawing "slScrDisp"
Synchronize screen "slSynch"

Accessing VRAM and color RAM
If VRAM or color RAM is accessed during the monitor's display period, noise is generated on the monitor.

Therefore, accesses to these two RAM areas should either be made during a non-display interval (during blanking) by using the function "slSynch", be made after interrupting drawing processing by using the function "slTVOff", or else be made by turning off the drawing setting with the function "slScrDisp" and then accessing the VRAM bank not being accessed.

Normal Scroll Screens

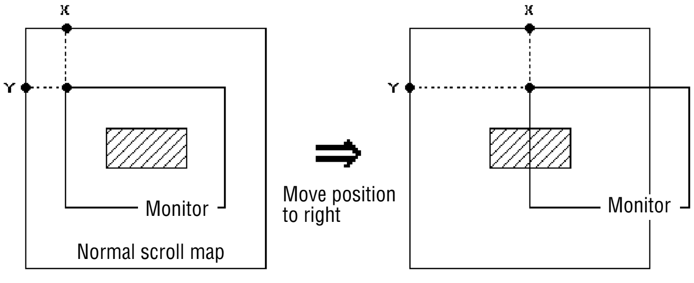
The normal scroll screens NBG0 to 3 permit vertical and horizontal movement of the scroll and also expansion/reduction of the scroll (NBG0 and NBG1 only). These two functions are explained below via a sample program.

Normal scroll screen movement

The normal scroll screens NBG0 to NBG3 can be moved horizontally and vertically by changing the scroll display position.

This concept is illustrated below.

Fig 8-18 Scroll Display Position Concept



a) Initial state

b) Move to right

- The scroll display position is processed through the scroll screen coordinate system.
- This coordinate system designates the upper-left corner of each scroll or map as the origin.
- The scroll display position is specified by indicating where in the coordinate system the monitor should be positioned. (The representative point is the upper-left corner of the monitor.)
- As a result, if the scroll display position coordinates are moved in the positive direction along the X axis (to the right), the monitor moves to the right on the scroll map, giving the appearance that the scroll is moving to the left.

The library function “slScrPosNbg0 to 3” is used to move the scroll display position. “slScrPosNbg0 to 3” is also used to set the initial position of the scroll.

[void slScrPosNbg0 to 3 (FIXED posx, FIXED posy);]

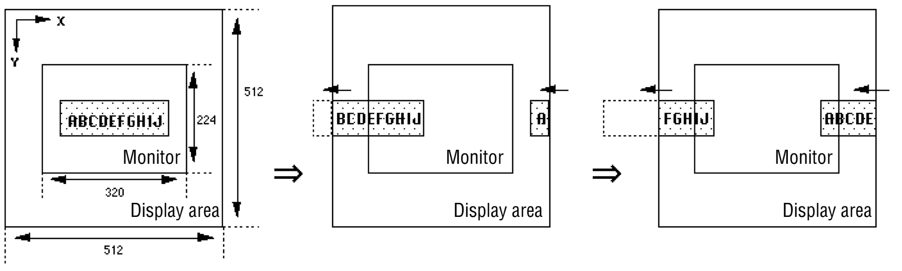
This function sets the display start position for the normal scroll screens NBG0 to NBG3.

The scroll display position is determined by where the monitor is placed on the scroll map. The upper left corner of the monitor is used as the representative point, and so only one point is specified on the scroll map as a parameter.

For the parameter, specify the XY coordinates on the scroll coordinate system.

In addition, as the scroll display position moves up and down and left and right, if it goes outside of the display area, the scroll wraps around from the other side.

Fig 8-19 Scroll Wraparound Processing



a) Initial state

b) Display area has gone beyond left edge

c) The excess portion is drawn at the right edge

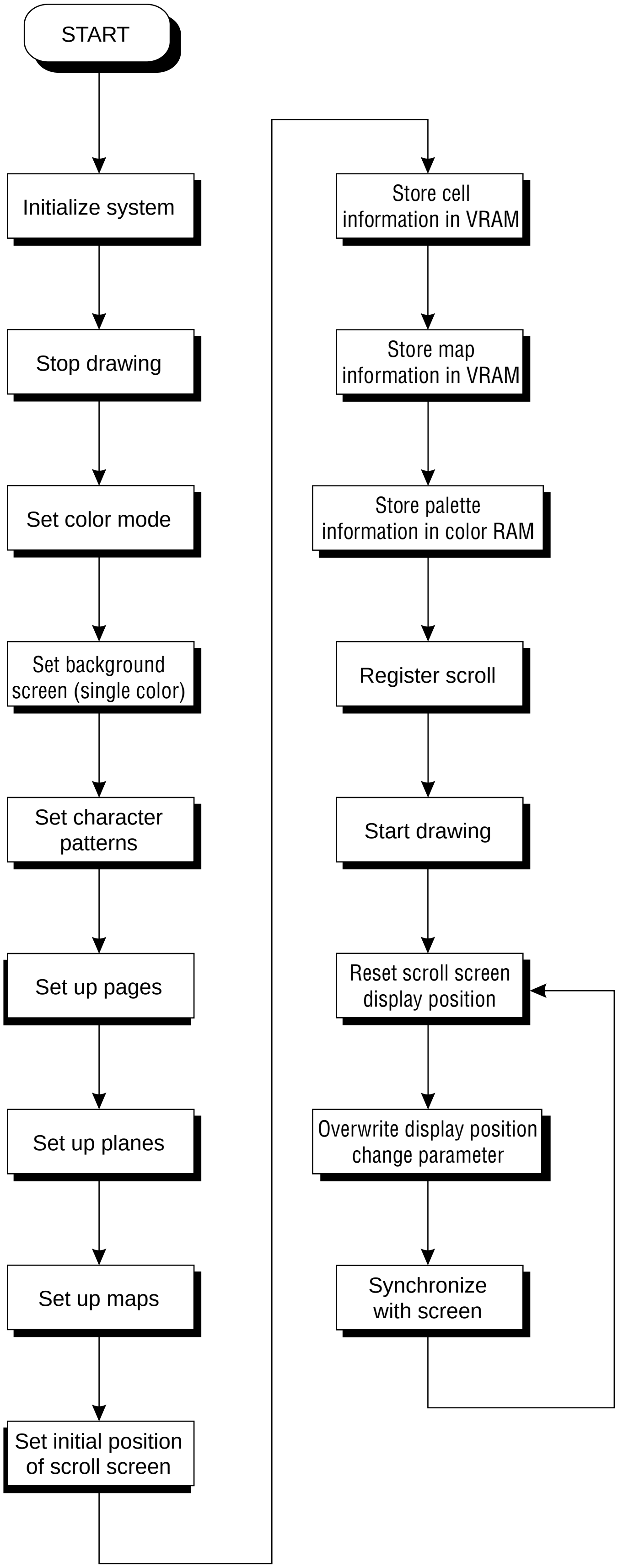
The two sample programs that follow each use SGL library functions to move a scroll horizontally and to move a scroll horizontally and vertically.

List 8-2 sample_8_8_1: Horizontal Scroll Movement

```
/*----------------------------------------------------*/
/*      Graphic Scroll [X axis]        *
/*----------------------------------------------------*/
#include        "sgl.h"                    /* include file containing various settings */
#include        "ss_scrol.h"

#define         NBG1_CEL_ADR    (VDP2_VRAM_B1+0x02000)
#define         NBG1_MAP_ADR    (VDP2_VRAM_B1+0x12000)
#define         NBG1_COL_ADR    (VDP2_COLRAM+0x00200)
#define         BACK_COL_ADR    (VDP2_VRAM_A1+0x1fffe)

void main()
{
        FIXEDyama_posx=SIPOSX,yama_posy=SIPOSY;

        slInitSystem(TV_320x224,NULL,1);    /* screen mode setting */
        slTVOff();                          /* drawing off */
        slPrint("Sample program 8.8.1",slLocate(9,2));

        slColRam(CRM16_1024);               /* color mode setting */
        slBack1ColSet(BACK_COL_ADR,0);      /* background screen setup */

        slCharNbg1(COL_TYPE-256,CHAR_SIZE_1x1);    /* scroll function setup */
        slPageNbg1(NBG1_CEL_ADR,0,PNB_1WORD|CN_12BIT);
        slPlaneNbg1(PL_SIZE_1x1);
        slMapNbg1(NBG1_MAP_ADR,NBG1_MAP_ADR,NBG1_MAP_ADR,NBG1_MAP_ADR);

        Cel2VRAM(yama_cel,NBG1_CEL_ADR,31808);    /* scroll data storage */
        Map2VRAM(yama_map,NBG1_MAP_ADR,32,16,1,256);
        Pal2CRAM(yama_pal,NBG1_COL_ADR,256);

        slScrPosNbg1(yama_posx,yama_posy);  /* initial display position setting */

        slScrAutoDisp(NBG1ON);              /* scroll registration */
        slTVOn;                             /* drawing start declaration */

        while(-1){
                slScrPosNbg1(yama_posx,yama_posy);    /* scroll data overwrite */
                yama_posx+=POSX_UP;

                slSynch();                  /* screen synchronization */
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "ss.scroll.h".

Flow Chart 8-3 sample_8_8_1: Horizontal Scroll Movement

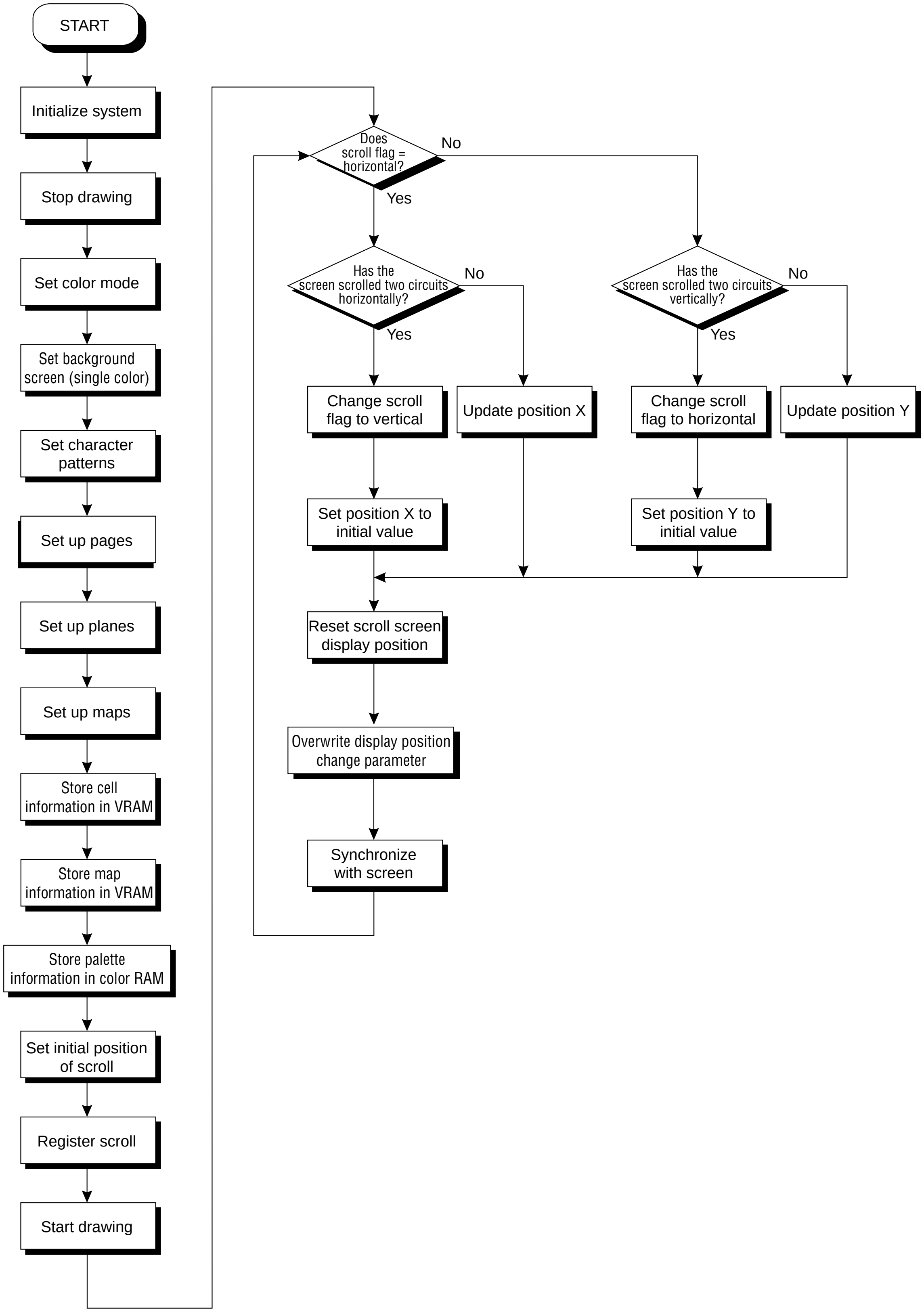

START
Initialize system
Stop drawing
Set color mode
Set background screen (single color)
Set character patterns
Set up pages
Set up planes
Set up maps
Set initial position of scroll screen
Store cell information in VRAM
Store map information in VRAM
Store palette information in color RAM
Register scroll
Start drawing
Reset scroll screen display position
Overwrite display position change parameter
Synchronize with screen

List 8-3 sample_8_8_2: Horizontal and Vertical Scroll MovementL

```
/*----------------------------------------------------*/
/*      Graphic Scroll [X & Y axis]            *
/*----------------------------------------------------*/
#include        "sgl.h"                                      /* include file containing various settings */
#include        "ss_scrol.h"

#define         NBG1_CEL_ADR    (VDP2_VRAM_B1+0x02000)
#define         NBG1_MAP_ADR    (VDP2_VRAM_B1+0x12000)
#define         NBG1_COL_ADR    (VDP2_COLRAM+0x00200)
#define         BACK_COL_ADR    (VDP2_VRAM_A1+0x1fffe)

void main()
{
        FIXED yama_posx=SIPOSX,yama_posy=SIPOSY;
        Uint16scroll_flg=YOKO;

        slInitSystem(TV_320x224,NULL,1);                     /* screen mode setting */
        TVOff();                                             /* drawing off */
        slPrint("Sample program 8.8.2",slLocate(9,2));

        slColRam(CRM16_1024);                                /* color mode setting */
        slBack1ColSet(BACK_COL_ADR,0);                       /* background screen setup */

        slCharNbg1(COL_TYPE_256,CHAR_SIZE_1x1);              /* scroll function setup */
        slPageNbg1(NBG1_CEL_ADR,0,PNB_1WORD|CN_12BIT);
        slPlaneNbg1(PL_SIZE_1x1);
        slMapNbg1(NBG1_MAP_ADR,NBG1_MAP_ADR,NBG1_MAP_ADR,NBG1_MAP_ADR);

        Cel2VRAM(yama_cel,NBG1_CEL_ADR,31808);               /* scroll data storage */
        Map2VRAM(yama_map,NBG1_MAP_ADR,32,16,1,256);
        Pal2CRAM(yama_pal,NBG1_COL_ADR,256);

        slScrPosNbg1(yama_posx,yama_posy);                   /* initial display position setting */

        slScrAutoDisp(NBG0ON|NBG1ON);                        /* scroll registration */
        slTVOn();                                            /* drawing start declaration */

        while(-1){
                if(scroll_flg==YOKO){                        /* scroll data overwrite */
                        if(yama_posx>=(SX*2+SIPOSX)){
                                scroll_flg=TATE;
                                yama_posx+SIPOSX;
                        }elseyama_posx+=POSX_UP;
                }elseif(scroll_flg==TATE){
                        if(yama_posy>-(SY*2+SIPOSY)){
                                scroll_flg=YOKO;
                                yama_posy=SIPOSY;
                        }elseyama_posy+=POSY_UP;
                }
                siScrPosNbg1(yama_posx,yama_posy);

                slSynch();                                   /* screen synchronization */
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "ss.scroll.h".

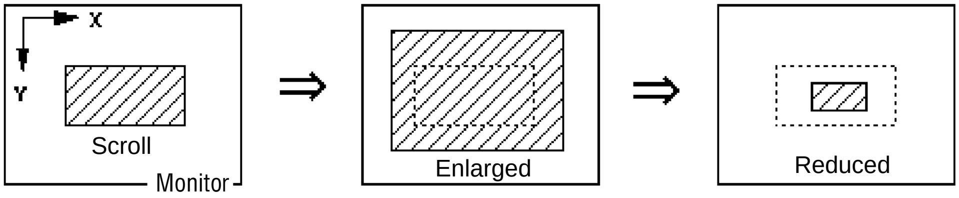
Flow Chart 8-4 sample_8_8_2: Horizontal and Vertical Scroll Movement


START
Initialize system
Stop drawing
Set color mode
Set background screen (single color)
Set character patterns
Set up pages
Set up planes
Set up maps
Store cell information in VRAM
Store map information in VRAM
Store palette information in color RAM
Set initial position of scroll
Register scroll
Start drawing
Does scroll flag = horizontal?
No
Yes
Has the screen scrolled two circuits horizontally?
No
Yes
Has the screen scrolled two circuits vertically?
No
Yes
Change scroll flag to vertical
Update position X
Change scroll flag to horizontal
Update position Y
Set position X to initial value
Set position Y to initial value
Reset scroll screen display position
Overwrite display position change parameter
Synchronize with screen

Normal scroll screen enlargement/reduction

Among the normal scroll screens, NBG0 and NBG1 can be enlarged or reduced. (Maximum range: 1/4x to 256x) The following diagrams illustrate the concept.

Fig 8-20 Scroll Enlargement and Reduction



a) Initial state b) Enlarged c) Reduced

When using the normal scroll screens NBG0 or NBG1, the possible range of reduction differs depending on the reduction setting in the scroll function settings.

Table 8-20 Enlargement/reduction range depending on the reduction setting

	Reduction setting		
	1x	1/2x	1/4x
Enlargement/reduction range	1x to 256x	1/2x to 256x	1/4x to 256x

In the SGL, in order to enlarge or reduce normal scroll screen NBG0 or NBG1, use the library function “slZoomNbg0” or “slZoomNbg1”, whichever corresponds to the scroll screen in question.

[void slZoomNbg0, 1 (FIXED scale_x, FIXED scale_y);]

This function enlarges or reduces the normal scroll screen NBG0 or NBG1. For the parameters, substitute the reciprocals of the vertical and horizontal scroll ratios. For example, to enlarge by a factor of 2, substitute “1/2” for the parameter; to reduce by 1/2, substitute “2” for the parameter. The lower limit for the reduction range changes, depending on the reduction setting. (Refer to the above table.)

Enlargement/reduction function parameters settings:
When substituting for the parameters in the scroll enlargement/reduction function, it is necessary to use the reciprocal of the desired ratio. (Ex,: To enlarge by a factor of 2, substitute “1/2”.)
The reason is that the values in the parameters do not show the scale value as is. The values substituted for the enlargement/reduction function parameters show, after displaying one dot of the scroll, the amount to move before displaying the next dot.
If the movement amount is specified as “2.0”, the scroll skips one dot after displaying each dot, with the result that the scroll is drawn at half size.
If the movement amount is 1.0, the resulting image scale is 1.0, and if the movement amount is 2.0, the resulting image scale is 1/2; if the movement amount is 1/2, the same dot is displayed twice, with the result that the displayed image becomes twice as big.

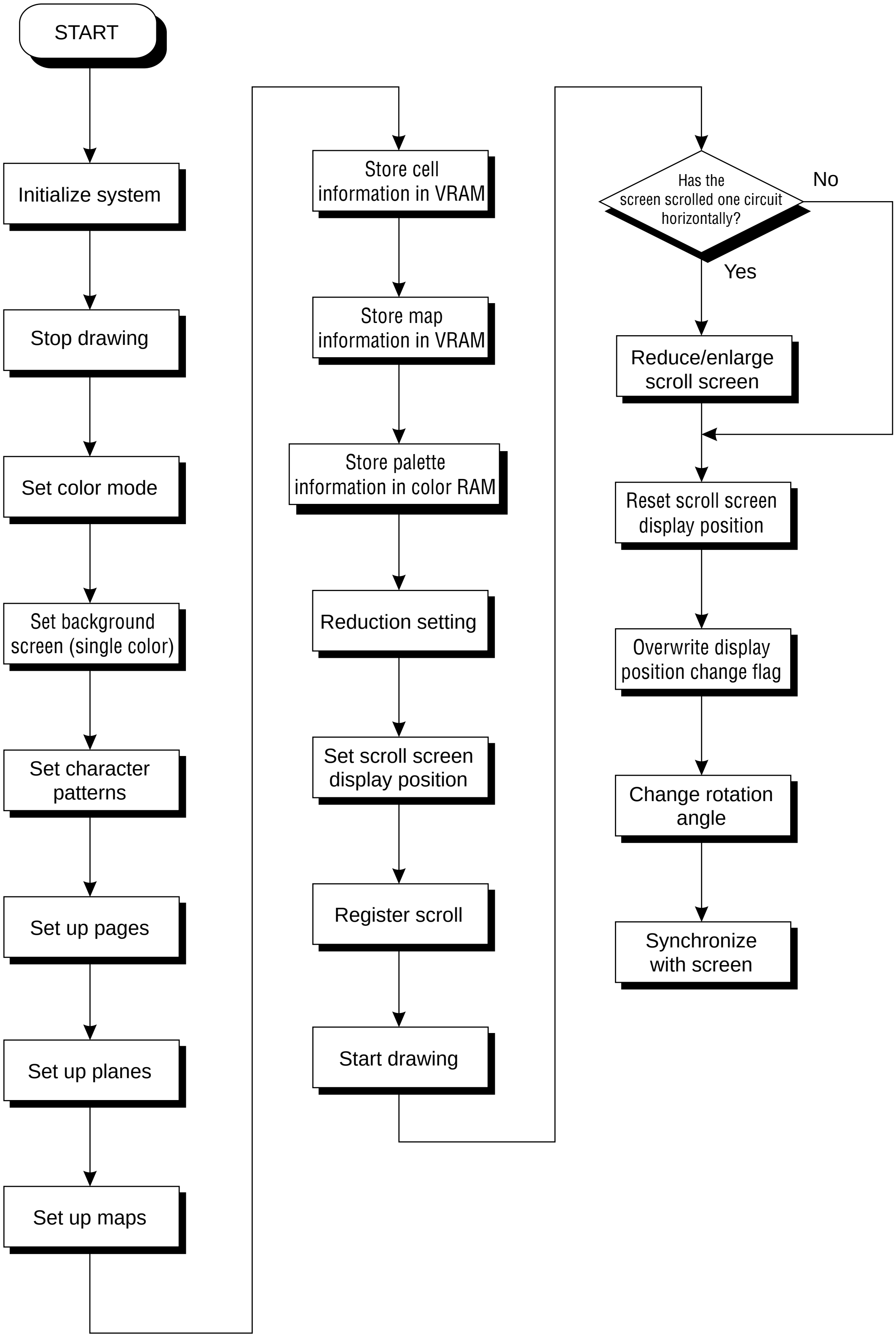
The following sample program (List 8-4) shows how to use the SGL library functions to actually enlarge and reduce a normal scroll screen.

List 8-4 sample_8_8_3: Scroll Enlargement/Reduction

```
/*----------------------------------------------------*/
/*      Graphic Scroll & Expansion & Reduction  *
/*----------------------------------------------------*/
#include        "sgl.h"                               /* include file containing various settings */
#include        "ss_scrol.h"

#define         NBG1_CEL_ADR    VDP2_VRAM_B0
#define         NBG1_MAP_ADR    (VDP2_VRAM_B0+0x10000)
#define         NBG1_COL_ADR    (VDP2_COLRAM+0x00200)
#define         BACK_COL_ADR    (VDP2_VRAM_A1+0x1fffe)

void main()
{
        FIXED yama_posx=toFIXED(0.0),yama_posy=toFIXED(0.0);
        FIXED yama_zoom=toFIXED(1.0)
        FIXED up_down=toFIXED(-0.1);

        slInitSystem(TV_320x224,NULL,1);              /* screen mode setting */
        slTVOff();                                    /* drawing off */
        slPrint("Sample program 8.8.3",slLocate(9,2));

        slColRAMMode(CRM16_1024);                     /* color mode setting */
        slBack1ColSet(BACK_COL_ADR,0);                /* background screen setup */

        slCharNbg1(COL_TYPE_256,CHAR_SIZE_1x1);       /* scroll function setup */
        slPageNbg1(NBG1_CEL_ADR,0,PNB_1WORD|CN_10BIT);
        slPlaneNbg1(PL_SIZE_1x1);
        slMapNbg1(NBG1_MAP_ADR,NBG1_MAP_ADR,NBG1_MAP_ADR,NBG1_MAP_ADR);

        Cel2VRAM(yama_cel,NBG1_CEL_ADR,31808);        /* scroll data storage */
        Map2VRAM(yama_map,NBG1_MAP_ADR,32,16,1,0);
        Pal2CRAM(yama_pal,NBG1_COL_ADR,256);

        slZoomModeNbg1(ZOOM_HALF);                    /* reduction setting */

        slScrPosNbg1(yama_posx,yama_posy);            /* initial display position setting */

        slScrAutoDisp(NBG1ON);                        /* scroll registration */
        slTVOn();                                     /* drawing start declaration */

        while(-1){
                if(yama_posx>=SX){                    /* scroll data overwrite */
                        if(yama_zoom>=toFIXED(1.5))
                                up_down=toFIXED(-0.1)
                        elseif(yama_zoom<=toFIXED(0.7))
                                up_down=toFIXED(0.1)
                        yama_zoom+=up_down;
                        yama_posx=toFIXED(0.0);
                        slZoomNbg1(yama_zoom,yama_zoom);   /* scroll enlargement/reduction */
                }
                siScrPosNbg1(yama_posx,yama_posy);
                yama_posx+=POSX_UP;

                slSynch();                            /* screen synchronization */
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "ss.scroll.h".

Flow Chart 8-5 sample_8_8_3: Scroll Enlargement/Reduction


START
Initialize system
Stop drawing
Set color mode
Set background screen (single color)
Set character patterns
Set up pages
Set up planes
Set up maps
Store cell information in VRAM
Store map information in VRAM
Store palette information in color RAM
Reduction setting
Set scroll screen display position
Register scroll
Start drawing
Has the screen scrolled one circuit horizontally?
No
Yes
Reduce/enlarge scroll screen
Reset scroll screen display position
Overwrite display position change flag
Change rotation angle
Synchronize with screen

Rotating Scroll Screen

The rotating scroll screen RGB0 permits scroll enlargement/reduction and rotation. In addition, unlike normal scroll screens, the scroll can be moved both in the horizontal and the vertical directions, respectively.

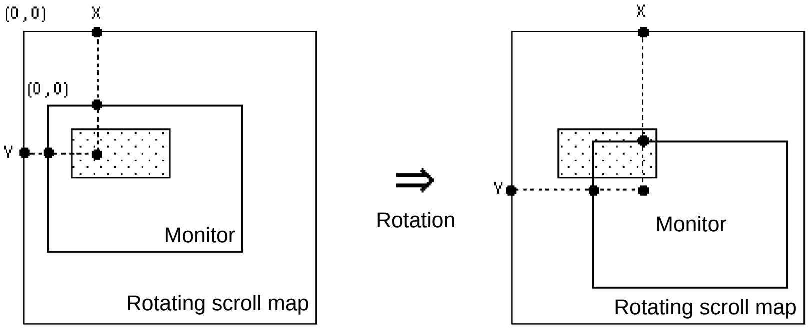
In this section, these three functions (rotating scroll movement, enlargement/reduction, and rotation) are explained in conjunction with a sample program.

Rotating scroll shift

Rotating scroll shifting is also actually realized by changing the scroll display position.

By using the “slLookR” function, it is possible to create the illusion that the scroll is moving up and down or right and left across the monitor.

Fig 8-21 Rotating Scroll Movement



- The rotating scroll display position is determined by the placement coordinates and by the rotation center coordinates.
- To shift the rotating scroll, fixing the rotation center coordinates in place and moving the placement coordinates as shown in the diagram at left, are sufficient to move the rotating scroll.

Rotating scroll screen enlargement/reduction

In the SGL, the enlargement/reduction operation can also be performed on the rotating scroll screen. Unlike enlargement/reduction of normal scroll screens, enlargement/reduction of rotating scroll screens can always be done at any desired ratio.

In addition, in the case of a rotating scroll screen, the scroll rotation operation described later, the enlargement/reduction operation, and the movement operation can all be used together.

In the SGL, use the library function “slZoomR” to enlarge/reduce rotating scroll screens.

[void slZoomR (FIXED scale_x, FIXED scale_y);]

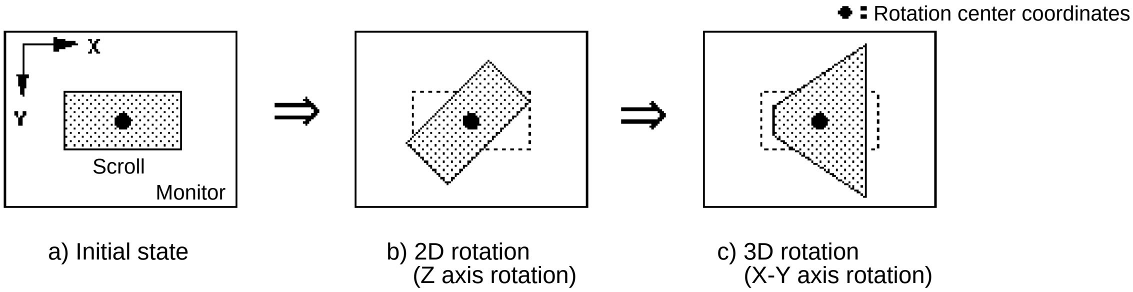
This function enlarges/reduces the rotating scroll screen RGB0, and saves the current state in the current rotation parameters. (The current parameters can be switched by using the “slCurRpara” function.)

For the parameters, substitute the reciprocals of the horizontal and vertical scroll ratios. For example, to enlarge by a factor of 2, substitute “1/2” for the parameter; to reduce by 1/2, substitute “2” for the parameter. In the case of the rotating scroll, the enlargement/reduction ratio can always be set to any desired value.

Rotating scroll screen rotation

In the Sega Saturn system, the rotating scroll screen can be rotated around any desired axis at any desired angle. (The diagrams below illustrate the concept.)

Fig 8-22 Scroll Rotation Concept



a) Initial state

b) 2D rotation
(Z axis rotation)

c) 3D rotation
(X-Y axis rotation)

2D rotation (Z axis rotation)

In the SGL, use the library function “slZrotR” to perform the 2D rotation operation (Z axis rotation) on the rotating scroll screen.

The point that is the center of rotation (one point on the scroll map) is the point that was set by the library function “slDispCenterR”.

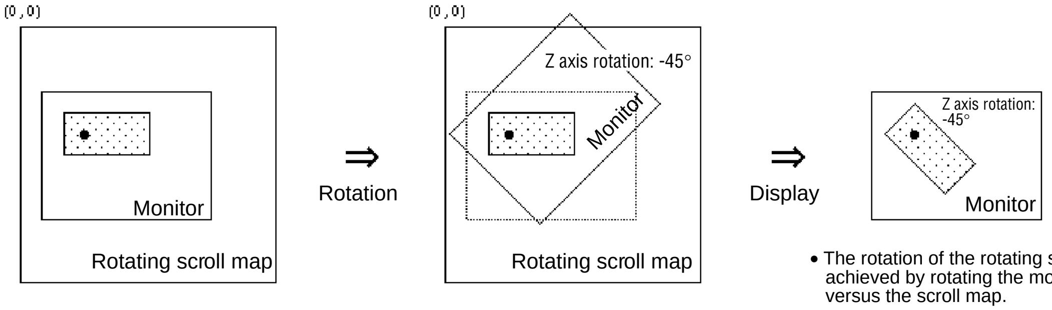
[void slZrotR (ANGLE z_angle);]

This function rotates the rotating scroll screen RBG0 around the Z axis.

For the parameter, specify the Z axis rotation angle for the current rotation parameters. Specify the rotation angle not as the angle from the current position, but as the absolute angle. (The current parameters can be switched by using the “slCurRpara” function.)

The point set by the library function “slDispCenterR” is used as the center of rotation.

Fig 8-23 Actual Operation of Scroll Rotation



• The rotation of the rotating scroll is achieved by rotating the monitor versus the scroll map.

Note on Function Usage
The functions “slZrotR”, “slZoomR”, and “slLookR” used for the rotating scroll transformation operations cannot be used at the same time with the same rotation parameters as the function “slScrMatSet” which performs the same transformation operations on the rotating scroll.
This is because while the former group of functions overwrites a specific area in the rotation parameters, the latter function overwrites the entire rotation parameter area.

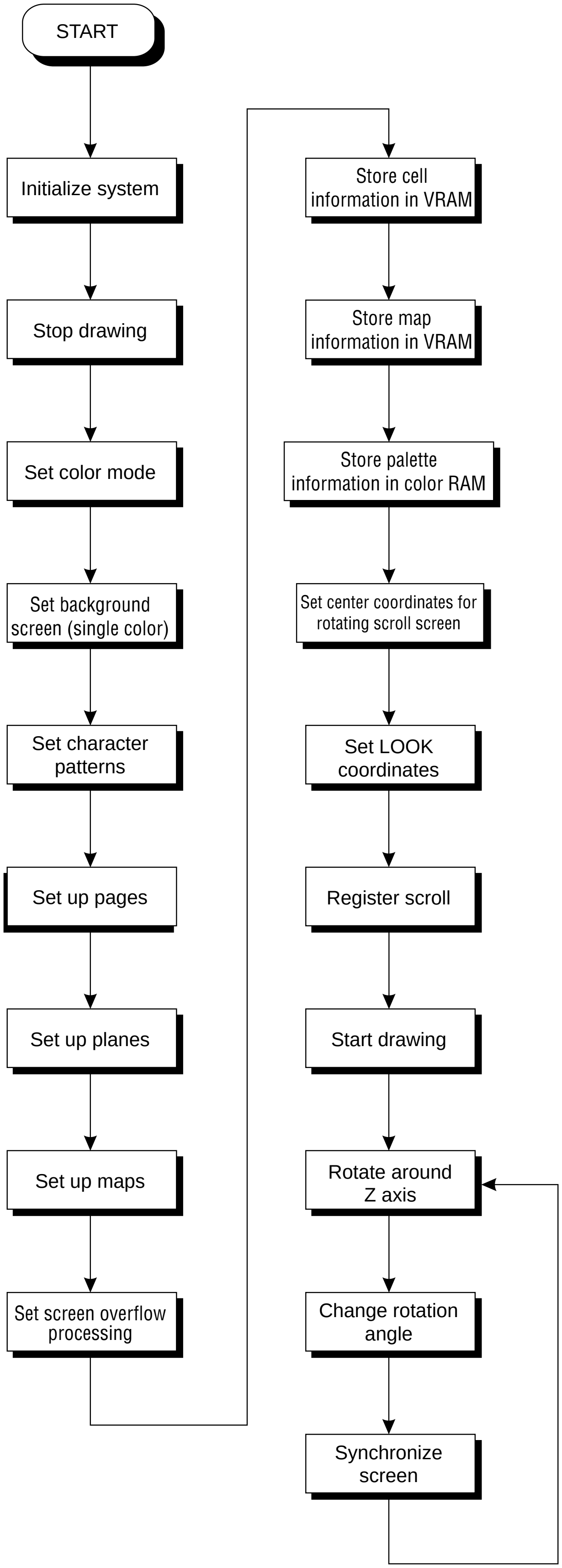
The following sample program (List 8-5) shows how to use the SGL library functions to actually rotate the rotating scroll screen.

List 8-5 sample_8_9_1: Scroll 2D Rotation

```
/*----------------------------------------------------*/
/*      Graphic Rotation                *
/*----------------------------------------------------*/
#include        "sgl.h"                         /* include file containing various settings */
#include        "ss_scrol.h"

#define         RBG0_CEL_ADR    VDP2_VRAM_A0
#define         RBG0_MAP_ADR    VDP2_VRAM_B0
#define         RBG0_COL_ADR    (VDP2_COLRAM+0x00200)
#define         RBG0_PAR_ADR    (VDP2_VRAM_A1+0x1fe00)
#define         BACK_COL_ADR    (VDP2_VRAM_A1+0x1fffe)

void main()
{
        ANGLEyama_angz=DEGtoANG(0.0);
        FIXEDposx=toFIXED(128.0),posy=toFIXED(64.0);

        slInitSystem(TV_320x224,NULL,1);        /* screen mode setting */
        slTVOff();                              /* drawing off */
        slPrint("Sample program 8.9.1",slLocate(9,2));

        slColRAMMode(CRM16_1024);               /* color mode setting */
        slBack1ColSet(BACK_COL_ADR,0);          /* background screen setup */

        slRparaInitSet(RBG0_PAR_ADR);           /* rotation parameter setting */

        slCharRbg0(COL_TYPE_256,CHAR_SIZE_1x1); /* scroll function setup */
        slPageRbg0(RBG0_CEL_ADR,0,PNB_1WORD|CN_10BIT);  /* use rotation parameters A */
        slPlaneRA(PL_SIZE_1x1);
        sl1MapRA(RBG0_MAP_ADR);

        slOverRA(2);                            /* screen overflow processing */

        Cel2VRAM(yama_cel,RBG0_CEL_ADR,31808);  /* scroll data storage */
        Map2VRAM(yama_map,RBG0_MAP_ADR,32,16,1,0);
        Pal2CRAM(yama_pal,RBG0_COL_ADR,256);

        slDispCenterR(toFIXED(160.0),toFIXED(112.0));   /* initial display position setting */
        slLookR(toFIXED(128.0),toFIXED(64.0));

        slScrAutoDisp(RBG0ON);                  /* scroll registration */
        slTVOn();                               /* drawing start declaration */

        while(-1){
                slZrotR(yama_angz);             /* scroll Z axis rotation */
                yama_angz+=DEGtoANG(1.0);
                slSynch();                      /* screen synchronization */
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "ss.scroll.h".

Flow Chart 8-6 sample_8_9_1: Scroll 2D Rotation



3D rotation using the current matrix

In the SGL, it is necessary to follow the procedure described below when performing a 3D rotation operation (rotation around all axes) on the rotating scroll screen.

1) Rotating scroll setup

Complete all of the settings required when using the rotating scroll, such as the rotation parameter settings, screen overflow processing, and coefficient table setup.

2) Coordinate operations

3D rotation operations involving the rotating scroll should first be executed against the current matrix.

The same function group is used, namely, “slRotX”, “slTranslate”, “slScale”, etc. However, the sequence of operations (rotation, shift, and enlargement/reduction) is the opposite of that for normal coordinate transformation operations. (Refer to chapter 4, “Coordinate Transformations,” for details on the transformation operation sequence.)

In addition, the scroll coordinate system is a left-hand system in which the positive and negative directions on the Z axis are reversed. However, because the conceptual image entails rotating and moving the monitor versus the scroll, the resulting effect is actually the same.

If you wish to perform coordinate transformation operations with the same matrix operation procedure as used with normal coordinate transformation operations, use the function “slScrMatConv” before the matrix data transfer. The function “slScrMatConv” converts the current matrix that was transformed through the normal coordinate transformation procedure, into a coordinate transformation matrix for scrolls and then makes the resulting matrix into the current matrix.

[void slScrMatConv (void);]

This matrix converts the current matrix into coordinate transformation data for scrolls and then replaces the current matrix with the results. Naturally, if this function is used on the current matrix after executing the scroll coordinate transformation operation, the current matrix is replaced with a matrix that can be used for normal coordinate transformations.

3) Transferring the operation results to the rotation parameters

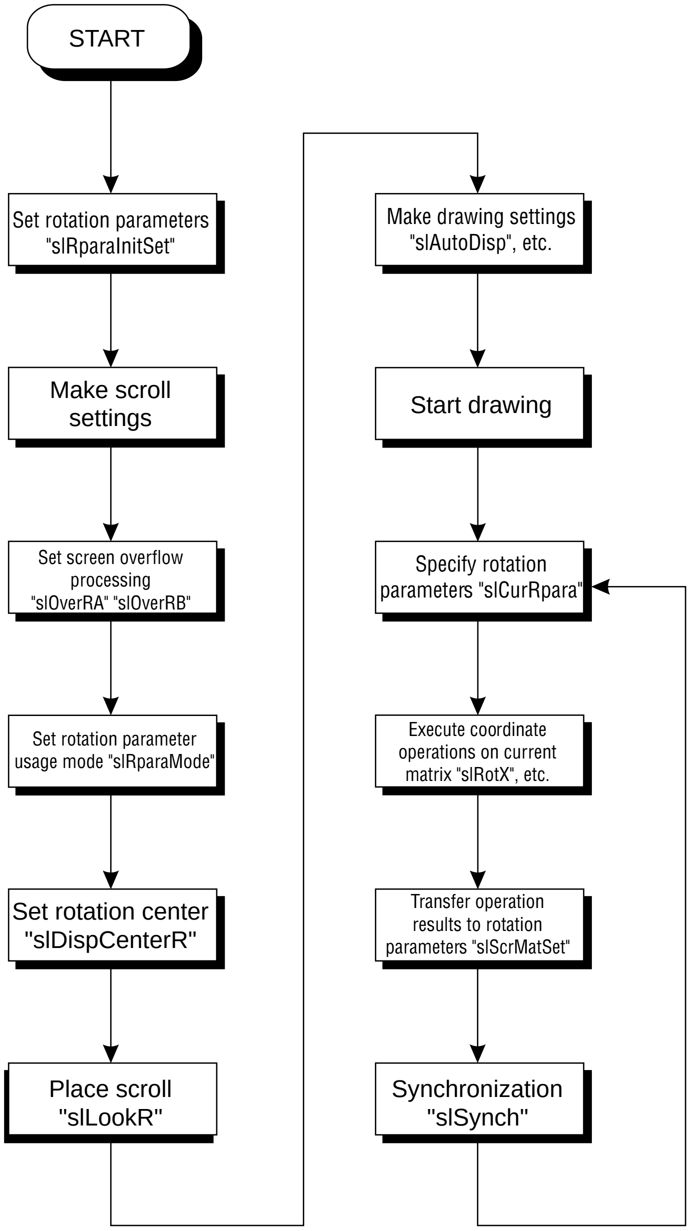
Next, transfer the results of the coordinate operations executed on the current matrix to the rotation parameters. The rotating scroll is then altered and drawn according to the rotating parameter data that was transferred.

Use “slScrMatSet” to transfer the data.

[void slScrMatSet (void));]

This function transfers the current matrix data to the current rotation parameters. Use for transferring the current matrix on which the coordinate transformation operation for the rotating scroll has been performed.

Flow Chart 8-7 3D Rotation Operation Procedure Using the current Matrix


START
Set rotation parameters "slRparaInitSet"
Make scroll settings
Set screen overflow processing "slOverRA" "slOverRB"
Set rotation parameter usage mode "slRparaMode"
Set rotation center "slDispCenterR"
Place scroll "slLookR"
Make drawing settings "slAutoDisp", etc.
Start drawing
Specify rotation parameters "slCurRpara"
Execute coordinate operations on current matrix "slRotX", etc.
Transfer operation results to rotation parameters "slScrMatSet"
Synchronization "slSynch"

Controlling the zoom ratio by using the coefficient table

When executing a 3D rotation operation on the rotating scroll, the scroll is scaled according to its “depth” in the screen. Normally, this scaling ratio is calculated on the basis of the parameters used in 3D coordinate operations, such as perspective transformations and then the results are used to reshape the scroll; it is possible, however, to set this reshaping ratio for the individual lines or dots beforehand and then use these ratios when reshaping the scroll. These ratios as a group are called the “coefficient table.”

The following two functions are needed when using the coefficient table.

1) Coefficient table creation:

First, it is necessary to allocate an area in VRAM for the coefficient table. The coefficient table must be created in VRAM. In addition, the coefficient table will occupy one bank in VRAM. This is because the coefficient table references the VRAM area at the maximum access rate (8 times) for one bank.

[void slMakeKtable (void *adr);]

This function creates the coefficient table to be used in the 3D rotation operations at the specified address. For the parameter, substitute the starting address of the area where the coefficient table is to be created. The coefficient table must always be allocated in VRAM.

2) Coefficient table usage mode setting

When using the area that was specified as the coefficient table, this function determines the usage mode, which indicates how the coefficient table is to be used.

[void slKtableRA, RB (void *table_adr, Uint16 mode);]

This function specifies the address of the coefficient table to be used, and also determines which of the contents of the coefficient table are to be used. For the parameters, substitute the starting address of the coefficient table, and also values (which can be connected by using the “or” operator “|”) from the following figure indicating coefficient table usage modes.

The function “slKtableRA” sets the coefficient table for rotation parameters A, and “slKtableRB” sets the coefficient table for rotation parameters B.

Fig 8-24 slKtableRA, RB Parameter Substitution Values (mode)

● slKtableRA, RB substitution values ●

```
Table usage:            [K_OFF     | K_ON     ]|
Coefficient data size:  [K_2WORD   | K_1WORD  ]|
Coefficient mode:       [K_MODE0   | K_MODE1  | K_MODE2 | K_MODE3 ]|
Line color:             [K_LINECOL            ]|
Reshaping unit:         [K_DOT     | K_LINE   ]|
Fixed coefficients:     [K_FIX                ]|
```

Note: If "fixed coefficients" is specified as a parameter, the coefficient table is assumed to have been created beforehand, and the coefficient table is not executed in real time.

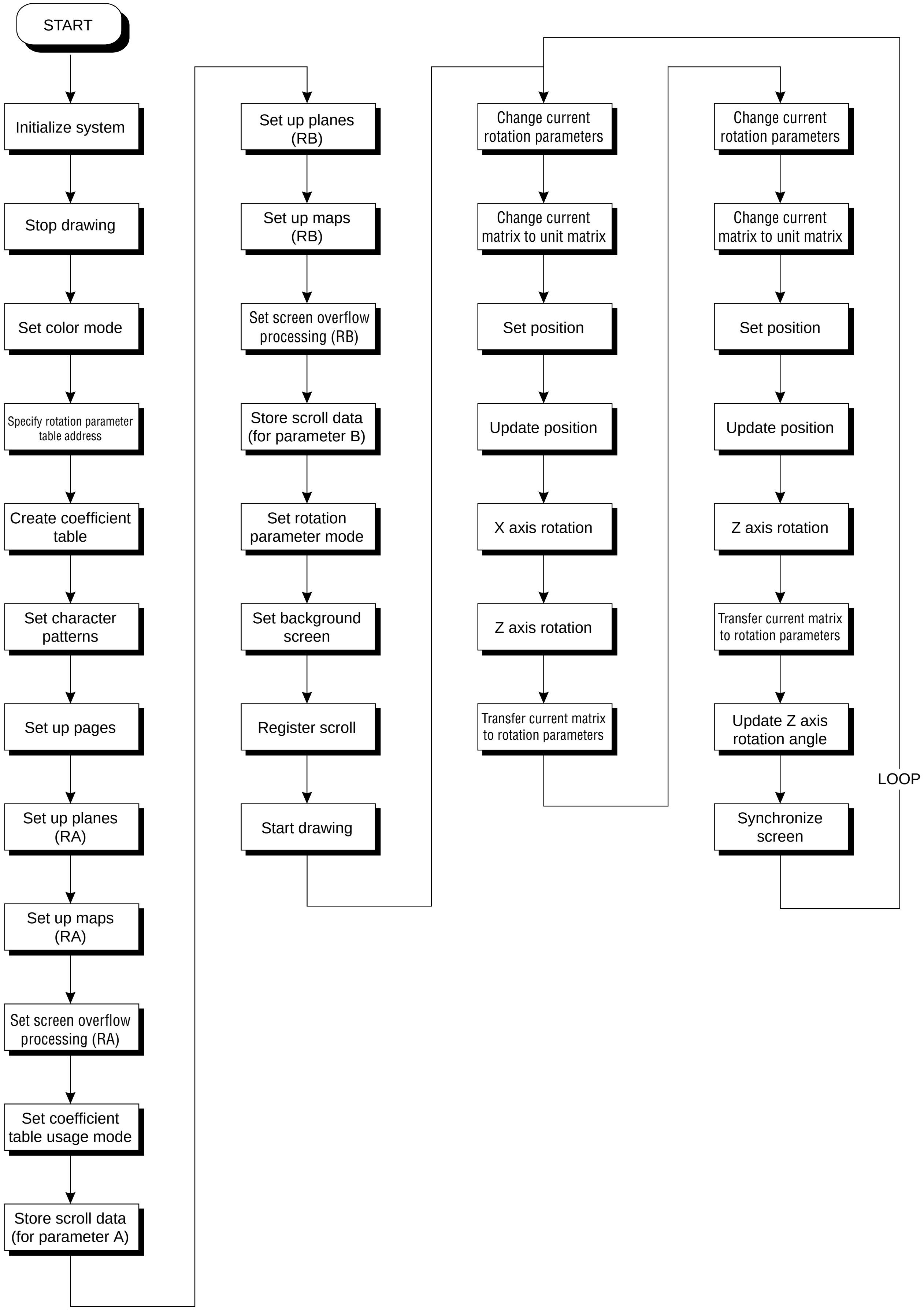
Note:
For details on coefficient tables, refer to “HARDWARE MANUAL vol. 2: VDP2, p. 163.”

List 8-6 sample_8_9_2: 3D Rotation

```
#include        "sgl.h"                                     /* include file containing various settings */
#include        "ss_scrol.h"

#define         RBG0RB_CEL_ADR  VDP2_VRAM_A0
#define         RBG0RB_MAP_ADR  VDP2_VRAM_B0
#define         RBG0RB_COL_ADR  (VDP2_COLRAM+0x00200)
#define         RBG0RA_CEL_ADR  (RBG0RB_CEL_ADR+0x06e80)
#define         RBG0RA_MAP_ADR  (RBG0RB_MAP_ADR+0x02000)
#define         RBG0RA_COL_ADR  (RBG0RB_COL_ADR+0x00200)
#define         RBG0_KTB_ADR    VDP2_VRAM_A1
#define         RBG0_PRA_ADR    (VDP2_VRAM_A1+0x1fe00)
#define         RBG0_PRB_ADR    (RBG0RB_PRA_ADR+0x00080)
#define         BACK_COL_ADR    (VDP2_VRAM_A1+0x1fffe)

void main()
{
        FIXED   posy=toFIXED(0.0);
        ANGLE   angz=DEGtoANG(0.0);
        ANGLE   angz_up=DEGtoANG(0.0);

        slInitSystem(TV_320x224,NULL,1);                    /* screen mode setting */
        slTVOff();                                          /* drawing off */
        slPrint("Sample program 8.9.2",slLocate(9,2));

        slColRam(CRM16_1024);                               /* color mode setting */

        slRparaInitSet(RBG0_PRA_ADR);                       /* rotation parameter setting */
        slMakeKtable(RBG0_KTB_ADR);                         /* coefficient table setup */
        slCharRbg0(COL_TYPE_256,CHAR_SIZE_1x1);
        slPageRbg0(RBG0RB_CEL_ADR,0,PNB_1WORD|CN_12BIT);
        slPlaneRA(PL_SIZE_1x1);
        sl1MapRA(RBG0_MAP_ADR);
        slOverRA(0);                                        /* screen overflow processing (RA) */
        slKtableRA(RBG0_KTB_ADR,K_FIX|K_DOT|K_2WORD|K_ON);
        Cel2VRAM(tuti_cel,RBG0RA_CEL_ADR,65536):            /* scroll data storage (RA) */
        Map2VRAM(tuti_map,RBG0RA_MAP_ADR,64,64,2,884);
        Pal2CRAM(tuti_pal,RBG0RA_COL_ADR,160);

        slPlaneRB(PL_SIZE_1X1);
        slMapRB(RBG0RB_MAP_ADR);
        slOverRB(0);                                        /* screen overflow processing (RB) */
        Cel2VRAM(sora_cel,RBG0RB_CEL_ADR,28288);            /* scroll data storage (RB) */
        Map2VRAM(sora_map,RBG0RB_MAP_ADR,64,20,1,0);
        Pal2VRAM(sora_pal,RBG0RB_COL_ADR,256);

        slRparaMode(K_CHANGE);                              /* rotation parameter usage mode setting

        slBack1ColSet(BACK_COL_ADR,0);                      /* background screen setup */

        slScrAutoDisp(RBG0ON);                              /* scroll registration */
        slTVOn();                                           /* drawing start declaration */

        while(1)
        {
                slCurRpara(RA);                             /* scroll 3D rotation */
                slUnitMatrix(CURRENT);                      /* use rotation parameters A */
                slTranslate(toFIXED(0.0),toFIXED(0.0)+posy,toFIXED(100.0));
                posy-=toFIXED(5.0);
                slRotX(DEGtoANG(-90.0));
                slRotZ(angz);
                slScrMatSet();

                slCurRpara(RB);                             /* scroll Z axis rotation */
                slUnitMatrix(CURRENT);                      /* use rotation parameters B */
                slTranslate(toFIXED(160.0),toFIXED(155.0),toFIXED(100.0));
                slRotZ(angz);
                slScrMatSet();

                angz_up+=DEGtoANG(0.5);
                angz=(slSin(angz_up)>>4):

                slSynch();                                  /* screen synchronization */
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "ss.scroll.h".

Flow Chart 8-8 sample_8_9_2: 3D Rotation


START
Initialize system
Stop drawing
Set color mode
Specify rotation parameter table address
Create coefficient table
Set character patterns
Set up pages
Set up planes (RA)
Set up maps (RA)
Set screen overflow processing (RA)
Set coefficient table usage mode
Store scroll data (for parameter A)
Set up planes (RB)
Set up maps (RB)
Set screen overflow processing (RB)
Store scroll data (for parameter B)
Set rotation parameter mode
Set background screen
Register scroll
Start drawing
Change current rotation parameters
Change current matrix to unit matrix
Set position
Update position
X axis rotation
Z axis rotation
Transfer current matrix to rotation parameters
Change current rotation parameters
Change current matrix to unit matrix
Set position
Update position
Z axis rotation
Transfer current matrix to rotation parameters
Update Z axis rotation angle
Synchronize screen
LOOP

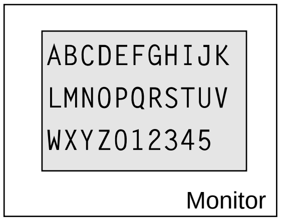
Special Scroll Functions

In the Sega Saturn system, several special scroll functions are provided in addition to the normal scroll functions. Of these, the SGL supports the ASCII scroll function and the transparent color bit control function.

ASCII scrolls

The ASCII scroll function uses data called “ASCII cells” as the character pattern data in place of normal scroll character pattern data. ASCII cells are normal ASCII data (ABCDEFG...) that has been converted into a data format (cell data) that can be used by scrolls. This concept is illustrated below.

Fig 8-25 ASCII Scrolls



- An ASCII scroll uses ASCII data as the scroll data.
- Half-sized alphanumerics can be drawn continuously, and the sequence is the same as the sequence of the ASCII codes.

In the SGL, the ASCII cells are stored in VRAM during system initialization. ASCII scrolls can be used by using this data in normal scroll function settings.

When the system is initialized, an ASCII scroll consists of 128 cells and 256 colors, and is set to use the normal scroll screen NBG0.

The ASCII scroll data is stored in the following RAM areas:

Character data:	2000H starting from address 0x25e76000
Map data:	1000H starting from address 0x25e60000
Palette data:	20H starting from address 0x25f00000

Note: If, for some reason, other scroll data is later written to the above areas, the ASCII scroll data will be overwritten by the new data, with the result that the default ASCII scroll data will no longer be available.

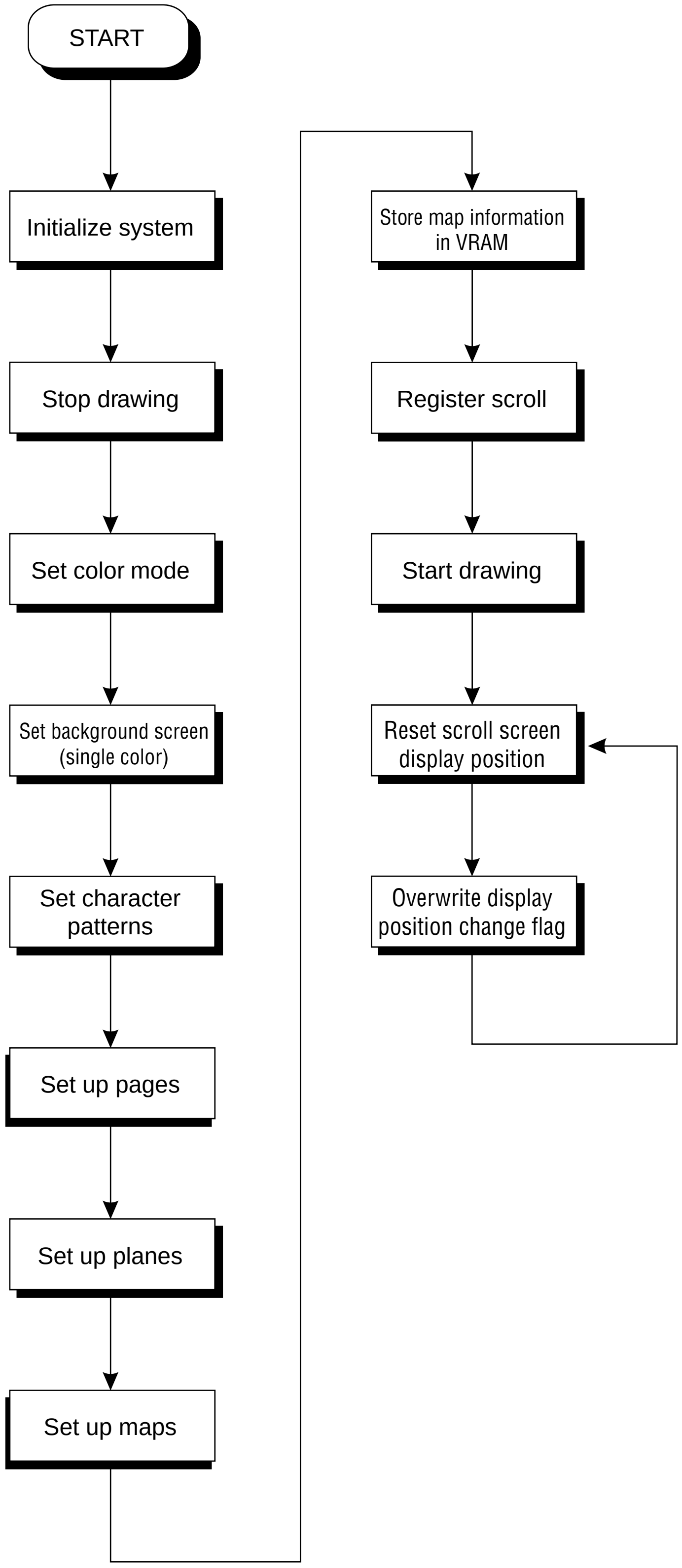
The following sample program (List 8-7) draws an ASCII scroll on the TV screen.

List 8-7 sample_8_10_1: ASCII Scrolls

```
/*----------------------------------------------------------*/
/*      Ascii Scroll                                        */
/*----------------------------------------------------------*/
#include        "sgl.h"                                  /* include file containing various settings */
#include        "ss_scrol.h"

#define         NBG1_CEL_ADR    VDP2_VRAM_B1
#define         NBG1_MAP_ADR    (VDP2_VRAM_B1+0x18000)
#define         NBG1_COL_ADR    VDP2_COLRAM
#define         BACK_COL_ADR    (VDP2_VRAM_A1+0x1fffe)

void main()
{
        FIXEDascii_posx=SIPOSX,ascii_posy=SIPOSY;

        slInitSystem(TV_320x224,NULL,1);                 /* screen mode setting */
        slTVOff();                                       /* drawing off */
        slPrint("Sample program 8.10.1",slLocate(9,2));

        slColRAMMode(CRM16_1024);                        /* color mode setting */
        slBack1ColSet(BACK_COL_ADR,0);                   /* background screen setup */

        slCharNbg1(COL_TYPE_256,CHAR_SIZE_1x1);          /* scroll function setup */
        slPageNbg1(NBG1_CEL_ADR,0,PNB_1WORD|CN_10BIT);
        slPlaneNbg1(PL_SIZE_1x1);
        slMapNbg1(NBG1_MAP_ADR,NBG1_MAP_ADR,NBG1_MAP_ADR,NBG1_MAP_ADR);

        Map2VRAM(ascii_map,NBG1_MAP_ADR,32,4,0,0);       /* scroll data storage */

        slScrAutoDisp(NBG0ON|NBP1ON);                    /* scroll registration */
        slTVOn();                                        /* drawing start declaration */

        while(1){
                slScrPosNbg1(ascii_posx,ascii_posy);     /* scroll placement */
                ascii_posx+=POSX_UP;
                slSynch();                               /* screen synchronization */
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "ss.scroll.h".

Flow Chart 8-9 sample_8_10_1: ASCII Scrolls

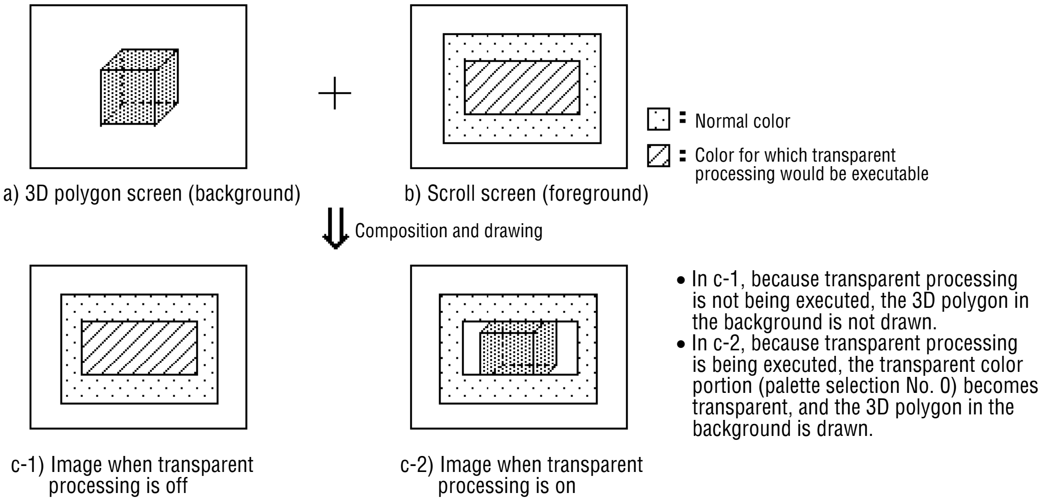

START
Initialize system
Stop drawing
Set color mode
Set background screen (single color)
Set character patterns
Set up pages
Set up planes
Set up maps
Store map information in VRAM
Register scroll
Start drawing
Reset scroll screen display position
Overwrite display position change flag

Transparent color bits

In the Sega Saturn, when palette format is selected for the scroll color data, the first (No. 0) color data in one palette can be specified as transparent color, regardless of the previously registered color data.

The transparent color is a color specification that when dots are specified as having the transparent color, processing is performed to determine if the transparent specification is on, and if it is, the display of graphics such as a scroll that are behind a scroll for which the transparent color specification was made are given priority. This concept is illustrated in the diagrams below.

Fig 8-26 Conceptual Model of Transparency Setting


+
⬚ : Normal color
▨ : Color for which transparent processing would be executable
Composition and drawing

a) 3D polygon screen (background)

b) Scroll screen (foreground)

c-1) Image when transparent processing is off

c-2) Image when transparent processing is on

- In c-1, because transparent processing is not being executed, the 3D polygon in the background is not drawn.
- In c-2, because transparent processing is being executed, the transparent color portion (palette selection No. 0) becomes transparent, and the 3D polygon in the background is drawn.

In the SGL, use the library function “slScrTransparent” to use the transparent color function.

Subsequent to the use of the “slScrTransparent” function, scrolls are drawn according to the specification.

[void slScrTransparent (Uint16 trns_flag);]

When the palette format is selected for the scroll color data, this function selects whether or not to perform transparent processing on palette selection number 0 in the palette data.

For the parameter, substitute the value from the following chart corresponding to the scroll screen for which transparent processing is to be executed. Transparent processing can be specified for multiple scroll screens by stringing together multiple parameters with the “or” (“|”) operator.

Table 8-21 "slScrTransparent" Parameter Substitution Values (trns_flag)

	Scroll screen for which transparent processing is to be executed				
	NBG0	NBG1	NBG2	NBG3	RBG0
Substitution value	NBG0ON	NBG1ON	NBG2ON	NBG3ON	RBG0ON

Note: The values in the table above are defined in “sl_def.h”, which is included with the system.

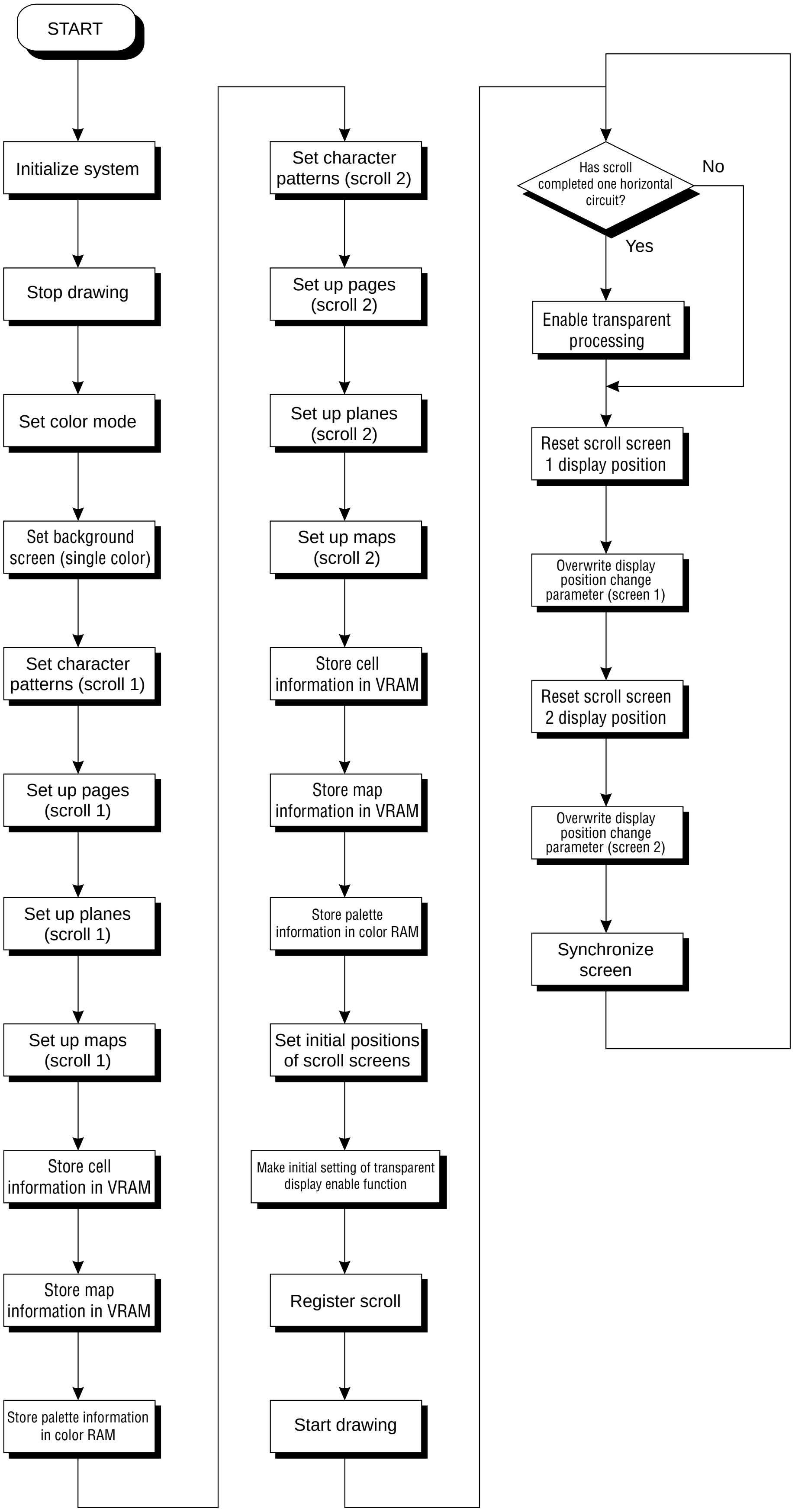
The following sample program (List 8-8) demonstrates transparent color processing with scrolls using the SGL library function “slScrTransparent”.

List 8-8 sample_8_10_2: Transparent Code Control

```
/*----------------------------------------------------*/
/*      Priority Control                               */
/*----------------------------------------------------*/
#include        "sgl.h"                                          /* include file containing various settings */
#include        "ss_scrol.h"

#define         NBG1_CEL_ADR    VDP2_VRAM_B0
#define         NBG1_MAP_ADR    (VDP2_VRAM_B0+0x10000)
#define         NBG1_COL_ADR    (VDP2_COLRAM+0x00200)
#define         NBG2_CEL_ADR    (VDP2_VRAM_B1+0x02000)
#define         NBG2_MAP_ADR    (VDP2_VRAM_B1+0x12000)
#define         NBG2_COL_ADR    (VDP2_ COLRAM+0x00400)
#define         BACK_COL_ADR    (VDP2_VRAM_A1+0x1fffe)

void main()
{
        Uint16trns_flg=NBG1ON;
        FIXED yama_posx=SIPOSX,yama_posy=SIPOSY;
        FIXED am2_posx=SIPOSX,am2_posy=SIPOSY;

        slInitSystem(TV_320x224,NULL,1);                         /* screen mode setting */
        slTVOff();                                               /* drawing off */
        slPrint("Sample program 8.10.2",slLocate(9,2));

        slColRam(CRM16_1024);                                    /* color mode setting */
        slBack1ColSet(BACK_COL_ADR,0);                           /* background screen setup */

        slCharNbg1(COL_TYPE_256,CHAR_SIZE_1x1);                  /* scroll function setup */
        slPageNbg1(NBG1_CEL_ADR,0,PNB_1WORD|CN_10BIT);           /* NBG1 */
        slPlaneNbg1(PL_SIZE_1x1);
        slMapNbg1(NBG1_MAP_ADR,NBG1_MAP_ADR,NBG1_MAP_ADR,NBG1_MAP_ADR);

        Cel2VRAM(am2_cel,NBG1_CEL_ADR,16000);
        Map2VRAM(am2_map,NBG1_MAP_ADR,32,32,1,0);
        Pal2CRAM(am2_pal,NBG1_COL_ADR,256);

        slCharNbg2(COL_TYPE_256,CHAR_SIZE_1x1);                  /* scroll function setup */
        slPageNbg2(NBG2_CEL_ADR,0,PNB_1WORD|CN_12BIT);           /* NBG2 */
        slPlaneNbg2(PL_SIZE_1x1);
        slMapNbg2(NBG2_MAP_ADR,NBG2_MAP_ADR,NBG2_MAP_ADR,NBG2_MAP_ADR);

        Cel2VRAM(yama_cel,NBG2_CEL_ADR,31808);
        Map2VRAM(yama_map,NBG2_MAP_ADR,32,16,2,256);
        Pal2CRAM(yama_pal,NBG2_COL_ADR,256);

        slScrPosNbg2(yama_posx,yama_posy);                       /* initial display position setting */
        slScrPosNbg1(am2_posx,am2_posy);

        slScrTransparent(trns_flg);

        slScrAutoDisp(NBG1ON|NBG2ON);                            /* scroll registration */
        slTVOn;                                                  /* drawing start declaration */

        while(1){                                                /* scroll data overwrite */
                if(yama_posx>=(SX+SIPOSX)){
                        if(trns_flg==NBG1ON)
                                trns_flg=NBG1OFF;
                        else
                                trns_flg=NBG1ON;
                        yama_posx+SIPOSX;
                        slScrTransparent(trns_flg);              /* change transparent enable bit */
                }

                slScrPosNbg2(yama_posx,yama_posy);
                yama_posx+=POSX_UP;

                slScrPosNbg1(am2_posx,am2_posy);
                am2_posy+=POSY_UP;

                slSynch();                                       /* screen synchronization */
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "ss.scroll.h".

Flow Chart 8-10 sample_8_10_2: Transparent Code Control


START
Initialize system
Stop drawing
Set color mode
Set background screen (single color)
Set character patterns (scroll 1)
Set up pages (scroll 1)
Set up planes (scroll 1)
Set up maps (scroll 1)
Store cell information in VRAM
Store map information in VRAM
Store palette information in color RAM
Set character patterns (scroll 2)
Set up pages (scroll 2)
Set up planes (scroll 2)
Set up maps (scroll 2)
Store cell information in VRAM
Store map information in VRAM
Store palette information in color RAM
Set initial positions of scroll screens
Make initial setting of transparent display enable function
Register scroll
Start drawing
Has scroll completed one horizontal circuit?
No
Yes
Enable transparent processing
Reset scroll screen 1 display position
Overwrite display position change parameter (screen 1)
Reset scroll screen 2 display position
Overwrite display position change parameter (screen 2)
Synchronize screen

Color calculations

In the SGL, it is possible to compare the priority of sprites and each scroll screen and perform calculations on the color data for the top image and the second image in the specified proportions and display the result on the screen.

Using this function, it is possible to have a scroll screen or sprite hidden behind another scroll to gradually fade into view.

The following procedure is required in order to perform color calculation processing.

1) Color calculation processing settings

Use the function “slColorCalc” to make the various settings for color operation processing, and use the function “slColorCalcOn” to determine the scroll screens that are to be affected by color calculations.

[void slColorCalc (Uint16 flag);]

This function makes the various settings needed for color calculation processing.

For the parameters, substitute the values from the following table corresponding to the color calculation processing controls to be used.

For details on the parameters, refer to Chapter 12, "Color Operations," in Hardware Manual vol.2: VDP2."

Fig 8-27 slColorCalc Substitution Values (flag)

● ColorCalc Substitution Values ●

```
Calculation method:                       [CC_RATE| CC_ADD ]|
Image for which calculation is specified: [CC_TOP | CC_2ND ]|
Extended color calculations:              [CC_EXT ]|
Registered screen:                        [NBG0|NBG1|NBG2|NBG3|RBG0|LNCLON|SPRON]|
```

Note: The above values are defined in "sl_def.h" provided with the system.

There are basically two color calculation modes.

Proportional addition: Perform color calculation with specified calculation ratio between the top image and the second image. (CC_RATE)

Direct addition: Perform color calculation simply by adding the top image and the second image together. (CC_ADD)

[void slColorCalcOn (Uint16 flag);]

This function determines the scroll screens that are affected by color calculation processing.

For the parameters, substitute the values form the table below corresponding to the scroll screens for which color calculations are to be performed. Color calculation can be specified for multiple scroll screens at the same time by stringing together multiple parameters with the “or” (“|”) operator.

Table 8-22 slColorCalcOn Parameter Substitution Values (flag)

	Scroll screen for which color calculations are to be executed							
	NBG0	NBG1	NBG2	NBG3	RBG0	LNCL	SPRITE	
Substitution value	NBG0ON	NGB1ON	NBG2ON	NBG3ON	RBG0ON	LNCLON	SPRON	

Note: The values in the table above are defined in “sl_def.h”.

2) Setting the color calculation values

Once the color calculation settings and registration process have been completed for the scroll screens, the actual color calculation processing can be executed (specified by proportion) on the scroll screens by using the functions “slColRateNbg0 to 3”, “slColRateRbg0”, “slColRateLNCL” and “slColRateBACK”.

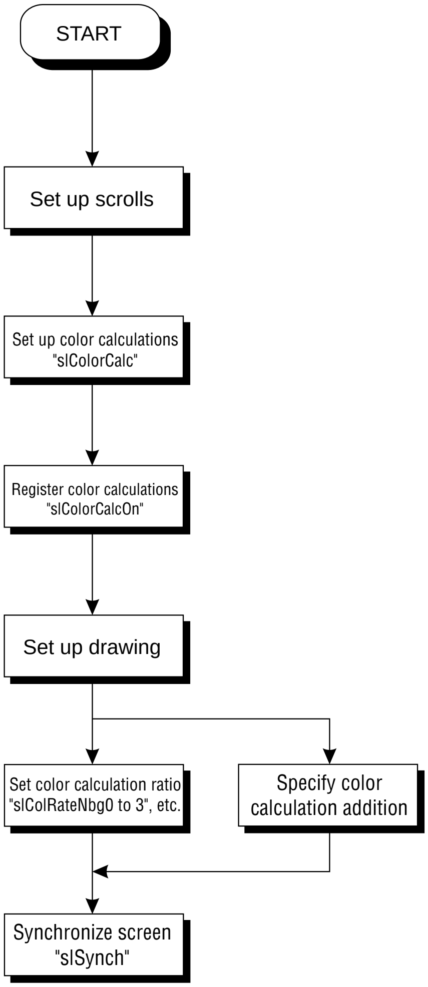
However, the proportion specification has no meaning in cases where the addition method is adopted for the color calculations.

[void slColRateNbg0 to 3 (Uint16 rate);]
[void slColRateRbg0 (Uint16 rate);]
[void slColRateLNCL (Uint16 rate);]
[void slColRateBACK (Uint16 rate);]

These functions set the color calculation ratios for the scroll screens specified by the functions. For the parameters, substitute the color calculation ratio (range: 0 to 31) to be used in the color calculation. The function “slColRateNbg0 to 3” is used to set the color calculation ratio for each normal scroll screen, the function “slColRateRbg0” is used to set the color calculation ratio for the rotating scroll screen, the function “slColRateLNCL” is used to set the color calculation ratio for line color screens, and the function “slColRateBACK” is used to set the color calculation ratio for the background screen.

The flow of color calculation processing is summarized in the flow chart below.

Flow Chart 8-11 Flow of Color Calculation Processing



Line color screen

The line color screen is a special scroll screen provided specifically to be forcibly inserted as a second image behind the top image (the image actually displayed on the monitor) on the specified scroll screen.

The line color screen permits the setting of a color for either the entire screen or for each line of the screen.

It is necessary to store the collection of color RAM address data for the colors used for each line as a line color table in VRAM.

> **Note: For details on the line color screen, refer to "Line Screen," in the “HARDWARE MANUAL vol. 2:VDP2."**

The procedure described below must be followed in order to use the line color screen.

1) Line color screen setup

When using the line color screen, it is first necessary to specify the line color table in which the line color data is to be stored.

Also, do not forget to store in color RAM the color data specified in the line color table.

[void slLineColTable (void *adr);]

This function specifies the line color table address.

For the parameter, specify the address in VRAM where the line color table is to be stored.

To use only a single color on the line color screen, use the function “slLine1ColSet”.

[void slLine1ColSet (void *adr, Uint16 col);]

This function sets the line color screen to a single color.

For the parameters, substitute the starting address of the area where the line color table is to be stored, and also the color number of the desired color.

2) Scroll screen registration

Next, register the scroll screens that will be affected by the line color screen.

Use the function “slLineColDisp” to register scroll screens.

[void slLine1ColDisp (Uint16 flag);]

This function determines the scroll screens that will be affected by the line color screen.

For the parameters, substitute the values from the following table that correspond with the scroll screens to be registered.

Multiple scroll screens can be registered by stringing together multiple parameters with the “or” (“|”) operator.

Table 8-23 slLineColDisp Parameter Substitution Values (flag)

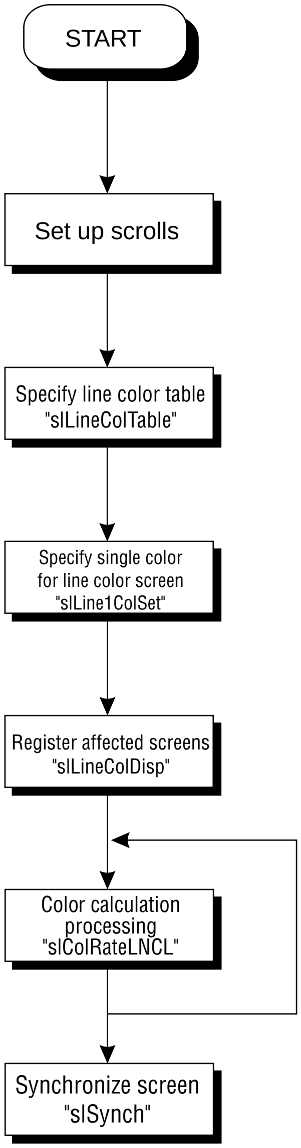
	Scroll screen to be registered				
	NBG0	NBG1	NBG2	NBG3	RBG0
Substitution value	NBG0ON	NBG1ON	NBG2ON	NBG3ON	RBG0ON

Note: The above values are defined in “sl_def.h” provided with the system.

3) Color calculations using the line color screen

Scroll screens which have been registered with the function “slLineColDisp” can be used in color calculation processing with the line color screen when used in conjunction with the color calculation processing settings described earlier. For details on color calculation processing, refer to the previous item, “Color calculations.”

Flow Chart 8-12 Flow of Line Color Screen Processing



Color offset

In the SGL, it is possible to change the colors displayed on the screen by adding or subtracting an offset value to the color RAM data (without changing the actual value) for sprites and each scroll screen.

The procedure described below must be followed in order to use the color offset function.

1) Color offset setup

There are two color offsets: A and B.

To use the color offset function with a scroll screen, it is necessary to register the scroll screen with one of the two color offsets.

To register scrolls, use the functions “slColOffsetOn” and “slColOffsetBUse”.

[void slColOffsetOn (Uint16 flag);]

This function registers a scroll screen with the color offset function.

For the parameter, substitute a value from the table below corresponding to the scroll screen to be registered.

[void slColOffsetBUse (Uint16 flag);]

This function registers scroll screens to be used with color offset B.

Scroll screens registered with just function “slColOffsetOn” use offset A. For the parameter, substitute a value from the table below corresponding to the scroll screen to be registered.

Table 8-24 "slColOffsetOn", "slColOffsetBUse" Parameter Substitution Values (flag)

	Scroll screen to be registered						
	NBG0	NBG2	NBG3	RBG0	BACK	SPRITE	
Substitution value	NBG0ON	NBG2ON	NBG3ON	RBG0ON	BACKON	SPRON	

Note: The above values are defined in “sl_def.h”.

2) Setting the offset values

The scroll screens that have been registered are displayed with the effects of the color offset in place.

Use the function “slColOffsetA, B” to set the color offset values.

[void slColOffsetA (Sint16 r, Sint16 g, Sint16 b);]
[void slColOffsetB (Sint16 r, Sint16 g, Sint16 b);]

These functions set the color offset values.

For the parameters, substitute the offset values (9 bits, signed) for red, green, and blue.

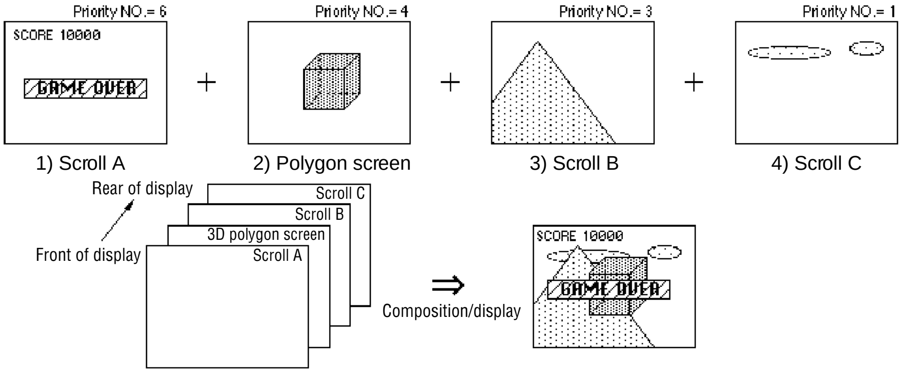
Use the function “slColOffsetA” to set the color offset values A, and the function “slColOffsetB” to set the color offset values B.

Priority

In the Sega Saturn system, a priority ranking can be set for all screen types that are drawn on the screen. By using priority it is possible to divide multiple scroll screens according to those that are for use as background and those that are for text display, and to insert a 3D polygon screen in between. However, the background screen is always displayed behind all of the other screens.

Fig 8-28 Priority

a) Screens to be combined



b) Priority ranking

c) Display image

In the SGL, use the corresponding library commands “slPriorityNbg0 to 3” and “slPriorityRbg0” to set the priority for the various scroll screens.

[void slPriorityNbg0 to 3 (Uint16 priority_num);]
[void slPriorityRbg0 (Uint16 priority_num);]

These functions set the priority for the corresponding scroll screens.

For the parameter, substitute the priority number, a value from 0 to 7.

The scroll screens with the higher priority number are displayed in front. If “0” is specified, that scroll screen is regarded as being transparent and is not actually displayed.

If the same priority number is assigned to multiple screens, the relative priority accords with the following diagram:

Fig 8-29 Relative Priority When the Same Priority Numbers Are Assigned

● Relative priority when the same priority numbers are assigned ●

SPRITE>RBG0>NBG0>NBG1>NBG2>NBG3

High (front) ◀────────▶ Low (rear)

Note:Polygons are considered to be sprites.

In addition, in the SGL, default priorities are assigned as follows:

Table 8-25 Priority of Each Screen in the Default State

	Priority number							
	7	6	5	4	3	2	1	0
Graphics screen	NBG0	SPRITE	SPRITE	RBG0	NBG1	NBG2	NBG3	Reserved

Note: Polygons are considered to be sprites.

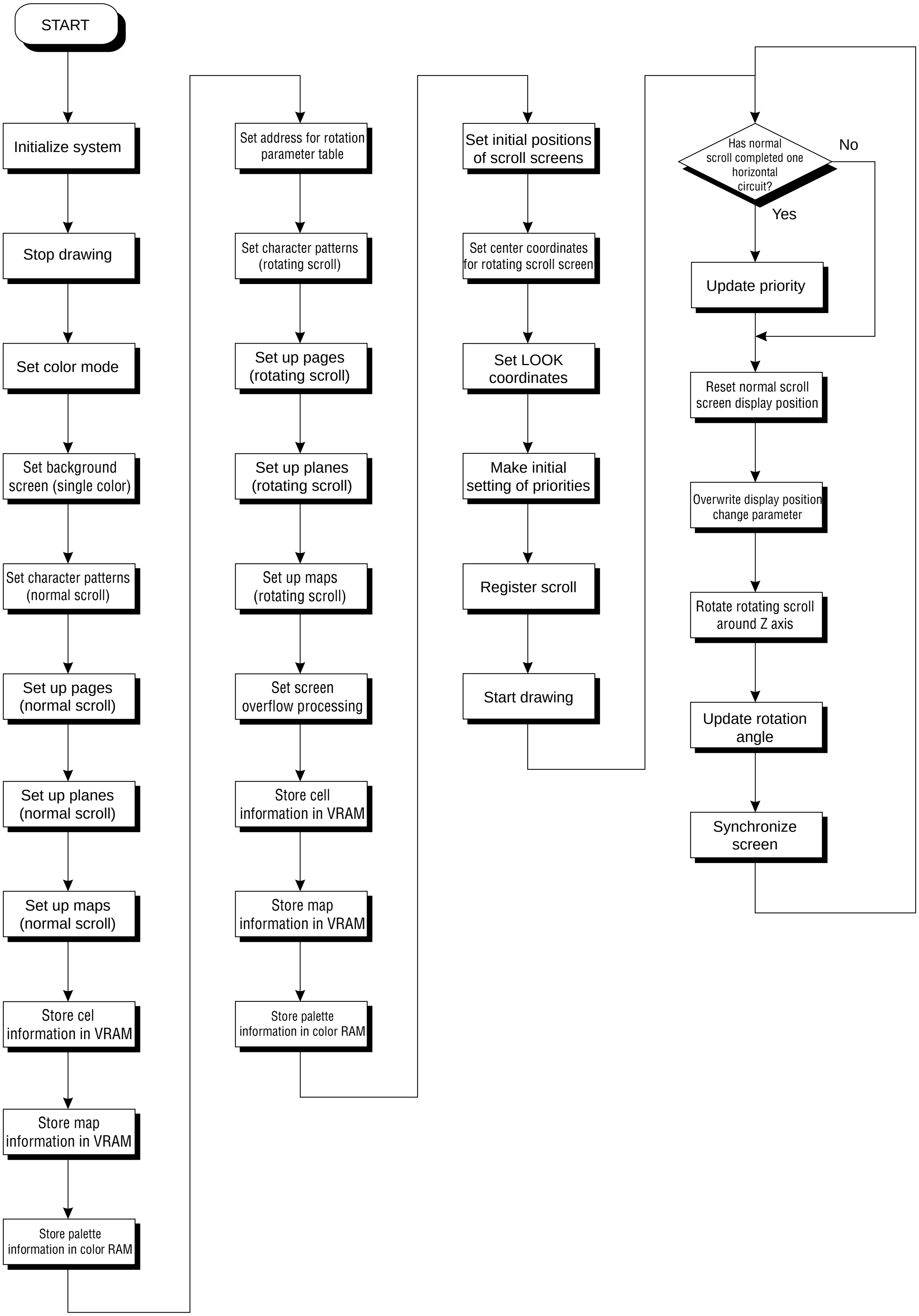
The following sample program (List 8-9) demonstrates scroll priority processing using the SGL library functions “slPriorityNbg0 to 3, Rbg0”.

List 8-9 for sample_8_11: Scroll Display Priority

```
/*----------------------------------------------------*/
/*      Scroll Priority Change                         */
/*----------------------------------------------------*/
#include        "sgl.h"                                        /* include file containing various settings */
#include        "ss_scrol.h"

#define         NBG1_CEL_ADR    (VDP2_VRAM_B1+0x02000)
#define         NBG1_MAP_ADR    (VDP2_VRAM_B1+0x12000)
#define         NBG1_COL_ADR    (VDP2_COLRAM+0x00200)
#define         RBG0_CEL_ADR    VDP2_VRAM_A0
#define         RBG0_MAP_ADR    VDP2_VRAM_B0
#define         RBG0_PAR_ADR    (VDP2_VRAM_A1+0x1fe00)
#define         BACK_COL_ADR    (VDP2_VRAM_A1+0x1fffe)

void main()
{
        Uint16PryNBG=4,PryRBG=1,PryWRK;
        FIXED yama_posx=SIPOSX,yama_posy=SIPOSY;
        ANGLE ascii_angz=DEGtoANG(0.0);

        slInitSystem(TV_320x224,NULL,1);                        /* screen mode setting */
        slTVOff();                                              /* drawing off */
        slPrint("Sample program 8.11",slLocate(9,2));

        slColRAMMode(CRM16_1024);                               /* color mode setting */
        slBack1ColSet(BACK_COL_ADR,0);                          /* background screen setup */

        slCharNbg1(COL_TYPE_256,CHAR_SIZE_1x1);                 /* scroll function setup */
        slPageNbg1(NBG1_CEL_ADR,0,PNB_1WORD|CN_12BIT);          /* NBG1 */
        slPlaneNbg1(PL_SIZE_1x1);
        slMapNbg1(NBG1_MAP_ADR,NBG1_MAP_ADR,NBG1_MAP_ADR,NBG1_MAP_ADR);
        Cel2VRAM(yama_cel,NBG1_CEL_ADR,31808);
        Map2VRAM(yama_map,NBG1_MAP_ADR,32,16,1,256);
        Pal2CRAM(yama_pal,NBG1_COL_ADR,256);
         slRparaInitSet(RBG0_PAR_ADR);                          /* scroll function setup */
         slCharRbg0(COL_TYPE_256,CHAR_SIZE_1X1)                 /* RBG0 */
         slPageRbg0(NBG0_CEL_ADR,0,PNB_1WORD|CN_10BIT);
         slPlaneRA(PL_SIZE_1x1);
         sl1MapRA(RBG0_MAP_ADR);
         slOverRA(2);
         Map2VRAM(ascii_map,NBG0_MAP_ADR,32,4,0,0);

         slScrPosNbg1(yama_posx,yama_posy);                     /* initial display position setting */
         slDisp CenterR(toFIXED(160.0),toFIXED(112.0);
         slLookR(toFIXED(128.0),toFIXED(24.0));

         slPriorityNbg1(PryNBG);                                /* initial priority setting */
         slPriorityNbg0(PryRBG);

         slScrAutoDisp(NBG1ON|RBG0ON);                          /* scroll registration */
         slTVOn;                                                /* drawing start declaration */

         while(-1){
                 if(yama_posx>=(SX+SIPOSX)){
                         PryWRK=PryNBG;
                         PryNBG=PryRBG;
                         PryRBG=PryWRK;
                         slPriorityNbg1(PryNBG);                /* priority change */
                         slPriorityRbg0(PryRBG);
                         yama_posx=SIPOSX;
                 }

                 siScrPosNbg1(yama_posx,yama_posy);
                 yama_posx+=POSX_UP;

                 slZrotR(ascii_angz);
                 ascii_angz+=DEGtoANG(1.0);

                 slSynch();                                     /* screen synchronization */
         }
 }
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "ss.scroll.h".

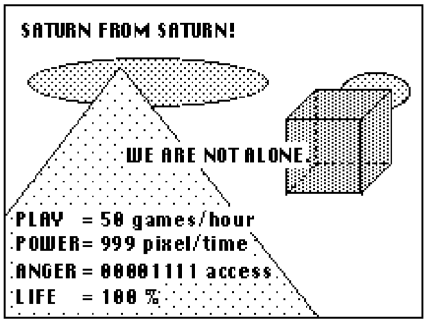
Flow Chart 8-13 sample_8_11: Scroll Display Priority


START
Initialize system
Stop drawing
Set color mode
Set background screen (single color)
Set character patterns (normal scroll)
Set up pages (normal scroll)
Set up planes (normal scroll)
Set up maps (normal scroll)
Store cel information in VRAM
Store map information in VRAM
Store palette information in color RAM
Set address for rotation parameter table
Set character patterns (rotating scroll)
Set up pages (rotating scroll)
Set up planes (rotating scroll)
Set up maps (rotating scroll)
Set screen overflow processing
Store cell information in VRAM
Store map information in VRAM
Store palette information in color RAM
Set initial positions of scroll screens
Set center coordinates for rotating scroll screen
Set LOOK coordinates
Make initial setting of priorities
Register scroll
Start drawing
Has normal scroll completed one horizontal circuit?
No
Yes
Update priority
Reset normal scroll screen display position
Overwrite display position change parameter
Rotate rotating scroll around Z axis
Update rotation angle
Synchronize screen

Displaying Text and Numeric Values

The SGL library functions explained here are primarily used for program debugging. These functions display the specified character string, numeric values, and matrices on the monitor by using scroll screens. The default settings when the system is initialized allow the use of the ASCII cell data for the scroll data and the rotating scroll screen as the scroll screen.

Fig 8-30 Displaying Text and Numeric Values



```
SATURN FROM SATURN!

WE ARE NOT ALONE.

PLAY  = 50 games/hour
POWER= 999 pixel/time
ANGER = 00001111 access
LIFE   = 100 %
```

- As the very front graphic, a character string is displayed using a scroll screen.
- The character string consists only of half-size alphanumerics, and ASCII cell data is used for the scroll data.

The text and numeric value display functions can be broadly classified into four groups:

Display position calculation: Creates the display position parameters to be used in the functions.

Character string display: Displays the specified character string on the display.

Numeric value display: Displays the specified number on the screen.

Matrix display: Displays the specified matrix on the screen.

Each of these four function groups is explained below:

1) Display position calculation:

This function sets the character and number display positions in cell units, and converts the positions to formats that can be used by the other functions below.

[void *slLocate (Uint16 cell_x, Uint16 cell_y);]

This function creates the display position parameter variables (void *type) in a format that can be used by the alphanumerics display functions. For the parameters, substitute the XY coordinates that show the display position on the monitor screen in cell units (count eight dots as one cell).

2) Character string display

This function displays a character string consisting of half-size alphanumerics on the screen.

[void slPrint (char*disp_character, void *disp_pos);]

This function displays the specified character string on the screen. For the parameters, substitute the character string to be displayed (a char-type variable enclosed in double quotes), and the display position (converted to the void *type with the “slLocate” function), respectively. However, the character string can only include half-size alphanumerics.

3) Numeric value display

These functions display numeric values on the screen.

[void slPrintFX (FIXED disp_num, void *disp_pos);]

This function displays the specified FIXED-type numeric value on the screen.

For the parameters, substitute the numeric value to be displayed (FIXED-type variable), and the display position (converted to the void *type with the “slLocate” function), respectively.

[void slPrintHex (Uint32 disp_num, void *disp_pos);]

This function displays the specified HEX-type numeric value on the screen.

For the parameters, substitute the numeric value to be displayed (HEX-type variable), and the display position (converted to the void *type with the “slLocate” function), respectively.

The function “slPrintHex” does not display zeroes in the high-order bits when displaying a number; instead, the function inserts spaces.

[void slDispHex (Uint32 disp_num, void *disp_pos);]

This function displays the specified HEX-type numeric value on the screen.

For the parameters, substitute the numeric value to be displayed (HEX-type variable), and the display position (converted to the void *type with the “slLocate” function), respectively.

Unlike the function “slPrintHex”, “slDispHex” does display zeroes in the high-order bits when displaying a number.

While the functions “slPrintHex” and “slDispHex” both display HEX-type numbers on the screen, they differ as to whether they display zeroes in the high-order bits. In either case, however, the values displayed are right-justified.

Table 8-26 Difference Between "slPrintHex" and "slDispHex"

	Substituted value	Output value
slPrintHex	00001111	1111
slDispHex	00001111	00001111

Note: The output values are the values that are actually displayed on the screen.

4) Matrix display:

Displays a matrix on the screen.

[void slPrintMatrix (MATRIX disp_matrix, void * disp_pos);]

This function displays the specified matrix on the screen. For the parameters, substitute the matrix variable to be displayed, and the display position (converted to the void *type with the “slLocate” function), respectively.

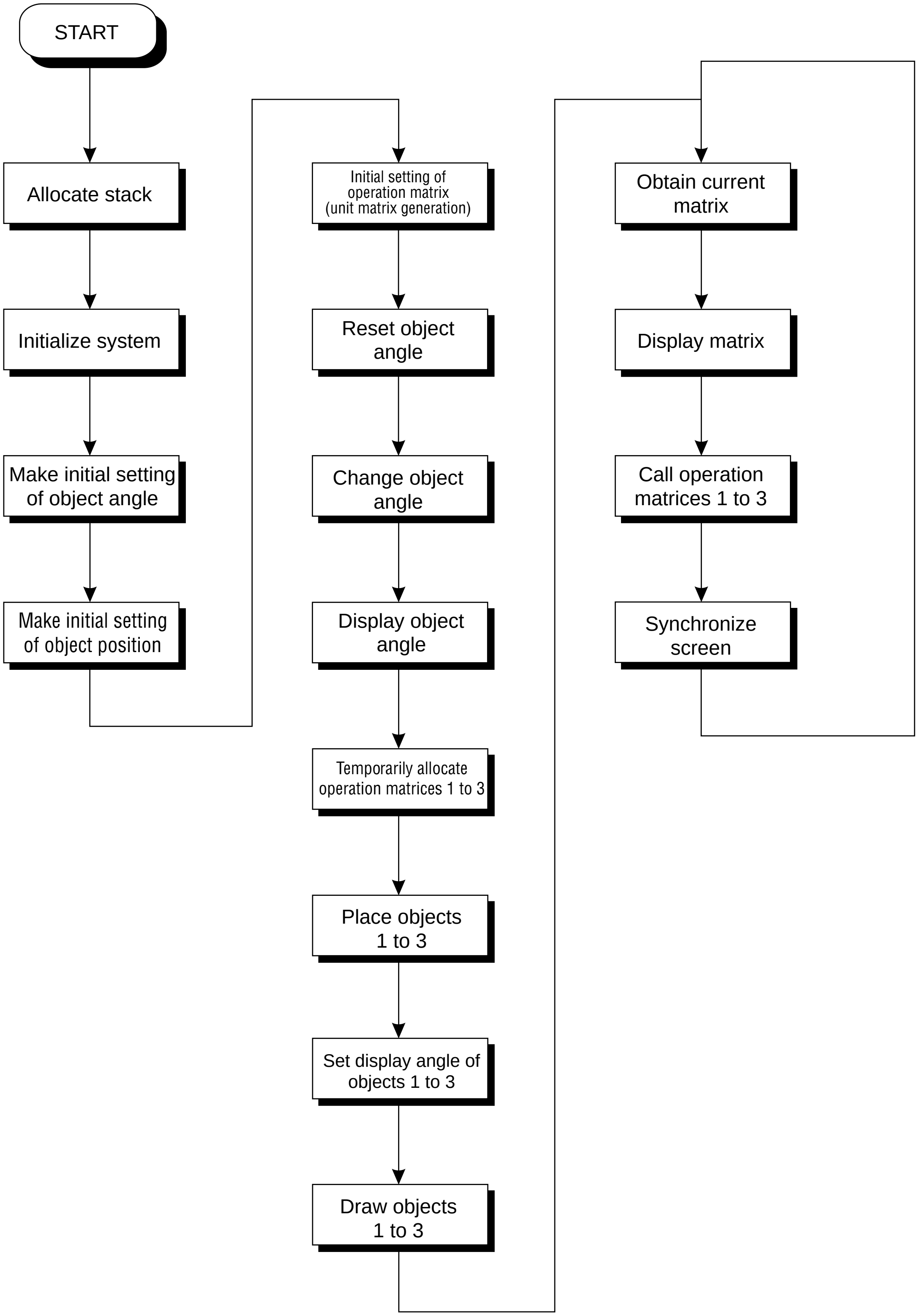
The following sample program (List 8-10) demonstrates the display of character strings and numeric values on the display screen through the use of scroll screens by using the text and numeric value display functions.

List 8-10 sample_8_12: Text and Numeric Value Display

```
/*-----------------------------------------------------*/
/*      Text & Value Display                            */
/*-----------------------------------------------------*/
#include        "sgl.h"                                      /* include file containing various settings */

extem PDATA PD_PLANE1,PD_PLANE2,PD_PLANE3;
static void set_poly(ANGLE ang[XYZ],FIXEDpos[XYZ])
{
        slTranslate(pos[X],pos[Y],pos[Z]);
        slRotX(ang[X]);
        slRotY(ang[Y]);
        slRotZ(ang[Z]);
}

void main()
{
        static ANGLE ang1[XYZ],ang2[XYZ],ang3[XYZ];
        static FIXED pos1[XYZ],pos2[XYZ],pos3[XYZ];
        static MATRIX mtptr;
        static ANGLE adang=DEGtoANG(0.5);
        static ANGLE tmp=DEGtoANG(0.0);

        slInitSystem(TV_320x224,NULL1);                      /* screen mode setting */

        slPrint("Sample program8.12",slLocate(6,2)));

        ang1[X]=ang1[Y]=ang1[Z]=DEGtoANG(0.0);
        ang2[X]=ang2[Y]=ang2[Z]=DEGtoANG(0.0);
        ang3[X]=ang3[Y]=ang3[Z]=DEGtoANG(0.0);
        pos1[X]=toFIXED(0.0);
        pos1[Y]=toFIXED(40.0);
        pos1[Z]=toFIXED(170.0);
        pos2[X]=toFIXED(0.0);
        pos2[Y]=toFIXED(-40.0);
        pos2[Z]=toFIXED(0.0);
        pos3[X]=toFIXED(0.0);
        pos3[Y]=toFIXED(-40.0);
        pos3[Z]=toFIXED(0.0);

        slPrint("POLYGON ANGLE[Hex] =",slLocate(1,4));
        slPrint("POLYGON ANGLE[Dec] =",slLocate(1,6));
        slPrint("POLYGON ANGLE[Hex&0] =",slLocate(1,8));
        slPrint("POLYGON ANGLE[Dec&0] =",slLocate(1,10));
        slPrint("POLYGON ANGLE[Fix] =",slLocate(1,12));
        slPrint("DISPLAY Matrix:",slLocate(1,18));

        while(-1){
                slUnitMatrix(CURRENT);
                ang1[Z]=tmp;
                ang2[Z]=tmp;
                tmp+<adang;
                if(tmp<DEGtoANG(-90.0)){
                        adang=<DEGtoANG(0.5);
                }deseif(tmp>DEGtoANG(90.0)){
                        adang=<DEGtoANG(-0.5);
                }
                slDispoHex(slAng2Hex(tmp),slLocate(26,4));   /* numeric value display */
                slDispoHex(slAng2Dec(tmp),slLocate(26,6));
                slPrintHex(slAng2Hex(tmp),slLocate(26,8));
                slPrintHex(slAng2Dec(tmp),slLocate(26,10));
                slPrintFX(slAng2FX(tmp),slLocate(26,12));

                slPush Matrix();
                {
                        set_poly(ang1, pos1);
                        slPutPolygon(&PD_PLANE1);

                        slPush Matrix();
                        {
                                set_poly(ang2, pos2);
                                slPutPolygon(&PD_PLANE2);

                                slPush Matrix();
                                {
                                        set_poly(ang3,pos3);
                                        ang3[Y]+=DEGtoANG(5.0);
                                        slPutPolygon(&PD_PLANE3);
                                        slGetMatrix(mtptr);
                                        slPrintMatrix(mtptr,slLocate(0,20));
                                }
                                slPopMatrix();                          /* matrix display */
                        }
                        slPopMatrix();
                }
                slPopMatrix();

                slSynch();                                   /* screen synchronization */
        }
}
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "ss.scroll.h".

Flow Chart 8-14 sample_8_12: Text and Numeric Value Display


START
Allocate stack
Initialize system
Make initial setting of object angle
Make initial setting of object position
Initial setting of operation matrix (unit matrix generation)
Reset object angle
Change object angle
Display object angle
Temporarily allocate operation matrices 1 to 3
Place objects 1 to 3
Set display angle of objects 1 to 3
Draw objects 1 to 3
Obtain current matrix
Display matrix
Call operation matrices 1 to 3
Synchronize screen

Supplement. SGL Library Functions Covered in this Chapter

The functions listed in the following table were explained in this chapter.

Table 8-27 SGL Library Functions Covered in this Chapter (1)

Function type	Function name	Parameters	Function
void	siInitSystem	TV_MODE type, TEXTURE*ptr, Uint16 cnt	Initialize the system (screen mode settings, etc.)
void	slColRAMMode	Uint16 mode	Select color RAM mode
void	slCharNbg0,1,2,3	Uinit16 color, Uint16 chra_size	Set up NBG character pattern
void	slCharRbg0	Uint16 color, Uint16 char_size	Set up RGB character pattern
void	slPagNbg0,1,2,3	void*celadr, void*coladr, Uint16 type	Set up NBG page
void	slPageRbg0	void*celadr, void*coladr, Uint16 type	Set up RBG page
void	slPlaneNbg0,1,2,3	Uint16 plane_size	Set up NBG plane
void	slPlaneRA,RB	Uint16 plane_size	Set up RBG plane
void	slMapNbg0,1,2,3	void*a, void*b, void*c, void*d	Set up NBG map
void	slMap1RA, RB	void*a	Set up RBG map
void	slZoomModeNbg0,1	Uint16 zoom_mode	Set reduction setting for normal scroll screen
void	slRparaInitSet	ROTSCROLL*adr	Set rotation parameters
void	slRparaMode	Uint16 mode	Set rotation parameter usage mode
void	slCurRpara	Uint16 flag	Switch current rotation parameters
void	slOverRA,RB	Uint16 mode	Set rotating scroll display overflow processing
▨	▨	▨	▨
void	slBack1ColSet	void*adr, Uint16 rgb_col	Set background screen
void	slScrPosNbg0,1,2,3	FIXED posx, FIXED posy	Set display position of normal scroll screen
void	slDispCenterR	FIXED posx, FIXED posy	Set rotation center for rotating scroll screen
void	slLookR	FIXED posx, FIXED posy	Set rotating scroll screen viewpoint coordinates
Bool	slScrAutoDisp	Uint32 entry_scr_bit	Register scroll
void	slTVOn	void	Start drawing processing on monitor
void	slTVOff	void	Stop drawing processing on monitor
void	slScrDisp	Uint32 mode	Set scroll to be drawn
void	slSynch	void	Synchronize screen

Table 8-28 SGL Library Functions Covered in this Chapter (2)

Function type	Function name	Parameters	Function
void	slZoomNbg0,1	FIXED scale_x, FIXED scale_y	Enlarge/reduce normal scroll screen
void	slZoomR	FIXED scale_x, FIXED scale_y	Enlarge/reduce rotating scroll screen
void	slZrotR	ANGLE zang	Rotate rotating scroll screen around Z axis
void	slTransparent	Uint16 flag	Enable transparent display
void	slPriorityNbg0,1,2,3	Uint16 priority_num	Set priority for normal scroll screen
void	slPriorityRbg0	Uint16 priority_num	Set priority for rotating scroll screen
▨	▨	▨	▨
void	slScrMatConv	void	Convert current matrix for a polygon into current matrix for a scroll
void	slScrMatSet	void	Transfer the current matrix state to the rotation parameters
void	slMakeKtable	void*table_adr	Create coefficient table
void	slKtableRA,RB	void*table_adr, Uint16 mode	Set up coefficient table control
void	slColorCalc	Uint16 flag	Set up color calculations
void	slColorCalcOn	Uint16 flag	Enable color calculation control
void	slColRateNbg0,1,2,3	Uint16 rate	Set NBG color calculation ratio
void	slColRateRbg0	Uint16 rate	Set RBG color calculation ratio
void	slColRateLNCL	Uint16 rate	Set line color screen color calculation ratio
void	slCorRateBACK	Uint16 rate	Set background screen color calculation ratio
void	slColOffsetOn	Uint16 flag	Enable color offset
void	slColOffsetBUse	Uint16 flag	Correct color offset
void	slColOffsetA,B	Uint16 r, Uint16 g, Uint16b	Set offset value
void	slLine l ColSet	void*adr, Uint16 col	Set line single-color matrix
void	slLineColDisp	Uint16 flag	Enable line color screen
void	slLineColTable	void*adr	Set up line color table

Table 8-29 SGL Library Functions Covered in this Chapter (3)

Function type	Function name	Parameters	Function
void*	slLocate	Uint16 cell_x, Uint16 cell_y	Convert parameters for text and numeric value display functions (parameters are specified in cells)
void	slPrint	char*character, void*locate	Display text string specified as a parameter on screen
void	slPrintFX	FIXED disp_num, void*locate	Display FIXED-type numeric value specified as a parameter on screen
void	slPrintHex	Uint32 num, void*locate	Display HEX-type numeric value specified as a parameter on screen (zeroes in high-order bits are not displayed)
void	slDispHex	Uint32 num, void*locate	Display HEX-type numeric value specified as a parameter on screen (zeroes in high-order bits are displayed)
void	slPrintMatrix	MATRIX mtptr, void*locate	Display matrix specified as a parameter on screen

Table 8-30 User-Defined Functions Covered in this Chapter

Function type	Function name	Parameters	Function
void	Cel2VRAM	cel_adr, VRAM_adr, char_size	Store character pattern data in VRAM
void	Map2VRAM	pn_adr, VRAM_adr, map_ysize, map_xsize, pal_offset, map_offset	Store pattern name data in VRAM
void	Pal2CRAM	color_adr, CRAM_adr, color_size	Store color palette data in VRAM

9

Programmer’s Tutorial

Controller Input

This chapter describes how the SEGA Saturn system recognizes the data input device and how the device operates, using the Saturn Pad as a representative input device for the SEGA Saturn system.

The Saturn Pad has a number of input mechanisms: a direction key that can be used to indicate four directions, six buttons (A, B, C, X, Y, and Z), left and right buttons at the top of the controller, and a Start button.

Sample programs will be used to show how the SEGA Saturn system internally recognizes the data that is input using the various input devices on the controller.

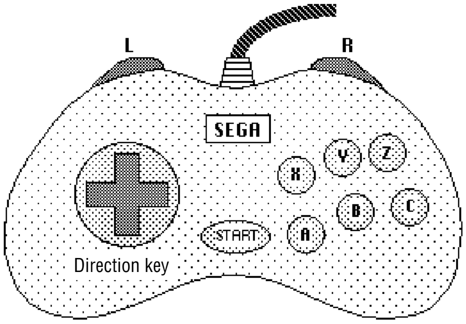
Input System Used by the SEGA Saturn

The SEGA Saturn system can receive data from various data input devices connected to the input ports and reflect that data in the program.

The primary data input device used with the SEGA Saturn system is the control pad, called the “Saturn Pad,” provided with the unit.

The Saturn Pad includes a direction key that can be used to indicate four directions; a Start button; buttons A, B, C, X, Y, and Z; and left (L) and right (R) buttons.

Fig 9-1 Example Input Device (Saturn Pad)



- In the case of the Saturn Pad, the following data can be input:
  - Direction key: Generally indicates movement to the right, left, up, or down.
  - Start key: Generally used to start a game.
  - Buttons A, B, and C: Three buttons located on the lower-right portion of the pad.
  - Buttons X, Y, and Z: Three buttons located on the upper-right portion of the pad.
  - Buttons L and R: Two buttons located on top of the controller.

In addition to the Saturn Pad, the SEGA Saturn system also supports the input devices shown in Table 9-1 below.

Note that some of the devices in the table below have not yet been placed on the market, and are scheduled for introduction in the future.

Table 9-1 List of Input Devices

Attribute	Name	Input configuration	Remarks
Digital	Saturn Pad	Direction key, Start, 8 buttons	Standard Saturn pad
	Saturn Mouse	XY movement, Start, 3 buttons	Mouse movement data stored as absolute values
	Megadrive 3-Button Pad	Direction key, Start, 3 buttons	Can be connected using SEGA Tap
	Megadrive 6-Button Pad	Direction key, Start, Mode, 6 buttons	Can be connected using SEGA Tap
Analog	Analog Joystick	Direction stick, Start, 8 buttons	Unsigned A/D output of absolute value of movement amount (scheduled for future release)
Special	Saturn Keyboard	(Details to be determined)	Compatible with IBM keyboards (scheduled for future release)
Auxiliary device	Saturn 6P Multitap	6 connects	(Scheduled for future release)
	SEGA Tap	4 connects	Used to connect Megadrive pads

Note: For details on each input device, refer to the “Hardware Manual,” vol. 1.

Actual Operation

When an input mechanism (direction key, button, etc.) on an input device connected to an input port is in the "on" state, a signal is sent to the SEGA Saturn main unit.

The SEGA Saturn main unit receives the signal, and the device bits provided in the system change; by reading these changes, it is possible for the programmer to read the status of the input device.

This chapter will describe the actual operation of the system, using as an example the Saturn Pad, a typical SEGA Saturn input device.

Bits used by the input system

The devices (such as a Saturn Pad) connected to the input ports are recognized by the system, and a fixed area is allocated within the system for each device.

This area includes the peripheral ID (8 bits), which is a device recognition bit string (that is unique to each device), followed by the input status bit strings.

The input status bit strings consists of an 8-bit data string, and enough data strings are allocated to satisfy the needs of the connected device.

In the input status bit strings, the bit values are maintained at "1" when there is no input and change to "0" only when there is input for as long as the key or button is pressed.

The allocation of the Saturn Pad bit strings is shown in the following table.

Table 9-2 Peripheral Data Format of the Saturn Pad

	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
Peripheral ID	0	0	0	0	0	0	1	0
1st DATA	→	←	↓	↑	Start	A	C	B
2nd DATA	R	X	Y	Z	L	1	1	1

Note: The last three bits in the second data string are not used, and are shown as "1" for the sake of convenience.

Note: For details on the peripheral data formats for input devices other than the Saturn Pad, refer to the "SEGA SATURN HARDWARE MANUAL," vol. 1.

Data format storage
The bit strings that show the status of each device are automatically stored in an area specified by the system.

Peripherals
"Peripheral" is used as a collective term for all input/output and other peripheral devices, and the peripheral ID is used to identify peripheral devices.

Bit operations resulting from input

The information about each device connected to an input port is allocated to space in the system area as a grouping of the peripheral ID and the associated data strings (which show the input status of the device).

Subsequent changes in the status of the device are reflected through changes in the status bits in the specified area; the programmer can get information from the input device by referencing the status bits in this area.

Of the Saturn Pad device information, Fig 9-2 shows only the device status information expanded as a 16-bit data string, and exclude the peripheral ID portion. (The SGL also expands the data that is output as peripheral data in this form.)

In the case of devices other than the Saturn Pad, only this portion of the device data is actually used in device processing (although the data length varies among devices).

The input status bits are all “1” when there is no input at all; if there is any input, the bit corresponding to the input mechanism changes to “0” only while the key or button is pressed.

Fig 9-2 Input Status Bit String for the Saturn Pad (shown as 16 bits)

a) Input status bit string

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	bit
→	←	↓	↑	Start	A	C	B	R	X	Y	Z	L	Not used			
Direction key				Start	Buttons A, B, C, X, Y, Z, L, R								Not used			

Fig 9-3 shows the changes in the 16-bit status bit string that occur when there is input, after starting with no input.

Fig 9-3 Changes in the Input Status Bit String (Saturn Pad)

a) No input

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	bit
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Direction key				Start	Buttons A, B, C, X, Y, Z, L, R								Not used			

⇩ When button A is pressed, bit 10 is cleared

b) Input made (button A)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	bit
1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	

⇩ When button A is released, bit 10 returns to "1"; when the direction key is pressed to indicate the down and right directions, bits 13 and 15 are cleared.

c) Input made (down and right)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	bit
0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	

Handling of Device Information in SGL

In the SGL, information on the Saturn Pads connected to the input ports is stored in the system variables that correspond to those ports, “dgt_pad_info[0]” and “dgt_pad_info[1]”.

dgt_pad_info[0]: Input device information for input port 1
dgt_pad_info[1]: Input device information for input port 2

The system-defined PerDgtInfo-type structure is stored in the system variable “dgt_pad_info[]”; each member of the structure includes the information shown below:

Fig 9-4 PerDgtInfo Structure Definition

● Contents of PerDgtInfo Structure Definition ●

```
typedef struct{                         /* for digital devices */
        PerDgtData   data;              /* current peripheral data */
        PerDgtData   push;              /* data on switch that was pressed */
        PerDgtData   pull;              /* data on switch that was released */
        PerId        id;                /* peripheral ID */
}PerDgtInfo;
```

Note: The above structure is defined in the system header file "per_def.h".

data: 16-bit peripheral data (shows current bit status)

push: 16-bit peripheral data (bits change only the instant that the input is executed)

pull: 16-bit peripheral data (bits change only the instant that the input is released)

id: 8-bit data string that shows the peripheral ID of the device

Of the grouping of data described earlier, excluding the peripheral ID, the peripheral data is a grouping of bits that only shows the input status; in the case of the Saturn Pad, the input status bits are represented in a format expanded out to 16 bits.

Peripheral data output
The members of the structure that shows the Saturn Pad data introduced here show only the peripheral ID (size: 8 bits) and the on/off status of the input mechanism switches (size: 16 bits). The structures corresponding to other devices, however, are not necessarily limited to this information.
This is because the data sent from such devices is not limited solely to the on/off status of switches. For example, in the case of the Saturn Mouse, a pointing device, the peripheral data includes data on the amount of absolute movement of the mouse, the status of the point corresponding to the movement amount, as well as the on/off status of the buttons on the mouse. The data length for each type of data also varies.

Note: For details on peripherals, refer to the “HARDWARE MANUAL,” vol. 1, and the system header file “sega_per.h”.

Input data discrimination

Discrimination of the information input from a device is accomplished by cross-referencing the peripheral data described previously and the assignment data described next.

The assignment data is defined within the system header file “sega_per.h”; for example, the assignments corresponding to each input mechanism on the Saturn Pad are defined as shown below.

Fig 9-5 Assignment Data #define Values (Saturn Pad)

● Pad assignments ●

```
#define   PER_DGT_KR       (1<<15)        /* direction key (right) */
#define   PER_DGT_KL       (1<<14)        /* direction key (left) */
#define   PER_DGT_KD       (1<<13)        /* direction key (down) */
#define   PER_DGT_KU       (1<<12)        /* direction key (up) */
#define   PER_DGT_ST       (1<<11)        /* start button */
#define   PER_DGT_TA       (1<<10)        /* button A */
#define   PER_DGT_TC       (1<<9)         /* button C */
#define   PER_DGT_TB       (1<<8)         /* button B */
#define   PER_DGT_TR       (1<<7)         /* R trigger */
#define   PER_DGT_TX       (1<<6)         /* button X */
#define   PER_DGT_TY       (1<<5)         /* button Y */
#define   PER_DGT_TZ       (1<<4)         /* button Z */
#define   PER_DGT_TL       (1<<3)         /* L trigger */
```

Because these assignments are used for cross-referencing with the peripheral data, they correspond with the length of the peripheral data for each device; for example, the Saturn Pad assignments are expanded as shown below (size: 16 bits). In addition, in the assignment data, the bit in the position corresponding to the input mechanism being identified is set to “1”, and the other bits are set to “0”.

Fig 9-6 Pad Assignments (for PER_DGT_A)

a) Hardware assignments (for PER_DGT_TA)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	bit
0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	

Note: When there is input from button A, the bit in the same position (bit 10), goes to "1".

In the case of the Saturn Pad, because the input mechanisms consist simply of switches that turn on and off, the status of the switches can be checked by performing a logical operation on the assignment data and the peripheral data.

Fig 9-7 is an example of how the input status is checked by performing an AND operation between the peripheral data and the assignment data. If the input mechanism designated by the assignment data is “on,” “0” is output as the result of the AND operation.

This method is used in the sample program; if the input mechanism pointed to by the pad assignment is “on,” a sprite is displayed on the screen.

Fig 9-7 checking the Input Status by Using the Assignment Data

a) Peripheral data (A, X, and Y are being input)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	bit
1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	

AND Execute AND operation between the peripheral data and the assignment data

b) Pad assignment (PER_DGT_A)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	bit
0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	

|| If the result is "0", the input mechanism indicated by the assignment is "on"

c) Result of AND operation

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	bit
0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	

= 0 (input is "on")

Although here the data was referenced by performing an AND operation on the peripheral data and the assignment data, it is not mandatory to use this method.

Sample Program

The following program listing was created to test controller input. The program displays a graphic representation of the Saturn Pad, and if there is any controller input, an indicator mark (shaped like a finger) is displayed on the button corresponding to the controller input.

This program uses sprites for the indicator mark, etc.

List 9-1 sample_9_1: Input Test (main.c)

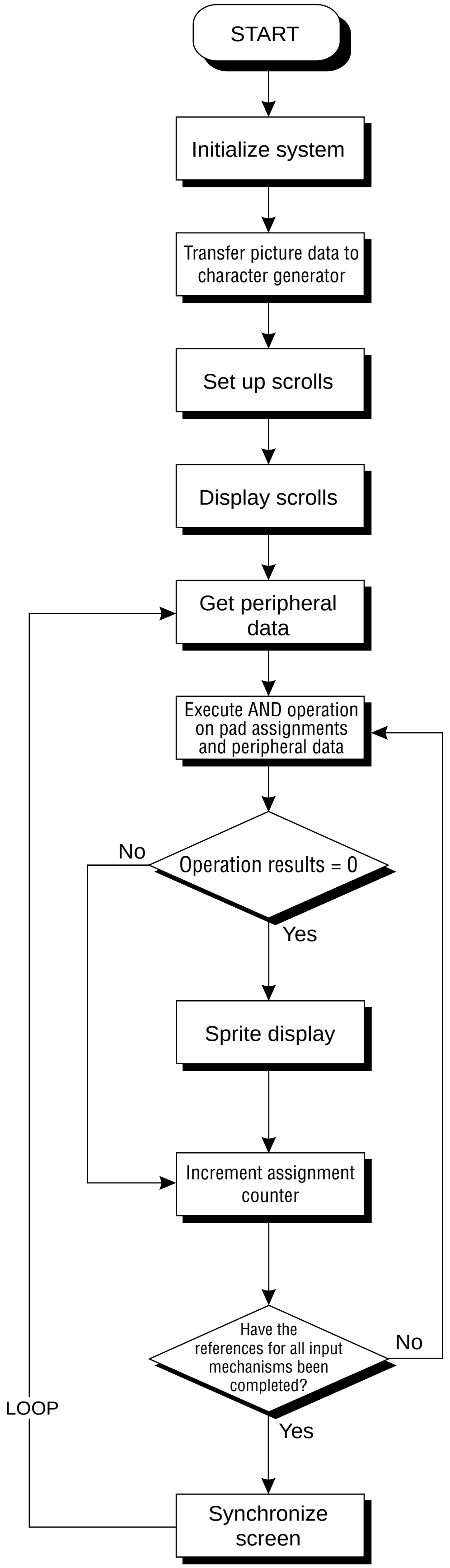
```
/*------------------------------------------------------*/
/*      Pad Control                                      */
/*------------------------------------------------------*/
#include        "sgl.h"                  /* include file containing various settings */
#include        "sega_per.h"             /* controller processing settings */

#define         NBG1_CEL_ADR    (VDP2_VRAM_B1+0x02000)
#define         NBG1_MAP_ADR    (VDP2_VRAM_B1+0x12000)
#define         NBG1_COL_ADR    (VDP2_COLRAM+0x00200)
#define         BACK_COL_ADR    (VDP2_VRAM_A1+0x1fffe)
#define         PAD_NUM         13

static Uint16pad_asign[]={               /* controller processing assignment settings */
        PER_DGT_KU,
        PER_DGT_KD,
        PER_DGT_KR,
        PER_DGT_KL,
        PER_DGT_TA,
        PER_DGT_TB,
        PER_DGT_TC,
        PER_DGT_ST,
        PER_DGT_TX,
        PER_DGT_TY,
        PER_DGT_TZ,
        PER_DGT_TR,
        PER_DGT_TL,
};

extern pad_cel[];
extern pad_map[];
extern pad_pal[];
extern TEXTURE  tex_spr[];               /* sprite data */
extern PICTURE  pic_spr[];
extern FIXED    stat[][XYZS];
extern SPR_ATTRattr[];
extern ANGLEangz[];

static void set_sprite(PICTURE *pcptr, Uint32 NbPicture)
{
        TEXTURE *txptr;                  /* transfer of texture data to character generator */

        for (: NbPicture-->0; pcptr++){
                txptr = tex_spr + pcptr->texno:
                slDMACopy((void *)pcptr->pcsrc,
                        (void *)(SpriteVRAM + ((txptr->CGadr)<<3)).
                        (Unit32)((txptr->Hsize * txptr->Vsize * 4)>>(pcptr->cmode))):
        }
}
```

(continued on next page)

```
static void disp_sprite()
{
        static Sint32 i;                                              /* display of sprite corresponding to input */
        Uint 16 data;

        if(!Per_Connect1)return;                                      /* device connect check */
        data = Smpc_Peripheral[0].data;

        for (i=0; i<PAD_NUM;i++){
                if((data & pad_asign [i])==0){                        /* controller input check */
                        slDispSprite((FIXED*)stat[i],
                                (SPR_ATTR *)(&attr[i],texno),(ANGLE)angz[i];
                }
        }
}

void main()
{
        slInitSystem(TV_320x224,tex_spr,1);
        set_sprite(pic_spr,1);
        slPrint("Sample program 9.1",slLocate(9,2));                  /* title display */

        slColRAMMode(CRM16_1024);                                     /* scroll settings */
        slback1ColSet((void*)BACK_COL_ADR,0);

        slCharNbg1(COL_TYPE_256,CHAR_SIZE_1x1);
        slPageNbg1((void*)NBG1_CEL_ADR,0,PNB_1WORD|CN_12BIT);
        slPlaneNbg1(PL_SIZE_1x1);
        slMapNbg1((void*)NBG1_MAP_ADR,(void*)NBG1_MAP_ADR,(void*)NBG1_MAP_ADR,
                        (void*)NBG1_MAP_ADR);
        Cel2VRAM(pad_cel,(void*)NBG1_CEL_ADR,483*64);
        Map2VRAM(pad_map,(void*)NBG1_MAP_ADR,32,19,1,256);
        Pal2CRAM(pad_pal,(void*)NBG1_COL_ADR,256);

        slScrPosNbg1(toFIXED(-32.0),toFIXED(-36.0));
        slScrAutoDisp(NBG0ON|NBG1ON);
        slTVOn();

        while(1){
                disp_sprite();
                slSynch();
        }
}
```

Note: The lightly shaded portion is defined in "spr_data.c".
Note: The darkly shaded portion is defined in "sega_per.h".

Flow Chart 9-1 sample_9_1: Input Test Flow Chart


START
Initialize system
Transfer picture data to character generator
Set up scrolls
Display scrolls
Get peripheral data
Execute AND operation on pad assignments and peripheral data
No
Operation results = 0
Yes
Sprite display
Increment assignment counter
Have the references for all input mechanisms been completed?
No
LOOP
Yes
Synchronize screen

Library Functions Used in the Sample Program

Of the library functions used in the sample program, the most important of those which have not been explained yet in previous chapters are introduced briefly below.

Several other functions that are related to these functions are also introduced briefly.

Sprite functions

These functions are used to display sprites.

Unlike a scroll, a sprite is a type of small unit of graphic data that can be moved and displayed freely; multiple sprites can be displayed at one time, as well.

Sprites are often used for mobile characters in games that use 3D graphics.

[void slDispSprite (FIXED *pos, ATTR *atrb, ANGLE Zrot);]

This function displays a sprite at the defined position, scale, and display angle.

For the parameters, substitute a four-dimensional array FIXED-type variable pointer that shows the XYZ coordinate values and the scale value, the starting address of the area where the sprite data is stored, and the display angle.

As with the library function “slPutPolygon”, sorting according to the Z value is performed, but the current matrix is unaffected.

In addition, if a negative value is substituted for the scale value, then after the scale is calculated according to the Z value, it is multiplied with the complement of the parameter scale value and the result is used as the display scale.

For example, if the scale value was specified as “-2.0”, and if the sprite is in a position that would be displayed at 0.5x, it is actually displayed at a scale of 1.0.

[void slPutSprite (FIXED *pos, ATTR atrb, ANGLE Zrot);]

This function calculates the position using the current matrix, and displays the sprite on the screen with scaling according to the perspective transformation.

For the parameters, substitute a four-dimensional array FIXED-type variable pointer that shows the XYZ coordinate values and the scale value, the starting address of the area where the sprite data is stored, and the display angle.

As with “slDispSprite”, the sprite is scaled according to the specified scale value, but if a negative value was substituted, the sprite is reversed top-to-bottom and left-to-right when it is displayed on the screen.

[void slSetSprite (SPRITE *parms, FIXED Zpos);]

This function sets the sprite control command data to be passed to the hardware into the transfer list.

For the parameters, substitute the starting address of the area where the sprite data is stored, and the Z coordinate position.

This function is used only in cases such as when it is desired to set an altered sprite that cannot be produced with a library function or to set up a window that will affect only special sprites.

Other functions

The two functions introduced here are used for DMA transfers.

In the sample program, the function “slDMACopy” is used to transfer the sprite picture data (a data transfer from the picture data storage area to the character generator area).

[void slDMACopy (void *src, void *dst, Uint32 cnt);]

This function uses the DMA built into the CPU to make block transfers of data.

For the parameters, substitute the starting address of the area in memory that is the source of the transfer, the starting address of the area in memory that is the destination of the transfer, and the size of the bloc transfer (in bytes).

Because this function completes the transfer right after DMA is activated, use the “slDMAWait” function if you wish to know when the transfer was completed.

[void slDMAWait (void);]

This function waits for completion of a DMA transfer initiated by the library function “slDMACopy”.

The function “slDMACopy” always performs data transfers using the same channel. As a result, if a previously executed DMA transfer is still in progress, subsequent data transfers are initiated only after waiting for the previous transfer to be completed.

Fig. 9-8 "slDMAXCopy" Parameter Substitution Values (mode)

		Destination		
		Increment	**Decrement**	**Fixed**
Source	Increment	Sinc_Dinc_Byte	Sinc_Ddec_Byte	Sinc_Dfix_Byte
	Decrement	Sdec_Dinc_Byte	Not allowed	Sdec_Dfix_Byte
	Fixed	Sfix_Dinc_Byte	Sfix_Ddec_Byte	Not allowed

Note: The above values are defined in "sl_def.h".

Note: The above values assume the unit of transfer is "byte". "Word" and "long" can also be specified as the unit of transfer.

Supplement. SGL Library Functions Covered in this Chapter

The functions listed in the following table were explained in this chapter.

Table 9-3 SGL Library Functions Covered in this Chapter

Function type	Function name	Parameters	Function
void	slDispSprite	FIXED *pos, ATTR *atrb, ANGLE Zrot	Display sprite at specified position, scale, and display angle
void	slPutSprite	FIXED *pos, ATTR *atrb, ANGLE Zrot	Display sprite with perspective transformation
void	slSetSprite	SPRITE *parms, FIXED Zpos	Set sprite data in hardware
void	slDMACopy	void *src, void *dst, Uint32 cnt	Perform DMA transfer from A to B, for C bytes (identical bus transfer possible)
void	slDMAWait	void	Wait until DMA transfer is completed

10

Programmer's Tutorial

Event Control

This chapter explains event structures and specifically how to use the event management functions. By using the event concept, it is possible to describe a program as a combination of program events (each of the elements within the program), making it very easy to understand the flow of the program as a whole.

In addition, because program events can be shared, program simplification is possible.

Structure of Events

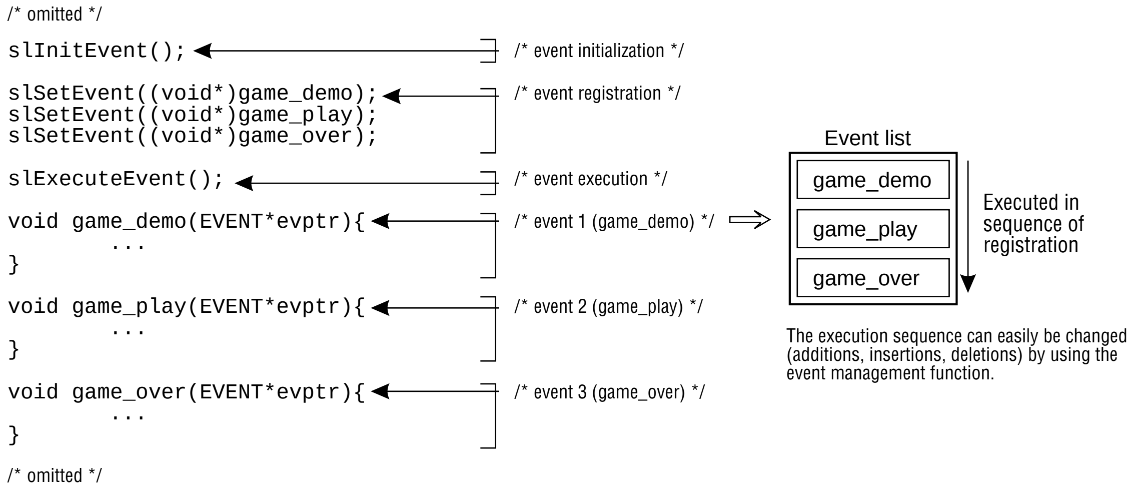
Event processing

Event processing consists of labeling a group of functions registered within the program listing as an "event" and then executing a list of consecutive events in order.

By using event processing, it becomes possible to process complex groups of consecutively executed functions as a simple list of labels. In addition, the execution sequence can be easily changed around by manipulating the labels registered as events.

This approach makes it possible to grasp the flow of a program as a whole; in addition, events can be shared, making program simplification possible.

Fig 10-1 The Event Concept



```
/* omitted */
slInitEvent();

slSetEvent((void*)game_demo);
slSetEvent((void*)game_play);
slSetEvent((void*)game_over);

slExecuteEvent();

void game_demo(EVENT*evptr){
        ...
}

void game_play(EVENT*evptr){
        ...
}

void game_over(EVENT*evptr){
        ...
}
/* omitted */
```

/* event initialization */
/* event registration */
/* event execution */
/* event 1 (game_demo) */
/* event 2 (game_play) */
/* event 3 (game_over) */
Event list
game_demo
game_play
game_over
Executed in sequence of registration
The execution sequence can easily be changed (additions, insertions, deletions) by using the event management function.

The function groups registered as events and the event execution sequence are processed in event management areas called "event structures" allocated in a RAM area used for events.

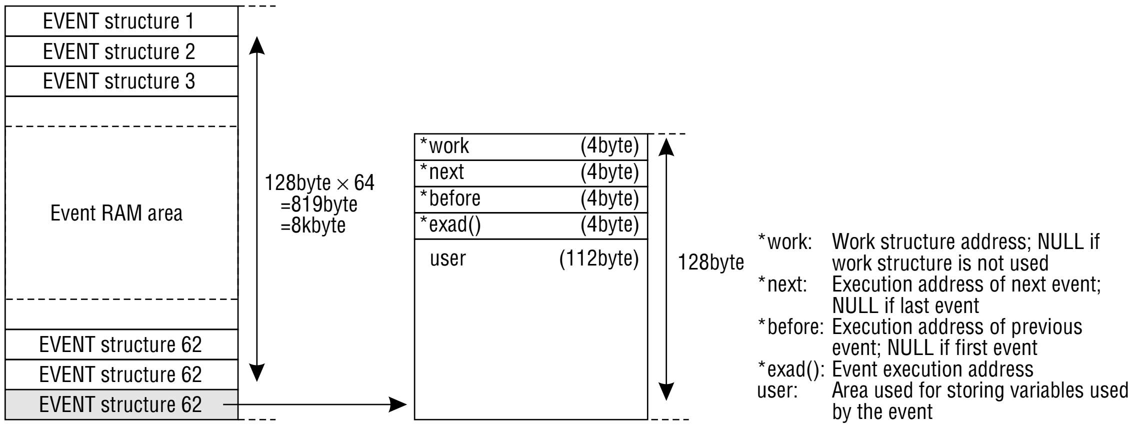
In the SGL, the event execution sequence is called the "event list."

Event structures

Events are defined as EVENT structures (size: 128 bytes) in the event RAM area (size: 8K); one EVENT structure consists of 128 bytes, and a maximum of 64 EVENT structures can be defined in this RAM area.

The configuration of an EVENT structure is shown in Fig 10-2.

Fig 10-2 EVENT Structure


EVENT structure 1
EVENT structure 2
EVENT structure 3
Event RAM area
EVENT structure 62
EVENT structure 62
EVENT structure 62
128byte × 64
=819byte
=8kbyte
*work (4byte)
*next (4byte)
*before (4byte)
*exad() (4byte)
user (112byte)
128byte
*work: Work structure address; NULL if work structure is not used
*next: Execution address of next event; NULL if last event
*before: Execution address of previous event; NULL if first event
*exad(): Event execution address
user: Area used for storing variables used by the event

a) Event RAM area

b) Event structure

Each EVENT structure consists of the following members:

*work: Starting address of the work structure used to extend the user area

*next: Starting address of the event to be executed next

*before: Starting address of the event that was executed last

*exad(): Starting address where the functions that are to be executed as the event are stored

user[]: User area used for storing variables used by the functions registered in the event; the user
area can be extended by using a work structure, etc.

If there is no corresponding address for “*work”, “*next”, or “*before”, NULL is substituted.

If the user is going to use the user area within the EVENT structure, it is useful to “cast” the user area as a structure defined for users.

Although the user area in one EVENT structure consists of 112 bytes, the work structure, etc., can be used to extend the user area if desired. For details on how to extend the user area, refer to the section on user area extension.

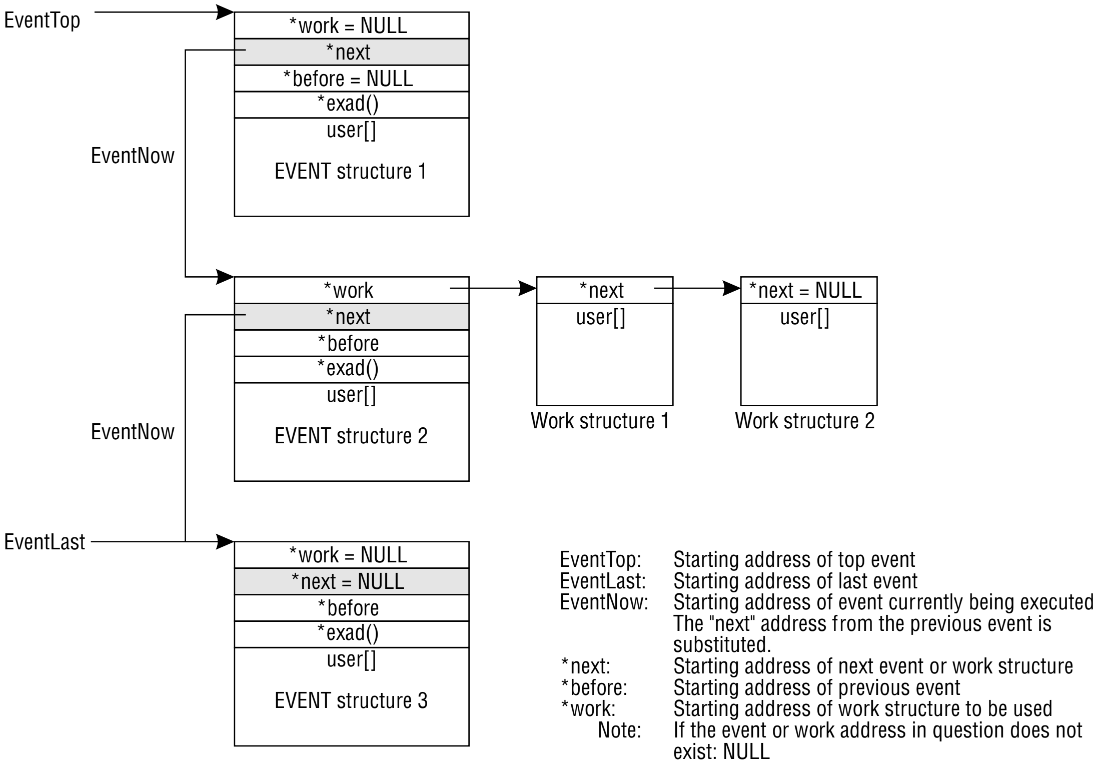
Event lists

Each event defined as an EVENT structure within the event RAM area forms a list of events in the sequence they are to be executed in.

The list is tied together by the members “*next” and “*before” reserved in the EVENT structure. The series of events to be executed is called an “event list.”

The events executed in sequence within the event list do not have to be stored in sequence in the event RAM; as long as the events are linked by the “*next” and “*before” pointers, the events will be executed in the proper sequence.

Fig 10-3 Event List Structure


EventTop
*work = NULL
*next
*before = NULL
*exad()
user[]
EVENT structure 1
EventNow
*work
*next
*before
*exad()
user[]
EVENT structure 2
*next
user[]
Work structure 1
*next = NULL
user[]
Work structure 2
EventNow
EventLast
*work = NULL
*next = NULL
*before
*exad()
user[]
EVENT structure 3
EventTop: Starting address of top event
EventLast: Starting address of last event
EventNow: Starting address of event currently being executed The "next" address from the previous event is substituted.
*next: Starting address of next event or work structure
*before: Starting address of previous event
*work: Starting address of work structure to be used
Note: If the event or work address in question does not exist: NULL

The system puts the starting address of the EVENT structure registered at the start of the event list into the variable “EventTop”; when the system executes the event list, it executes the events in sequence, starting with the event specified by “EventTop”.

The value of the “*next” pointer in the EVENT structure of the event that was just executed is passed to the “EventNow” variable, and the system next begins executing the EVENT structure that starts at the address indicated by “EventNow”. The system continues to execute the events in sequence according to “EventNow”, and then terminates event execution processing when the value of “*next” is null, indicating that there are no more subsequent events. The “EventLast” variable points to the starting address of the EVENT structure registered last in the list, and is used when adding or registering events. The “EventLast” variable is changed only by the execution of the following library functions: “slSetEvent”, “slSetEventNext”, and “slCloseEvent”. “*before” is used when inserting, registering, or deleting events.

Event Processing Using SGL Functions

This section explains actual event processing using the SGL library functions.

Event initialization

In order to use event processing in the SGL, it is necessary to first initialize the event-related buffers and the event list.

Note that if event processing is used without executing event initialization, coordination with the uninitialized buffers and event list will not be possible, with the result in the worst case being that the CPU stops operating. (For details, refer to "Cautions Concerning Event Processing.")

In the SGL, use the library function "slInitEvent" to execute event initialization.

[void slInitEvent (void);]

This function performs all initializations (event list and buffer initializations, etc.) involved in event processing.

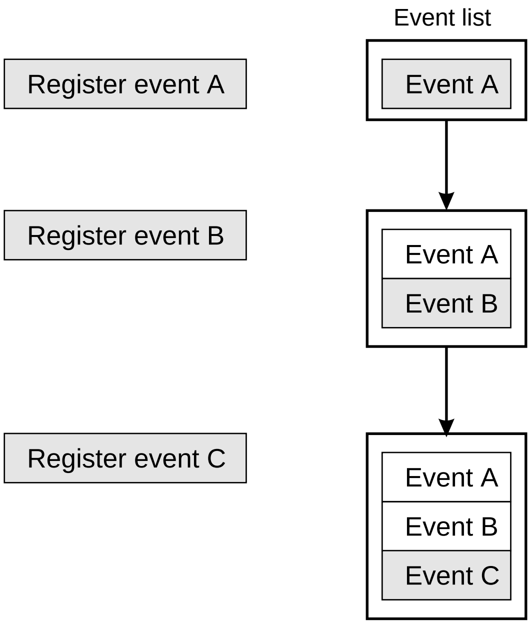
Creating an Event List

In order to perform event processing, it is necessary to register events in the event list in the order that they are to be executed in.

Events are added to an event list as shown in Fig 10-4 below by the event registration library function "slSetEvent".

The registered events are appended in sequence at the end of the event list. The event execution library function "slExecuteEvent" is used to initiate execution of the event list, starting from the top of the list.

Fig 10-4 Creating an Event List



Use the library function "slSetEvent" to register events.

[EVENT *slSetEvent (void (*func)();]

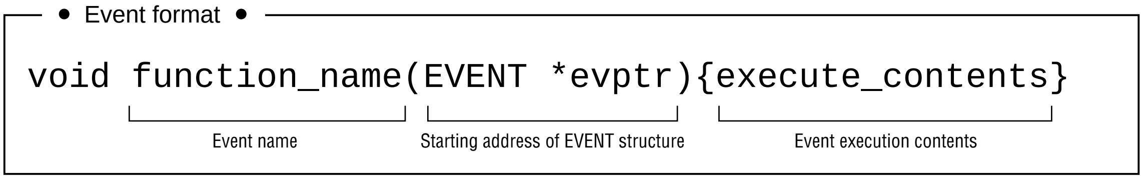
This function allocates an EVENT structure (size: 128 bytes) in the event RAM area, and adds/registers new events at the end of the event list. For the parameter, substitute the execution address for the event being registered. As a return value, this function returns the starting address of the EVENT structure that was registered. If event registration failed, the null value is returned.

For details on event format and structure, refer to the next page.

Event format

The group of functions registered as events must have the format shown in Fig 10-5:

Fig 10-5 Event Format



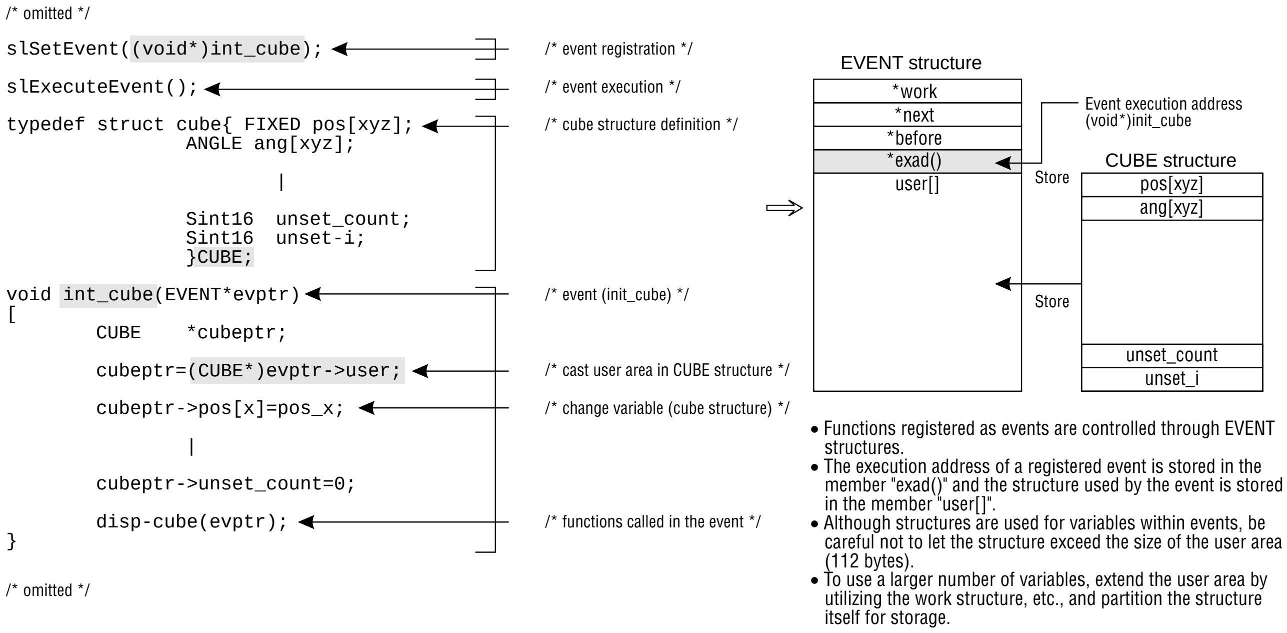
● Event format ●

```
void function_name(EVENT *evptr){execute_contents}
```

The events that are to be registered or executed are managed through the EVENT structure.

The execution addresses of the registered events and the structures for the variables used within the events are stored in the EVENT structure; these two elements are used to manage the events.

Fig 10-6 Structure of an Event



```
/* omitted */

slSetEvent((void*)int_cube);

slExecuteEvent();

typedef struct cube{ FIXED pos[xyz];
                ANGLE ang[xyz];

                        |

                Sint16  unset_count;
                Sint16  unset-i;
                }CUBE;

void int_cube(EVENT*evptr)
[
        CUBE    *cubeptr;

        cubeptr=(CUBE*)evptr->user;

        cubeptr->pos[x]=pos_x;

                |

        cubeptr->unset_count=0;

        disp-cube(evptr);
}

/* omitted */
```

- Functions registered as events are controlled through EVENT structures.
- The execution address of a registered event is stored in the member "exad()" and the structure used by the event is stored in the member "user[]".
- Although structures are used for variables within events, be careful not to let the structure exceed the size of the user area (112 bytes).
- To use a larger number of variables, extend the user area by utilizing the work structure, etc., and partition the structure itself for storage.

Structures for variables within an event
When a variety of variables are used within an event, it is necessary to define that variable group as a structure.
The defined event variable structure is stored in the user area (size: 112 bytes) in the EVENT structure when the event is registered (the user must perform the storage task); the event variable structure can thereafter be used immediately.

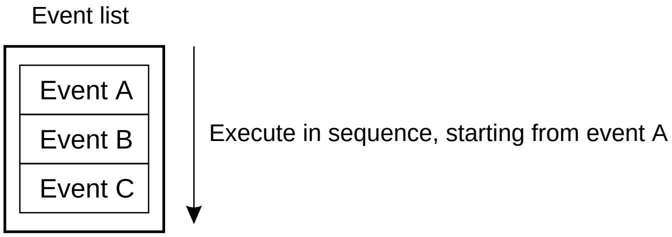
Accordingly, the event variable structure cannot be set up so that it exceeds the size (112 bytes) of the user area in which the structure is stored.
However, use even more variables, extend the user area by utilizing the work structure, etc., and partition and store the event variable structure so that it does not exceed the size of the user area. (For details on how to extend the user area, refer to "Extending the User Area.")

Event execution

The events registered in the event list are executed in sequence by the event management functions. Use the library function "slExecuteEvent" to execute the events.

For example, after the library function "slSetEvent" is used to register event A, event B, and event C in the event list in that sequence, each event is executed according to the event list in the sequence shown in the following diagram.

Fig 10-7 Event Execution



[void slExecuteEvent (void);]

This function executes the events registered in the event list in the sequence that they have in the list.

Changing the Event List

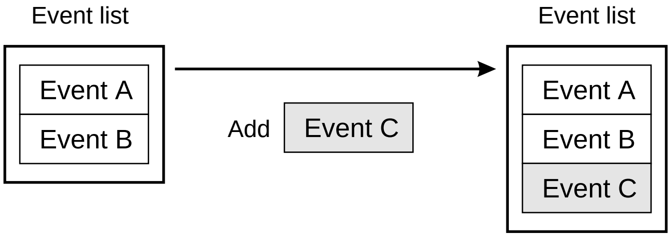
Adding events

Events can be added to the events registered in the event list.

Events are added at the end of the event list.

The same library function, “slSetEvent”, that was used to register events is also used to add events.

Fig 10-8 Adding Events



[EVENT *slSetEvent (void (*func)());]

This function allocates an EVENT structure (size: 128 bytes) in the event RAM area, and adds/registers new events at the end of the event list. For the parameter, substitute the execution address for the event being registered. As a return value, this function returns the starting address of the EVENT structure that was registered. If event registration failed, the null value is returned.

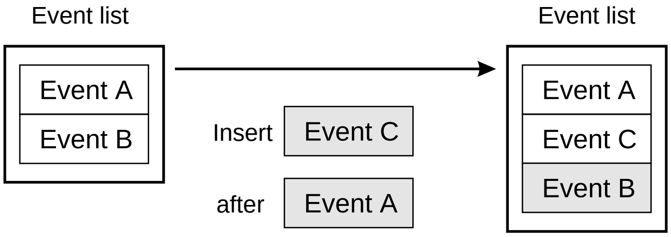
Event insertion

This function inserts an event among the events registered in the event list.

The new event is inserted right after the specified event.

The library library function “slSetEventNext” is used to insert events.

Fig 10-9 Event Insertion



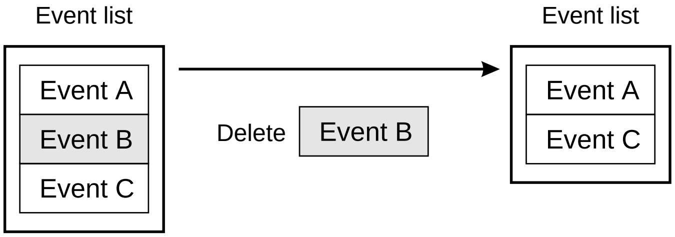
[EVENT *slSetEventNext (EVENT *evptr, void (*func)());]

This function allocates an EVENT structure (size: 128 bytes) in the event RAM area, and inserts/registers new events in the middle of the event list. For the parameter, substitute the starting address of the EVENT structure immediately before the point where the new event is to be inserted, and the execution address for the event being inserted/registered. As a return value, this function returns the starting address of the EVENT structure that was registered. If event registration failed, the null value is returned.

Event deletion

Events registered in an event list can be deleted from the list. Use the library function "slCloseEvent" to delete the event.

Fig 10-10 Event Deletion



[void slCloseEvent (EVENT *evptr);]

This function deletes the event specified by the parameter from the event list.

At the same time, if the member "work" of the specified event is not "NULL", all of the associated work is returned to the system as a work list.

For the parameter, substitute the starting address of the EVENT structure to be deleted.

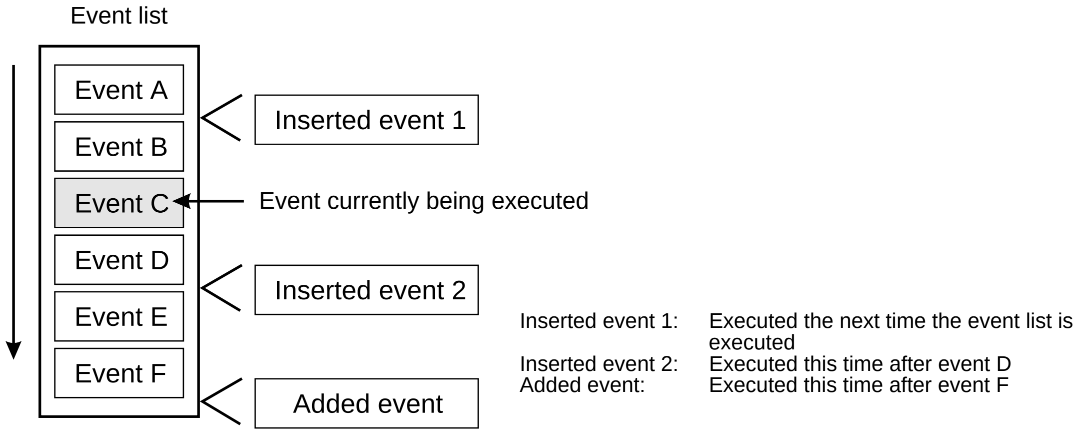
In addition, this function "slCloseEvent" does not check to make sure that the area being returned is an EVENT structure. Therefore, if you accidentally return an extended user area back to the system, this function will not detect the error.

If this type of mistake occurs, various problems can arise, and in the worst case the CPU will stop operating. (For details, refer to "Cautions Concerning Event Processing.")

Changing the event list during event execution

If any type of attempt is made to change an event list that contains registered events and is in the process of being executed (including changes among the events in the event list, etc.) the changed event is affected as shown in the following diagram.

Fig 10-11 Changing the Event List During Execution



Inserted event 1:	Executed the next time the event list is executed
Inserted event 2:	Executed this time after event D
Added event:	Executed this time after event F

Changes to the event list that are before the event currently being executed (in the part of the list that has already been executed) apply the next time the event list is executed.

Changes to the event list that are after the event currently being executed (in the part of the list that has not yet been executed) are executed according to the sequence of the newly changed event list during this execution of the event list.

All changes, whether additions, insertions, or deletions, are applied in the same way.

Extending the User Area

When describing a program by using event processing, there may be times when the variable group (structure) used by a function being executed as an event will not fit within the user area (112 bytes) of the event.

In these circumstances, it is possible in the SGL to extend the user area.

There are two methods for extending the user area: one is to use the work area as a dedicated extension area, and the other is to allocate an extension area the same size as an EVENT structure within the event RAM area.

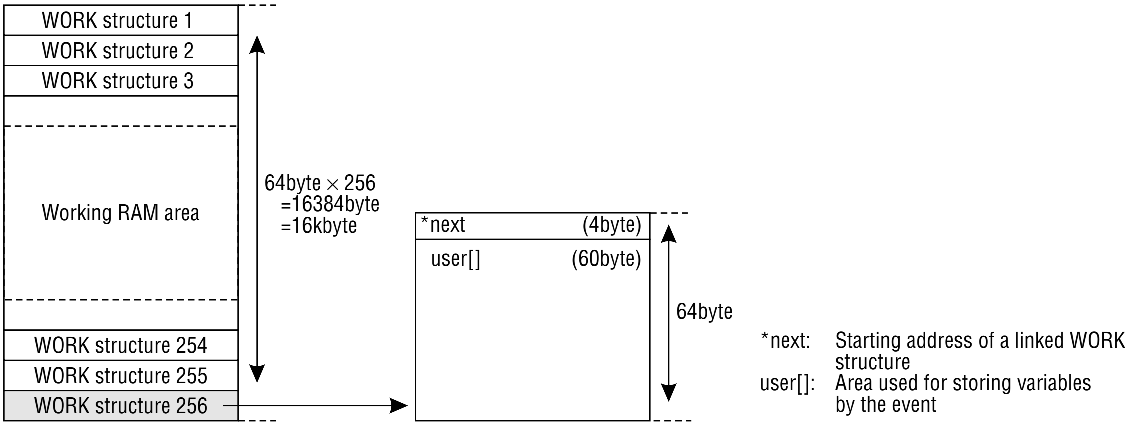
Extending a user area with a work area

In the SGL, it is possible to extend the user area in an EVENT structure by using a dedicated user area extension area called the “work area.”

A work area is defined as a WORK structure (size: 64 bytes) within the working RAM area; up to 256 work areas can be used.

One work area can increase the size of the user area by 60 bytes. The remaining four bytes of the WORK structure are used for specifying the address of a linked WORK structure.

Fig 10-12 WORK Structure



a) Working RAM area b) WORK structure

The WORK structure members are as follows:

*next:Starting address of a WORK structure linked in a chain; if there is no WORK structure that follows in a chain, NULL.

user[]:Extended user area (size: 60 bytes)

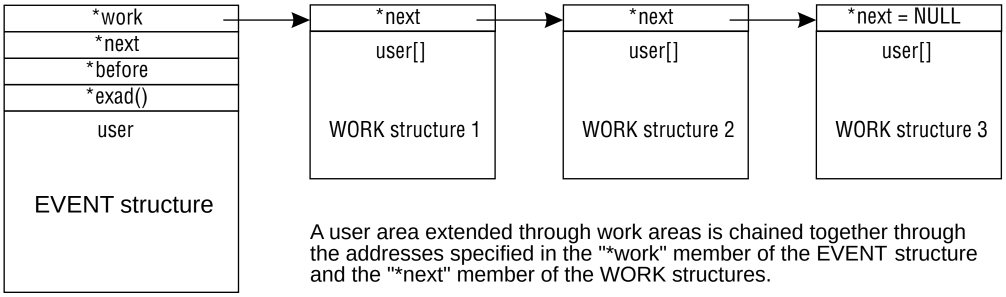
A work area allocated as a WORK structure can be linked in chain fashion by substituting the starting address for the WORK structure in the “*work” member of the EVENT structure.

In addition, by allocating another work area within a WORK structure, it is possible to further extend the user area.

In this case, by substituting the starting address of the next WORK structure to be chained in the “*next” member of the previous WORK structure, it is possible to chain together WORK structures.

If there is no WORK structure that follows in the chain, NULL is substituted for the "*next" member of the last WORK structure.

Fig 10-13 Work Area Chaining



A user area extended through work areas is chained together through the addresses specified in the "*work" member of the EVENT structure and the "*next" member of the WORK structures.

To use work areas in the SGL, use the library functions "slGetWork" and "slReturnWork".

[WORK *slGetWork (void);]

This function allocates a WORK structure (size: 64 bytes) in the working RAM area.

As a return value, this function returns the starting address of the WORK structure that was allocated. If area allocation failed, the null value is returned.

[void slReturnWork (WORK *wkptr);]

This function returns/releases the work area specified by the parameter. For the parameter, specify the WORK structure address of the work area being returned. In addition, if returning/releasing part of a chain of work areas to the system, adjust the chain structure of the remaining work areas so that the chain structure is correct. If adjustments are not made, it will be impossible to coordinate the chain structure and work processing, with the possible result that the CPU will stop operating. (For details, refer to the next section.)

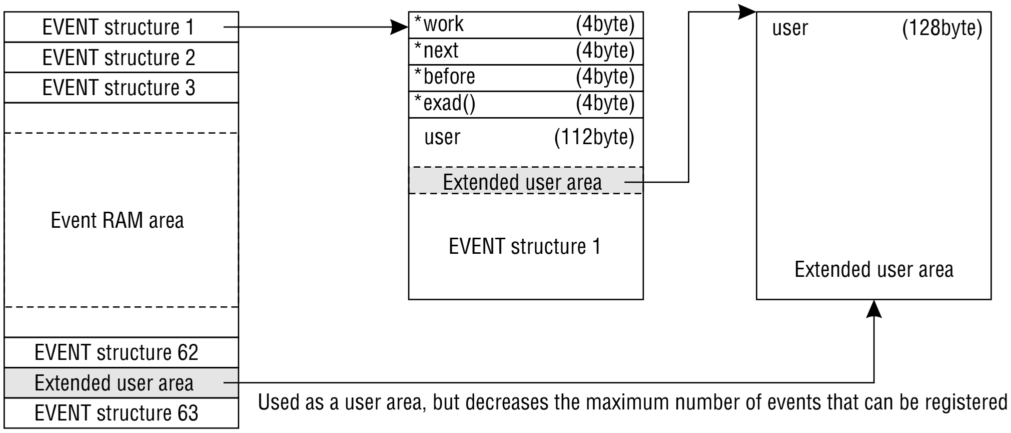
Operation of chained WORK structures after the release of an EVENT structure
Work areas do not necessarily have to be chained together by the "*work" and "*next" members; it is also possible to store the starting address of a linked WORK structure in the user area. Work areas chained together by the "*work" and "*next" members are returned/released to the system simultaneously if the associated event is released, but WORK structures linked through the user area are not released if the event is released. Therefore, when an event is released, it is necessary to use the library function "slReturnWork" to return/release to the system those WORK structures that were linked through the user area.

Extending the user area with event areas

If a WORK structure (size: 60 bytes) does not provide enough space for one user area to be extended it is possible to allocate a user area the same size as an EVENT structure (size: 128 bytes) in the event RAM area.

However because an area originally allocated for the use of an event is being used as a user area, the maximum number of events that can be registered decreases accordingly.

Fig 10-14 Using the Event RAM Area to Extend a User Area



In the SGL, when the user area of an EVENT structure is to be extended by using the event RAM area, use the library functions “slGetEvent” and “slReturnEvent”.

“slGetEvent” is used to allocate the user area, and “slReturnEvent” is used to release the user area.

[EVENT *slGetEvent (void);]

This function allocates a user area in event RAM the same size as an event (size 128 bytes). Because an area originally allocated for the use of an EVENT structure is being used as a user area, the maximum number of events that can be registered decreases accordingly.

As a return value, this function returns the starting address of the RAM area that was allocated. If area allocation failed, the null value is returned.

[void slReturnEvent (EVENT *evptr);]

This function returns/releases the event RAM area specified by the parameter back to the system.

For the parameter, substitute the starting address of the RAM area being returned.

In addition, this function “slReturnEvent” does not check to make sure that the area being returned is an extended user area. Therefore, if you accidentally return an EVENT structure that is registered as an event back to the system, this function will not detect the error.

If this type of mistake occurs, various problems can arise, and in the worst case the CPU will stop operating. (For details, refer to "Cautions Concerning Event Processing.")

Cautions Concerning Event Processing

In event processing, particular caution is required when returning/releasing various areas back to the system. This is because during the release/return operation, the function being used does not check to make sure that the area specified by the parameter is an area of the type for which the function is intended.

For example, if an attempt is made to return/release an extended user area with the library function “slReturnEvent”, but an area registered as a normal event is accidentally returned/ released, the problems like the following can arise, with the CPU ceasing to operate in the worst case.

1) Return of area:

The specified EVENT structure is returned to the system by the function “slReturnEvent”.

2) Event list

Because the event structure was not released as an event, it continues to exist in the event list.

3) New event registration

Because the area is free as far as the system is concerned, the area can be used by the function “slSetEvent”, etc.

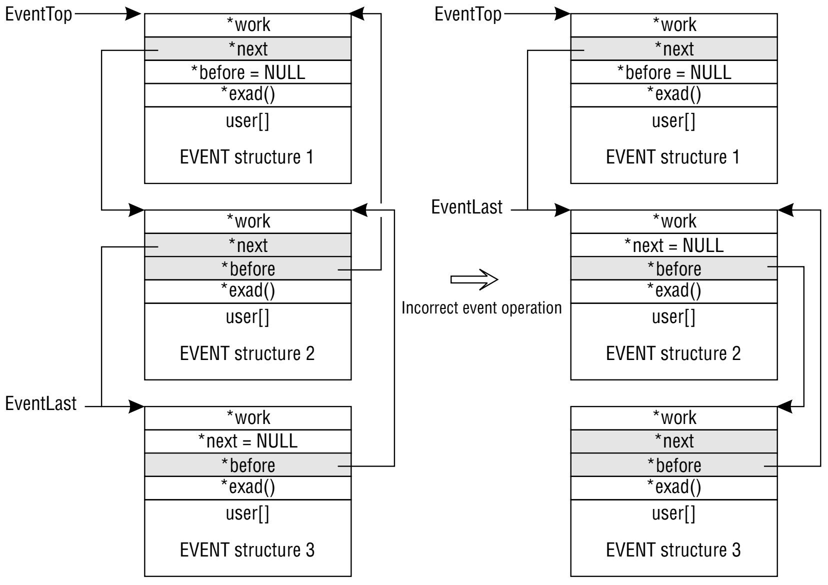
4) Chain structure conflict

Event though it is registered in the event list, the area is regarded to be free, so the contents of the EVENT structure are overwritten, which can create problems in chained structures.

5) CPU halt

Because the chain structure cannot be coordinated, in the worst case the CPU will stop operating.

Fig 10-15 Incorrect Event Operations



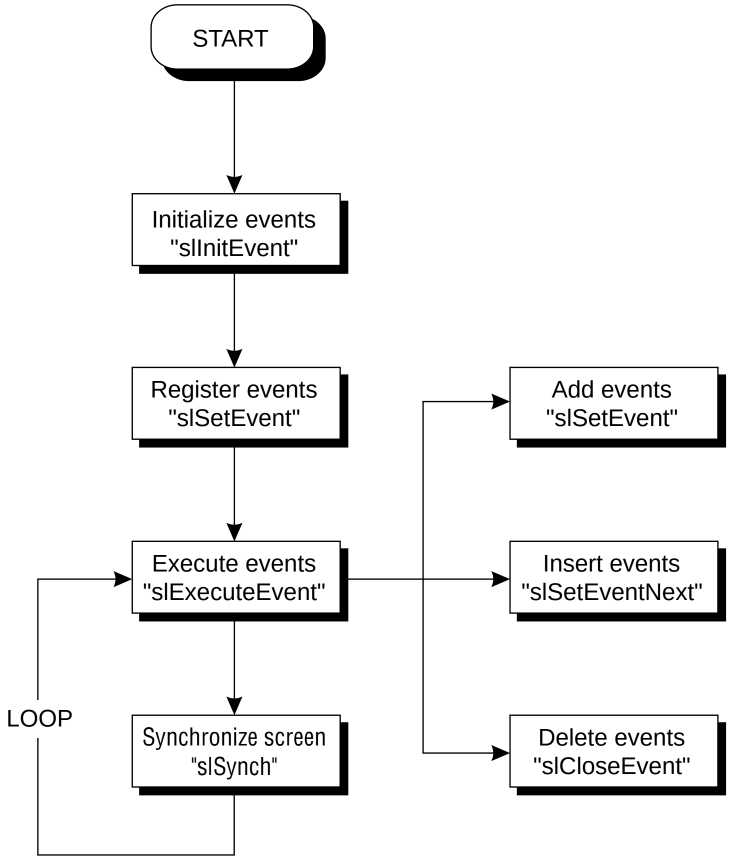
1) EVENT structure 2 is released by the function "slReturnEvent".
2) The event list is not changed.
3) The function "slSetEvent" is executed.
4) EVENT structure 2 is added/registered as a new, different event.
5) The chain structure is disrupted, and future event operations could result in the CPU ceasing to operate.

a) Normal chain structure b) Disrupted chain structure

Flow of Event Processing

The following flow chart is a broad summary of the flow of event processing. In event processing, it is also possible to extend the user area within the event being executed when necessary and to use variables in structures.

Flow Chart 10-1 Flow of Event Processing



Example of Event Usage

The following sample program, “sample_10” (List 10-1 and List 10-2), is an example of programming that actually uses event processing.

In the program, events are used to control/execute the display/non-display of a cube.

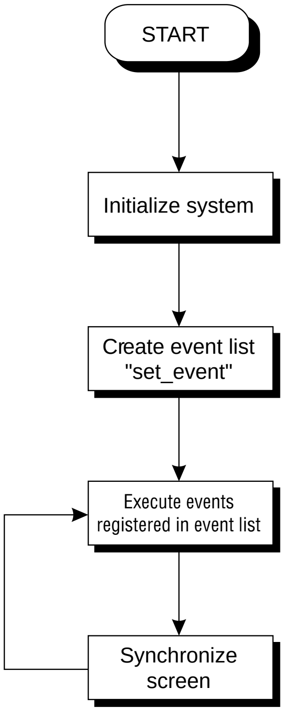
The program basically consists of two parts: “main.c” (List 10-1) initializes the system and executes the events, and “sample.c” (List 10-2) initializes the events, defines the contents of the events, and registers the events.

List 10-1 sample_10: Event Processing (main.c)

```
/*----------------------------------------------*/
/*              Event Control                  */
/*----------------------------------------------*/
#include "sgl.h"                                          /* include file containing various settings */

void set_event();

void main()
{
 slInitSystem(TV_320X224,NULL,1);                         /* system initialization */
 slPrint("Sample program 10",slLocate(9,2));              /* title display */

 set_event();                                             /* event list creation */
 while(-1)
        {
                slExecuteEvent();                         /* event execution */
                slSynch();                                /* scan line synchronization */
        }
}
/*----------------------------------------------*/
```

Note: The lightly shaded portion is defined in "sgl.h" and "sl_def.h".
Note: The darkly shaded portion is defined in "sample.c".

Flow Chart 10-2 sample_10: Main Loop


START
Initialize system
Create event list "set_event"
Execute events registered in event list
Synchronize screen

The following listing from sample_10_1 shows the portion where events are registered and the contents of the events are defined.

In the user-defined function “disp_cube”, the contents of the event list are changed (added/ deleted).

List 10-2 sample_10: Event Processing (sample.c)

```
#include        "sgl.h"                                        /* include file containing various settings */

extem PDATA PD_CUBE;

#define         POS_X           toFIXED(0.0)
#define         POS_X_UP        200.0
#define         POS_Y           toFIXED(20.0)
#define         POS_Z           toFIXED(270.0)
#define         POS_Z_UP        50.0
#define         SET_COUNT       500

static void init_cube2(EVENT*);

typedef struct cube{                                           /* CUBE structure definition */
        FIXEDpos[XYZ];
        ANGLE   ang[XYZ];
        ANGLE   angx,angz;
        ANGLE   anx_up,angz_up;
        PDATA*poly;
        Sint16 set_count,set_i;
        Sint16 unset_count,unset_i;
}CUBE;

static void disp_cube(EVENT*evptr)                             /* polygon drawing routine */
{
        CUBE *cubeptr;

        cubeptr=(CUBE*)evptr->user;
        slPushMatrix();
        {
                slTranslate(cubeptr->pos[X],cubeptr->pos[Y],cubeptr->pos[Z];
                cubeptr->pos[X]=POS_X+POS_X_UP*slSin(cubeptr->angx);   /* CUBE structure modification */
                cubeptr->pos[Y]=cubeptr->pos[Y];
                cubeptr->pos[Z]=POS_Z+POS_Z_UP*slCos(cubeptr->angz);
                cubeptr->angx+=cubeptr->angx_up;
                cubeptr->angz+=cubeptr->angz_up;
                slRotY(cubeptr->ang[Y];
                slRotX(cubeptr->ang[X];
                slRotZ(cubeptr->ang[Z];
                cubeptr->ang[X]+=DEGtoANG(5.0);
                cubeptr->ang[Y]+=DEGtoANG(5.0);
                cubeptr->ang[Z]+=DEGtoANG(5.0);
                slPutPolygon(cubeptr->poly);                   /* polygon drawing start */
        }
        slPopMatrix();
        cubeptr->set_count-=cubeptr->set_i;                    /* event list change routine */
        if(cubeptr->set_count<0){
                slSetEvent((void*)init_cube2);                 /* event addition (init_cube2) */
                cubeptr->set_count=SET_COUNT;
        }
        cubeptr->unset_count-=cubeptr->unset_i;
        if(cubeptr->unset_count<0)slCloseEvent(evptr);         /* event deletion (init_cube2) */
}
```

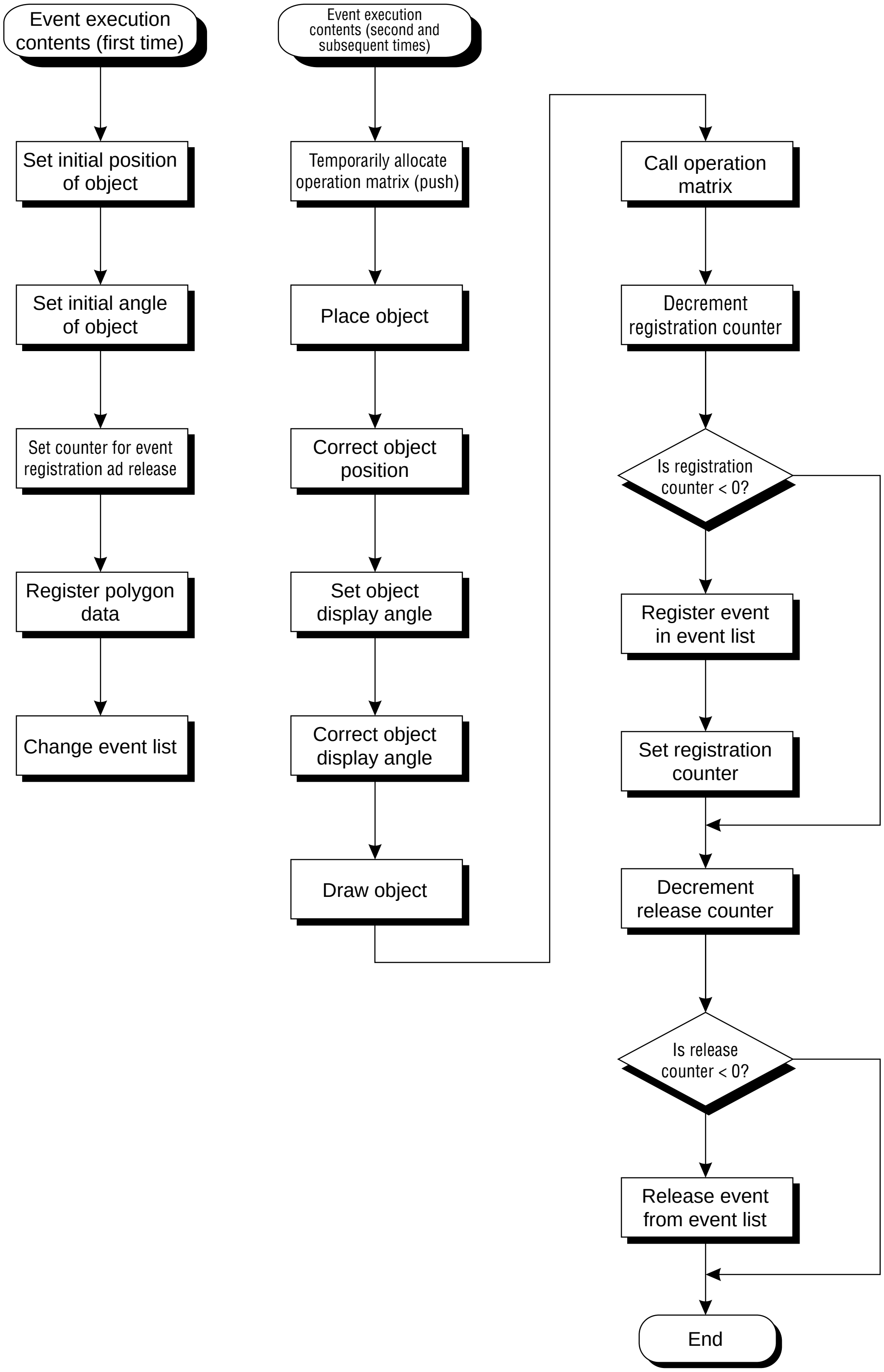
(continued on next page)

```
static void init_cubel(EVENT*evptr)                                   /* event 1 (init_cube1) */
{
        CUBE *cubeptr;                                                /* event 1 execution contents */

        cubeptr=(CUBE*)evptr->user;
        cubeptr->pos[X]=POS_X;
        cubeptr->pos[Y]=POS_Y;
        cubeptr->pos[Z]=POS_Z;
        cubeptr->ang[X]=cubeptr->ang[Y]=cubeptr->pos[Z]=DEGtoANG(0.0);
        cubeptr->angx=cubeptr->angz=DEGtoANG(0.0);
        cubeptr->angx up=cubeptr->angz_up=DEGtoANG(0.0);
        cubeptr->set_count=SET_COUNT;
        cubeptr->set_i=1;
        cubeptr->unset_count=0;
        cubeptr->unset i=0;
        cubeptr->poly=&PD_CUBE;
        evptr->exad=(void*)disp_cube;
        disp_cube(evptr);                                             /* CUBE1 display */
}

static void init_cube2(EVENT *evptr)                                  /* event 2 (init_cube1) */
{
        CUBE *cubeptr;                                                /* event 2 execution contents */

        cubeptr=(CUBE*)evptr->user;
        cubeptr->pos[X]=POS_X;
        cubeptr->pos[Y]=POS_Y-toFIXED(50);
        cubeptr->pos[Z]=POS_Z+POS_Z_UP;
        cubeptr->ang[X]=cubeptr->ang[Y]->cubeptr->ang[Z]=DEGtoANG(0.0);
        cubeptr->angx=cubeptr->angz=DEGtoANG(0.0);
        cubeptr->angx_up=cubeptr->angz_up=DEGtoANG(3.0)*(-1);
        cubeptr->set_count=0;
        cubeptr->set_i=0;
        cubeptr->unset_count=SET_COUNT/2;
        cubeptr->unset_i=1;
        cubeptr->poly=&PD_CUBE:
        evptr->exad=(void*)disp_CUBE;
        disp_cube(evptr);                                             /* CUBE2 display */
}
staric Void init_cube3(EVENT*evptr)                                   /* event 3 (init_cube1) */
{
        CUBE *cubetr;                                                 /* event 3 execution contents */

        cubeptr=(CUBE*)evptr->user;
        cubeptr->pos[X]=POS_X;
        cubeptr->pos[Y]=POS_Y-toFIXED(50);
        cubeptr->pos[Z]=POS_Z+POS_Z_UP;
        cubeptr->ang[X]=cubeptr->ang[Y]->cubeptr->ang[Z]=DEGtoANG(0.0);
        cubeptr->angx=cubeptr->angz=DEGtoANG(0.0);
        cubeptr->angx_up=cubeptr->angz_up=DEGtoANG(3.0);
        cubeptr->set_count=0;
        cubeptr->set_i=0;
        cubeptr->unset_count=0;
        cubeptr->unset_i=0;
        cubeptr->poly=&PD_CUBE:
        evptr->exad=(void*)disp_cube;
        disp_cube(evptr);                                             /* CUBE3 display */
}

void*event_tbl[]={                                                    /* event registration table */
        init_cube1,
        init_cube2,
        init_cube3
};
void set_event()
{
        EVENT*evptr;
        void  **exptr;
        Uint16 cnt

        slInitEvent();                                                /* event initialization */
        for(exptr=event_tbl,cnt=sizeof(event_tbl)/sizeof(void*);cnt-->0;){   /* set events according to event table */
                evptr=slSetEvent(*exptr++);
        }
}
```

The following flow chart is a summary of the event execution contents.

The event execution contents differ the first time through the loop compared to the second and subsequent times through the loop. In the flow chart, the left side indicates the event execution contents the first time through the loop, and the right side indicates the event execution contents the second and subsequent times through the loop.

Flow Chart 10-3 sample_10_1: Event Execution Contents



Event execution contents (first time)
Set initial position of object
Set initial angle of object
Set counter for event registration ad release
Register polygon data
Change event list
Event execution contents (second and subsequent times)
Temporarily allocate operation matrix (push)
Place object
Correct object position
Set object display angle
Correct object display angle
Draw object
Call operation matrix
Decrement registration counter
Is registration counter < 0?
Register event in event list
Set registration counter
Decrement release counter
Is release counter < 0?
Release event from event list
End

Supplement. SGL Library Functions Covered in this Chapter

The functions listed in the following table were explained in this chapter.

Table 10-1 SGL Library Functions Covered in this Chapter

Function type	Function name	Parameters	Function
void	slInitEvent	void	Initialize events
EVENT	*slSetEvent	void (*func)()	Register/add an event to the event list
void	slExecuteEvent	void	Execute events registered in the event list in sequence
EVENT	*slSetEventNext	EVENT *evptr, void (*func)()	Insert/register a new event right after the specified registered event
void	slcloseEvent	EVENT *evptr	Delete an event from the event list and return release the associated work areas to the system
WORK	*slGetWord	void	Allocate a work area
void	slReturnWork	void	Return/release a work area
EVENT	*slGetEvent	void	Allocate a RAM area the same size as an event in the event RAM area
void	slReturnEvent	EVENT *evptr	Return/release to the system an area that was allocated by using “slGetEvent”

11

Programmer's Tutorial

Mathematical Operation Functions

This chapter introduces the various mathematical operation functions supported in the SGL.

General Mathematical Operation Functions

The following are the general mathematical operation functions.

[FIXED slDivFX (FIXED a, FIXED b);]
This function divides parameter “b” by parameter “a”.

[FIXED slMulFX (FIXED a, FIXED b);]
This function multiplies parameter “a” by parameter “b”.

[FIXED slSquartFX (FIXED sqrtfx);]
This function returns the square root of an unsigned fixed-point (FIXED-type) value.

[Uint32 slSquart (Uint32 sqrt);]
This function returns the square root of an unsigned integer value.

Trigonometric Functions

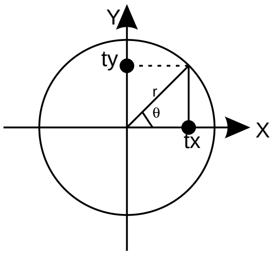
The trigonometric operation functions are listed below.

[FIXED slSin (ANGLE angs);]
This function returns the sine value of the specified angle (ANGLE-type).

[FIXED slCos (ANGLE angs);]
This function returns the cosine value of the specified angle (ANGLE-type).

[FIXED slTan (ANGLE angs);]
This function returns the tangent value of the specified angle (ANGLE-type).

Fig 11-1 Model of Trigonometric Functions



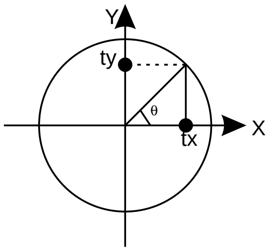
$\sin \theta = ty/r = slSin(\theta)$

$\cos \theta = tx/r = slCos\ (\theta)$

$Tan\ \theta = ty/tx = slTan(\theta)$

[ANGLE slAtan (FIXED tx, FIXED ty);]
This function returns the angle of the specified direction.

Fig 11-2 Model of "slAtan"



$Tan\ \theta = ty/tx\ ;$

$\theta = \tan^{-1} ty/tx = slAtan(tx,ty)\ ;$

Special Operation Functions

The special operation functions are listed below.

[FIXED slCalcPoint (FIXED cx, FIXED cy, FIXED cz, FIXED *ret);]

This function multiplies the specified point by the current matrix and substitutes the result in the parameter "ret".

[FIXED slInnerProduct (VECTOR a, VECTOR b);]

This function calculates the vector inner product between the specified parameters.

The value shown in Fig 11-3 is returned.

Fig 11-3 Value Returned by the Vector Inner Product Operation

● Value Returned by the Vector Inner Product Operation ●

```
A(X1,Y1,Z1)*B(X2,Y2,Z2) = X1*X2+Y1*Y2+Z1*Z2
                        = Return Value;
```

[Uint32 slDec2Hex (Uint32 val);]

This function converts a value expressed in BCD code to hexadecimal code.

[Uint32 slHex2Dec (Uint32 val);]

This function converts a value expressed in hexadecimal code to BCD code.

[Uint16 slAng2Hex (ANGLE ang);]

This function converts an angle value expressed in ANGLE code to hexadecimal code. The converted value that is returned ranges from 0 to 359.

[Uint16 slAng2Dec (ANGLE ang);]

This function converts an angle value expressed in ANGLE code to BCD code. The converted value that is returned ranges from 0 to 359.

[FIXED slAng2FX (ANGLE ang);]

This function converts an angle value expressed in FIXED code to binary code. The converted value that is returned ranges from 0 to 359.

Table 11-1 Examples of value notation using each notation method

	Decimal	BCD	Hexadecimal
Notation	92	0x92	0x5cH

Supplement. SGL Library Functions Covered in this Chapter

The functions listed in the following table were explained in this chapter.

Table 11-2 SGL Library Functions Covered in this Chapter

Function type	Function name	Parameters	Function
FIXED	slDivFX	FIXED a, FIXED b	Division (B/A)
FIXED	slMulFX	FIXED a, FIXED b	Multiplication (A * B)
FIXED	slSquartFX	FIXED sqrtfx	Return square root of unsigned fixed-point value
Uint32	slSquart	Uint32 sqrt	Return square root of unsigned integer value
FIXED	slSin	ANGLE angs	Return sine value of specified angle
FIXED	slCos	ANGLE angc	Return cosine value of specified angle
FIXED	slTan	ANGLE angt	Return tangent value of specified angle
ANGLE	slAtan	FIXED tx, FIXED ty	Return angle of specified direction
FIXED	slCalcPoint	FIXED zx, cy, cz, FIXED *ret	Multiply specified point by the current matrix
FIXED	slInnerProduct	VECTOR a, VECTOR b	Calculate vector inner product
Uint32	slDec2Hex	Uint32 val	Convert from BCD code to Hexadecimal code
Uint32	slHex2Dec	Uint32 val	Convert from Hexadecimal code to BCD code
Uint16	slAng2Hex	ANGLE ang	Convert from ANGLE code to Hexadecimal code
Uint16	slAng2Dec	ANGLE ang	Convert from ANGLE code to BCD code
FIXED	slAng2FX	ANGLE ang	Convert from ANGLE code to FIXED code

12

Programmer’s Tutorial

CD-ROM Library

This chapter explains how to use the CD-ROM library to access CD-ROM. The CD-ROM library makes it possible to load programs and data from CD-ROM and also to play music.

This chapter also includes the function reference for the CD-ROM library.

The CD-ROM Library

The SGL includes functions for accessing CD-ROM and virtual CDs.

These functions can be used to implement the following functions:

- Loading programs and data from CD-ROM
- Loading data according to the CD-ROM XA standard
- Playing back music using CDDA files

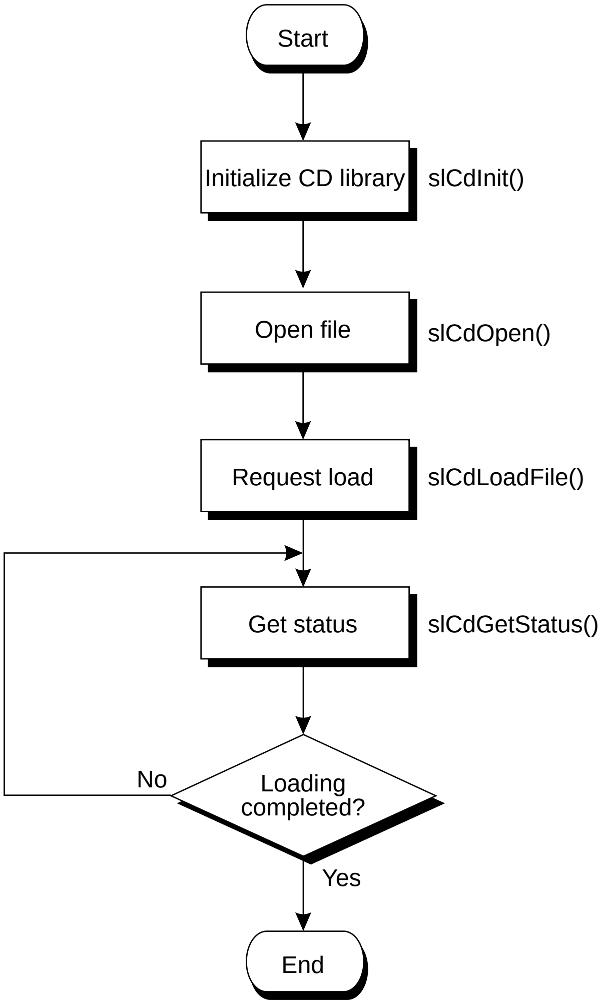
Note: The CD-ROM library functions are not listed in the separate Function Reference. Instead, they are included at the end of this chapter.

For details on writing to a CD-ROM, refer to the reference Transferring Data, chapter 3, “Writing CD-ROM.”

Accessing CD-ROM

The flow of operations for loading data from a CD-ROM is described below.

Fig 12-1 CD-ROM Access Flow Chart

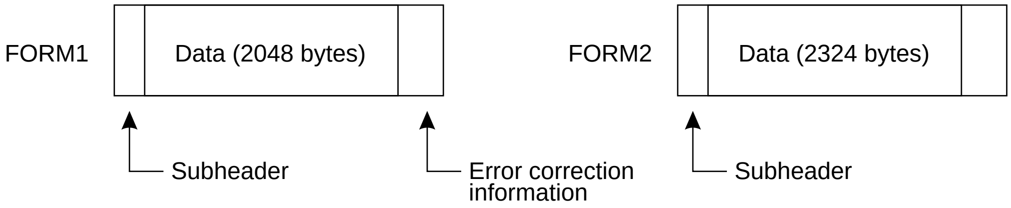


Because CD-ROM access entails mechanical operations, the data is not loaded into memory at the instant that the load request is made. In addition, in comparison with the operational speed of the CPU, the speed at which the data is loaded from the CD-ROM is extremely slow. In order to permit the execution of operations aside from the CD-ROM access during this wait, the SGL supports a method in which the loading status is monitored during CD-ROM access.

Logical Structure of CD-ROM

CD-ROM consists of units called “sectors.” Although sectors generally contain 2048 bytes (FORM1), in cases such as music where a few misread bits will not cause problems and a high transfer capacity is desired, it is possible to put 2324 bytes (FORM2) into each sector. Each sector within a file contains a subheader consisting of the channel number, submode, and coding information.

Fig 12-2 Sector Structure



The SGL includes a function that classifies data according to the subheader. This information is called a “key” in the SGL. Each bit of the submode and coding information is significant, and in the SGL, only those sectors in which the specified bits are set to “1” are selected and loaded.

Loading files

Use the functions “slCdOpen”, “slCdLoadFile”, and “slCdGetStatus” to load files.

CDHN slCdOpen (Sint8 *pathname, CDKEY key []);]

This function specifies the file to be loaded.

“key” specifies the type of sector to be loaded. Multiple sector types can be specified. After all sector types have been specified, specify “CDKEY_TERM” for the last channel number.

Once the file is opened correctly, a file handle other than “NULL” is returned.

If the maximum number of keys for an open file reaches 24 or more, the open operation fails. The open file is closed automatically when the loading operation is interrupted or completed.

[Sint32 slCdLoadFile (CDHN cdhn, CDBUF buf []);]

This function specifies the area into which the file is to be loaded.

The sequence of “buf” corresponds to the sequence of “key” in the function “slCdOpen”.

When copying the CD-ROM data to the work RAM, make the following specifications:

buf[i].type = CDBUF_COPY;

buf[i].trans.copy.addr = loading area address;

buf[i].trans.copy.unit = loading area unit of size
(CDBUF_FORM1/ CDBUF_FORM2/CDBUF_BYTE);

buf[i].trans.copy.size = number of units in loading area

Data is not loaded if “NULL” is set for “addr” and “0” is set for “size”. Set “unit”, the loading area unit of size, in accordance with the CD-ROM sector type. This allows data to be loaded efficiently. The actual area loaded is “unit” x “size” and must be a multiple of four bytes..

When processing the data while loading it, the function can be registered as follows.

buf[i].type = CDBUF_FUNC;

buf[i].trans.func.func = function pointer;

buf[i].trans.func.obj = value to be passed to first parameter of function;

The registration function is “Sint32 (*func) (void *obj, Uint32 *addr, Sint32 adinc, Sint32 nsct)”.

"obj" is the value of "buf[i].trans.func.obj".

"addr" is the address the data is copied from.

"adinc" is the incremented value of "addr" after four bytes were retrieved.

"nsct" is the number of sectors that can be loaded. The return value is the number of sectors actually transferred. Once all transfer areas have been specified, specify "CDBUF_TERM" for the last "buf[].type".

[Sint32 slCdGetStatus (CDHN cdhn, Sint32 ndata[]);]

Monitor the loading status by regularly calling the function "slCdGetStatus" in the main loop, etc. When the function value is "CDSTAT_COMPLETED", the loading operation is completed.

The number of bytes that have been loaded is stored in "ndata" in the sequence corresponding to "key" of the function "slCdOpen".

Sample program 1 shows a file loading program.

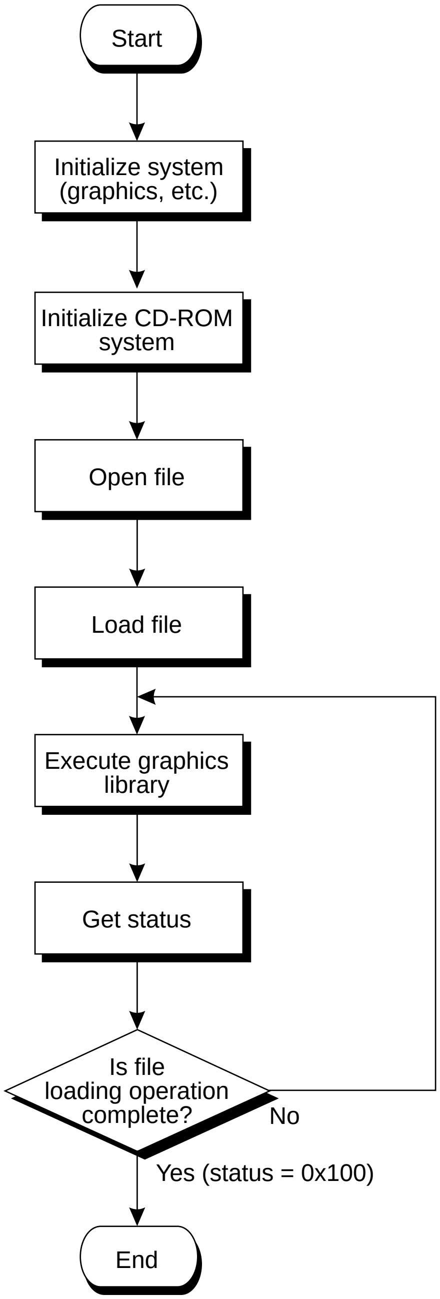
This sample program performs the necessary processing for loading files stored in a CD-ROM, and serves as an example of how to use the basic library functions for loading files from a CD-ROM. The sequence of the processing performed by the program is explained below in accordance with Flow Chart 12-1.

1) Initialize the system (graphics, etc.).
2) Initialize the CD-ROM system.
3) Open the file.

   Because the key information used to classify the data is contained in the input parameters of the function that opens the file, set this information as necessary.
4) Load the file, using the file handle that was returned by the function that opened the file and the information on the loading area as parameters.
5) Execute the graphics library (function "slSynch()").

   The file that was specified for loading is now actually loaded, a little at a time.
6) Get the status information and confirm whether the file loading operation has been completed or not. If the file loading operation has not been completed, stay in the loop until the loading operation is completed. This loop is designed so that the function "slSynch()" is called within the loop.

Flow Chart 12-1 Sample Program 1 (File loading sample_cd1/main.c)



List 12-1 Sample Program 1 (File loading sample_cd1/main.c)

```
/*************************************************************************************
*       CD library Sample program
*
*       Copyright       (c)     1994    SEGA
*
*       Library : CD library
*       Module  : File loading sample 1
*       File    : main.c
*       Date    : 1995-02-20
*       Version : 0.00
*       Auther  : ?.T
*
*       File load
*
***********************************************************************************/
/**********************************************************************************
*       Include files                                                              * *****
#include        <stdlib.h>
#include        <sgl.h>
#include        <sgl_cd.h>

/**********************************************************************************
*       Definition macro                                                           *
***********************************************************************************/
#define         MAX_FILE        128
#define         READSECT        50
/**********************************************************************************
*       Variable definition                                                        *
***********************************************************************************/
Sint32          dirwork[SLCD_WORK_SIZE(MAX_FILE)/sizeof(Sint32)];
Sint32          readbuf[ (READSECT*CDBUF_FORM1/sizeof(Sint32)];

/**********************************************************************************
*       Simple file loading sample program                                         *
***********************************************************************************/
void            main(void)
{
        Sint32  ndir;
        CDHN    cdhn;
        CDKEY   key[2];
        CDBUF   buf[2]
        Sint32  stat;
        Sint32  len[2];
        Sint32  ypos=1;

/* ------------------------- File system initialization ------------------------ */
        SlInitSystem(TV_320x224, NULL, 1);              /* system initialization (graphics, etc.) */
        ndir=.slCdInit(MAX_FILE, dirwork);              /* CD-ROM system initialization */
        slPrint("slCdInit:",slLocate(1,ypos));
        slPrintFX(toFIXED(ndir), slLocate(11,ypos));
        ypos++;

/* --------------------------------- File open --------------------------------- */
        key[0].cn=key[0].sm=key[0].ci=CDKEY_NONE;       /* setting of unselected keys */
        key[1].cn=CDKEY_TERM;                           /* key end setting */
        cdhn=slCdOpen("S2100D0_.M" ,key);               /* file open */
        slPrint("slCdOpen:", slLocate(1,ypos));
        slDispHex((Uint32)cdhn, slLocate(11,ypos));
```

List 12-1 Sample Program 1 (File loading sample_cd1/main.c) (continued)

```
/* ------------------------------- File loading ------------------------------- */
        buf[0].type=CDBUF_COPY;                 /* loading method setting (copy to work RAM) */
        buf[0].trans.copy.addr=readbuf;         /* loading destination area address setting */
        buf[0].trans.copy.unit=CDBUF_FORM1;     /* loading area unit size setting */
        buf[0].trans.copy.size=READSECT;        /* loading area unit number setting */
        buf[1].type=CDBUF_TERM;         /* loading method setting (loading area information specification end) */
        slCdLoadFile(cdhn,buf);                 /* file loading */
        ypos++;

/* -------------------------- Get status information -------------------------- */
        while (1) {
                slsynch();                              /* execute graphics library */
                stat=slCdGetStatus(cdhn, len);          /* get status */
                slPrint("stat:", slLocate(1, ypos));
                slDispHex((Uint32)stat, slLocate(7, ypos));
                ypos++;
                if (ypos>=27)   ypos=1;
                if (stat==CDSTAT_COMPLETED) break;      /* end of file loading? */

        }
        while(1);
}
```

Partitioned file loading

Use the function “slCdResetBuf” to partition and load large volumes of data, such as for moving images, etc.

[Bool slCdResetBuf (CDHN cdhn, CDKEY *key);]

This function returns the destination area for the loading of data corresponding to the file handle “key” to the start of the area specified by the function “slCdLoadFile”.

Use the function “slCdGetStatus” to get the number of valid data elements in the loading area; if the loading area becomes full, process the data and call the function “slCdResetBuf”.

Sample program 2 shows an example of a program that partitions and loads data.

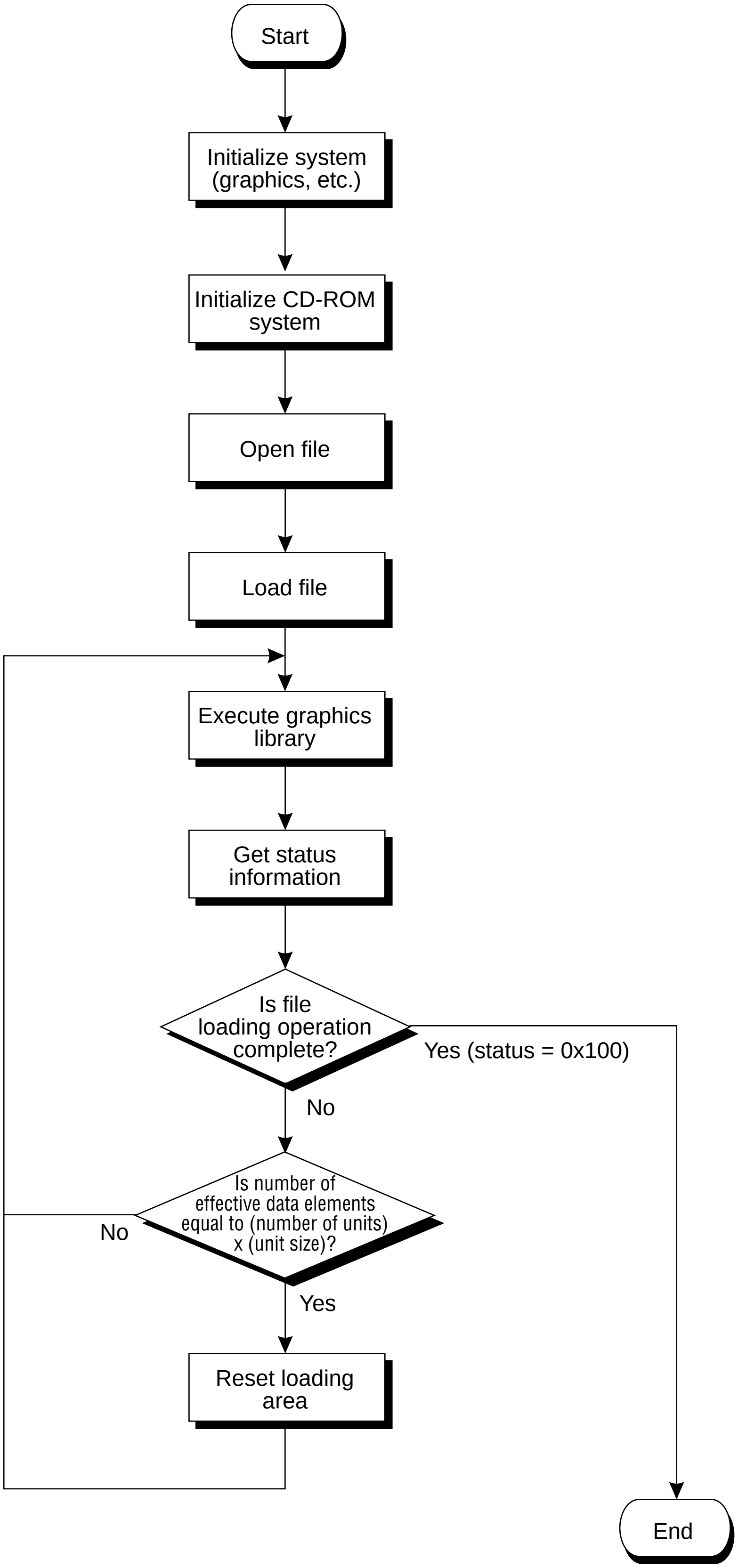
This sample program performs the necessary processing for partitioning and loading files stored in a CD-ROM, and serves as an example of how to use the basic library functions for loading files from a CD-ROM. The sequence of the processing performed by the program is explained below in accordance with Flow Chart 12-2.

1) Initialize the system (graphics, etc.).
2) Initialize the CD-ROM system.
3) Open the file.

   Because the key information used to classify the data is contained in the input parameters of the function that opens the file, set this information as necessary.
4) Load the file, using the file handle that was returned by the function that opened the file and the information on the loading area as parameters.
5) Execute the graphics library (function “slSynch()”).

   The file that was specified for loading is now actually loaded, a little at a time.
6) Get the status information and confirm whether the file loading operation has been completed or not. At the same time, also check to see whether or not the loading area is full; if it is, process the data as necessary and then reset the loading area. If the file loading operation has not been completed, stay in the loop until the loading operation is completed. This loop is designed so that the function “slSynch()” is called within the loop.

Flow Chart 12-2 Sample Program 2 (Partitioned file loading sample_cd2/main.c)


Start
Initialize system (graphics, etc.)
Initialize CD-ROM system
Open file
Load file
Execute graphics library
Get status information
Is file loading operation complete?
Yes (status = 0x100)
No
Is number of effective data elements equal to (number of units) x (unit size)?
No
Yes
Reset loading area
End

List 12-2 Sample Program 2 (Partitioned file loading sample_cd2/main.c)

```
/************************************************************************************
*       CD library Sample program
*
*       Copyright       (c)     1994    SEGA
*
*       Library : CD library
*       Module  : File loading sample 2
*       File    : main.c
*       Date    : 1995-02-20
*       Version : 0.00
*       Auther  : Y.W
*
*       Partitioned file loading
*
************************************************************************************/
/************************************************************************************
*       Include files                                                               *
************************************************************************************/
#include        <stdlib.h>
#include        <sgl.h>
#include        <sgl_cd.h>

/************************************************************************************
*       Definition macro                                                            *
************************************************************************************/
#define         MAX_OPEN        128                     /* number of files that can be open simultaneously */

#define         FNAME           "S2100D0_.M"            /* name of file to be accessed */

#define         slsize          2                       /* number of sectors in loading buffer */

/************************************************************************************
*       Variable definition                                                         *
************************************************************************************/
/* initial processing work area */
Sint32          lib_work[SLCD_WORK_SIZE(MAX_OPEN)/sizeof(Sint32)];

/* file loading buffer */
Sint32          readbuf[(CDBUF_FORM1 *slsize)/sizeof(Sint32)];

/************************************************************************************
*       File loading sample program                                                 *
************************************************************************************/
Sint32          main()
{
        Sint32          ndir;                           /*  */
        Sint32          ypos=1;                         /*  */
        Sint32          ret;                            /* return code */
        Sint32          ndata[2];                       /* number of valid data elements in loading area */
        CDHN            cdhn;                           /* file handle */
        CDKEY           key[2];                         /* key information used to partition data */
        CDBUF           buf[2];                         /* loading area information */

/* ------------------------- File system initialization ------------------------- */
        SlInitSystem(TV_320x224, NULL, 1);              /* system initialization (graphics, etc.) */
        ndir=slCdInit(MAX_OPEN, lib_work);              /* CD-ROM system initialization */
        slPrint("slCdInit:",slLocate(1,ypos));
        slPrintFX(toFIXED(ndir), slLocate(11,ypos));
        ypos++;
```

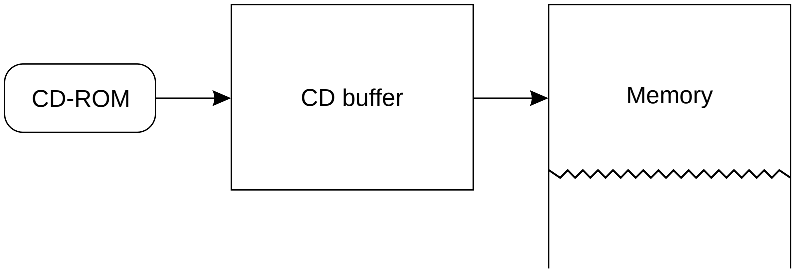
List 12-2 Sample Program 2 (Partitioned file loading sample_cd2/main.c) (continued)

```
/* ---------------------------------- File open ----------------------------------- */
        key[0].cn=key[0].sm=key[0].ci=CDKEY_NONE;        /* setting of unselected keys */
        key[1].cn=CDKEY_TERM;                            /* key end setting */
        cdhn=slCdOpen(FNAME,key);                        /* file open */
        slPrint("slCdOpen:", slLocate(1,ypos));
        slDispHex((Uint32)cdhn, slLocate(11,ypos));

/* -------------------------------- File loading ---------------------------------- */
        buf[0].type=CDBUF_COPY;                          /* loading method setting (copy to work RAM) */
        buf[0].trans.copy.addr=readbuf;                  /* loading destination area address setting */
        buf[0].trans.copy.unit=CDBUF_FORM1;              /* loading area unit size setting */
        buf[0].trans.copy.size=slsize;                   /* loading area unit number setting */
        buf[1].type=CDBUF_TERM;             /* loading method setting (loading area information specification end) */
        ypos++;

        slCdLoadFile(cdhn,buf);                          /* file loading */

        while (1) {
/* --------------------------- Get status information --------------------------- */
                slsynch();                               /* execute graphics library */
                ret=slCdGetStatus(cdhn, ndata);          /* get status */
                slPrint("stat:", slLocate(1, ypos));
                slDispHex((Uint32)ref, slLocate(7, ypos));
                ypos++;
                if(ypos>=27)    ypos=3;
                if(ret==CDSTAT_COMPLETED) break;
                if(ndata[0]==CDBUF_FORM1* slsize) {
                   slCdResetBuf(cdhn, & (key[0])):       /* reset loading area */
                }
        }
        while(1);
}
```

Read-ahead function

Because loading data from a CD-ROM entails mechanical operations, the data is not actually loaded at the instant that the loading operation begins. The read-ahead function is designed to minimize the waiting period. The Sega Saturn system has an area where data loaded from the CD-ROM can be temporarily stored. This area is called the “CD buffer.” Once the next file to be loaded is determined, the data is loaded into the CD buffer, from which it is transferred to memory once it is needed.

Fig 12-3 CD Buffer



When NULL is set for loading area address and the loading area size is set to “0” for the function “slCdLoadFile” (described earlier), and the function “slCdGetStatus” return value is “CDSTAT_WAIT”, the read-ahead operation is complete. If the loading area address and size are subsequently set by the function “slCdLoadFile”, the transfer of data begins right away. The loading area address and size can also be set before the read-ahead operation into the CD buffer is complete.

[Sint32 slCdLoadFile (CDHN cdhn, CDBUF buf[]);]

This function specifies the following for reading ahead into the CD buffer.

```
    buf[i].type = CDBUF_COPY;
    buf[i].trans.copy.addr = NULL;
    buf[i].trans.copy.unit = CDBUF_FORM1;
    buf[i].trans.copy.size = 0;
```

After all areas to which data is to be transferred have been specified, specify “CDBUF_TERM” for the last type.

Sample program 3 shows an example of a read-ahead program.

This sample program performs the necessary processing for loading files stored in a CD-ROM, and serves as an example of how to use the basic library functions for loading files from a CD-ROM. The sequence of the processing performed by the program is explained below in accordance with Flow Chart 12-3.

1) Initialize the system (graphics, etc.).
2) Initialize the CD-ROM system.
3) Open the file.

   Because the key information used to classify the data is contained in the input parameters of the function that opens the file, set this information as necessary.
4) Load the file, using the file handle that was returned by the function that opened the file and the information on the loading area as parameters.

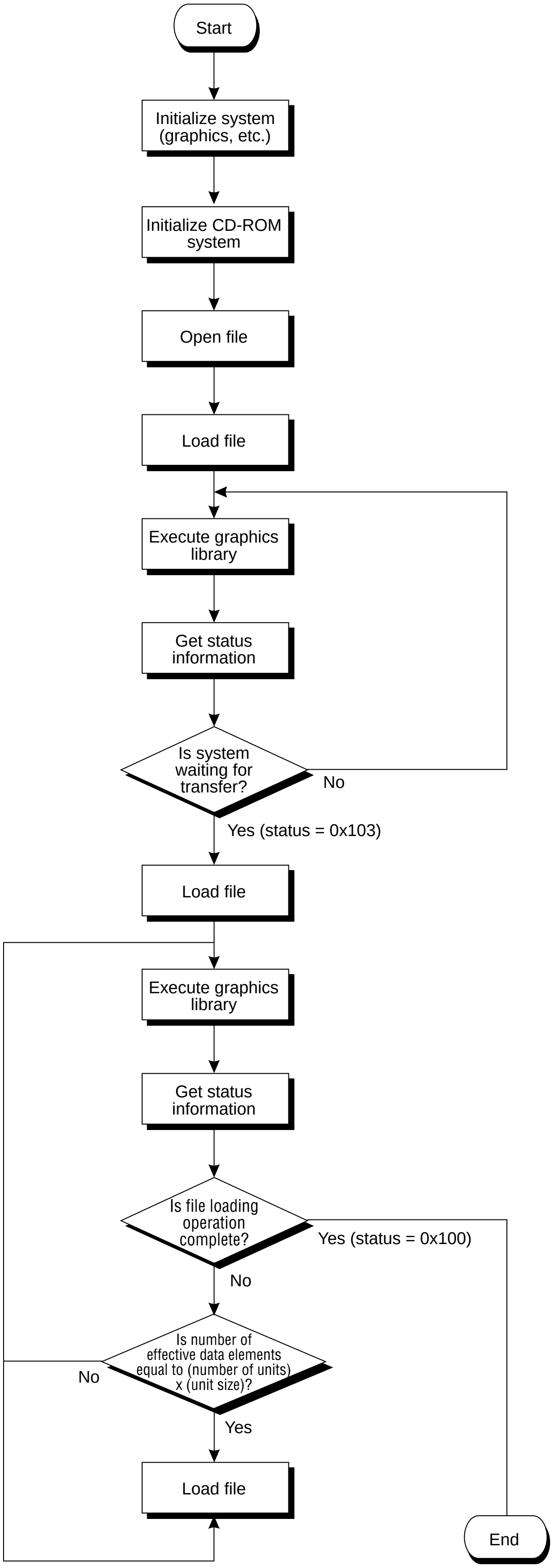
   Set "NULL" for the loading area address and "0" for the size in the loading area information in order to perform the read-ahead operation on the file.
5) Execute the graphics library (function “slSynch()”).
6) Get the status information and confirm whether the system is waiting for transfer. If the system is waiting for transfer, exit the loop.

   This loop is designed so that the function “slSynch()” is called within the loop.
7) Load the file again.

   In this case, set the address for the loading area address in the loading area information and load the file.
8) Execute the graphics library (function “slSynch()”).

   The file that was specified for loading is now actually loaded.
9) Get the status information and confirm whether the file loading operation has been completed or not. If the file loading operation has not been completed, stay in the loop until the loading operation is completed. This loop is designed so that the function “slSynch()” is called within the loop.

Flow Chart 12-3 Sample Program 3 (Read-ahead sample_cd3/main.c)



List 12-3 Sample Program 3 (Read-ahead sample_cd3/main.c)

```
/************************************************************************************
*       CD library Sample program
*
*       Copyright       (c)     1994    SEGA
*
*       Library : CD library
*       Module  : File loading sample 3
*       File    : main.c
*       Date    : 1995-02-20
*       Version : 0.00
*       Auther  : Y.W
*
*       File read-ahead
*
***********************************************************************************/
\************************************************************************************
*       Include files                                                               *
***********************************************************************************/
#include        <stdlib.h>
#include        <sgl.h>
#include        <sgl_cd.h>

\************************************************************************************
*       Definition macro                                                            *
***********************************************************************************/
#define         MAX_OPEN        128             /* number of files that can be open simultaneously */

#define         FNAME           "S2100D0_.M"    /* name of file to be accessed */

#define         slsize          2               /* number of sectors in loading buffer */

\************************************************************************************
*       Variable definition                                                         *
***********************************************************************************/
/* initial processing work area */
Sint32  lib_work[SLCD_WORK_SIZE(MAX_OPEN)/sizeof(Sint32)];

/* file loading buffer */
Sint32  readbuf[(CDBUF_FORM1 *slsize)/sizeof(Sint32)];

\************************************************************************************
*       File loading sample program                                                 *
***********************************************************************************/
Sint32  main()
{
        Sint32  ndir;                                   /*  */
        Sint32  ypos=1;                                 /*  */
        Sint32  ret;                                    /* return code */
        Sint32  ndata[2];                               /* number of valid data elements in loading area */
        CDHN    cdhn;                                   /* file handle */
        CDKEY   key[2];                                 /* key information used to partition data */
        CDBUF   buf[2];                                 /* loading area information */

/* ------------------------ File system initialization ------------------------ */

        SlInitSystem(TV_320x224, NULL, 1);              /* system initialization (graphics, etc.) */
        ndir=slCdInit(MAX_OPEN, lib_work);              /* CD-ROM system initialization */
        slPrint("slCdInit:",slLocate(1,ypos));
        slPrintFX(toFIXED(ndir), slLocate(11,ypos));
        ypos++;

/* --------------------------------- File open --------------------------------- */

        key[0].cn=key[0].sm=key[0].ci=CDKEY_NONE;       /* setting of unselected keys */
        key[1].cn=CDKEY_TERM;                           /* key end setting */
        cdhn=slCdOpen(FNAME,key);                       /* file open */
        slPrint("slCdOpen:", slLocate(1,ypos));
        slDispHex((Uint32)cdhn, slLocate(11,ypos));
```

List 12-3 Sample Program 3 (Read-ahead sample_cd3/main.c) (continued)

```
/* ------------------------- File read-ahead operation -------------------------- */

        buf[0].type=CDBUF_COPY;                         /* loading method setting (copy to work RAM) */
        buf[0].trans.copy.addr=NULL;                    /* loading destination area address setting */
        buf[0].trans.copy.unit=CDBUF_FORM1;             /* loading area unit size setting */
        buf[0].trans.copy.size=0;                       /* loading area unit number setting */
        buf[1].type=CDBUF_TERM;            /* loading method setting (loading area information specification end) */
        slCdLoadFile(cdhn,buf);                         /* file loading */
        ypos++;

        while (1) {
                slsynch();                              /* execute graphics library */
                ret=slCdGetStatus(cdhn, NULL);          /* get status */
                slPrint("stat1:", slLocate(1, ypos));
                slDispHex((Uint32)ret, slLocate(7, ypos));
                ypos++;
                if (ypos>=27)   ypos=3;
                if (ret==CDSTAT_WAIT) {                 /* waiting for transfer? */
                        buf[0].trans.copy.addr=readbuf; /* loading destination area address setting */
                        buf[0].trans.copy.size=slsize;  /* loading area unit number setting */
                        break;
                }
        }
/* -------------------------------- File loading -------------------------------- */
        slCdLoadFile(cdhn,buf);                         /* file loading*/
        while (1) {
                slsynch();                              /* execute graphics library */
                ret=slCdGetStatus(cdhn, ndata);         /* get status */
                slPrint("stat2:", slLocate(1, ypos));
                slDispHex (ret, slLocate(7, ypos));
                ypos++;
                slPrint("ndata:", slLocate (1, ypos));
                slDispHex (ndata(0), slLocate (7, ypos));
                ypos++;
                if (ypos>=27)   ypos=3;
                if(ret == CDSTAT_COMPLETED) break;      /* loading complete? */
                if(ndata[0]== CDBUF_FORM1 *sIsize){
                        slCdLoadFile(cdhn, buf);        /* load file */
                }
        }
        while(1);
}
```

CDDA file playback

To play back a CDDA file, initialize the sound and then use the functions “slCdOpen”, “slCdLoadFile”, and “slCdGetStatus”.

[Sint32 slCdLoadFile (CDHN cdhn, CDBUF buf []);]

Make the following specifications in order to play back a CDDA file.

```
buf[0].type = CDBUF_COPY;
buf[0].trans.copy.addr = NULL;
buf[0].trans.copy.unit = CDBUF_FORM1;
buf[0].trans.copy.size = 0;
buf[1].type = CDBUF_TERM
```

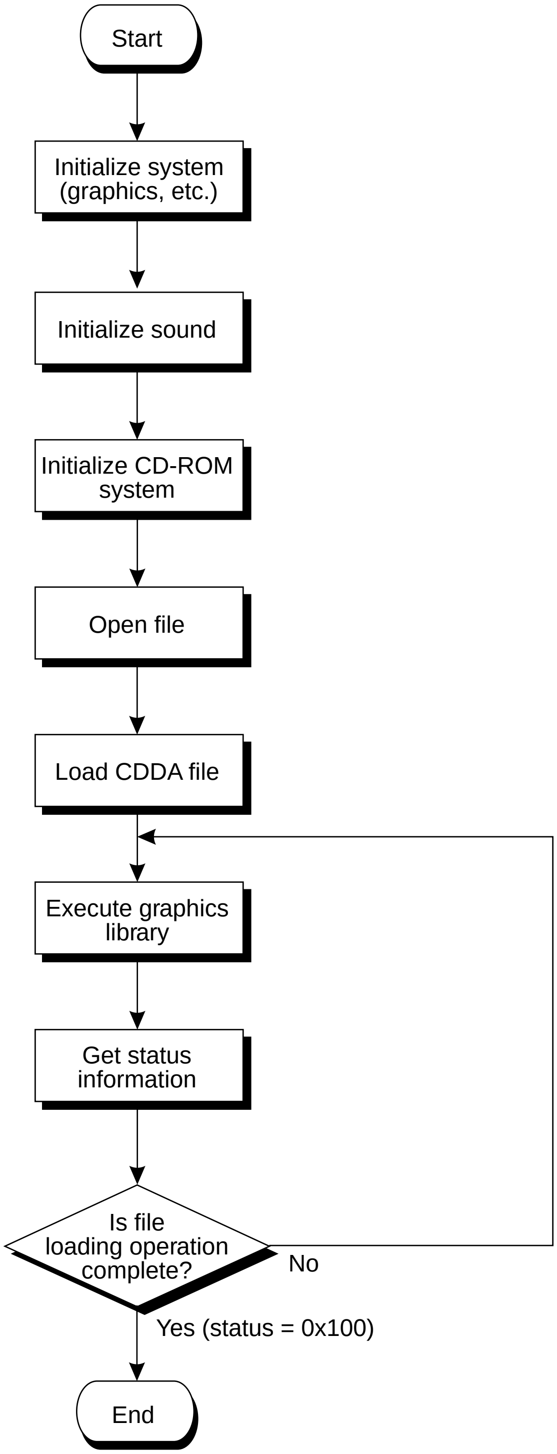
Sample program 4 shows an example of a CDDA file playback program.

This sample program performs the necessary processing for loading CDDA files stored in a CD-ROM, and serves as an example of how to use the basic library functions for playing back CDDA files from a CD-ROM. The sequence of the processing performed by the program is explained below in accordance with Flow Chart 12-4.

1) Initialize the system (graphics, etc.).
2) Initialize the sound.
3) Initialize the CD-ROM system.
4) Open the file.

   Although the key information used to classify the data is contained in the input parameters of the function that opens the file, it is not needed for this program, so do not select the information.
5) Play back the CDDA file, using the file handle that was returned by the function that opened the file and the information on the loading area as parameters.
6) Execute the graphics library (function “slSynch()”).
7) Get the status information and confirm whether CDDA file playback has been completed or not. If playback has been completed, exit the loop. This loop is designed so that the function “slSynch()” is called within the loop.

Flow Chart 12-4 Sample Program 4 (CDDA file playback sample_cd4/main.c)



List 12-4 Sample Program 4 (CDDA file playback sample_cd4/main.c)

```
/************************************************************************************
*       CD library Sample program
*
*       Copyright       (c)     1994    SEGA
*
*       Library : CD library
*       Module  : CDDA playback
*       File    : sample04.c
*       Date    : 1995-02-20
*       Version : 0.00
*       Auther  :
*
*       CDDA file playback
*
************************************************************************************/
/************************************************************************************
*       Include files                                                               *
************************************************************************************/
#include        <stdlib.h>
#include        <sgl.h>
#include        <sgl_cd.h>
#include        "sddrvs.dmp"

/************************************************************************************
*       Variable definition                                                         *
************************************************************************************/

#define MAX_FILE        128
Sint32  dirwork[SLCD_WORK_SIZE(MAX_FILE)/sizeof(Sint32)];

Uint8   sdmap[]={
        0x00, 0x00, 0xB0, 0x00, 0x00, 0x00, 0x80, 0x00,
        0x10, 0x01, 0x30, 0x00, 0x00, 0x00, 0x10, 0x00,
        0x11, 0x01, 0x40, 0x00, 0x00, 0x00, 0x20, 0x00,
        0x20, 0x01, 0x60, 0x00, 0x00, 0x00, 0x06, 0x00,
        0x21, 0x01, 0x68, 0x00, 0x00, 0x00, 0x06, 0x00,
        0x22, 0x01, 0x70, 0x00, 0x00, 0x00, 0x06, 0x00,
        0x23, 0x01, 0x78, 0x00, 0x00, 0x00, 0x06, 0x00,
        0x24, 0x01, 0x80, 0x00, 0x00, 0x00, 0x06, 0x00,
        0x01, 0x01, 0x86, 0x00, 0x00, 0x04, 0x00, 0x00,
        0x30, 0x05, 0xA0, 0x00, 0x00, 0x02, 0x00, 0x00,
        0xFF, 0xFF
};

/************************************************************************************
*       CDDA file sample program                                                    *
************************************************************************************/

void main(void)
{
        Sint32  ndir;
        CDHN    cdhn;
        CDBUF   buf[2];
        CDKEY   key[2];
        CDWIN   win;
        Sint32  stat;

/* ------------------------ File system initialization ------------------------ */
        SlInitSystem(TV_320x224, NULL, 1);
        slInitSound(sddrvstsk, sizeof(sddrvstsk), sdmap, sizeof(sdmap));
        slCDDAOn(127, 127, 0, 0);
        ndir=slCdInit(MAX_FILE, dirwork);
```

List 12-4 Sample Program 4 (CDDA file playback sample_cd4/main.c) (continued)

```
/* --------------------------------- File open ---------------------------------- */
        key[0].cn=CDKEY_NONE;
        key[0].sm=CDKEY_NONE;
        key[0].ci=CDKEY_NONE;
        key[1].cn=CDKEY_TERM;
        cdhn=slCdOpen("cddal",key);

/* ------------------------------- Load CDDA file ------------------------------- */

        buf[0].type=CDBUF_COPY;
        buf[0].trans.copy.addr=NULL;
        buf[0].trans.copy.unit=CDBUF_FORM1;
        buf[0].trans.copy.size=0;
        buf[1].type=CDBUF_TERM;
        slCdLoadFile(cdhn,buf);

        while (1) {
                slSynch();
                stat=slCdGetStatus(cdhn, NULL);
                if (stat==CDSTAT_COMPLETED) break;
        }
        while (1)
        ;
}
```

General Information

Read errors

If a read error occurs during a loading operation, then first the CD block attempts a hardware recovery. If recovery is not possible, the library attempts recovery a certain number of times. If recovery is still not possible, the "get status" function interrupts loading and returns the error code corresponding to the read error.

Bus name

The directory specification is indicated either by "/" or by "+". Furthermore, upper- and lower-case letters can both be used in directory names and file names.

Advanced use of the CD-ROM library

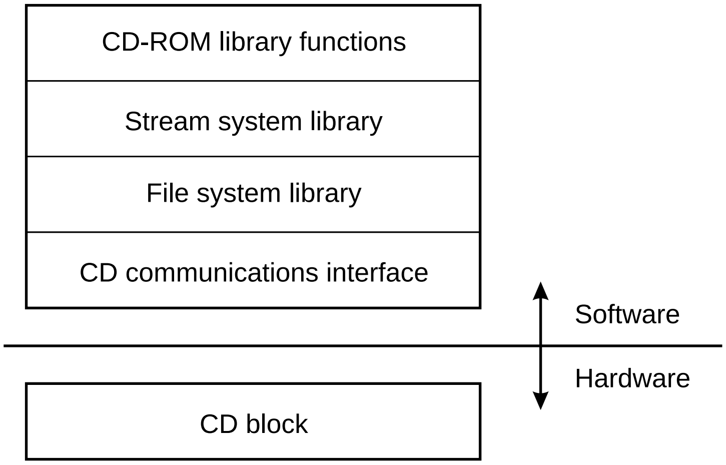
The SGL permits use of both the file system library and the stream system library. When using Cinepak, MPEG, etc., use those functions. For details, refer to the manual provided for each library.

If the function "slCdInit" is called, it is not necessary to initialize the file system and the stream system.

In the SGL, when using the file system or stream system while loading a file, either call the function "slCdPause" and confirm that the status is "CDSTAT_PAUSE", or else call the function "slCdAbort".

Even when loading by the file system or the stream system is completed and you are returning to the SGL, it is necessary to terminate loading operations.

Fig 12-4 Internal Structure of CD-ROM Library



CDHN File handle

Explanation This is the file handle used to load files.

CDKEY Key used to classify sector data

Structure:

```
typedef   struct {
          Sint16 cn;
          Sint16 sm;
          Sint16 ci;
}CDKEY;
```

Members:

cn	Channel number
sm	Submode
ci	Coding information

Explanation: This function uses the subheader to specify the key that classifies sector data.

Remarks: If not selected, specify “CDKEY_NONE.
For the last “cn”, specify “CDKEY_TERM”.

CDBUF Loading area information

Structure:

```
typedef   struct{
          void      *addr;
          Sint32    unit;
          Sint32    size;
}TRANS_COPY;

typedef   struct{
          Sint32    (*func)(void*obj.Uint32*addr, Sint32 adinc, Sint32 nsct);
          void      *obj;
}TRANS_FUNC;

typedef   struct{
          Sint32    type;
          union{
                    TRANS_COPY    copy;
                    TRANS_FUNC    fucn;
          }trans;
}CDBUF;
```

Members:	type	CBBUF_COPY	Copy to work RAM
		CDBUF_FUNC	Transfer function
		CDBUF_TERM	End
	When type = CDBUF_COPY: copy		
	addr	Address of loading area (NULL when not loading)	
	unit	CDBUF_FORM1	Size of loading area is expressed in 2048-byte units
		CDBUF_FORM2	Size of loading area is expressed in 2324-byte units
		CDBUF_BYTE	Size of loading area is expressed in byte units
	size		Number of units in loading area (“0” when not loading)
	When type = CDBUF_FUNC: func		
	func	Transfer function	
	obj	Object	

Explanation: This function specifies the loading area or the transfer function.

Remarks: The loading area size must be a multiple of four bytes.

Sint32 clCdInit (Sint32 nfile, void *work) Initialization

Parameters: nfile Maximum number of files in one directory
work Work area

Function: This function makes the initial settings necessary in order to use the CD.

Return value: Number of files in the root directory. (When negative, the value is an error code.)

Remarks: The area size is determined by “SLCD_WORK_SIZE (nfile).
nfile Maximum number of files in each directory
The work area size must be a multiple of four bytes.

Sint32 clCdChgDir (Sint8 *pathname) Change directory

Parameters:	pathname	Path name (relative path or absolute path may be specified)

Function: This function changes the directory.

Return value: Number of files in the directory. (When negative, the value is an error code.)

CDHN clCdOpen (Sint8 *pathname, CDKEY key[])) Open file

Parameters:	pathname	Path name (relative path or absolute path may be specified)
	key	Key information used to classify the stream data

Function: This function opens a file.

Return value: File handle. ("NULL" if file could not be opened.)

Remarks: When loading is interrupted or completed, the file is closed automatically.

Sint32 slCdLoadFile (CDHN cdhn, CDBUF buf[]) Load file

Parameters:	cdhn	File handle
	buf	Loading area information (corresponds to key when open)

Function: This function starts playback and loads data from the CD.

Return value: Error code.

Remarks: If "NULL" is specified for the loading area and "0" is specified for the units, the "read-ahead" function is executed. If a loading area is specified, cpu DMA is used to transfer the data.

Sint32 slCdTrans (CDHN cdhn, CDBUF buf[], Sint32 ndata[]) Stream transfer

Parameters:	cdhn	File handle
	buf	Loading area information (corresponds to key when open)
	ndata	Number of valid data elements in transfer area ("NULL" when not needed)

Function: This function performs only data transfers while file loading is paused.

Return value: Error code.

Remarks: It is possible to transfer only to a key for which "NULL" was specified for the transfer area in "slCdLoadfile()". This function does not terminate until the transfer is completed.

Bool slCdResetBuf (CDHN cdhn, CDKEY *key) Reset transfer area

Parameters:	cdhn	File handle
	key	Key information used to classify data

Function: This function initializes the destination pointer.

Return values:	TRUE	Normal end
	FALSE	A key which has not been opened was specified.

Sint32 slCdAbort (CDHN cdhn) Interrupt loading

Parameters: cdhn File handle

Function: This function interrupts file loading.

Return value: Error code.

Sint32 slCdPause (CDHN cdhn)Pause loading

Parameters: cdhn File handle

Function: This function pauses file loading.

Return value: Error code.

Sint32 slCdGetStatus (CDHN cdhn, Sint32 ndata[])Get status

Parameters: cdhn File handle

However, by specifying the following constants, it is possible to get status information on the CD block:

CDREQ_FREE	Get number of free sectors in the CD block
CDREQ_FAD	Current pickup position
CDREQ_DRV	CD drive status

ndata Number of valid data elements, if a file handle is specified (“NULL” if not needed)

Function: This function gets status information in response to the request that was issued.

Return values: Status when a file handle was specified (When negative, the value is an error code.)

CDSTAT_PAUSE	Loading paused
CDSTAT_DOING	Loading in progress
CDSTAT_WAIT	Waiting for transfer
CDSTAT_COMPLETED	Loading completed

When CDREQ_FREE was specified: number of free sectors in CD block

When CDREQ_FAD was specified: pickup position

When CDREQ_DRV was specified: CD drive status

CDDRV_BUSY	Status in transition
CDDRV_PAUSE	Paused
CDDRV_STDBY	Standby
CDDRV_PLAY	CD playback in progress
CDDRV_SEEK	Seek in progress
CDDRV_SCAN	Scan playback in progress
CDDRV_OPEN	Tray open
CDDRV_NODISC	No disc loaded
CDDRV_RETRY	Read retry processing in progress
CDDRV_ERROR	Read error occurred
CDDRV_FATAL	Fatal error occurred

Error Codes

Table 12-1 Error Codes

Constant name	Meaning	Constant value
CDERR_OK	Normal end	(0)
CDERR_RDERR	Read error	(-1)
CDERR_NODISC	Disc not loaded	(-2)
CDERR_CDROM	Disc not a CD-ROM	(-3)
CDERR_IPARA	Illegal initialization parameter	(-4)
CDERR_DIR	Change attempted to structure that was not a directory	(-6)
CDERR_NEXIST	File not found	(-9)
CDERR_NUM	Negative byte count	(-14)
CDERR_PUINUSE	Pickup in operation	(-20)
CDERR_ALIGN	Work area not a multiple of four bytes	(-21)
CDERR_TMOUT	Timeout	(-22)
CDERR_OPEN	Tray open	(-23)
CDERR_FATAL	CD drive status: “FATAL”	(-25)
CDERR_BUSY	Status in transition	(-50)

13

Programmer's Tutorial

Backup Library

The Sega Saturn system has a 32K internal buffer memory. This chapter explains the backup library provided in order to use this internal buffer memory.

The backup library itself is compressed and stored in the Sega Saturn boot ROM.

This backup library can be used to transfer data between buffer memory and external cartridges.

Features of the Backup Library

Devices

Supported devices

The backup library can access devices (currently limited to the internal backup memory and external cartridges) with a non-hierarchical file format. (Table 13-1.) Furthermore, these devices are partitioned as shown in Fig. 13-1.

Device connection information (Config)

The connection (Config) information of each device can be gotten during the initialization processing of the backup library.

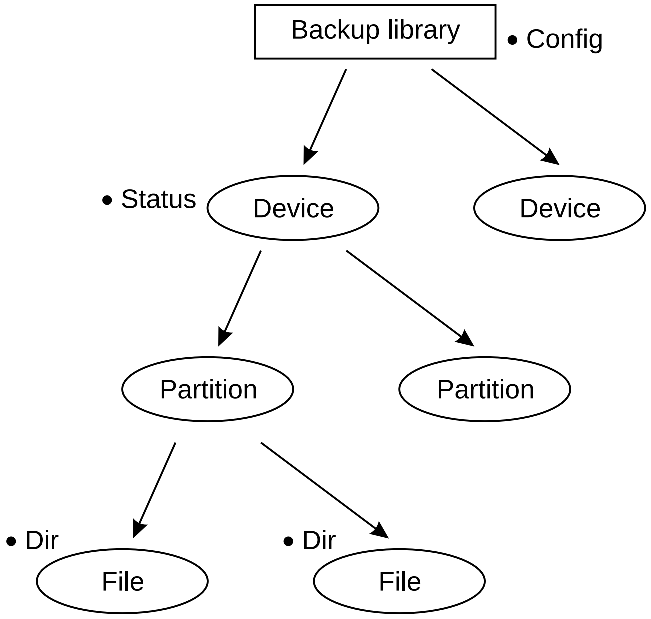
Information on each device (Status: connected/not connected, formatted/ unformatted, etc.)

Status information can be gotten by using a backup library function. In addition, it is possible to specify the size of a file that you want to write and determine whether or not it is possible to write a file of that size.

Table 13-1 Device List

Device Number	Device type
0	Internal memory cartridge
1	Memory cartridge or parallel interface

Fig 13-1 Device Configuration



Files

Information on each file (Dir: name, creation date, etc.) can be gotten by using a backup library function.

When a file is created, the file information is set as desired by the user; the backup library itself does not create the file information.

Library expansion

The backup library is stored in compressed form within the Sega Saturn Boot ROM. When the user uses the backup library, it allocates a program expansion area and work area and then performs initialization processing. All of the functions can be used as desired thereafter.

> **Note: If backup library processing is interrupted while data is being written, the data is destroyed. Therefore, whenever you are performing backup library initialization, formatting, writing, or deletion processing, use the system library function "slResetDisable()" (peripheral function) to disable the reset button.**

Basic Flow of Processing

The backup library functions are explained below in accordance with the basic flow of processing.

1) Initialization [BUP_Init()]

This function reads the backup library from the boot ROM and expands it in the specified address space. The device information at that time is returned.

2) Select partition (BUP_SelPart()]

This function specifies the device partition to be used. The default partition is No. 0 (internal memory cartridge).

3) Get status [BUP_Stat()]

This function gets the status of the device to be written/read. When writing, specify the number of bytes of data to be written; the return value will indicate whether that much data can be written to the device or not.

4) Format (BUP_Format()]

After getting the status, if it is discovered that the device to be used is unformatted, it is necessary to first format the device. Formatting is limited to the specified partition in the specified device.

5) Get directory information [BUP_Dir()]

This function gets the directory information for the specified file name (or for all files). If the directory information for all files is desired, specify "NULL" for the file name.

6) Write data [BUP_Write()]

This function writes a file to the specified device. The necessary file information must be created by the user.

7) Verify data [BUP_Verify()]

This function verifies a file written to the specified device.

8) Read data [BUP_Read()]

This function reads a file written on a specified device.

9) Delete data [BUP_Delete()]

This function deletes a file from the specified device.

10) Expand date data [BUP_GetDate()]

This function expands the date data stored in the compressed file information.

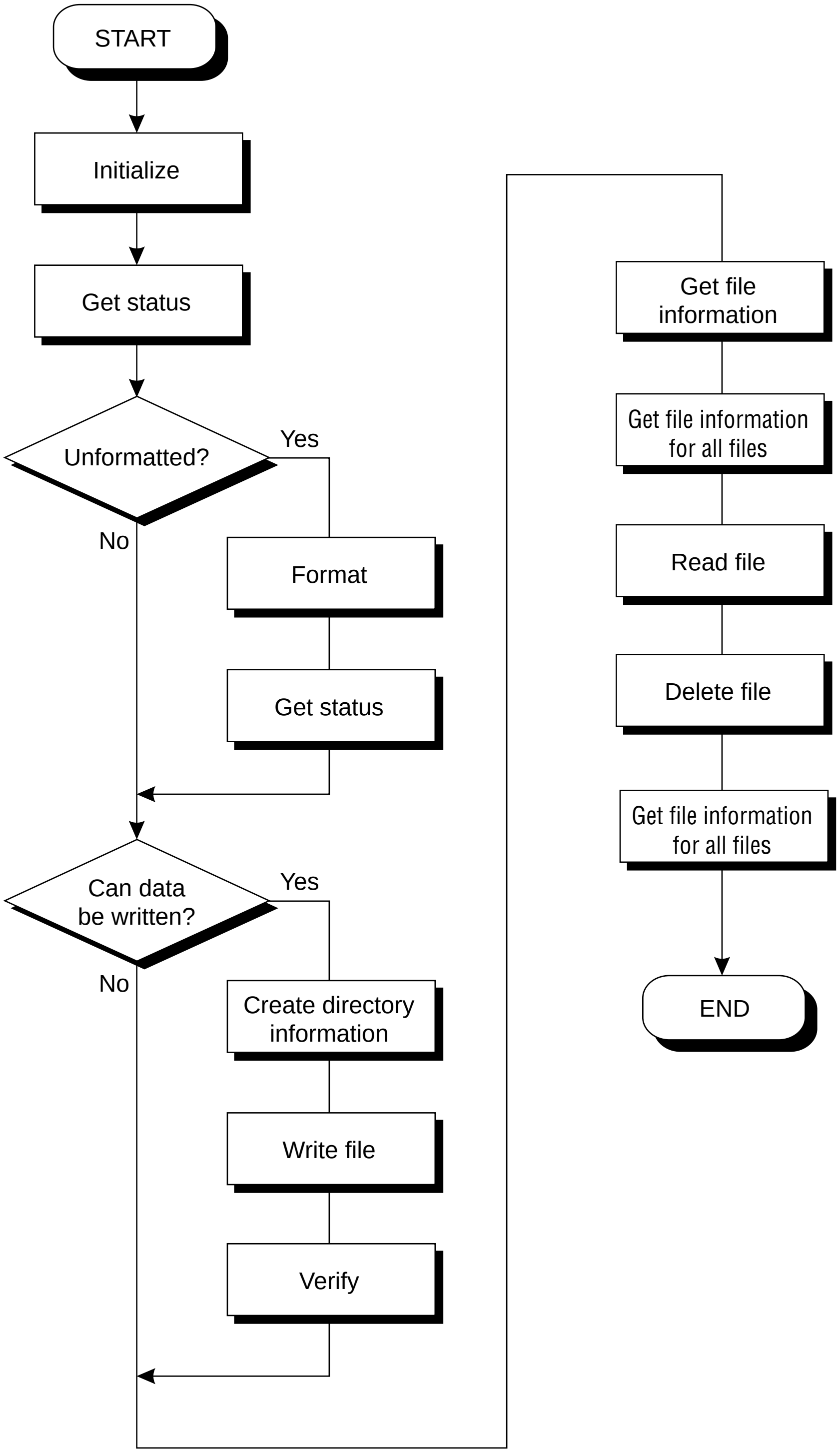
11) Compress date data (BUP_GetDate()]

This function compresses and stores the date data in the file information.

Sample Program

The following flow chart shows the flow of operations in the sample program that uses the backup library.

Flow Chart 13-1 Backup Library Sample Program



List 13-1 is the program listing for the sample program.

List 13-1 Sample Program

```
#include        "sgl.h"
#include        "sega_per.h"
#define                 BUP_STAT_ADDR   0x6070000                       /* specification of address where library is to be expanded */
#include        "sega_bup.h"

#define FILE_NAME"FILE_NAME01"
#define BACKUP_DEVICE(Uint32)0                                          /* use internal memory */
#define TEST_DATA"It's a pen"
#define TEST_SIZE 10
#define DIR_SIZE  8

/****************************************

Backup RAM sample program

*****************************************/

/**************************************
* Library initialization processing *
***************************************/
void    BackUplnit(BupConfig cntb|3|)
{
Uint32  BackUpRamWork|2048|;

        slResetDisable();                                               /* reset button disabled */
        BUP_Init((Uint32*)BUP_STAT_ADDR.BackUpRamWork.cntb):
        slResetEnable();                                                /* reset button enabled */
}

/*************************
* Write processing *
**************************/
Sint32  BackUpWrite(Uint32 device, BupDir*dir, Uint8 *data, Uint8 sw)
{
        Sint32  ret;
        SmpcDateTime    *time;
        BupDate date;

        if(!dir->date){                                                 /* if date data is "0", input current date */
        time=&(Smpc_Status->rtc);                                       /* get date data */
        date.year=(Uint8)(slDec2Hex(time->year)-1980);
        date.month=(Uint8)(time->month&0x0f);
        date.week=(Uint8)(time->month>>4);
        date.day=(Uint8)(time->date);
        date.time=(Uint8)(time->hour);
        date.min=(Uint8)(time->minute);
        dir->date=BUP_SetDate(&date);
        }
        slResetDisable();                                               /* reset button disabled */
        ret=BUP_Write(device,dir,data,sw);
        slResetEnable();                                                /* reset button enabled */

        return(ret);
}

/**************************/
/* Deletion processing */
/**************************/
Sint32  BackUpDelete(Uint32 device,Uint8 *filename)
{
        Sint32 ret;

        slResetDisable();                                               /* reset button disabled */
        ret=BUP_Delete(device,filename);
        slResetEnable();                                                /* reset button enabled */

        return(ret);
}
```

Listing 13-1 Sample Program (continued)

```
/**************************/
/* Format processing */
/**************************/
Sint32  BackUpFormat(Uint32 device)
{
        Sint32 ret;

        slResetDisable();                                       /* reset button disabled */
        ret = BUP_Delete(device);
        slResetEnable();                                        /* reset button enabled */

        return(ret);
}

void    main()
{
        BupConfig       conf[3];
        BupStat         sttb;
        BupDir          dir,dirs[DIR_SIZE];
        BupDate         datetb,date;
        Uint8 *time;
        Sint32 status;
        Uint8 buf[256];
        int             i;
        slInitSystem(TV_352x224,(TEXTURE*)NULL.1);

        slGetStatus();
        for(i=0;i<100;i++)                                      /* get time */
        {
                slSynch();
        }
                                                                /* initialization processing */
        BackUpInit(conf);

        if(( status=BUP_Stat(BACKUP_DEVICE.10.&sttb))==BUP_UNFORMAT )   /* get status */
        {
        status=BackUpFormat(BACKUP_DEVICE);                     /* format */
        BUP_Stat(BACKUP_DEVICE.TEST_SIZE,&sttb);
        }

        if( sttb.freeblock>0)
        {
        stmcpy(dir.filename. FILE_NAME,11);
        stmcpy(dir.comment. "Test.desu".10);
        dir.language=BUP_ENGLISH;
        dir.datasize=TEST_SIZE;
        dir.date = 0;
        status=BackUpWrite(BACKUP_DEVICE.&dir.(Uint8*)TEST_DATA.OFF);   /* write */
        status=BUP_Verify(BACKUP_DEVICE.(Uint8*)FILE_NAME.(Uint8*)TEST_DATA):   /* verify */
        }

        status=BUP_Dir(BACKUP_DEVICE.(Uint8*)FILE_NAME DIR_SIZE.dirs):  /* directory information */
        status=BUP_Dir(BACKUP_DEVICE.(Uint8*)"".DIR_SIZE.dirs): /* all directory information */
        status=BUP_Read(BACKUP_DEVICE.(Uint8*)FILE_NAME.buf):   /* read */
        status=BackUpDelete(BACKUP_DEVICE.(Uint8*)FILE_NAME):   /* delete */
        status=BUP_Dir(BACKUP_DEVICE.(Uint8*)"",DIR_SIZE.dirs): /* all directory information */
}
```

Supplement. Backup Library functions

Table 13-2 lists the functions used in the backup library.

For details on the functions, refer to the PROGRAMMER'S GUIDE, vol. 1.

Table 13-2 Backup Library Functions

Number	Function Name	Function
1	BUP_Init	Initializes backup library
2	BUP_SelPart	Selects partition
3	BUP_Format	Executes formatting operation
4	BUP_Stat	Gets status
5	BUP_Write	Writes data
6	BUP_Read	Reads data
7	BUP_Delete	Deletes data
8	BUP_Dir	Gets directory information
9	BUP_Verify	Verifies data
10	BUP_GetDate	Expands date data
11	BUP_SetDate	Compresses date data

14

Programmer’s Tutorial

Sound Library

This chapter describes the procedures and cautions relevant to outputting sound on the Sega Saturn system using the sound control library.

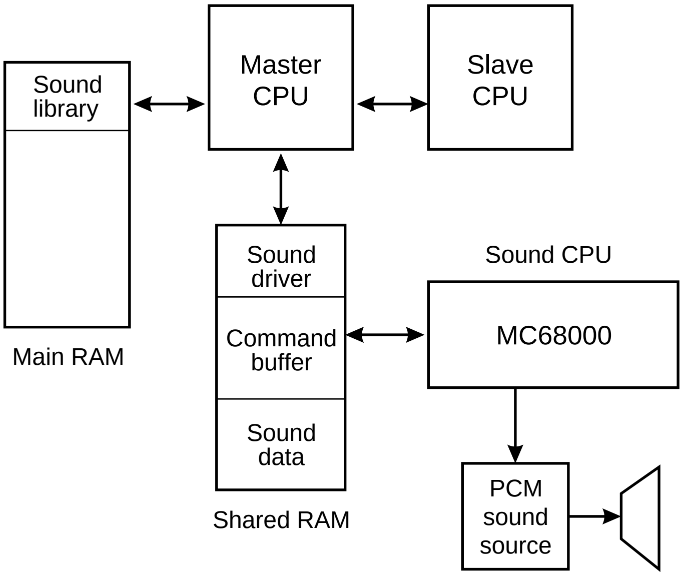
Sound Control Overview

The Sega Saturn system is equipped with an MC68000 as a sound control CPU that is capable of operating independently of the master CPU.

The master CPU and the sound CPU exchange functions through a portion of RAM called the “command buffer.” Because the functions are issued by the sound control library, sound is controlled without the user being aware of the interactions between the CPUs.

The sound sources that can be used with the Sega Saturn system are PCM and CDs; the sound driver controls PCM sound sources.

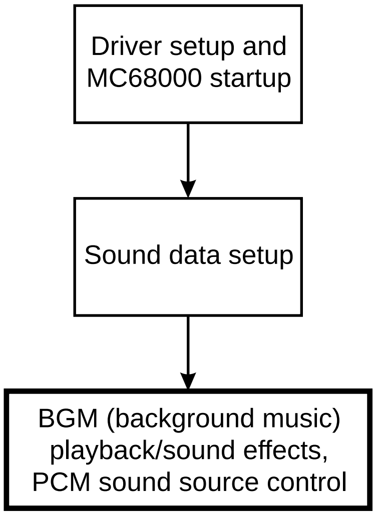
Fig 14-1 Sound Driver System Configuration



Sound Driver Setup

The following procedure is required in order to use the sound driver to control sound in the Sega Saturn system.

Fig 14-2 Sound Control Procedure


Driver setup and MC68000 startup
Sound data setup
BGM (background music) playback/sound effects, PCM sound source control

Sound driver setup and MC68000 startup

In order to use sound, it is first essential to start up the MC68000 that is used to control sound. The driver program that runs on the MC68000 is also needed. This program can be set up by executing the library function “slInitSound()”.

[void slInitSound (void *drv, Uint32 drvsz, void *map, Uint32 mapsz);]

This function sets up the sound driver and initializes the sound CPU (MC68000). “drv” is the sound driver program that runs on the MC68000, and is loaded into the area starting from address 0 in the MC68000. “drvsz” is the size of the driver program.

Normally, this function is specified as follows:

```
slInitSound (drv, sizeof(drv), maptbl, sizeof(maptbl));
```

The “slInitSound” function executes the following sequence of operations:

1) Reset MC68000.
2) Clear with zeroes the memory area up to address 0xB000 in the MC68000.
3) Transfer the driver program (size starting from address 0).
4) Transfer map data (size starting from address 0xA000).
5) Register memory area for PCM playback.
6) Start up MC68000.
7) Register map data.

Sound data setup

Because executing only the “slInitSound” function described above does not set up the playback data, it is necessary to do so now. The playback data is stored starting from address 0xB000 in the MC68000 memory area (0x25A0B000 in the program). (These addresses may vary, depending on the map data; consult with the sound designer.) Use the following function to transfer the data:

Fig 14-3 Sound Data Setup Example

```
slDMACopy(sounnad,(voied*)0x25a0b000,sizeof(sounddat));
slDMAWait();
```

Preparations for playback are now complete.

Background music playback

Music (and sound effects) are handled in units called “sequences.” A sequence is the playback of a series of sound combinations from start to finish (and can either be an entire song or a single sound effect). With the Sega Saturn sound driver, up to eight sequences can be played back simultaneously. In the SGL, of these eight sequences, No. 0 is allocated for background music. To play background music, execute the function “slBGMOn()”.

[Bool slBGMOn (Uint16 Song, Uint8 Prio, Uint8 Volume, Uint8 Rate);]

This function starts background music playback.

Song:	Song (sound effect) number
Prio:	Priority for using the sound source
Volume:	Volume
Rate:	Time until the volume is reached

“Prio” is the priority for using the sound source. Because the 32-channel sound source is shared by multiple sequences for sound output, if the total number of channels being sued exceeds 32, sounds with the lowest priority numbers are not allocated channels.

The volume (“Volume”) can be set from 0 to 127, with a higher value representing a louder volume. The rate (“Rate”) is the time taken to reach that volume, and can be specified with a value from 0 to 255. Specifying “0” means that the volume is reached immediately, while a value from 1 to 255 causes the volume to fade in from the 0 level to the specified level.

The following functions can be used to change the tempo and volume of the background music and to stop, pause, and resume playback.

```
slBGMTempo (Sint16, Tempo) /* change tempo */
slBGMFade (Uint8 Volume, Uint8 Rate); /* change volume */
slBGMOff(); /* stop playback */
slBGMPause(); /* pause playback */
slBGMCont(); /* resume playback */
slBGMStat(); /* check to determine if playback is in progress */
```

Sound effect output

Just as with background music, sound effects are also managed as sequences. To output a sound effect, execute the function “slSequenceOn()”.

[Uint8 slSequenceOn (Uint 16 Song, Uint8 Prio, Uint8 Volume, Uint8 Pan);]

Song:	Song (sound effect) number
Prio:	Priority for using the sound source
Volume:	Volume
Pan:	Left-right balance of volume

The parameters resemble those for the BGM function, except for the parameter “Pan”. This parameter represents the left-right balance of the volume, and can be used to give a sound directionality. A value ranging from -128 to +127 can be specified for “Pan”, with -128 representing the left, 0 representing the middle, and +127 representing the right.

Substitution values for the parameter “Pan”:
Left: -128 << 0 >> +127: Right

By using the “Volume” and “Pan” settings, sound can be used to create illusions of distance and directionality in games.

The function “slSequenceOn()” returns the sound control number that the specified sound effect is being output under. This sound control number can be used to alter the corresponding sound effect with the following functions:

```
slSequenceTempo (Uint8 Seqnm, Sint16 Tempo); /* change tempo */
slSequenceFade (Uint8 Seqnm, Uint16 Volume, Uint8 Rate); /* change volume */
slSequencePan (Uint8 Seqnm, Uint8 Pan); /* change directionality */
slSequenceOff (Uint8 Seqnm); /* stop sequence */
slSequencePause (Uint8 Seqnm); /* pause sequence */
slSequenceCont (Uint8 Seqnm); /* resume paused sequence */
slSequenceStat (Uint8 Seqnm); /* check to determine if sequence is being played back */
```

Outputting sound effects using the PCM sound source

The PCM sound source can be used when outputting sound effects created by audio sampling (voices, explosions, etc.). Unlike the sequences described above, sound effect playback via PCM stream can be output on a maximum of four channels. When using the PCM stream, execute the function “slPCMOn()”.

[Sint8 slPCMOn (PCM *pdat, void *data, Uint32 size);]

This function starts playback using the PCM sound source.

pdat:	PCM-type structure data for PCM stream playback mode, etc.
data:	PCM stream sound source data
size:	PCM stream data size

The organization of the PCM-type structure data is shown below; this data is used to specify the PCM stream playback parameters.

Fig 14-4 PCM-type Structure Data

```
typedef struct{
        Uint8 mode;             /* Mode */
        Uint8 channel;          /* PCM Channel Number */
        Uint8 level;            /* 0¯ 127 */
        Sint8 pan;              /* -128¯ +127 */
        Uint16pitch;
        Uint8 eflevelR;         /* Effect level for Right(mono) 0- 7 */
        Uint8 efselectR;        /* Effect select for Right(mono) 0- 15*/
        Unit8 eflevelL;         /* Effect level for Left 0¯ 7 */
        Uint8 efselectL;        /* Effect select for Left 0¯ 15 */
        }PCM;
```

mode:	Specify "_Stereo" or "_Mono" and "_PCM16Bit" or "_PCM8Bit".
channel:	PCM playback channel (set by this function)
level:	Volume
pan:	Left-right balance of volume
pitch:	Playback rate (changes pitch)
eflevelR:	Extent of applied effect (right channel)
efselectR:	Effect number (right channel)
eflevelL:	Extent of applied effect (left channel)
efselectL:	Effect number (left channel)

Because PCM streams are played back as the master CPU sets the data that is used by the sound SCSP LSI, unlike the sequences described earlier, the load on the master CPU increases.

Consult with the sound designer in order to determine whether sound is to be output using the sequences described earlier or by using PCM streams. The function “slPCMOn()” returns the control number that the specified PCM stream is being output under.

Other functions that are used for PCM stream sound effect playback are listed below.

```
slPCMOff (PCM *pdat); /* stop playback */
slPCMParmChange (PCM *pdat); /* change parameter */
slPCMStat (PCM *pdat); /* check to determine if playback is in progress on specified PCM channel */
```

Functions that affect sound output as a whole

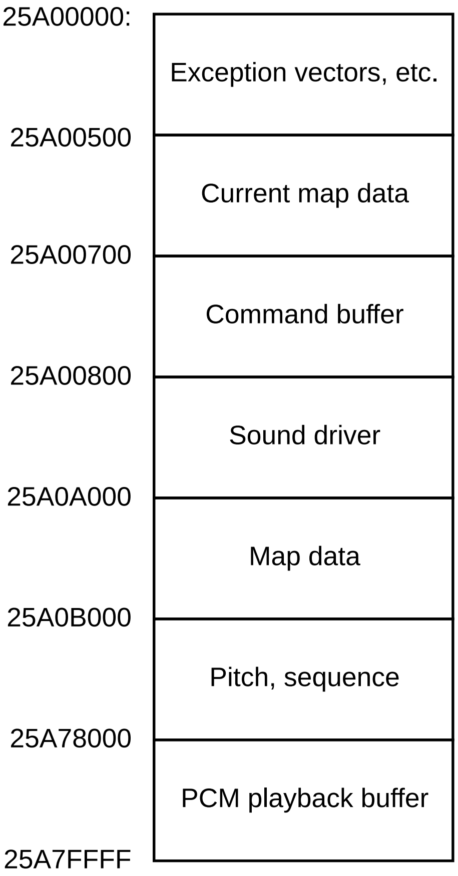
The functions described up to this point affect individual sound outputs; the following functions affect sound output as a whole.

```
slSndVolume (Uint8 Volume); /* overall volume */
slSoundAllOff(); /* stop all sound sequences */
slDSPOff(); /* stop effect DSP */
slSndMixChange (Uint8 Tbank, Uint8 Mixno); /* switch mixer */
slSndMixParmChange (Uint8 Effect, Uint8 Level, Uint8 Pan);
                                                        /* change mixer parameters */
```

Memory Map

The figure below shows a general memory map for the sound CPU. If PCM streams are not used, the PCM playback buffer can be used for sequence data since it is not needed for PCM streams.

Fig 14-5 Sound CPU Memory Map



Sample Program

Sample program for playback test of background music and sound effects

The following sample program is designed for a playback test of background music and sound effects. The organization of the data file used for this sample program is shown below.

Fig 14-6 Sample Program Data File

Bank	Song	Contents
0	0	Song (no loop)
	1	Song (with loop)
1	0	Sound effect (C3)
	1	Sound effect (D3)
	2	Sound effect (E3)
	3	Sound effect (F3)
	4	Sound effect (G3)
	5	Sound effect (A3)
	6	Sound effect (B3)
	7	Sound effect (C4)
2	0	Cheer
3	0	Long violin sound
	1	Short violin sound (loop)

The songs specified by “bank” and “song” are played back as background music when the X button is pressed, and as a sound effect when the A button is pressed. The “bank” and “song” specifications are made using the Start key and the direction key.

The Y and B buttons are used to pause and resume each of the background music and sound effects, and the Z and C buttons are used to fade in and out.

The sound effect sequence number specification is made by using the using the direction key in the left/right direction, and the overall volume is set by using the direction key in the up/down direction.

List 14-1 sampsnd1: Background Music and Sound Effect Playback Test

```
- sampsnd1 -
/*                              */
/* Sound control sample         */
/*                              */

#include "sl_def.h"                                                /* include files containing various settings */
#include "sddrvs.dat"                                              /* sound driver file */

/*----------------------------------------------*/

#define SoundSeqBuf     0x25a06000                                 /* sequence buffer address */

extern char sound_map[];
extern char sound_dat[];
extern Uint32 mapsize;
extern Uint32 datasize;
extern PDATA PD_Cube;

/*----------------------------------------------*/
```

List 14-1 sampsnd1: Background Music and Sound Effect Playback Test (continued)

```
#define _Play   0x01                                        /* status mode define */
#define _Pause  0x02
#define _Fade   0x04

typedef struct{
        struct{
        Sint8   stat;
        Sint16  tmp;
        sint8   pan;
        }seq|8|;
        Uint8 banknum ;
        Uint8 songnum ;
        Uint8 sequence ;
}SOUND_MAN;

/*----------------------------------------*/

void init_sound(){
        slInitSound(sddrvstsk, sizeof(sddrvstsk),(Uint8*)sound_map, mapsize);   /* driver/map transfer */
        slDMACopy(sound_dat,(void*)(SoundSeqBuf),datsize);      /* transfer sound data to sequence buffer */
}

void disp_vol(Uint16 vol){                                  /* set/display volume */
        slSndVolume(vol<<3);
        slPrint("Volume:",slLocate(2.6)):
        slPrintHex(vol, slLocate(11.6));
}

sound_test(EVENT*evptr){
        SOUND_MAN       *smptr;
        PerDigital      *pptr;
        Sint16  padd;
        Sint16  padp;

        int i :

        const Uint8 bank = 3 ;                              /* number of banks included in "sampdat.c" */
        const Uint8 song{}={1,7,0,1};                       /* number of songs in each bank */

        smptr=(SOUND_MAN*)evptr->user;
        pptr=Smpc_Peripheral;
        padd="pptr->data;
        padp="pptr->push;
```

List 14-1 sampsnd1: Background Music and Sound Effect Playback Test (continued)

```
for (i = 7: i>=();i--){
        if(smptr->seq|i|stat &&!(slSequenceStat(i))){          /* check for end of sequence playback */
        smptr->seq|i|stat=();                                   /* if playback is complete, clear status flag to "0" */
}
switch(smptr->seq{i}.stat)(                                     /* display message according to status flag */
        case0:slPrint("     ", slLocate(33.3+i));break ;
        case1:slPrint("Play ", slLocate(33.3+i));break ;
        case3:slPrint("Pause ", slLocate(33.3+i));break ;
        case5:slPrint("Fade Out", slLocate(33.3+i));break;
        case7:slPrint("Pause ", slLocate(33.3+i));break;
{
}

if(padd & PER_DGT_ST){                                          /* direction key input while Start button is pressed */
if(padd & PER_DGT_KU){
        if(++smptr->banknum>bank)smptr->banknum=0;
        if(smptr->songnum>song|smptr->banknum|)smptr->songnum=song|sinptr->banknum|:
}else if(padp & PER_DGT_KD){
        if(--smptr->banknum > bank) smptr->banknum = bank;
        if(smptr->songnum>song|smptr->banknum|)smptr->songnum=song|smptr->banknum|;
}
if(padp & PER_DGT_KR){
        if(++smptr->songnum > song|smptr->banknum|)smptr->songnum = ();
}else if(padp & PER_DGT_KL){
        if(--smptr->songnum>song|smptr->banknum|)smptr->songnum=song|smptr->banknum|;
}
}else{                                                          /* direction key input while Start button is not pressed */
if(padp & PER_DGT_KU){
        if(smptr->vol <15){
        disp_vol(++smptr->vol);
        }
} else if(padp & PER_DGT_KD){
        if(smptr->vol >()){
        disp_vol(++smptr->vol);
        }
{
if(pade & PER_DGT_KR){
        if(++smptr->sequence> 7)smptr->sequence=1;
} else if(pade & PER_DGT_KL){
        if(--smptr->sequence< 1)smptr->sequence=7;
}
}
slPrintHex(slHex2Dec(smptr->banknum), slLocate(7.10)):          /* Bank/song/sequence display */
slPrint("Bank :",slLocate(2.10));
slPrintHex(slHex2Dec(smptr->songnum), slLocate(7.11)):
```

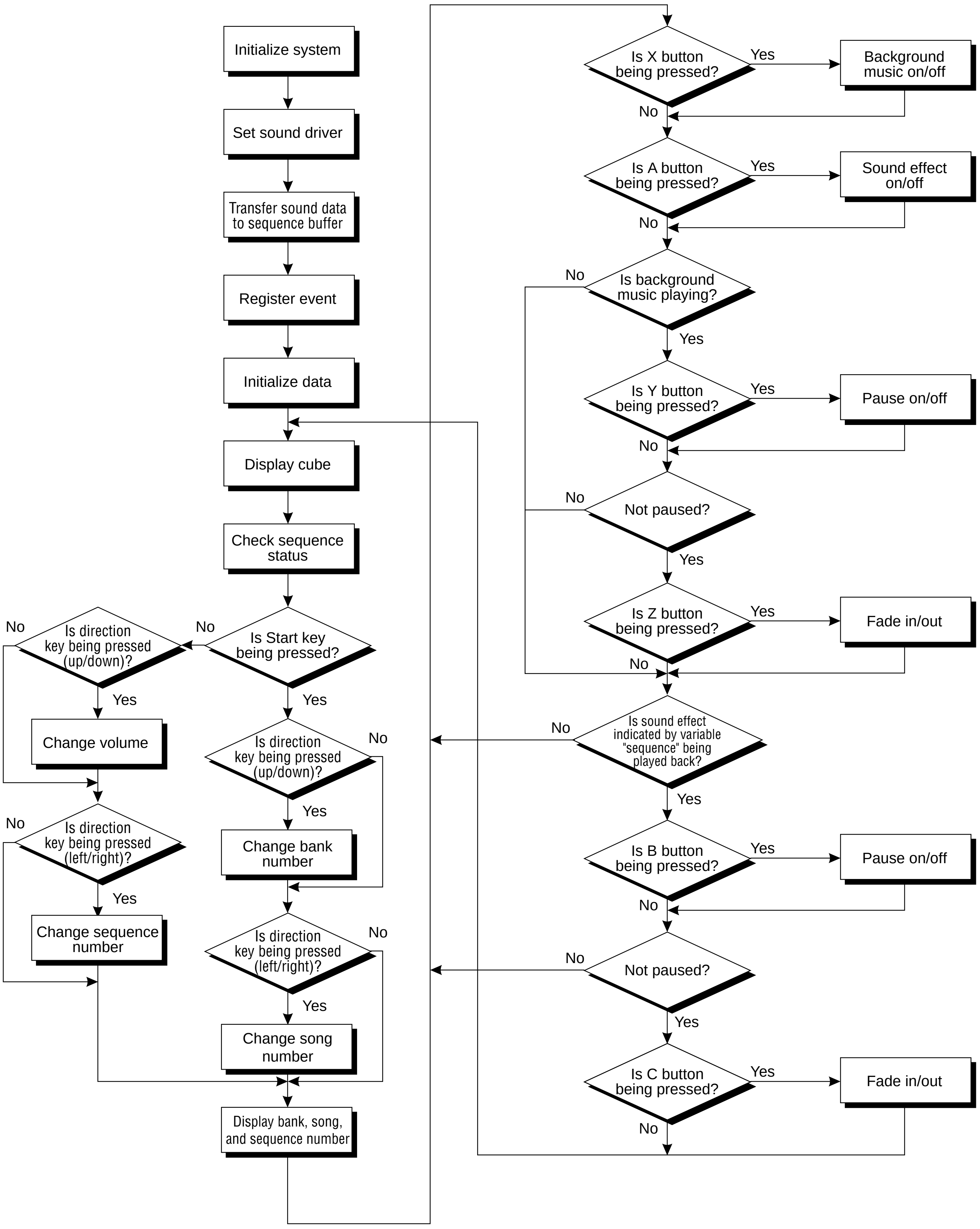
List 14-1 sampsnd1: Background Music and Sound Effect Playback Test (continued)

```
slPrint("Song  :", slLocate(2.11)):
slPrintHex(slHex2Dec(smptr->sequence), slLocate(7.12)):
slPrint("Sequence:", slLocate(2.12)):

if(padp & PER_DGT_TX){                                          /* X button input */
if(smptr->seq|()|.stat=&_Play){                                 /* background music on/off */
        slBGMOff():
        smptr->seq|0|.stat=0;
}else {
        slBGMOn(smptr->banknum<<8)+smptr->songnum,(0,127.0)
        smptr->seq|0|.stat:=_Play ;
}
}
if(pade & PER_DGT_TA){                                          /* A button input */
if(smptr->seq|smptr->sequence|.stat *_Play){                    /* sound effect on/off */
        slSequenceOff(smptr->sequence);
        smptr->seq|smptr->sequence|.stat=0;
}else {
        smptr->seq|slSequenceOn(smptr->banknum<<8)+smptr->songnum.0.1270)|.stat:=_Play :
}
}
if(smptr->seq|0|.stat &_Play){                                  /* background music is playing... */
if(pade & PER_DGT_TY){                                          /* Y button input */
        if(smptr->seq|0}.stat &_Pause){                         /* pause on/off */
        slBGMCont();
        smptr->seq|0|.stat & ="(_Pause);
} else {
        slBGMPause();
        smptr->seq|0|.stat:=_Pause;
}
}
if(!(smptr->seq|0|.stat &_Pause)){                              /* if not paused... */
        if(pade & PER_DGT_TZ){                                  /* Z button input */
        if(smptr->seq|0|.stat &_Fade){                          /* fade in/out */
        smptr->seq|0|.stat &="(_Fade);
        slBGMFade(127.25);                                      /* Fade In */
        } else {
        smptr->seq|0|.stat :=Fade ;
        slBGFade(1.25);                                         /* Fade Out */
        }
        }
}
}
if(smptr->seq|smptr->sequence|.stat &_Play){                    /* if sound effect of specified sequence is not being played... */
if(padp & PER_DGT_TB){                                          /* B button input */
        if(smptr->seq|smptr->sequence|.stat &_Pause){           /* pause on/off */
        if(smptr->seq|0|.stat &_Pause){

                slSequenceCont(smptr->sequence);\
                smptr->seq|smptr->sequence|.stat &="(_Pause);
        } else {
                slSequencePause(smptr->sequence);
                smptr->seq|smptr->sequence|.stat:=_Pause;
        }
}
if(!(smptr->seq|smptr->sequence|.stat &_Pause)){                /* if pause is not on... */
        if(padp & PER_DGT_TC){                                  /* C button input */
        if(smptr->seq|smptr->sequence|.stat &_Fade){            /* fade in/out */
                smptr->seq|smptr->sequence|.stat &="(_Fade);
                slSequenceFade(smptr->sequence . 127.25);/*Fade ln*/
        } else {
                smptr->seq|smptr->sequence|.stat:=Fade;
                slSequenceFade(smptr->sequence . 1.25);         /* Fade Out */
        }
        }
}
}
}
```

List 14-1 sampsnd1: Background Music and Sound Effect Playback Test (continued)

```
void init_sound_test(EVENT*evptr){
        SOUND_MAN *smptr;
        inti;

        evptr->exad=(void *)sound_test;
        smptr=(SOUND_MAN *)evptr->user;
        smptr->vol=15;                                                   /* data initialization */
        smptr->sequence=1;
        smptr->danknum=0;
        smptr->songnum=0;

        for(i=7;i>=0;i--){
        smptr->seq|i|.stat=0;
        slPringHex(i.slLocate(24.3+i));
        }
        disp_vol(smptr->vol);
}

/*---------------------------------------------*/

typedef struct{
        ANGLEangy;
}CUBE_MAN;

void disp_cube(EVENT*evptr){                                             /* cube display */

        CUBE_MAN        *cbptr;

        cbptr=(CUBE_MAN*)evptr->user;
        slPushUnitMatrix();
        {
        slTranslate(toFIXED(0),toFIXED(0),toFIXED(500));
        slRotY(cbptr->angy);
        cbptr->angy+=0x0|00;
        slPutPolygon(&PD_Cube);
        }
        slPopMatrix();
}
/*---------------------------------------------*/

sample(){
        init_sound();
        slInitEvent();
        slSetEvent((void*)init_sound_test);
        slSetEvent((void*)disp_cube);

        slScrAutoDisp(NBG0ON);
        slPrint("Sound test",slLocate(10.2));                            /* title display */
        while(-1){
        slExecuteEvent();
        slSynch();
        }
}
/*---------------------------------------------*/

void main(){
        slInitSystem(TV_352x224,NULL,1);
        sample();
}
/*---------------------------------------------*/
```

Flow Chart 14-1 sampsnd1: Background Music and Sound Effect Playback Test


Initialize system
Set sound driver
Transfer sound data to sequence buffer
Register event
Initialize data
Display cube
Check sequence status
Is Start key being pressed?
No
Yes
Is direction key being pressed (up/down)?
No
Yes
Change volume
Is direction key being pressed (left/right)?
No
Yes
Change sequence number
Is direction key being pressed (up/down)?
No
Yes
Change bank number
Is direction key being pressed (left/right)?
No
Yes
Change song number
Display bank, song, and sequence number
Is X button being pressed?
Yes
Background music on/off
No
Is A button being pressed?
Yes
Sound effect on/off
No
Is background music playing?
No
Yes
Is Y button being pressed?
Yes
Pause on/off
No
Not paused?
No
Yes
Is Z button being pressed?
Yes
Fade in/out
No
Is sound effect indicated by variable "sequence" being played back?
No
Yes
Is B button being pressed?
Yes
Pause on/off
No
Not paused?
No
Yes
Is C button being pressed?
Yes
Fade in/out
No

Sample program for playback test of PCM sound source

The following sample program is designed for a playback test of the PCM sound source.

There are three types of PCM sound source sample data: 16-bit stereo, 8-bit stereo, and 16-bit monaural. Each is played back by pressing the X button, Y button, and Z button, respectively.

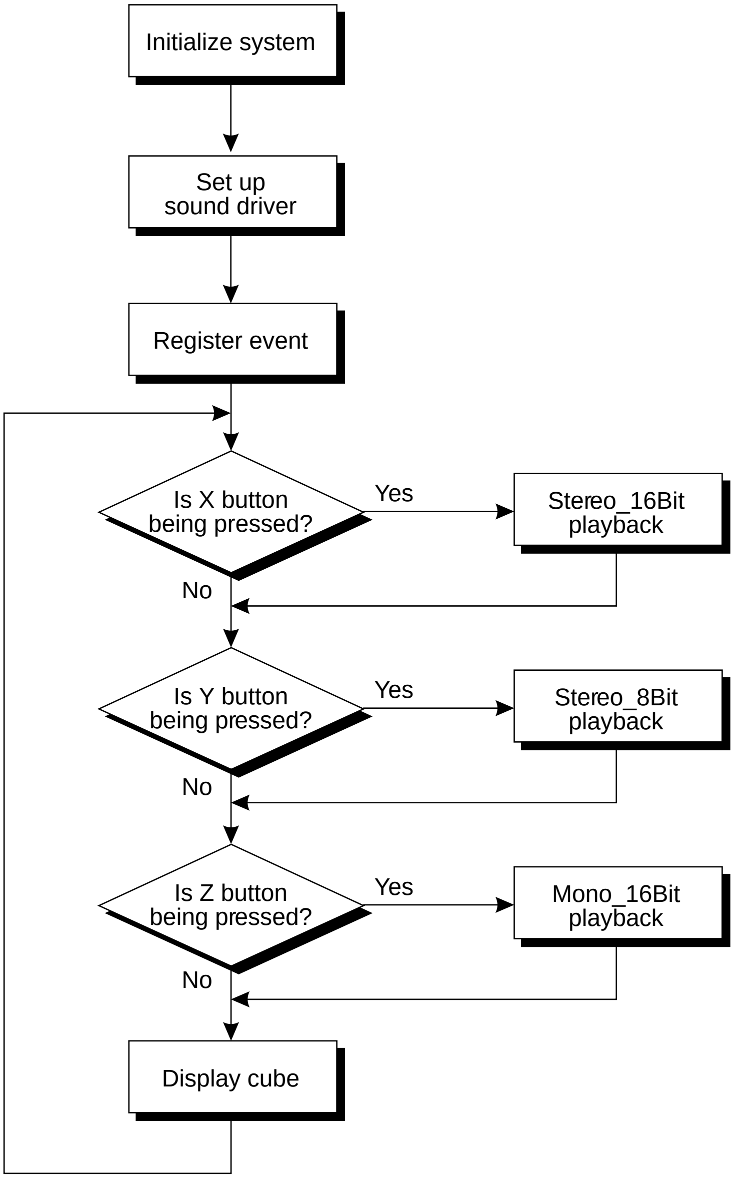
List 14-2 sampsnd2: PCM Sound Source Playback Test

```
-sampsnd2-

/*                                      */
/* Sound control sample                 */
/*                                      */

#include        "sl_def.h"                                      /* include files containing various settings */
#include        "sddrvs.dat"                                    /* sound driver file */

/*---------------------------------*/

extern char s_16{};
extern Uint32 s_16_size;
extern PCM s_16_dat;
extern char s_8{};
extern Uint32 s_8_size;
extern PCM s_8_dat;
extern char m_16{};
extern Uint32 m_16_size;
extern PCM m_16_dat;

extern PDATA PD_Cube;

/*--------------------------------*/

void init_sound(){
        char sound_map{}=(0xff,0xff};                           /* dummy map setting */
        slInitSound(sddrvstsk, sizeof(sddrvstsk),(Uint8*)sound_map, sizeof(sound_map)); /* driver map transfer */
}

sound_test(EVENT*evptr){
        PerDigital*pptr;
        Sint16  pad;

        pptr=Smpc_Peripheral;
        pad="pptr->push; /* Push data*/

        if(pad & PER_DGT_TX){                                   /* X button input */
        slPCMOn(&s_16_dat,s_16,s_16_size);                      /* Stereo_16Bit playback */
        }
```

List 14-2 sampsnd2: PCM Sound Source Playback Test (continued)

```
        if(pad & PER_DGT_TY){                                   /* Y button input */
        slPCMOn(&s_8_dat,s_8,s_8_size);                         /* Stereo_8Bit playback */
        }
        if(pad & PER_DGT_TZ){                                   /* Z button input */
        slPCMOn(&m_16_dat,m_16,m_16_size);                      /* Mono_16Bit playback */
        }
}

/*-------------------------------------*/

typedef struct{
        ANGLEangy;
}CUBE_MAN;

void disp_cube(EVENT*evptr){                                    /* cube display */
        CUBE_MAN        *cbptr;

        cbptr=(CUBE_MAN*)evptr->user;
        slPushUnitMatrix();
        {
        slTranslate(toFIXED(0),toFIXED(0),toFIXED(500));
        slRotY(cbptr->angy);
        cbptr->angy+=0x0100;
        slPutPolygon(&PD_Cube);
        }
        slPopMatrix();
}

/*----------------------------------*/

sample(){
        init_sound();
        slInitEvent();
        slSetEvent((void*)sound_test);
        slSetEvent((void*)disp_cube);

        slScrAutoDisp(NBG0ON);
        slPrint("Sound PCM test",slLocate(10.2));               /* title display */
        while(-1){
        slExcuteEvent();
        slSynch();
        }
}
/*---------------------------------*/

void main(){
        slInitSystem(TV_352x224,NULL,1);
        sample();
}

/*----------------------------------*/
```

Flow Chart 14-2 sampsnd2: PCM Sound Source Playback Test



Supplement. Sound Library Functions Appearing in This Chapter

The following functions were covered in this chapter.

Table 14-1 Sound Driver Functions Appearing in This Chapter

Function type	Name	Parameters	Function
void	slInitSound	void *drv, Uint32 drvsz, void *map, Uint32 mapsz	Setup sound driver and initialize sound CPU
Bool	slBGMOn	Uint16 Song, Uint8 Prio, Uint8 Volume, Uint8 Rate	Start background music playback
Bool	slBGMTempo	Sint16 Tempo	Change background music playback speed
Bool	slBGMFade	Uint8 Volume, Uint8 Rate	Change background music playback volume
Bool	slBGMOff	void	Stop background music playback
Bool	slBGMPause	void	Pause background music playback
Bool	slBGMCont	void	Resume playback of paused background music
Bool	slBGMStat	void	Check to determine if background music is being played back
Unit8	slSequenceOn	Uint16 Song, Uint8 Prio, Uint8 Volume, Uint8 Pan	Start generating specified sound effect
Bool	slSequenceTempo	Uint8 Seqnm, Sint16 Tempo	Change speed of specified sound effect
Bool	slSequenceFade	Uint8 seqnm, Unit8 Volume, Uint8 Rate	Change volume of specified sound effect
Bool	slSequencePan	Uint8 Seqnm, Uint Pan	Change directionality of specified sound effect
Bool	slSequenceOff	Uint8 Seqnm	Stop specified sound effect
Bool	slSequencePause	Uint8 Seqnm	Pause specified sound effect
Bool	slSequenceCont	Uint8 Seqnm	Resume paused sound effect
Bool	slSequenceStat	Uint8 Seqnm	Check to determine if specified sound effect is being played back
Sint8	slPCMOn	PCM *pdat, void *data, Uint32 size	Start PCM sound source playback
Bool	slPCMOff	PCM *pdat	Stop PCM sound source playback
Bool	slPCMParmChange	PCM *pdat	Change PCM playback parameters
Bool	slPCMStat	PCM *pdat	Check playback on specified PCM channel
Bool	slSndVolume	Uint8 Volume	Set overall volume
Bool	slSoundAllOff	void	Stop playback of all sound sequences
Bool	slDSPOff	void	Stop DSP playback
Bool	slSndMixChange	Uint8 Tbank, Uint8 Mixno	Switch mixer corresponding to tone bank
Bool	slSndMixParmChange	Uint Effect, Uint8 Level, Uint8	Pan Change mixer parameters

SEGA SATURN

Designer’s Tutorial

The Sega Saturn Designer’s Tutorial is designed to provide the knowledge required of designers in the development of 3D software for the Sega Saturn system.

This manual assumes that the design work is performed using SOFTIMAGE, and uses actual examples based on this software to explain the necessary procedures for creating 3D models. Because this manual also explains basic concepts of 3D models, it can be used even by designers with no 3D design work experience.

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Figures

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1

Designer's Tutorial

Introduction

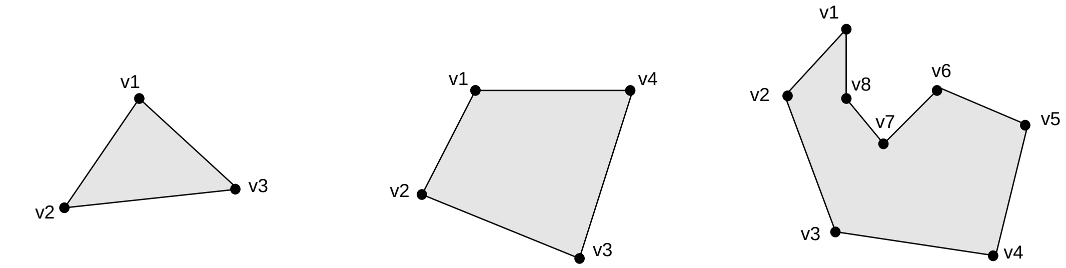
This chapter provides basic knowledge required in order to create 3D graphics data for the SEGA Saturn system, and also explains the basic operation of SOFTIMAGE.

What is a 3D Model?

Polygons

In the SEGA Saturn system, 3D models are represented by combinations of plane surfaces called “polygons.” A polygon is an area bounded by straight lines connecting three or more vertices. In this text, the lines surrounding the polygon are called “edges.”

Fig 1-1 Example of Polygons



a) Polygon with three vertices a) Polygon with four vertices c) Polygon with 8 vertices

Note: The "•" are vertices, and the straight lines connecting them are edges.

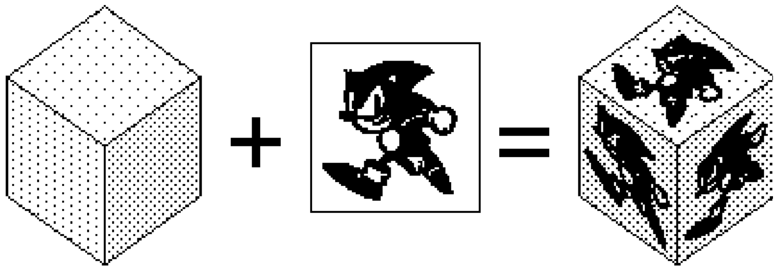
The SEGA Saturn system supports only polygons with four vertices. As a result, it is not possible to express polygons with three vertices or with five or more vertices. However, it is possible to draw a polygon that appears to only have three vertices by defining a polygon in which two of the four vertices have the same coordinates.

Texture mapping

Applying a 2D graphic to the surface of a polygon is called “texture mapping,” and the 2D graphic that is applied is called a “texture.”

With normal polygons, it is not possible to express textures or patterns using just surface colors, but by using the texture mapping function it is possible to add patterns to the surface of a 3D object expressed by polygons, making an even more realistic 3D representation possible.

Fig 1-2 Example of Texture Mapping



Polygon object Texture Texture-mapped object

Basic Operation of SOFTIMAGE

***To start up SOFTIMAGE, it is necessary to input the SOFTIMAGE startup command. Ask your system administrator for the startup command.**

Before starting up SOFTIMAGE (creating the directory)

1) Enter the UNIX shell and input the following:

```
mkdir SOFT [return]
mkdir CHECK [return]
```

(*mkdir: Make Directory)

You have no created two directories, called “SOFT” and “CHECK”, under your home directory (the directory that is displayed when you enter the shell).

Example: If [irs073:/usr1/people/osa:1]% is displayed when you enter the shell, “osa” is your home directory.

2) After executing the “mkdir” operations, input:

ll [return]

or,

ls-al [return]

The following information is then displayed:

```
drwxrwxr-x 2 (user name)(group name) 512 Nov 29 1994 SOFT/
drwxrwxr-x 2 (user name)(group name) 512 Nov 29 1994 CHECK/
```

The “d” at the head of “drwxrwxr-x” stands for “directory.”

Use the SOFT/ directory the next time that you start up SOFTIMAGE. Because SOFTIMAGE records the data that it outputs in the startup directory, it is best to always start up SOFTIMAGE in the same directory. If you do not, your data will be output to different directories.

The CHECK/ directory is used after a model has been created when using the programs allcon66 and allchk66 to convert the models and conduct error checking. More details are provided "Transferring Data."

SOFTIMAGE startup

1) After inputting the following:

```
cd SOFT [return]
```

the following prompt should appear on the screen:

```
[(name of logged-in machine):(home directory)/SOFT:2]%
```

For example:

```
[irs073:/usr1/people/osa/SOFT:2]%
```

2) Input the SOFTIMAGE startup command at this point as instructed by the system administrator in order to start up SOFTIMAGE.

Although the following messages appear in the UNIX shell. Ignore these messages.

```
ERROR:Database SI_Material_lib non-existent or invalid
```

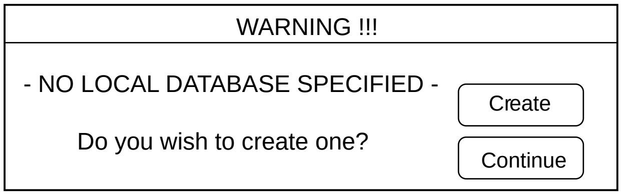
```
ERROR:Database SI_Channels_lib non-existent or invalid
ERROR:Database SI_Dynamics_lib non-existent or invalid
ERROR:Database SI_Animation_lib non-existent or invalid
```

3) **After the SOFTIMAGE title screen appears on the display, click one of the mouse keys.**
   The SOFTIMAGE startup process is now complete.

Database creation

The first time that you start up SOFTIMAGE, the alert box shown in Fig 1-3 appears. Click "Create".

Fig 1-3 Alert Box



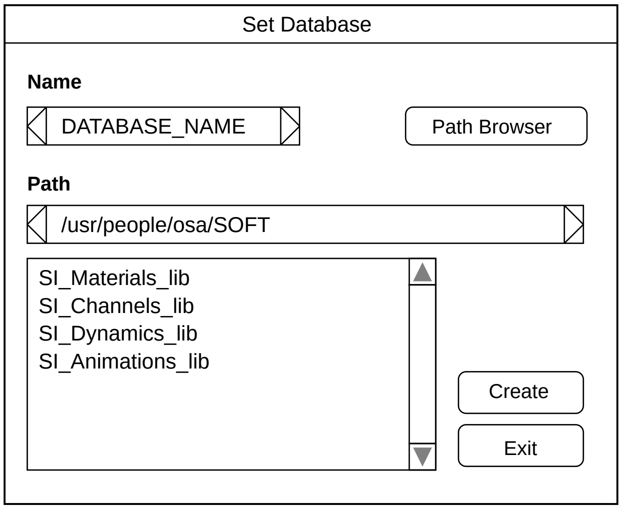
WARNING !!!

- NO LOCAL DATABASE SPECIFIED -

Do you wish to create one?

After clicking "Create", the "Set Database" window appears.

Fig 1-4 Set Database Window



Set Database

Name

DATABASE_NAME

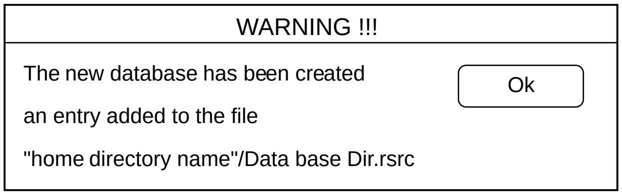
Path

/usr/people/osa/SOFT

SI_Materials_lib
SI_Channels_lib
SI_Dynamics_lib
SI_Animations_lib

Although the temporary name "DATABASE_NAME" appears in the "Name" field, replace this with any name you desire (for example, "STUDY") and then click "Create". The alert box shown in Fig 1-5 will appear, warning you that you have created a new data base.

Fig 1-5 Alert Box



WARNING !!!

The new database has been created

an entry added to the file

"home directory name"/Data base Dir.rsrc

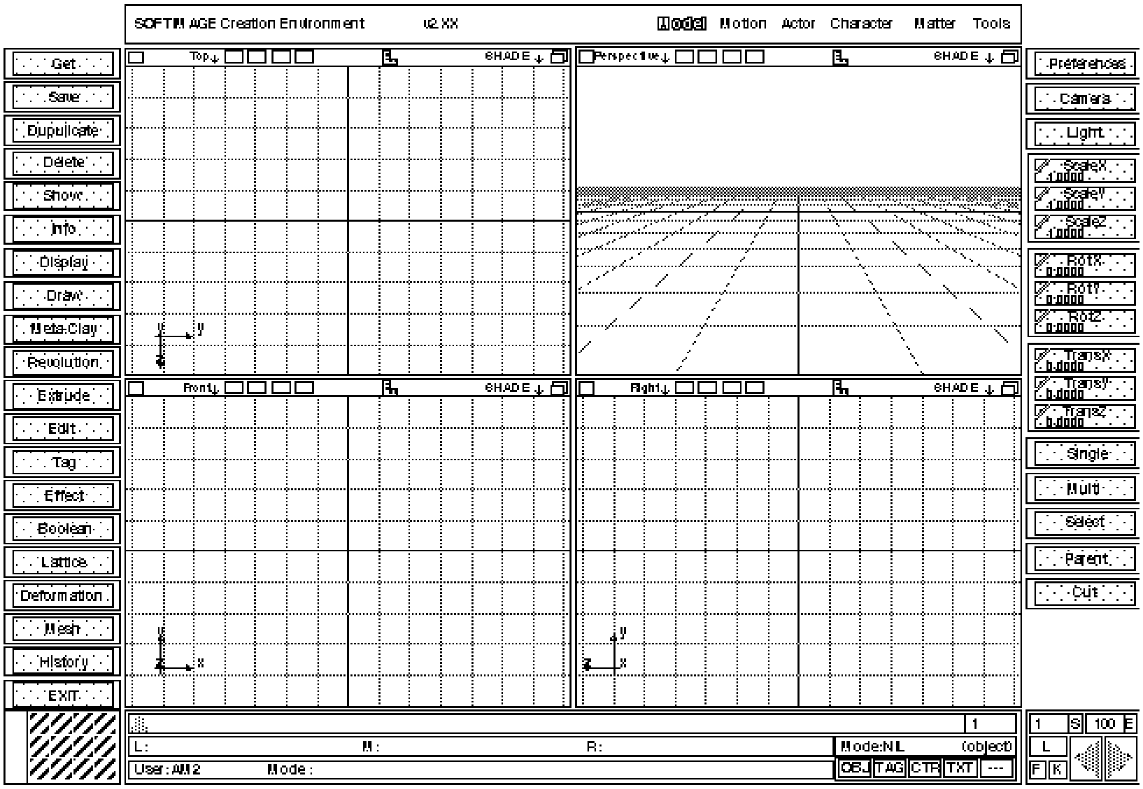
After you click “OK”, an item entitled “STUDY RW” should have been added under “SI_Animation_lib" in Fig 1-4. Preparations for work are now complete. Click “Exit” in Fig 1-4.

The screen

After SOFTIMAGE is started up, the following screen appears.

The first time SOFTIMAGE is started up, this screen appears after Fig 1-4. The second and subsequent times, this screen appears right after startup.

Fig 1-6 SOFTIMAGE Screen



Grids are displayed in the four windows at the center of the screen. These four windows allow you to monitor the appearance of your 3D model as you work. In the initial state, the windows show the following views:

Upper-left window: View from directly above

Lower-left window: View from directly in front

Upper-right window: View from any viewpoint, with perspective added

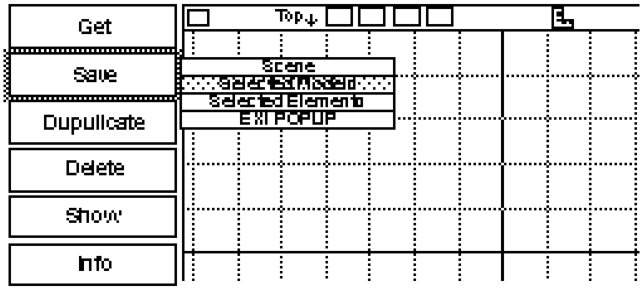
Lower-right window: View from right side

***Each window has a “compass” displaying the directions of the three axes, X, Y, and Z.**

The gray rectangles lining the vertical edges of the screen are called “menus”. When certain menus are clicked with the mouse, a smaller menu called a “submenu” or a “pop-up menu” appears.

To escape the submenu, click the right button on the mouse.

Fig 1-7 Menus and Submenus

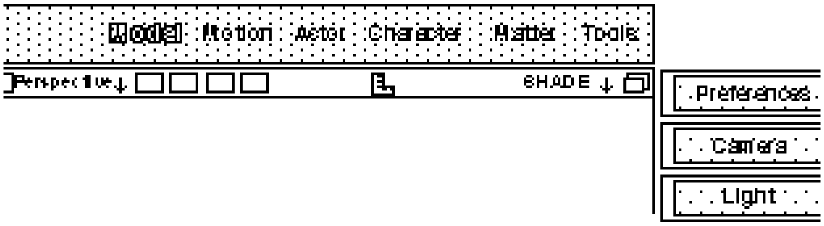


***In this manual, “[]” will be used to indicate a menu command, and “[]” will be used to indicate a submenu command.**

The colored portion of the screen at the top allows you to change work modes. The modes include a mode for creating 3D models, a mode for adding color, etc. When the mode is changed, the menu configuration also changes.

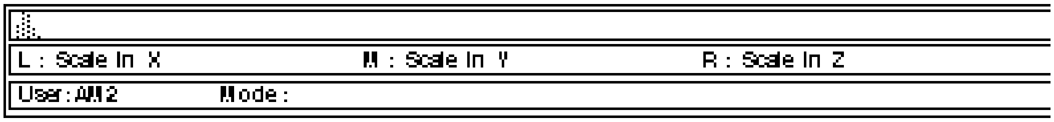
To change modes, simply click on the name of the desired mode with the mouse.

Fig 1-8 Mode Display



The bottom portion of the screen (where "L", "M", and "R" appear) displays the current function of each of the three mouse buttons.

Fig 1-9 Mouse Button Function Display



L : Scale In X M : Scale In Y R : Scale In Z

User : AM2 Mode :

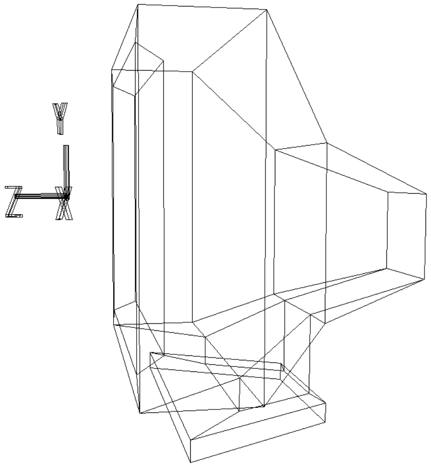
Displaying 3D models

There are two methods for displaying 3D models: Wire frame display and shaded display. These methods can be switched according to the type of work being performed. (The procedure for switching the method is described later.)

Wire frame display

In this display method, the edges of the polygons are represented by straight lines. Because the image can be displayed quickly when using this method, this method is commonly used while working.

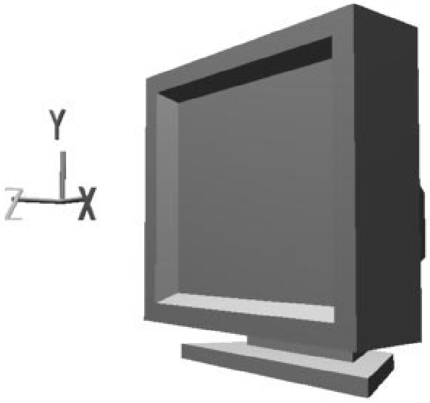
Fig 1-10 Wire Frame Display



Shaded display

This method displays the faces of the polygons. This method is used to check the appearance of the 3D model.

Fig 1-11 Shaded Display



Saving data

Select the object that you want to save. (If you wish to save multiple objects, click “Multi” in the menu bar on the right side of the screen to enable multiple selection.)

Select:

```
    [Save] -> [Selected Models]
```

A window appears. After confirming that the message says, “Saving in Database<STUDY>”, click “Save”.

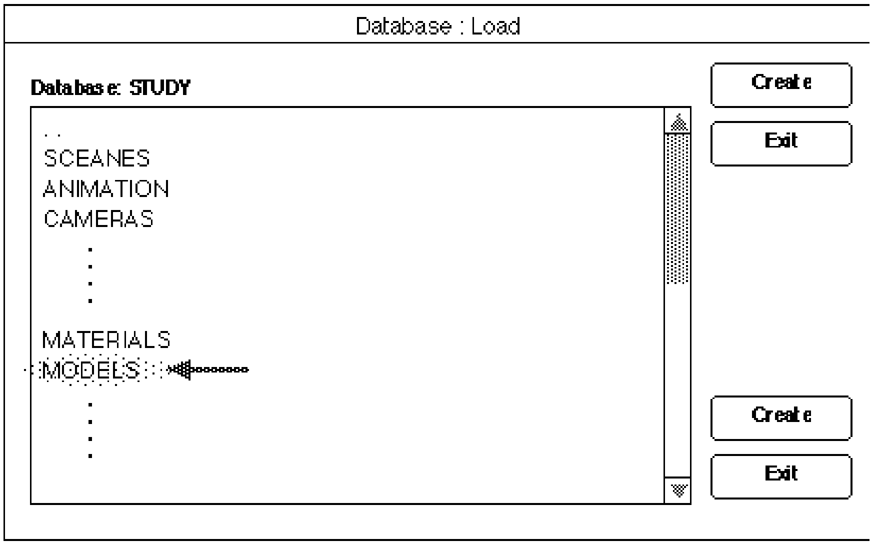
Loading data

Select:

```
    [Get] -> [Element]
```

The following window appears.

Fig 1-12 Loading Models



Database : Load

Database: STUDY

..
SCEANES
ANIMATION
CAMERAS
MATERIALS
MODELS

Double-click “MODELS”.

After the items saved in “MODELS” appear, click on the desired file and then click “Load”.

If there is more than one file that you wish to load, hold down the SHIFT key while clicking on each of the files, and then click “Load” last.

2

Designer’s Tutorial

Modeling Training: Beginning Level “TV Monitor”

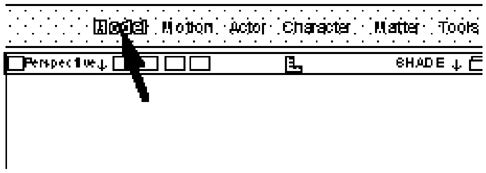
In this chapter we will practice modeling techniques using SOFTIMAGE’s polygon models. The object that we will model is a TV monitor.

***In this manual, “[]” will be used to indicate a menu command, and “[]” will be used to indicate a submenu command.**

Setting the mode

Set the mode to “Model”. (Fig 2-1)

Fig 2-1 Mode Selection (Model)



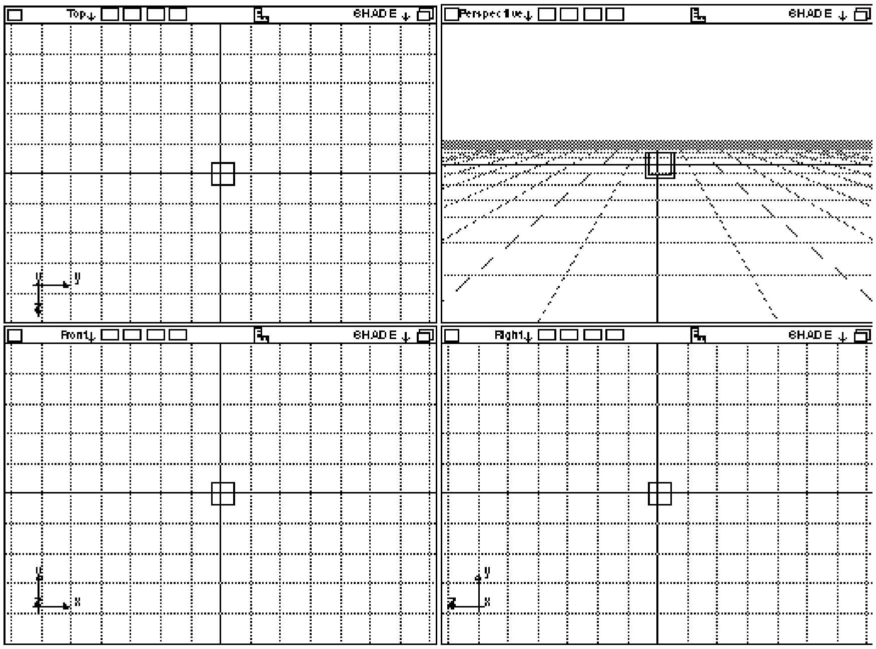
First, create a cube, which will be the shape for the foundation of the TV monitor.

Getting a cube

[Get] -> [**Primitive**] **->** [**Cube**]

In the dialog screen, input “0.5” in the “Length” field (for the length of one side of the cube) and click “OK”. A small cube then appears in wire frame form in each of the four windows. (Fig 2-2)

Fig 2-2 Display of Cube



***Deleting a model**

To delete a model, select the following:

`[Delete] -> [Selection]`

(You can also use the mouse to select an object while holding down the “Backspace” key.)

Changing the viewpoint

The position of the camera (viewpoint) in the perspective frame can be changed. Here we will actually change the position.

First, move the mouse cursor into the perspective frame. Pressing the “F” key at this point causes the object (in this case, the cube) to expand to fill the frame.

Rotating and moving the camera

The following operations allow you to gradually rotate and move the camera:

“O” key + left mouse button: Rotates freely
“O” key + middle mouse button: Rotates in vertical direction
“O” key + right mouse button: Rotates in horizontal direction
“P” key + dragging the mouse up or down: Changes distance between the camera and the object (left: slow; middle: medium; right: fast)
“Z” key + left mouse button + drag: Moves camera up and down, left and right

Enlarging/reducing objects on the screen

The following operations can be used to enlarge or reduce the size of the object on the screen:

“Shift” key + “Z” key + left mouse button + drag: Enlarge enclosed area
“Shift” key + “Z” key + right mouse button + drag: Enlarge enclosed area

Resetting the camera

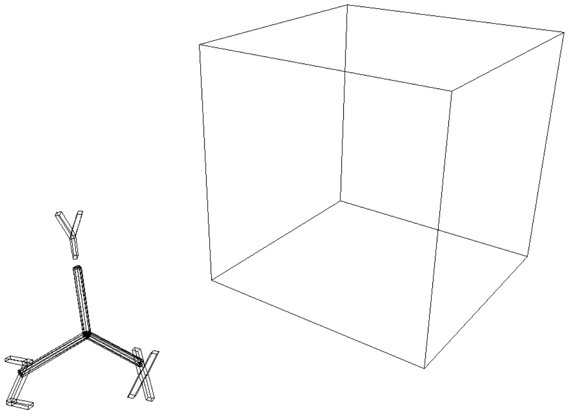
Although it is possible to zoom in by pressing the “Z” key and the middle mouse button or to zoom out by pressing the “Z” key and the right mouse button, doing so can upset the perspective information used for the image, so the use of these functions is not recommended. If the perspective does become skewed, select the following to reset the perspective:

```
[Camera] -> [Reset]
```

Note: In SOFTIMAGE 3D (version 3.0 or later), the term “mesh” in the menu means “poly

Using the operations described above, set the viewpoint so that the cube appears as shown in Fig 2-3.

Fig 2-3 Changing the Camera Position (Viewpoint)



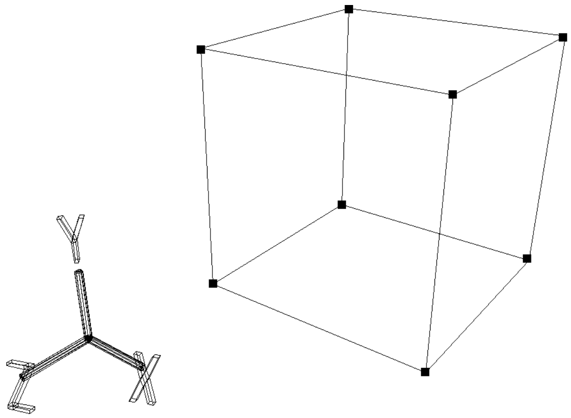
Displaying the Vertices

In order to display the vertices, select:

```
[Show] -> [Point]
```

(Fig 2-4) We will leave the vertices in the displayed state as we continue with our work.

Fig 2-4 Displaying the Vertices



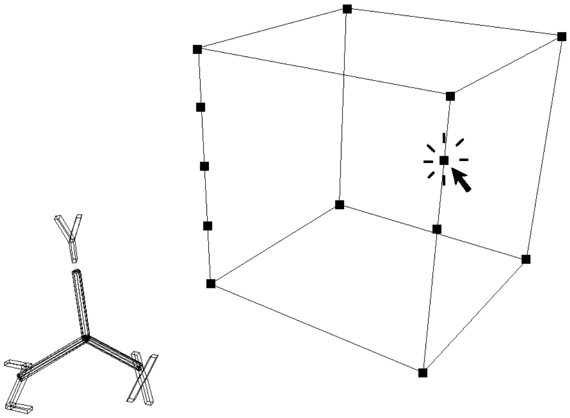
Adding middle vertices

Select:

```
[Mesh] -> [Vertex]
```

and then click an edge with the middle mouse button. This operation divides the edge at its midpoint and adds a new “vertex.” Click on the left and right edges three times each, dividing the edges into four parts. (Fig 2-5)

Fig 2-5 Adding Middle Vertices



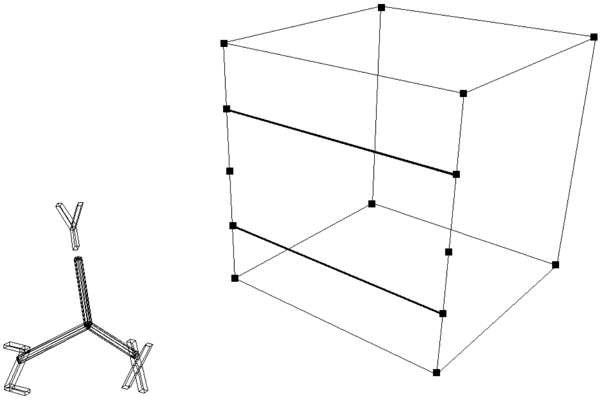
Adding edges

Select:

```
[Mesh] -> [Edge]
```

and then click on the starting point and ending points of new edges with the middle mouse button. (Fig 2-6)

Fig 2-6 Adding Edges



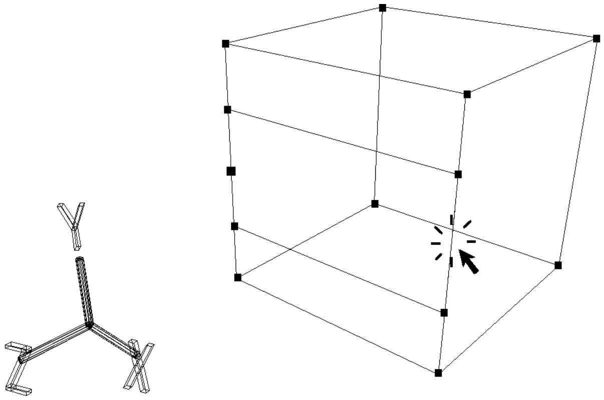
Removing vertices

Select:

```
[Mesh] -> [Vertex]
```

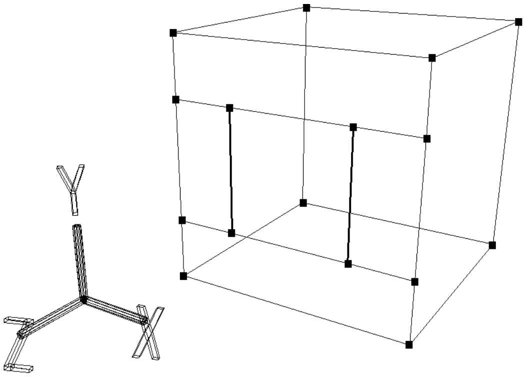
and then click with the right mouse button on the two remaining vertices that were added earlier to remove those vertices. (Fig 2-7)

Fig 2-7 Removing Vertices



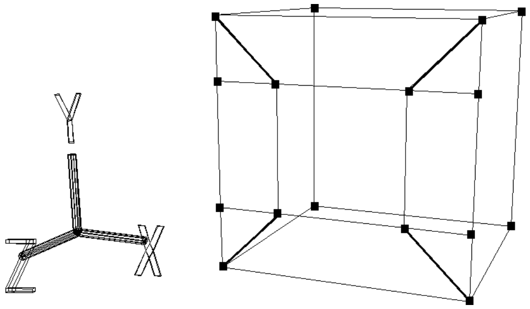
In the same manner as before, divide the new edges into four sections, add two new edges, and then delete the remaining unused vertices. (Fig 2-8)

Fig 2-8 Adding Edges



Add four more edges. (Fig 2-9)

Fig 2-9 Adding Edges



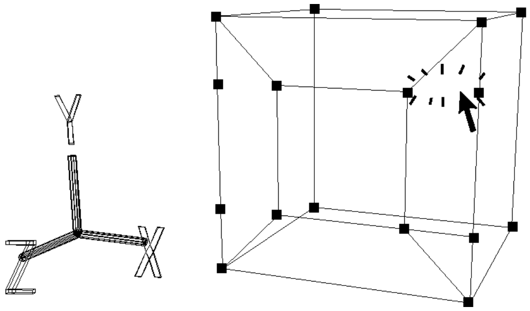
Removing edges

Select:

```
    [Mesh] -> [Edge]
```

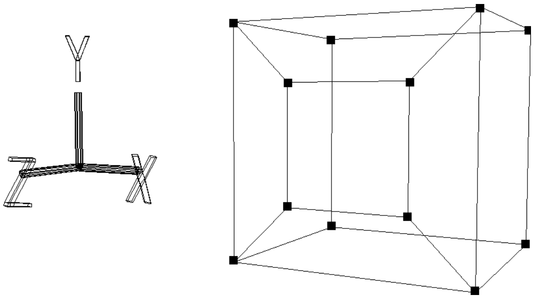
and then click on the four edges with the right mouse button as shown in the illustration to remove them. (Fig 2-10)

Fig 2-10 Removing Edges



Now delete the unnecessary vertices so that the image appears as shown below. (Fig 2-11)

Fig 2-11 Result of Edge Deletion



*Undo

If you make a mistake at any point, you can press the “U” key + left mouse button to undo the mistake and return to the previous state. You can set the number of steps that you can return by selecting:

```
[History] -> [Set up]
```

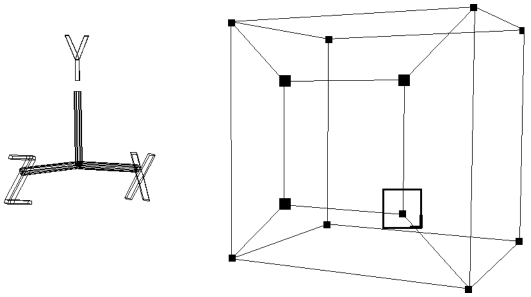
For beginners, a setting of 10 (undo up to 10 steps) is recommended.

Next, we will create the TV monitor screen.

Tag selection

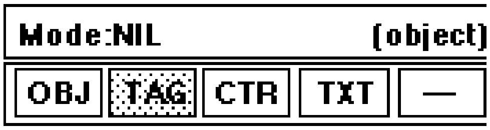
Press the “T” key + left mouse button and drag the mouse to enclose a vertex, and then repeat this procedure to select the four points shown in the illustration. (Fig 2-12) The selected points, called “tags,” are displayed in red.

Fig 2-12 Tag Selection



Now click the “TAG” button at the lower-right corner of the screen to change the operation mode to TAG mode. (Fig 2-13)

Fig 2-13 Switching the Operation Mode (TAG)



Switching the operation mode

If the operation mode is not set to “TAG,” tags cannot be manipulated. Likewise, if the operation mode is not set to “OBJ,” objects as a whole cannot be manipulated. Because the operation modes are switched frequently, the following short-cut keys have been assigned:

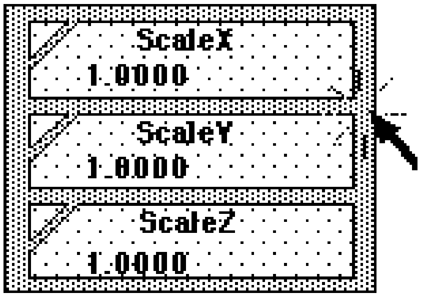
Short-cut keys
F8 key: OBJ mode
F9 key: TAG mode

Scaling (enlargement/reduction)

Next, the selected tags will be manipulated to enlarge the polygon enclosed by the tags.

Click on the border surrounding the **[**Scale**]** menu as shown in the illustration so that it is entirely highlighted in blue. (Fig 2-14)

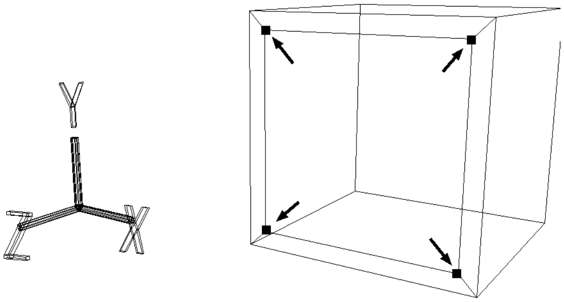
Fig 2-14 Scale Menu Selection



In this state, the left, middle, and right mouse buttons correspond to scaling functions in the X, Y, and Z directions, respectively. (Refer to the bar display at the bottom of the screen.)

Press the left and middle mouse buttons simultaneously and then drag the mouse to enlarge the polygon enclosed by the tags in the X and Y directions. (Fig 2-15)

Fig 2-15 Tag Movement



Next, we will copy and move this polygon to create an indented screen.

Duplicating polygons

Select:

```
    [Duplicate] -> [Immediate]
```

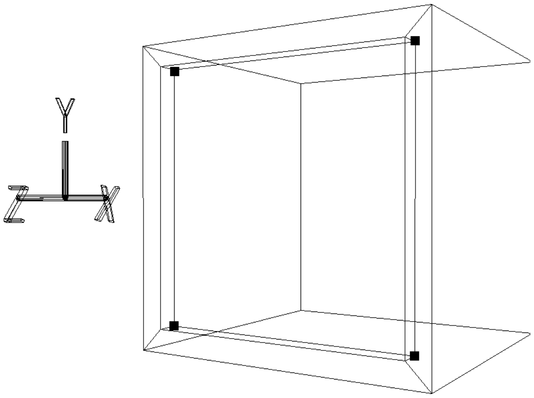
to duplicate the polygon enclosed by the tags.

***When this operation is performed, it looks as if nothing has changed, but in actuality the object has been duplicated.**

Polygon movement (Trans)

If **[TransZ]** is selected, the tags can move in the direction of the Z axis. Drag the mouse to move the selected tags in the direction of the Z axis as shown in the illustration. (Fig 2-16)

Fig 2-16 Pushing a Surface

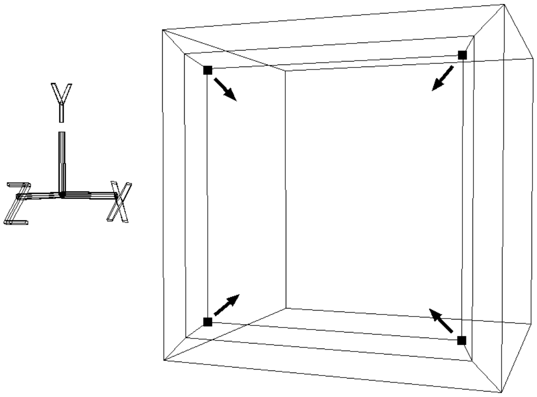


Note: This operation is called "pushing a surface." Be sure to learn it well, as it will be used often.

Next, we will reduce the size of the surface that we pushed.

Select the entire **[Scale]** menu again, hold down both the left and middle mouse buttons, and reduce the size of the pushed surface enclosed by tags. (Fig 2-17)

Fig 2-17 Reducing the Pushed Surface

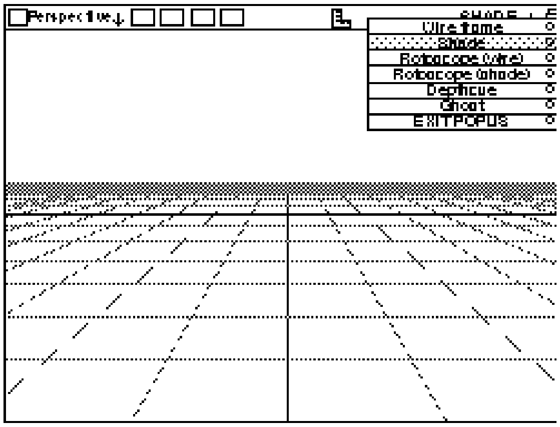


Shaded display

Now, in order to get a better idea of the state of the object, we will change the display method from “wire frame” to “shaded.”

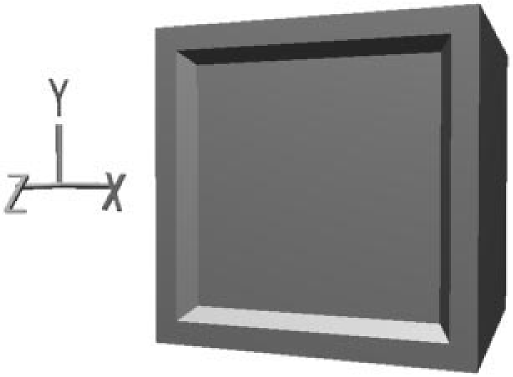
Switch the display method in the perspective window from “wire frame” to “shaded”. (Fig 2-18) (Click on “SHADE ↓” in the upper-right corner of the screen with the left mouse button to change the mode from “wire frame” to “shaded.”

Fig 2-18 Shaded Display



Now the object that we have created should appear as shown in the illustration.(Fig 2-19)

Fig 2-19 Object in Shaded Display



Although setting the display method to “shaded” is useful for checking the state of the object, it is best to use “wire-frame” mode during normal modeling work.

Next, we will reduce the height of the monitor slightly in the vertical direction (to 90%).

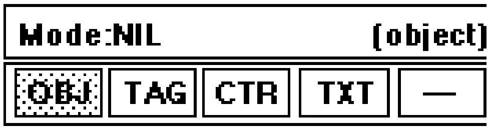
Object scaling

Click the **[**Scale**]** menu once again to de-select it.

Press the “T” key and the middle mouse button, and then drag the mouse to enclose each of the red selected tags and de-select them.

Now switch the operation mode to “OBJ”. (Fig 2-20)

Fig 2-20 Switching the Operation Mode (OBJ)



Mode:NIL [object]

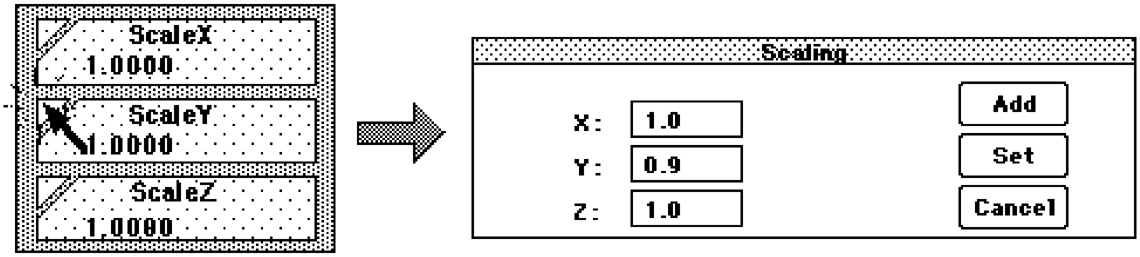
Now it is possible to work with the object as a whole.

If **[ScaleY]** is selected, scaling in the vertical direction is possible by dragging the mouse. The reduction ratio is displayed above the **[ScaleY]** menu button. Because it is difficult to drag the mouse precisely enough to set the reduction ratio to exactly “0.9000”, we will simply input the value directly.

Inputting the scale ratio value

Clicking on the triangular mark on the **[Scale]** menu as shown in the illustration causes a dialog box that permits direct input of scaling ratios to appear (Fig 2-21). Input “0.9” in the “Y” field and then click “Set” to reduce the size of the object in the Y direction to 90%.

Fig 2-21 Inputting the Scaling Ratio



ScaleX 1.0000

ScaleY 1.0000

ScaleZ 1.0000

Scaling

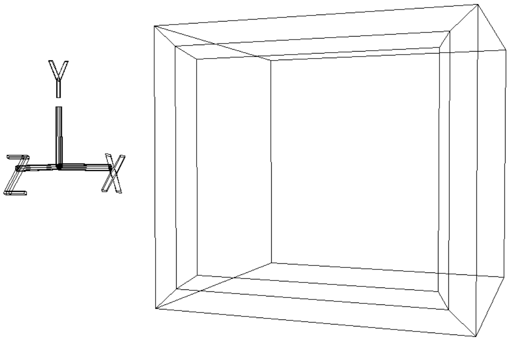
X: 1.0

Y: 0.9

Z: 1.0

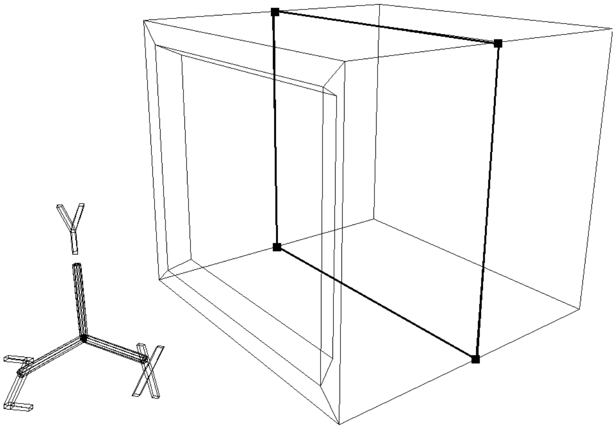
As a result the object should appear as shown in the illustration. (Fig 2-22)

Fig 2-22 Object Scaling



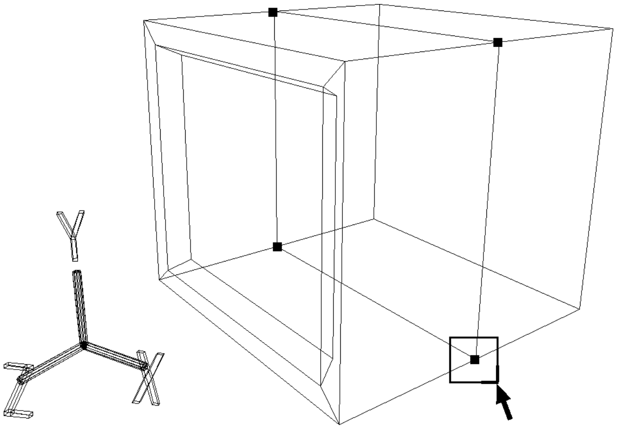
Next, by using the techniques for adding middle vertices and adding edges, add four edges so that they go around the monitor. (Fig 2-23)

Fig 2-23 Add Edges



Select the four new middle vertices by pressing the "T" key and the left mouse button and dragging. (Fig 2-24)

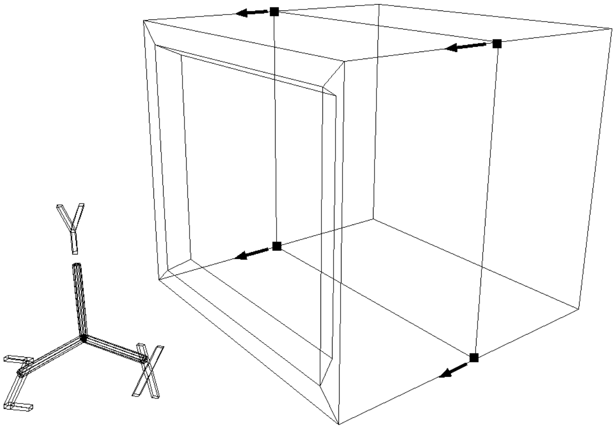
Fig 2-24 Tag Selection



Switch the operation mode from “OBJ” to “TAG”.

Click **[TransZ]** and move the selected tags in the positive Z direction. (Fig 2-25)

Fig 2-25 Moving a Polygon



Next, we will check the coordinates of the tags that we moved.

Checking the coordinates of vertices

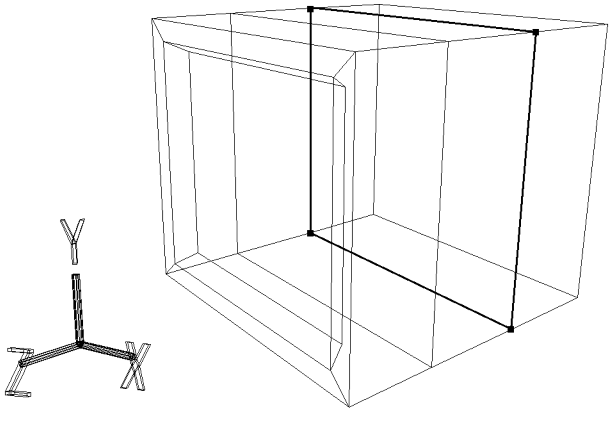
Select:

```
    [Edit] -> [Coordinate]
```

and then click the tag that you want to know the coordinates of. The X, Y, and Z positions are displayed; set the Z position to about 0.1. (Direct input can be used here.)

After the tags have been moved, de-select all of the tags and then use the techniques for adding middle vertices and adding edges to add four new edges. (Fig 2-26)

Fig 2-26 Adding Edges



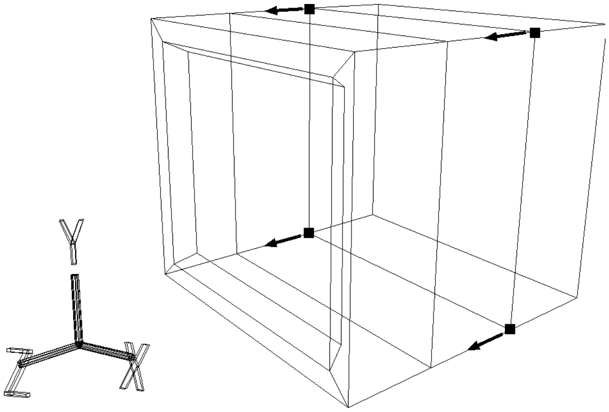
Next, set the vertices shown in the illustration as tags and move them in the positive direction on the Z axis. (Fig 2-27)

Select:

```
    [Edit] -> [Coordinate]
```

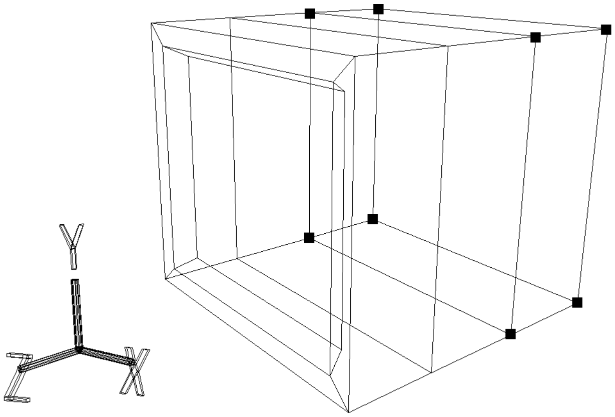
Check the Z coordinate of the tags that were moved and set them to about -0.01.

Fig 2-27 Tag Selection and Movement



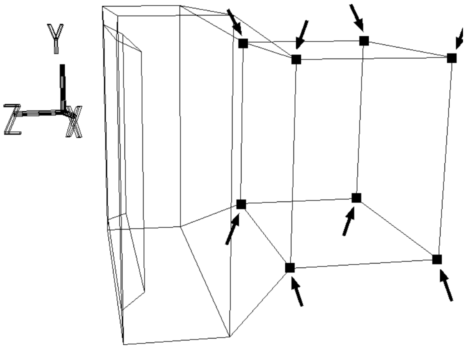
Leaving the tags selected, select four new tags. (Fig 2-28)

Fig 2-28 Tag Selection



Select **[ScaleX,Y,Z]** (select entire menu) and hold down the left and middle mouse buttons while dragging the mouse to reduce the size of the volume enclosed by the tags in the X and Y directions. (Fig 2-29)

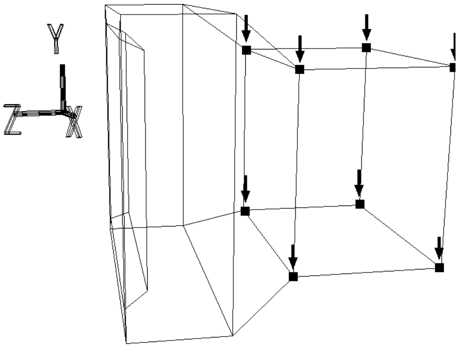
Fig 2-29 Scaling the Rear Portion of the Monitor



Now we will move the selected rear portion down (in the negative Y direction).

Select **[TransY]** and drag the mouse to move the selected portion slightly in the negative Y direction. (Fig 2-30)

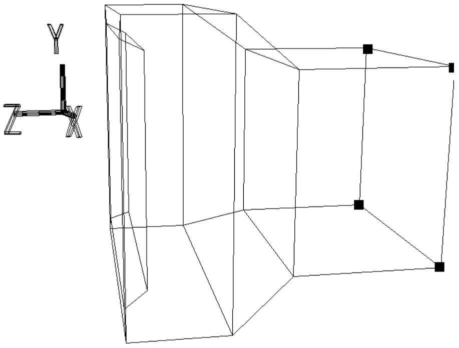
Fig 2-30 Moving the Selected Portion



Next we will change the shape of the rear portion.

De-select some of the tags as shown in the illustration. (Fig 2-31)

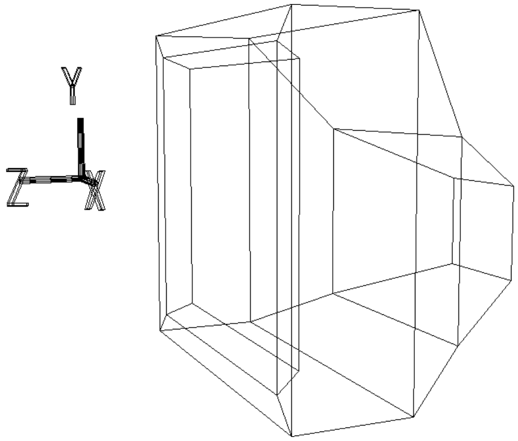
Fig 2-31 Tag De-Selection



Select **[ScaleX,Y,Z]** (select entire menu) and hold down the left and middle mouse buttons while dragging the mouse to reduce the size of the polygon surface enclosed by the tags in the X and Y directions.

Then select **[TransY]** and move the selected polygon surface in the negative Y direction, and then select **[TransZ]** and move the selected polygon surface in the negative Z direction. (Fig 2-32)

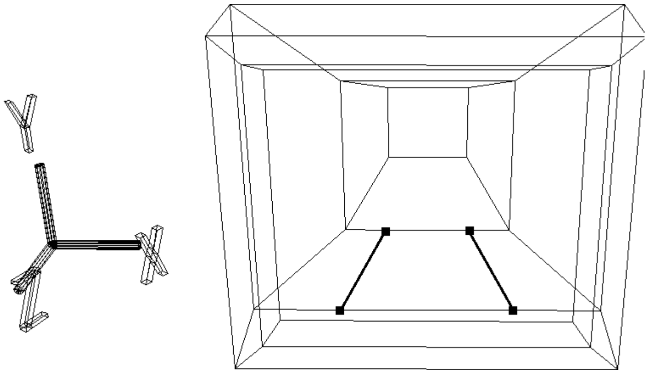
Fig 2-32 Changing the Shape of the Rear Portion



Next, we will create a base for the monitor.

By using the techniques for adding middle vertices and adding edges, add two new edges as shown in the illustration. (Fig 2-33)

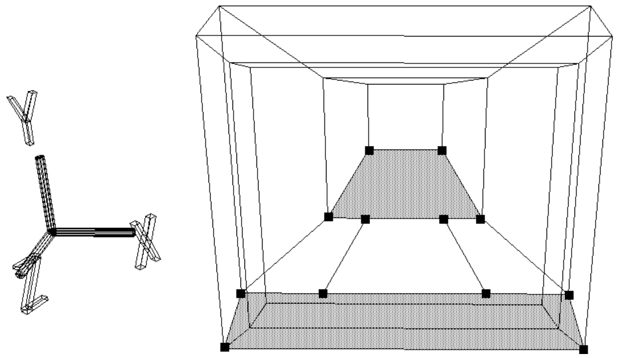
Fig 2-33 Adding Edges



Dividing polygons

There is one point that must be noted here. Although the shaded polygons in the illustration have only four corners, there are six vertices on the edges of the polygons; therefore, these polygons are regarded as being “hexagons.” (Fig 2-34)

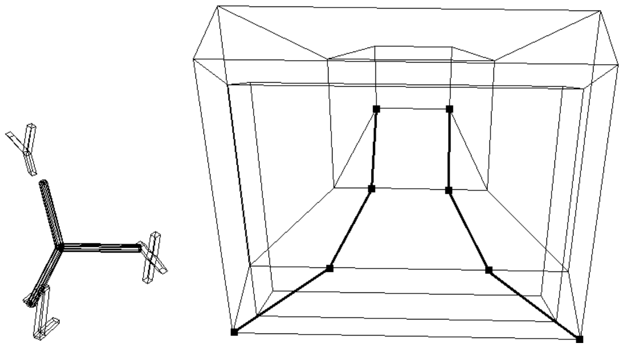
Fig 2-34 Polygons with Six Vertices



Because the SEGA Saturn system only supports polygons with four vertices, these polygons must be divided into two or more polygons with four vertices.

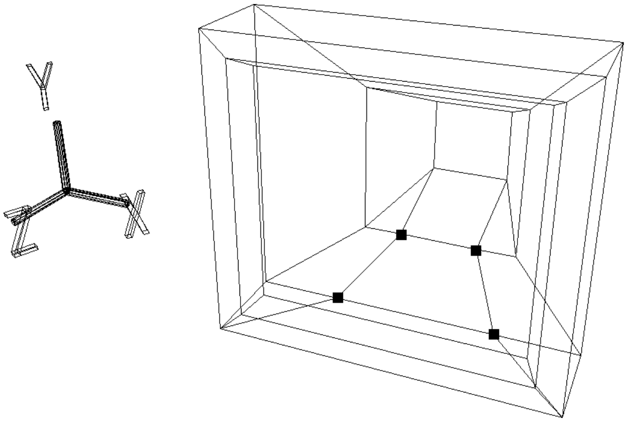
Add more edges so that the polygons are divided as shown in the illustration. (Fig 2-35)

Fig 2-35 Polygon Division



Next, set the four points shown in the illustration as tags. (Fig 2-36) If other points were previously tagged, de-select those points.

Fig 2-36 Tag Selection



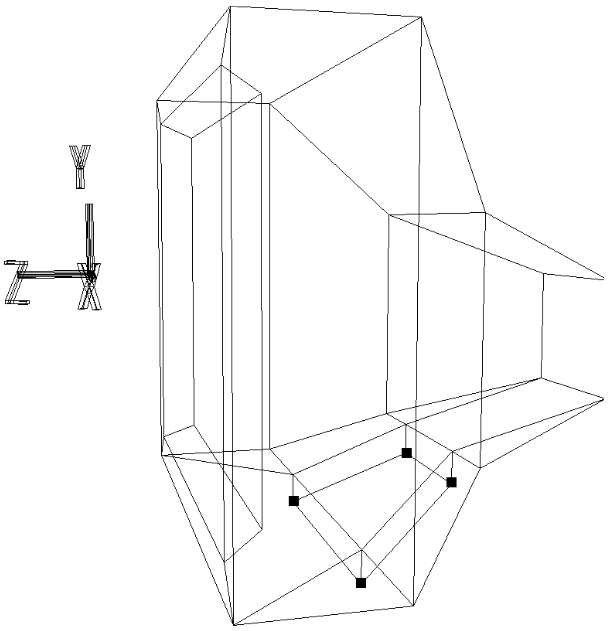
After confirming that the operation mode is set to “TAG,”, select:

[Duplicate] -> [Immediate]

to duplicate the polygon enclosed by the tags.

Next, select **[TransY]** and move the duplicated surface in the negative Y direction. (Fig 2-37)

Fig 2-37 Surface Duplication and Movement



Next, make the duplicated surface parallel with the top and bottom of the TV monitor screen. (Make them parallel in the ZX plane.)

For the four selected tags, select:

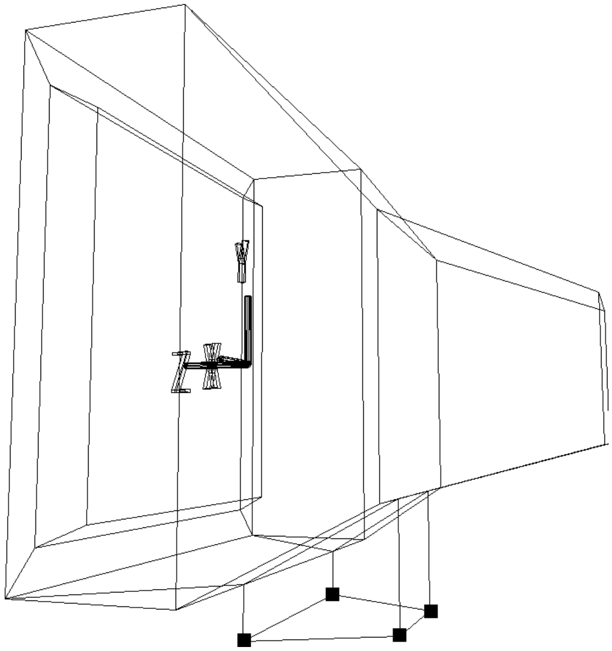
```
    [Edit] -> [Coordinate]
```

and set the Y position values to -0.3.

> *** In this instance, always make sure that “Local Coordinate” in the dialog box is selected.**

The resulting image should appear as shown in the illustration. (Fig 2-38)

Fig 2-38 Adjusting the Y Positions of the Tags

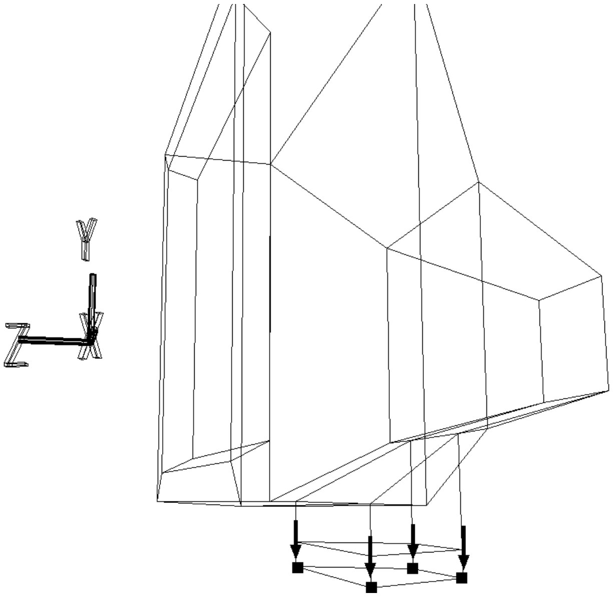


Next, with the previous four tagged points still tags, select:

```
     [Duplicate] -> [Immediate]
```

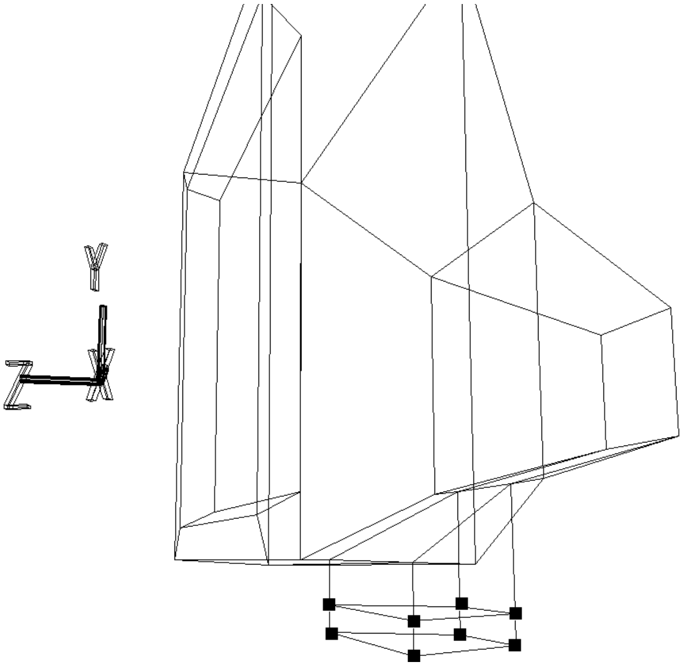
to duplicate the polygon surface enclosed by the tags, and then select **[TransY]** and move the duplicated surface down (in the negative Y direction). (Fig 2-39)

Fig 2-39 Surface Duplication and Movement



Next we will change the shape of the new part and create a base. Select the points shown in the illustration as tags. (Fig 2-40)

Fig 2-40 Tag Selection



After selecting:

```
     [Duplicate] -> [Immediate]
```

select **[ScaleX,Y,Z]** (select entire menu) and hold down the left and middle mouse buttons while dragging the mouse to enlarge the selected portion in the ZX plane. The resulting image should appear as shown in the illustrations. (Figs 2-41 and 2-42)

Fig 2-41 Enlarging the Base (Wire Frame)

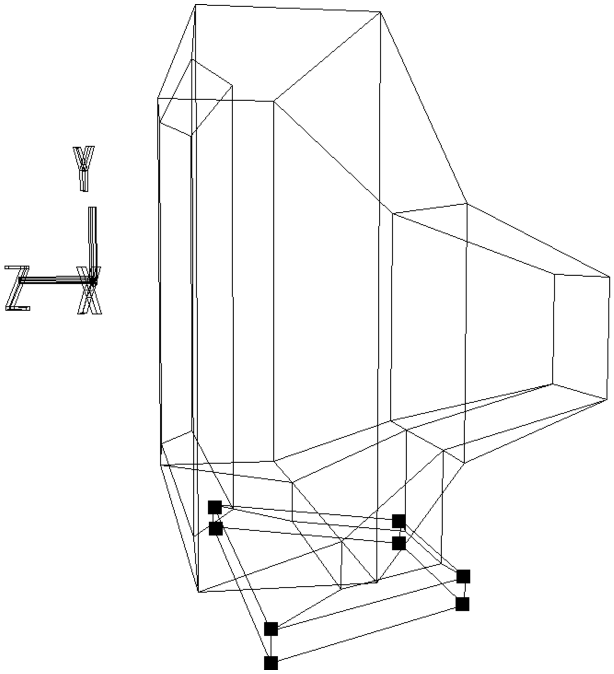
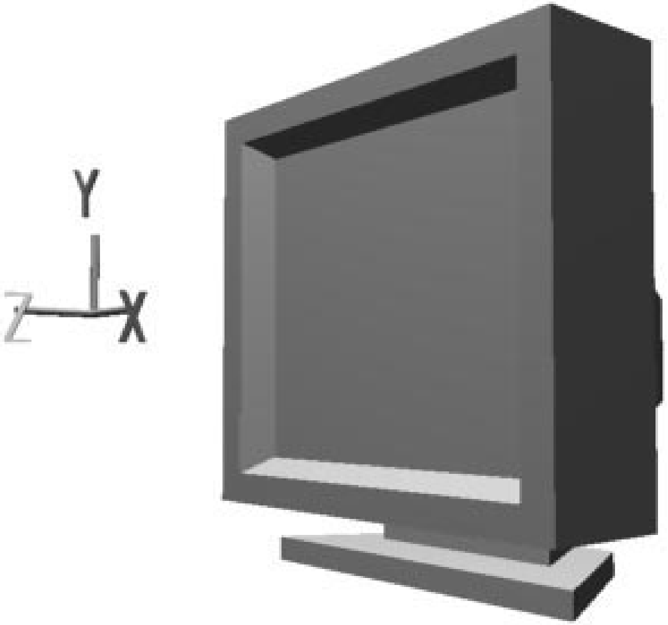


Fig 2-42 Enlarging the Base (Shaded)



Freezing the scale

At this point, checking the Y value in the **[ScaleY]** menu shows a value of 0.9000; however, once the size of the object has been determined, it is easier if the final size is made the reference. Therefore, select:

```
[Effect] -> [Freeze] -> [Scale]
```

The current size is now the reference size (1.0000).

The TV monitor model is now complete.

Saving the model

First, it is necessary to assign a name to the model. Select:

```
[Info] -> [Selection]
```

A dialog box that permits a name to be assigned to the model appears. Although the temporary name “Cube” appears in the “Name” field, change the name to any name that you desire (for example, “SATURN_TV_SET”) and then click “OK”.

To save the model, select:

```
[Save] -> [Select Models]
```

and then click “Save”.

3

Designer’s Tutorial

Modeling Training: Advanced Level “Automobile”

In this chapter we will interweave advanced modeling techniques that were not introduced in the beginning level modeling training. The object that we will model is an automobile.

*** In this manual, “[]” will be used to indicate a menu command, and “[]” will be used to indicate a submenu command.**

Creating the Fundamental Shape of the Car

Getting a cube

Switch to the “Model” menu.

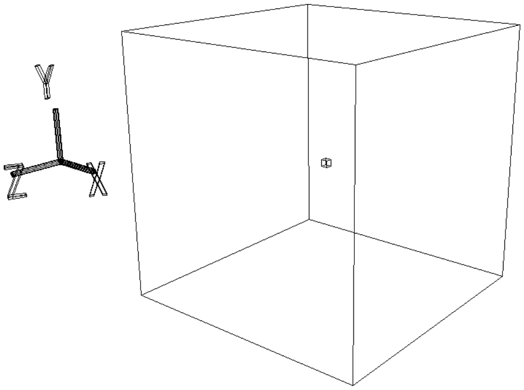
Short-cut key
F1 key: Select "Model" menu

Select:

```
[Get] -> [Primitive] -> [Cube]
```

And when the dialog box appears, input “4” in the “Length” field (which specifies the length of one side of the cube), and click “OK” to create the cube. (Fig 3-1)

Fig 3-1 Getting a Cube



Note: The small cube that appears in the center of the larger cube indicates the center of the object.

If the vertices are not displayed, select:

```
[Show] -> [Point]
```

to display the vertices.

Confirm that the object is selected (indicated when the wire frame is displayed in white). We will now use **[Scale]** in OBJ mode to reshape this cube into the shape of a car.

Creating the base

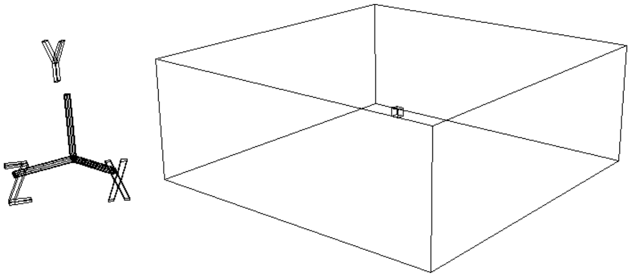
First, because there are not many cars that are 4 meters high, we will reduce the height to 1.5 meters.

Click the corner triangle in either the X, Y, or Z portion of the **[Scale]** icon to open the direct value input window. Because 1.5/4 = 0.375, input the following values in the window:

```
X : 1, Y : 0.375, Z : 1
```

Click “Set.” (Fig3-2)

Fig 3-2 Changing the Height



Next, set the new size as the reference size by selecting:

```
[Effect] -> [Freeze] -> [Scaling]
```

The Scale Y value changes from 0.3750 to 1.0000.

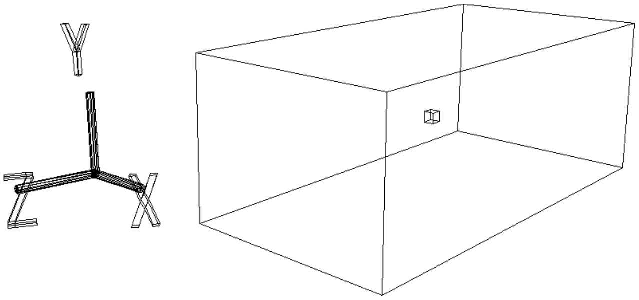
Furthermore, there are no cars that are 4 meters wide, either. We will change the width to 2 meters.

In the same way as when we compressed the height, click a corner triangle in the **[Scale]** icon to enter direct value input mode. Because 2/4 = 0.5, input the following values in the window:

```
X : 0.5, Y : 1, Z : 1
```

Click “Set.” (Fig 3-3)

Fig 3-3 Changing the Width



Since we also want to set this new width as the reference, select:

```
[Effect] -> [Freeze] -> [Scaling]
```

Confirm that the Scale X value has changed from 0.5000 to 1.0000.

Creating the roof

Next, we will create the roof.

Select:

```
    [Effect] -> [Subdivision]
```

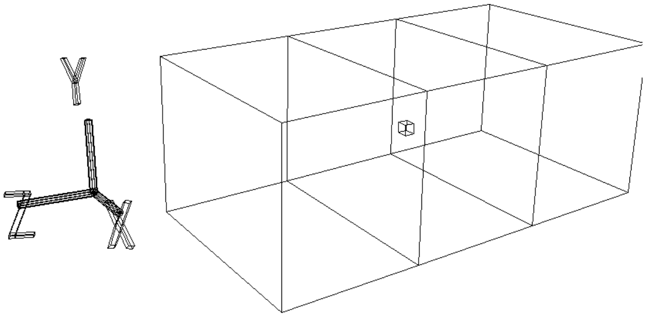
(This is used to set the number of line segments that are used to divide each surface in the X, Y, and Z directions.) This function is used to divide an object in any axial direction (X, Y, or Z). This command is ideal for dividing a rectangular solid such as the one we are working with. (This command is not suited for spherical objects, however.

When the “Mesh Subdivision” dialog box appears, input the following values:

```
    X: 0, Y: 0, Z: 2
```

and then click “OK.” (Fig 3-4)

Fig 3-4 Dividing an Object Along the Z Axis

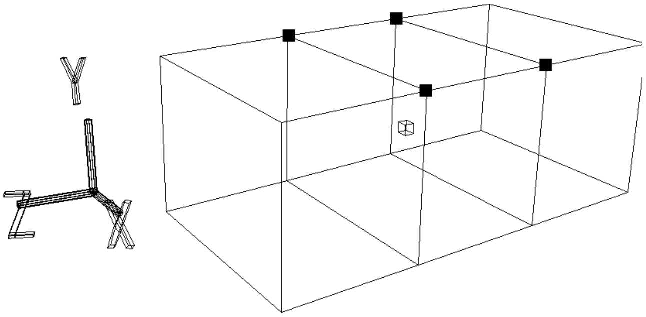


Note: This setting ("Z:2"does not mean, “Divide the object into two pieces along the Z axis;” instead, it means, “Draw two lines.” In other words, it divides the object along the Z axis twice, creating three pieces.

Next, set the vertices shown in the diagram (the four points corresponding to where the roof will be) as tags.

*** Press the “T” key and the left mouse button and then drag the mouse to encircle each point.**

Fig 3-5 Setting the Roof Vertices as Tags



At this point, look at the lower-right corner of the screen; "OBJ" should be highlighted in blue; click "TAG" to change the mode to "TAG mode." "TAG" is now highlighted in blue, and the tags can now be manipulated.

Short-cut keys
F8 key: Select OBJ mode
F9 key: Select TAG mode

Select:

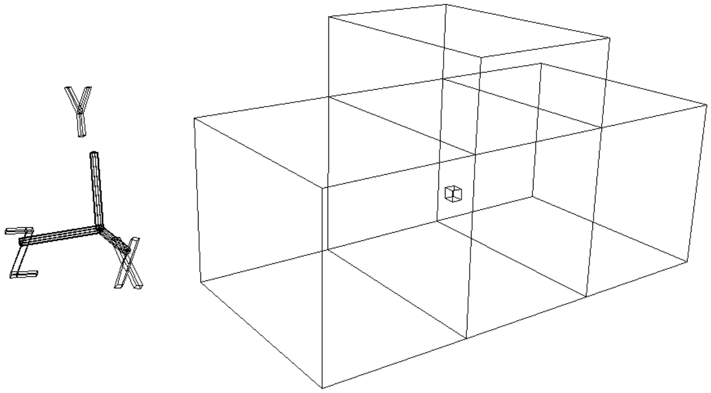
```
[Duplicate] -> [Immediate]
```

to copy the four red tags. As was the case in the beginning level (Chapter 2) with the TV monitor, it appears as if nothing has changed, but in actuality the tags have been duplicated in the same position as the originals. When using the Duplicate function, only duplicate once before moving the duplicate away. If you duplicate more than once before moving the duplicated object away, it is not possible to visually check how many duplicates you have made. Therefore, the safest procedure is to duplicate, move the points, duplicate, move the points, and so on.

Note: Because the Duplicate function places the duplicated points on top of the originals in the same position (making it impossible to tell them apost), it is a good idea to move the duplicates (by using [Trans], etc.) soon after executing the Duplicate function.

After executing the Duplicate function, click the **[TransY]** icon so that only it is highlighted, and then try moving the four copied tags in the positive Y direction. Watch the front-view window and move the tags until the Y value is close to 1.5 meters. (One mark on the scale is equivalent to one meter.) (Fig 3-6)

Fig 3-6 Lifting the Roof



After doing so, release the tags. (Press the "T" key and the middle mouse button, and encircle the points.)

If you wish to set the Y value precisely to 1.5 meters, select:

```
[Edit] -> [Coordinate]
```

and then select one of the new points. When you do so, the "Edit Coordinate" window appears, displaying the coordinates of the selected point. Enter "1.5" for the Y value and then click "OK." (Do not change the other values.) Repeat this process for each of the four points.

However, now the object is too long in the Y direction, so we will reduce it.

Click in the corner triangle of the **[Scale]** icon.

Notice that the window did not open when you clicked the triangle. Also, underneath a warning message (“There are no tagged points”) appeared. This is because when TAG mode is set, “Scale,” “Rot,” and “Trans” cannot be used if no points are tagged.

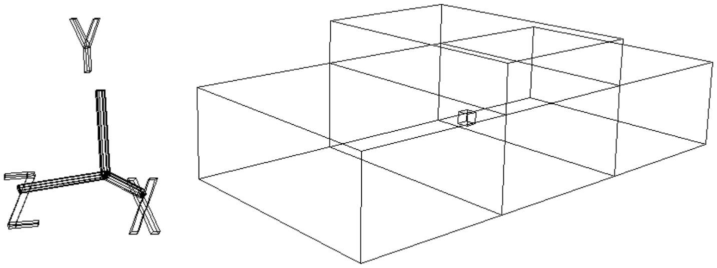
Because we want to scale the object as a whole, we will set the mode to “OBJ.” After setting OBJ mode, click the corner triangle of the **[Scale]** icon. After the window opens, enter the following values:

```
X: 1, Y: 0.5, Z: 1 (These settings reduce the height by half.)
```

Next, click “Set.” (Fig 3-7) Finally, to make the new scale into the reference value, select:

```
[Effect] -> [Freeze] -> [Scaling]
```

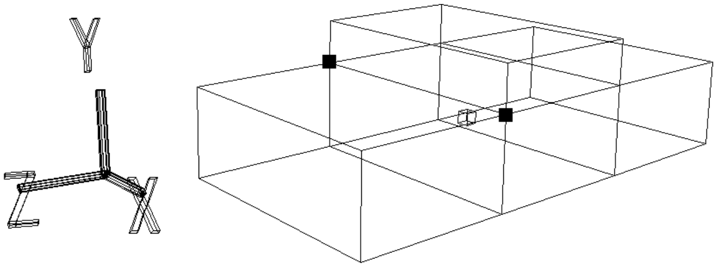
Fig 3-7Adjusting the Height



Adjusting the roof

Using **[Trans]** in TAG mode, we will change the position and shape of the roof so that it looks more like that of an automobile. Tag the points indicated in the illustration. (Fig 3-8)

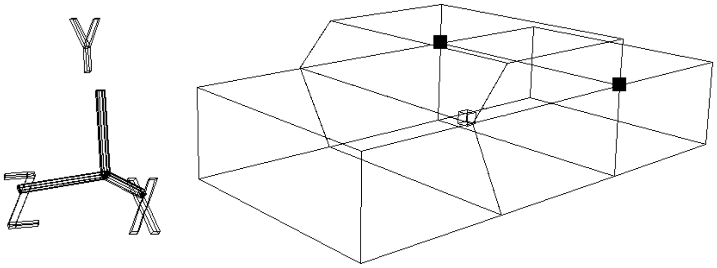
Fig 3-8 Tagging the Vertices at the Lower Front Portion of the Roof



After setting TAG mode, select the **[TransZ]** icon and move the tagged points in the positive Z direction. (Watch in the right-view window while moving the points until the Z value is about 1.0 meters.) Release the tagged points.

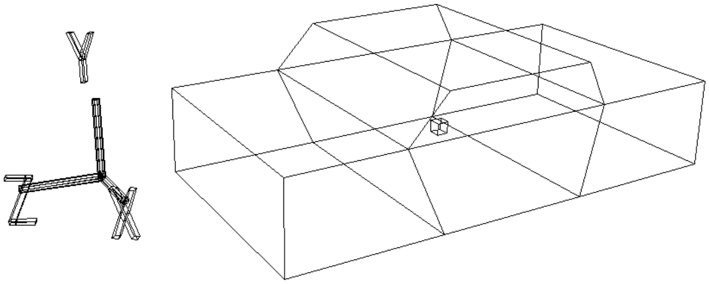
Next, tag the points shown in the illustration. (Fig 3-9)

Fig 3-9 Tagging the Vertices at the Lower Rear Portion of the Roof



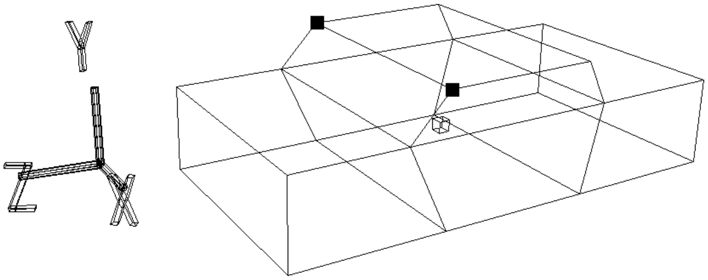
Select the **[TransZ]** icon and move the tagged points in the negative Z direction. (Watch in the right-view window while moving the points until the Z value is about -0.85 meters.) Release the tagged points. (Fig 3-10)

Fig 3-10 Appearance after Changes to Bottom of Roof



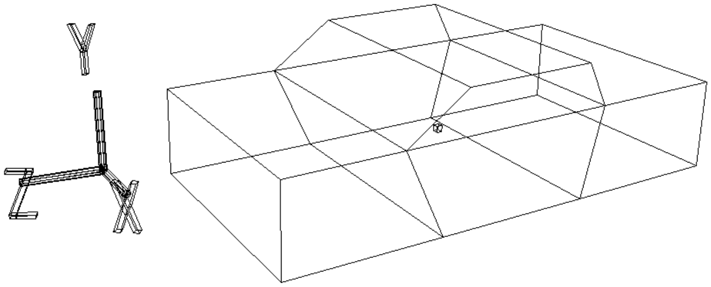
Next, tag the two points shown in the diagram below. (Fig 3-11)

Fig 3-11 Tagging the Vertices at the Upper Front Portion of the Roof



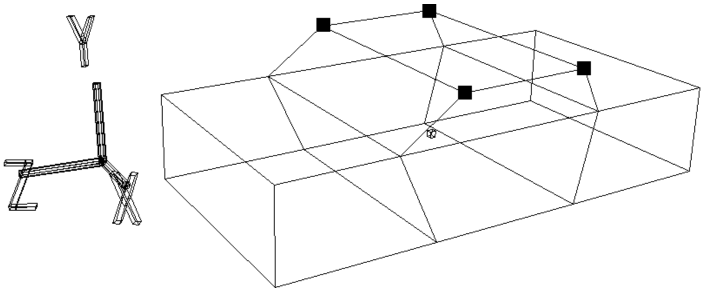
Select the **[TransZ]** icon and move the tagged points in the negative Z direction. (Fig 3-12) (Watch in the right-view window while moving the points until the Z value is about 0.5 meters.)

Fig 3-12 Appearance after Changes to Upper Front Portion of Roof



Next, we will change the shape of the roof itself. Tag the 4 points shown in the illustration. (Fig 3-13)

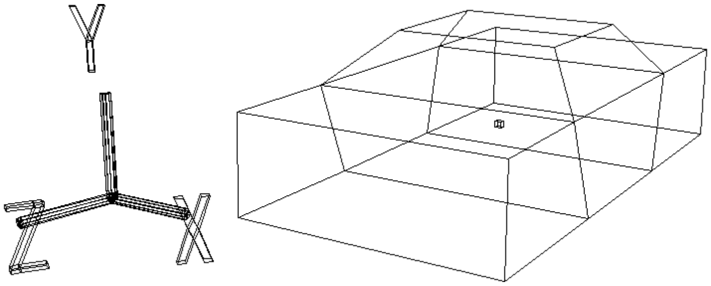
Fig 3-13 Tagging the Upper Portion of the Roof



Confirm that TAG mode is still on, click the **[ScaleX]** icon, and while holding down the appropriate button move the mouse to reduce the distance among the four points in the X direction.

The car should now appear as shown in the diagram. (Fig 3-14)

Fig 3-14 Appearance after Changes to the Upper Portion of the Roof



Adjusting the body of the car

In order to give the object a more “car-like” appearance, we will soften the edges.

First, change from TAG mode to OBJ mode.

After confirming that the car is selected, select:

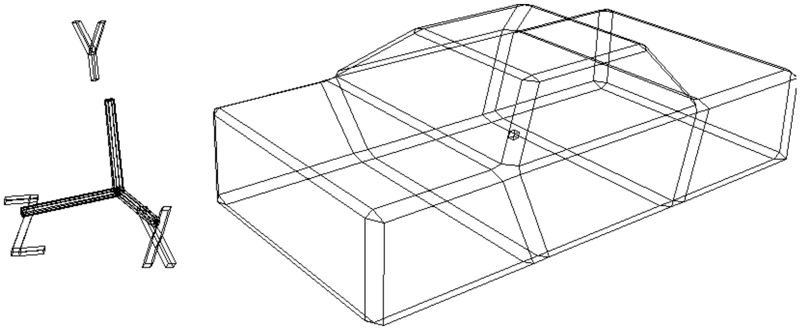
```
[Effect] -> [Rounding]
```

When the numeric value input window appears, input the following value:

```
Round: 0.1
```

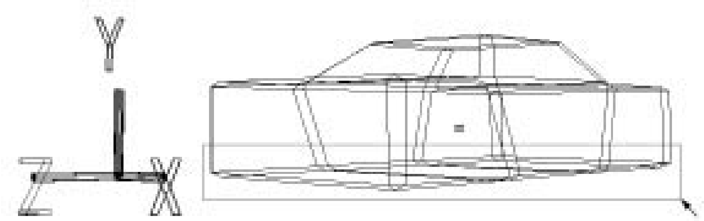
Click “OK.” After doing so, the model is transformed so that the corners are rounded, as shown in the illustration. (Fig 3-15)

Fig 3-15 After Execution of “Round”



Next, we will remove the polygons on the bottom of the body of the car (the chassis). After being sure to set TAG mode, tag each of the vertices on the bottom in the front-view window (tag the vertices with a negative Y value). (Fig 3-16)

Fig 3-16 Tagging the Bottom of the Car

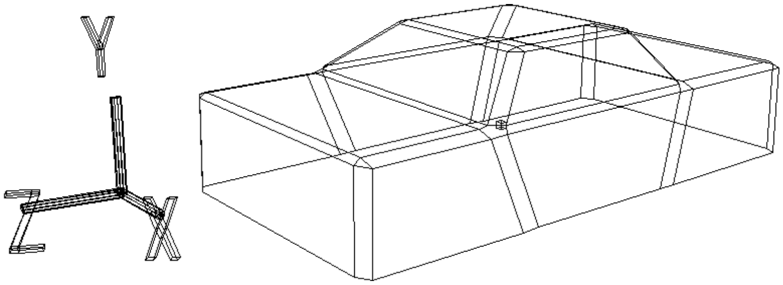


Execute:

```
     [Delete] -> [Selection]
```

The polygons surrounded by the tags are now deleted. (Fig 3-17)

Fig 3-17 After Bottom Polygons Are Deleted



Deleting polygons

This technique of tagging all of the vertices around a polygon and then deleting the polygon is used quite often, so you should make yourself familiar with it.

In the upper right portion of the window, click the left mouse button on “SHADE ↓” and then select “Shade” from the pop-up menu that appears. Doing so switches the display to shaded display (simple rendering); confirm that the polygons have been deleted. (Figs 3-18 and 3-19)

Fig 3-18 Appearance of Bottom of Car Before Polygons Are Deleted

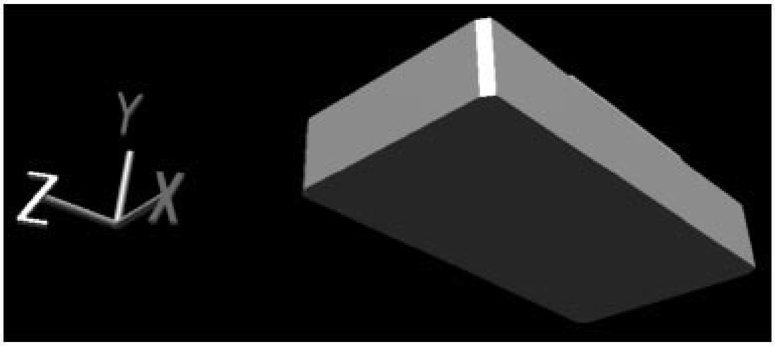
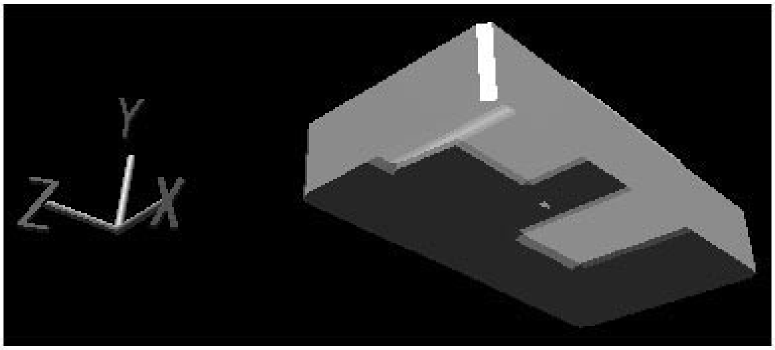


Fig 3-19 Appearance of Bottom of Car After Polygons Are Deleted



Creating the Wheel Wells

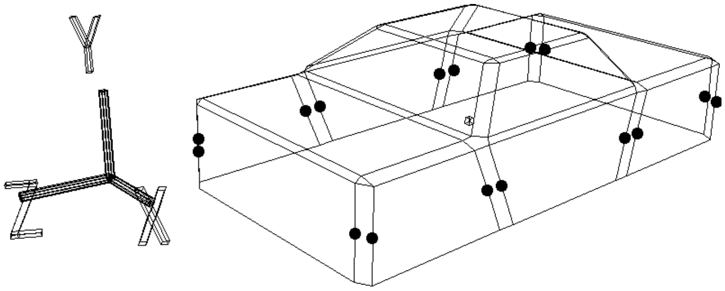
Creating indentations

By performing the following operation:

```
    [Mesh] -> [Vertex] -> center mouse button (add middle vertex)
```

add middle vertices to the line segments (16 in total) indicated in the illustration. (Fig 3-20)

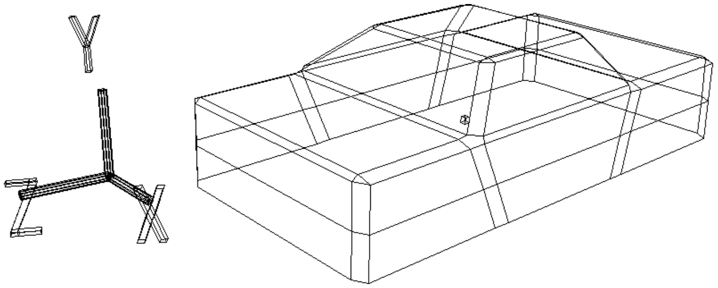
Fig 3-20 Adding Middle Vertices to Line Segments



Connect those middle vertices by performing the following operation:

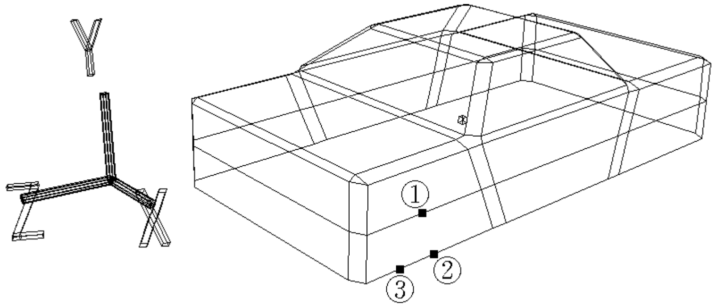
```
    [Mesh] -> [Edge] -> left mouse button (add one edge)
```

Fig 3-21 Linking the Middle Vertices



Perform the following operation again to add vertices as indicated in Fig 3-22 to the front and rear on the left and right sides (all four corners) of the car:

Fig 3-22 Adding Middle Vertices Where the Wheel Wells Will Be (Point 3 is a middle vertex between a normal vertex and a middle vertex)



Use the following operation to connect points 1 and 3:

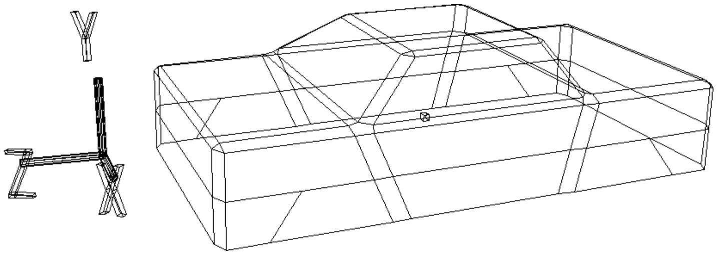
```
    [Mesh] -> [Edge] -> left mouse button (add one edge)
```

Perform the following operation to delete point 2: (Fig 3-23)

```
    [Mesh] -> [Vertex] -> right mouse button (remove vertex)
```

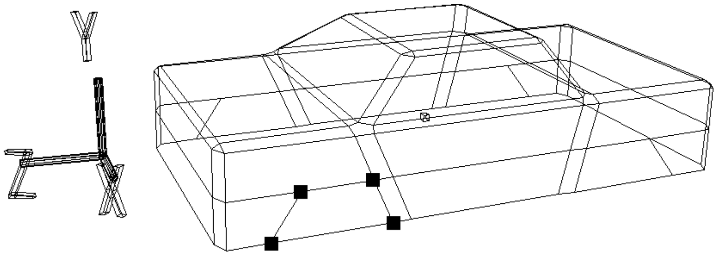
Perform these operations for all four corners of the car.

Fig 3-23 Drawing Lines Where the Wheel Wells Will Be



Next, tag the four vertices that surround the wheel well. (Fig 3-24)

Fig 3-24 Tagging the Wheel Wells



After confirming that TAG mode is set, select:

```
    [Duplicate] -> [Immediate]
```

Execute this operation only once.

Look at the top-view window.

(If the object is not visible in the frame, press either the “F” key or the “A” key.) Click the **[ScaleX]** icon, hold down the appropriate mouse button and drag the mouse so that the distance in the X direction between the tags is decreased. (The tags should each be at about ± 0.7 meters.) To set the tags at exactly ± 0.7 meters, select:

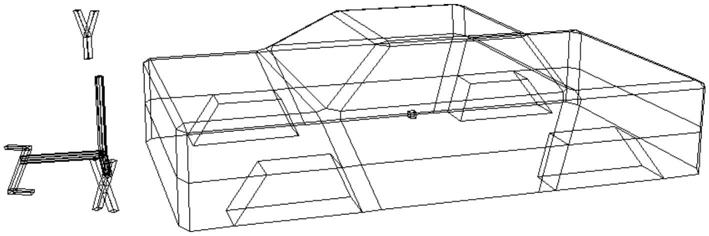
```
    [Edit] -> [Coordinate]
```

and then input 0.7 or -0.7 meters for each of the X values and then click “OK.” Release the tags. (Press the “T” key, hold down the center mouse button, and encircle the tags.)

Repeat the above procedure for each of the four corners of the car.

The result should look like the illustration below. (Fig 3-25)

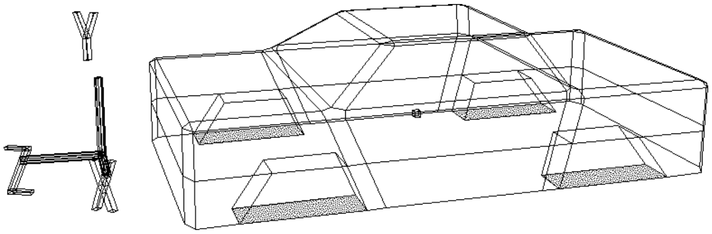
Fig 3-25 Creating the Wheel Wells



Deleting unnecessary surfaces

Pushing these surfaces has created some unnecessary surfaces. We will delete the bottom surfaces in the wheel wells as indicated in the illustration. (Fig 3-26)

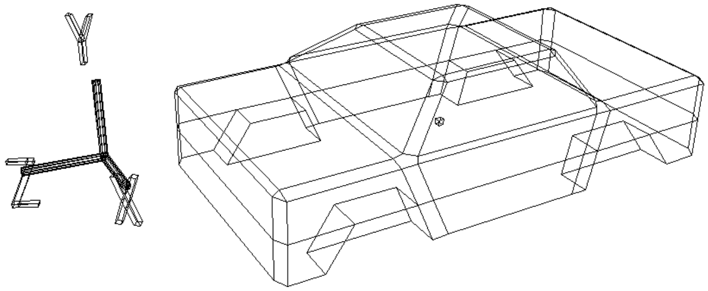
Fig 3-26 Unnecessary Surfaces in the Wheel Wells



Tag all of the vertices (a total of 16) surrounding these four surfaces. Confirm that TAG mode is set and then select: (Fig 3-27)

```
[Delete] -> [Selection]
```

Fig 3-27 Completing the Wheel Wells



The wheel wells are now complete.

Creating the Wheels

Getting a cylinder

Next we will get a new object, a cylinder, for the wheels. Select:

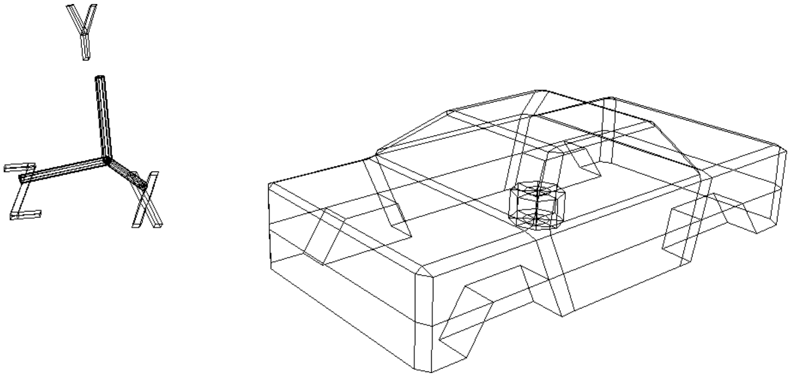
```
    [Get] -> [Primitive] -> [Cylinder]
```

When the numeric value input window appears, enter each of the following values:

Radius: 0.225, Height: 0.25, Longitude Step: 8, Latitude Step: 1, Base: 2

After closing the window, a squat cylinder like the one shown in the illustration will appear at the origin point. (Fig 3-28)

Fig 3-28 Getting a Cylinder

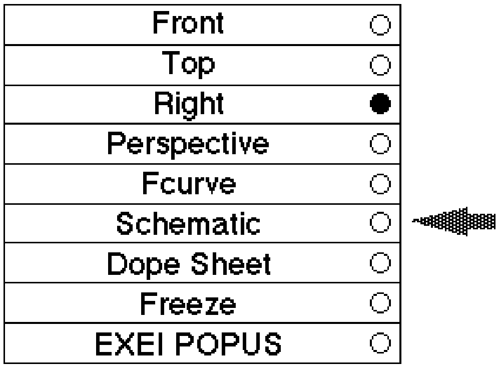


In addition, the car model will now appear as a black wire frame, and the new cylinder will appear as a white wire frame (indicating that the cylinder is selected).

Using the Schematic screen

Look at the right-view window. Click on the word “Right” with the left mouse button, and the pop-up menu shown in the figure appears. (Fig 3-29)

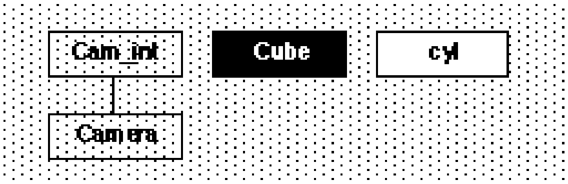
Fig 3-29 Pop-Up Menu



currently, “Right” is checked with a black circle. Select “Schematic.”

When schematic is clicked, the screen appears as shown in the following diagram. (Fig 3-30)

Fig 3-30 Schematic Screen



In this display, the items displayed in white are selected objects, and the items displayed in black are objects that are not selected.

On the Schematic screen, hold down the space bar, press the left mouse button, and drag the mouse so that the “Cube” box is enclosed. The “Cube” box should now be white (and the “cyl” box should be black).

Again, hold down the space bar, press the left mouse button, and drag the mouse so that the “Cube” box is enclosed. The “Cube” box is now de-selected, with the result that nothing is selected.

Using the method just described (space bar + left mouse button), select the “Cube” box (the car) again, so that it is highlighted in white. Once the “Cube” box is selected, select:

```
[Display] -> [Hide] -> [Toggle Selection]
```

The car should now have disappeared from the window. (Fig 3-31) Look at the Schematic screen. The “Cube” box color should now be the same as the “Cam_int” and “Camera” boxes. This is the hidden state.

Fig 3-31 Hiding the Car

Hiding objects (Hide)

From now one, many objects will be handled on the screen at one time, but because objects that are not being worked on at the present moment only clutter up the screen, use **[Display]** -> [hide] to hide those objects that are only in the way.

To display a hidden object again, select the hidden object on the “Schematic” screen (the “Cube” in this case) and again select:

```
[Display] -> [Hide] -> [Toggle Selection]
```

After doing so, the car should be displayed in wire frame form again.

Summary for [Hide] operation

```
[Display] -> [Hide] -> [Unselected]
```

This function hides unselected objects.

```
[Display] -> [Hide] -> [Unhide All]
```

This function displays all objects. The camera and the point of interest (focal point) are also displayed, but when these objects are displayed, camera movement on the perspective screen becomes very slow.

```
[Camera] -> [Hide Camera]
```

This function hides the camera and the point of interest.

```
[Display] -> [Hide] -> [Toggle Selection]
```

This function displays hidden objects that are selected and hides displayed objects that are selected.

Shaping the cylinder

Now that we have hidden the car, we will turn the cylinder into a wheel. First, perform the following operation to remove eight of the edges on the bottom of the cylinder:

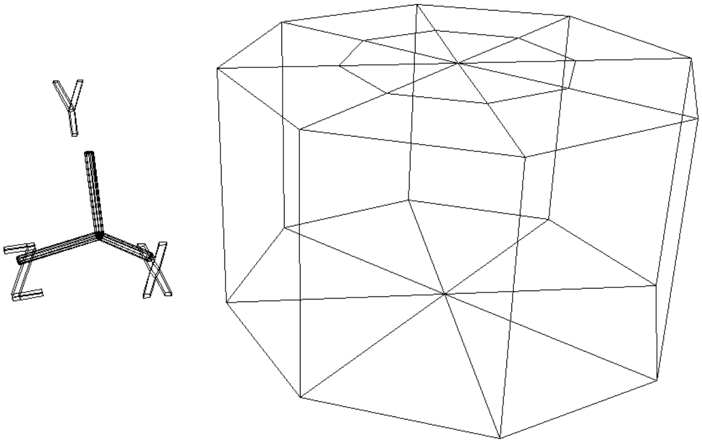
```
[Mesh] -> [Edge] -> right mouse button (Remove edge)
```

Next, remove the eight vertices left behind:

```
[Mesh] -> [Vertex] -> right mouse button (Remove vertex)
```

The resulting object should appear as shown in Fig 3-32 below:

Fig 3-32 Removing the Polygons on the Bottom of the Cylinder



*** Another method for deleting vertices**

When removing vertices, it is possible to remove “vertices” that are located in the middle of a straight line (i.e., vertices that are not actual vertices on a polygon) by selecting:

```
[Effect] -> [Cleanup]
```

To remove the vertices, do not check any of the check boxes, but simply click “OK.” The mid-line vertices will then disappear.

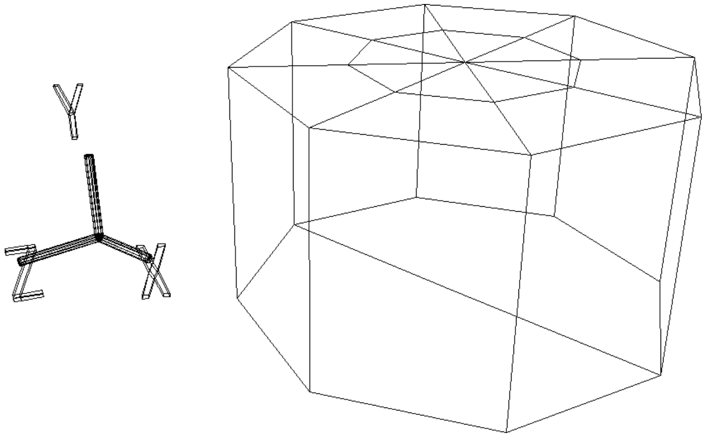
We will now modify the bottom of the cylinder further.

The Saturn system supports polygons with three vertices and four vertices. (Polygons with five or more vertices cannot be used.)

Basically, because processing is easier the fewer polygons that there are in a model, it is better to reduce the number of polygons by using a fewer number of polygons with four vertices than a larger number with three vertices.

First, delete edges until the object is as shown in the illustration. (Fig 3-33)

Fig 3-33 Reducing the Number of Polygons on the Bottom of the Cylinder



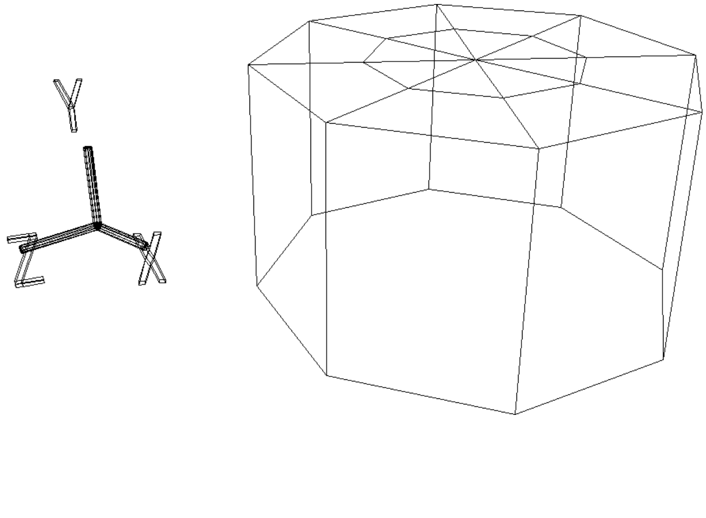
Delete the vertex in the middle of the bottom of the cylinder through the following operation:

```
     [Mesh] -> [Vertex] -> right mouse button
     (or [Effect] -> [Cleanup])
```

Then, delete the remaining edge. (Fig 3-34)

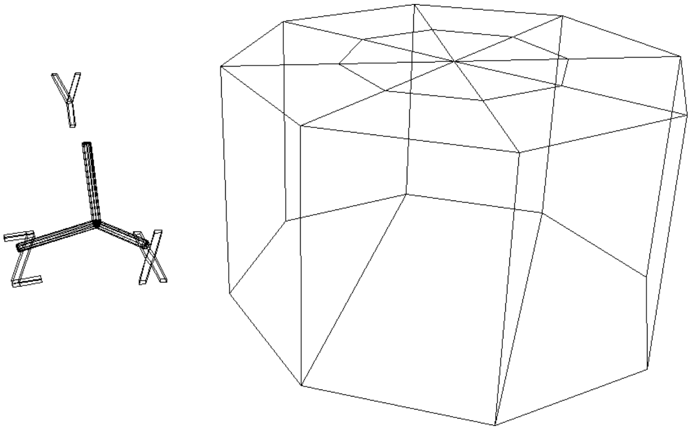
```
     [Mesh] -> [Edge] -> right mouse button (Remove edge)
```

Fig 3-34 Reducing the Number of Polygons on the Bottom to One



The bottom of the cylinder should now consist of a single octagon. Perform the following operation twice to divide the octagon as shown in the illustration. (Fig 3-35)

Fig 3-35 Dividing the Octagon into Polygons with Four Vertices



Compare the number of polygons in the top and bottom of the vertices. 16 polygons were reduced to 3 polygons.

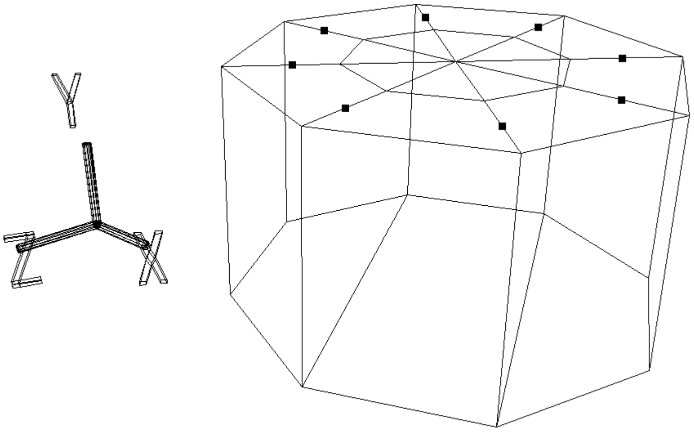
> **Note: This task of reducing the number of polygons is very important in the production of games involving 3D polygons. Be sure to familiarize yourself with this process.**

Preparing the surface

Assuming the bottom of the cylinder to be the backside of the wheel, we will give the top of the cylinder (which will be the outside of the wheel) more of a wheel-like appearance. First, add eight middle vertices as shown in the illustration, using the following operation:

```
    [Mesh] -> [Vertex] -> center mouse button (Add middle vertex)
```

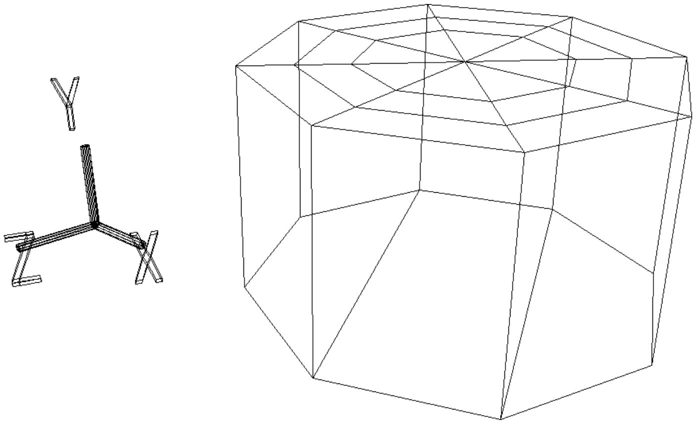
Fig 3-36 Adding Middle Vertices



Next, draw lines to connect these middle vertices, using the following operation: (Fig 3-37)

```
     [Mesh] -> [Edge] -> left mouse button (Add one edge)
```

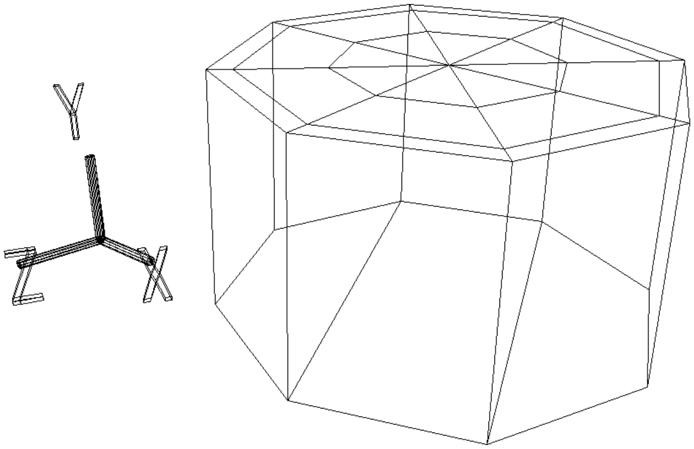
Fig 3-37 Adding Edges



Tag all eight of the middle vertices that were just created. (Press the “T” key and the left mouse button and enclose each of the vertices.)

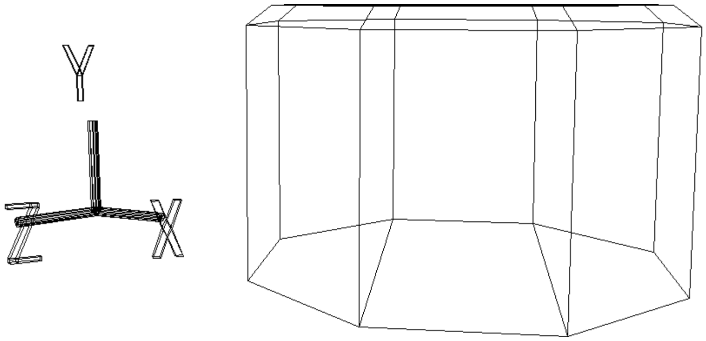
Confirm that TAG mode is in effect, and select **[Scale]** so that it is highlighted in blue. Hold down both the left and right mouse buttons simultaneously and drag the mouse so that the tagged points move and the resulting figure looks like the illustration below. (Fig 3-38)

Fig 3-38 Spreading Out the Tire Portion of the Wheel



Now tag all of the points to the inside of the tagged points. (This is probably easiest to do in the top-view window.) Once all of the points have been tagged, select the **[TransY]** icon. (At this stage, TAG mode should still be selected.) Next, move the tagged points a suitable amount in the positive Y direction. The object should appear as shown in the illustration. (Fig 3-39)

Fig 3-39 Raising the Outside of the Wheel



Next, release the outermost ring of tags (8 points).

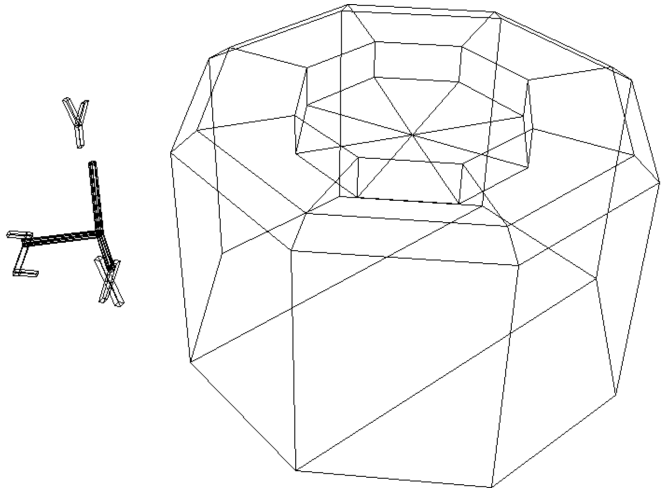
After confirming that TAG mode is set, perform the following operation once:

```
    [Duplicate] -> [Immediate]
```

(We will push this surface in.)

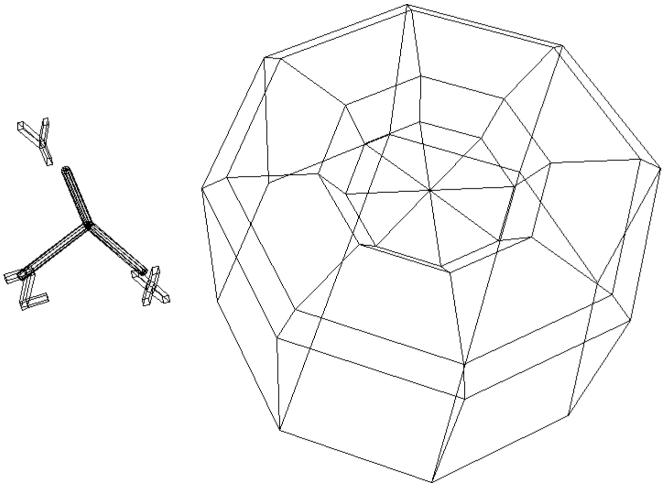
Click the **[TransY]** icon and move the tagged points in the negative Y direction by pushing the surface. (Fig 3-40)

Fig 3-40 Lowering the Inner Portion of the Wheel



Leaving the tags as they are, next click the **[Scale]** icon so that it is entirely highlighted in blue. Then, while holding down the left and right buttons simultaneously, drag the mouse so that the points come closer together and the object appears as shown in the illustration. (Fig 3-41)

Fig 3-41 Narrowing the Inner Portion



Now release all of the tags.

First, click the middle mouse button where “SHADE” is displayed in the upper right corner of the Perspective window. The object display should change from wire frame to shaded display. (To return to the original form, click the middle mouse button where “WIRE” is displayed.)

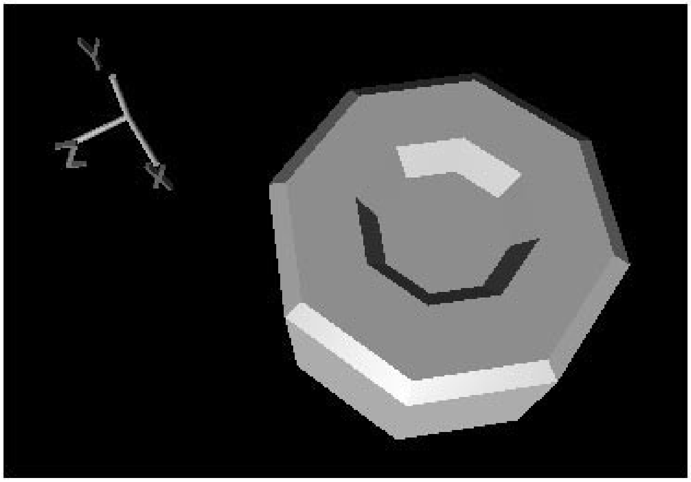
Looking at the shaded object, it does not look very much like polygons.

Select:

```
    [Info] -> [Selection]
```

A window appears. Switch from “Automatic Discontinuity” to “Faceted,” and then click “OK.” The shaded object now seems to consist of distinct polygons. (Fig 3-42)

Fig 3-42 Display with Polygons Delineated



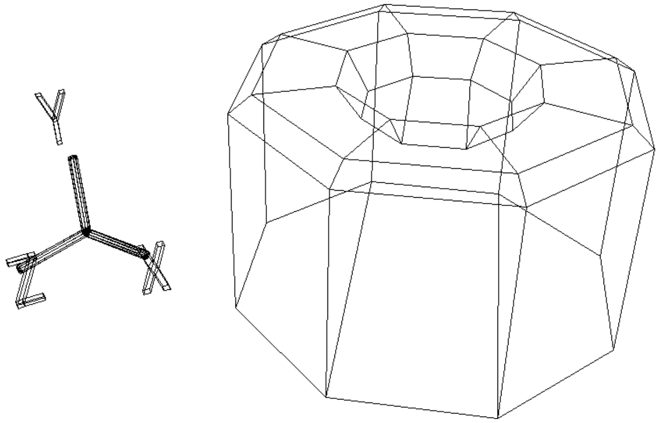
Note: Continue to use the “Faceted” setting during future modeling work.
For flat shading: Select "Faceted"
For glossy shading: Select "Automatic Discontinuity"

Adjusting the wheel

Although the wheel is practically complete, there is still some work to be done. One important task is to reduce the number of polygons in the hub of the wheel. In the same way as the number of polygons on the backside of the wheel was reduced, use the following operations to reduce the number of polygons in the indentation on the outside of the wheel from eight to three:

```
[Mesh] -> [Edge] -> right mouse button (Remove edge)
[Mesh] -> [Vertex] -> right mouse button (Remove vertex)
(or [Effect] -> [Cleanup])
[Mesh] -> [Edge] -> left mouse button (Add one edge)
```

Fig 3-43 Reducing the Number of Polygons in the Indentation



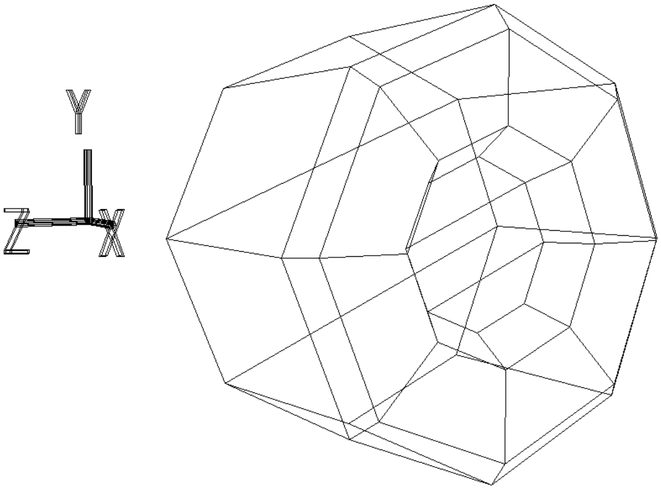
Now switch from TAG mode to OBJ mode.

Next, click on the corner triangle in the **[Rot]** icon and input the following values:

```
X: 0, Y: 0, Z: -90
```

Click “Set.” (Fig 3-44)

Fig 3-44 Standing the Tire Up



The wheel is now facing in the positive X direction. To make this orientation the standard, perform the following operation:

```
[Effect] -> [Freeze] -> [Rotation]
```

RotZ now has changed from -90.0000 to 0.0000.

Now select the hidden "Cube" box (space bar and left mouse button) on the Schematic screen and perform the following operation:

```
[Display] -> [Hide] -> [Toggle Selection]
```

The car re-appears.

Place the cursor in the center of the Perspective screen and press the "A" key.

Short-cut key

A key: [Display] -> [Frame All]

Now select the wheel ("Cyl") again. (space bar + left mouse button) We will now move the wheel so that it is positioned in the wheel well.

Click the **[Trans]** icon so that it is entirely highlighted in blue. In the bottom right corner of the screen, the display changes to LCL, GBL, PAR, REF, and DRG. In this state, if "Scale," "Rot" or "Trans" is selected, the display mode will change as follows:

If "Scale" is selected:

OBJ TAG CTR TXT -> XYZ UNI VOL — —

In most cases, "XYZ" will be selected.

If "Rot" is selected:

OBJ TAG CTR TXT -> LCL GBL ADD REF PLN

In most cases, "ADD" will be selected.

If "Trans" is selected:

OBJ TAG CTR TXT -> LCL GBL PAR REF DRG

The most commonly used selections are "LCL," "GBL," and "DRG."

LCL allows an object to be moved in the direction of the X axis (left mouse button), Y axis (center mouse button) or Z axis (right mouse button), in accordance with the axes of the object (displayed by [Show] -> [Centre]). Accordingly, the object may not necessarily move in parallel with the global axes.

Selecting GBL allows an object to be moved in the direction of the X axis (left mouse button), Y axis (center mouse button) or Z axis (right mouse button), always in accordance with the global axes.

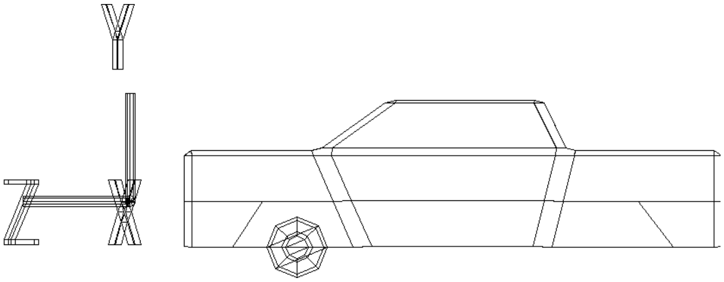
When DRG is selected, pressing the left mouse button allows an object to be moved freely. Pressing the center mouse button allows the object to be moved vertically on the screen, and the right mouse button allows the object to be moved horizontally on the screen.

In the present case, because we wish to move the wheel according to the global axes, click GBL. While watching the top-view window, hold down the right mouse button and move the object in the positive Z direction (to about 1.160), and then hold down the left mouse button and move the object in the positive X direction (to about 0.8600).

Now, we want to look at the right-view window, but that has been changed to "Schematic" display, so the object is not displayed in that window. Therefore, we will switch the view in the front-view window to the right view. Click the left mouse button where "Front" is displayed; when the menu appears, select "Right."

Now, while looking at the right-view window, hold down the center mouse button and move the Wheel in the negative Y direction (to about 0.3400).

Fig 3-45 Comparing the Wheel and the Car



The wheel is now in position. (Fig 3-45)

We don’t want the wheel to be this small, so we will make it larger.

First, select OBJ mode.

Click on the **[Scale]** icon so that it is highlighted entirely in blue. Then hold down the center mouse button and the right mouse button and drag the mouse to make the wheel larger.

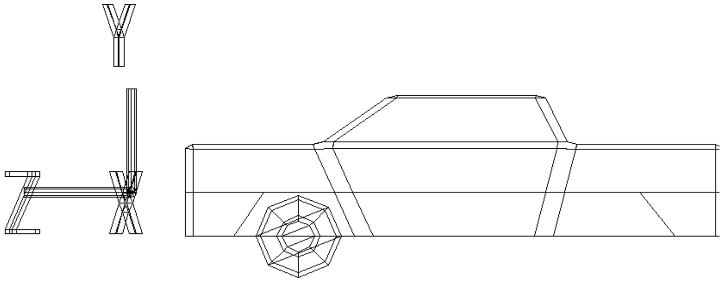
Set the values as follows: Scale Y: 1.4100, Scale Z: 1.4100. (Fig 3-46) You can also set the size by inputting the values.

Since we now want to set the larger wheel as the reference, perform the following operation:

```
    [Effect] -> [Freeze] -> [Scaling]
```

(Do not use [All], as doing so would also freeze the Trans information.)

Fig 3-46 Making the Wheel Larger



We have now completed one wheel.

Wheel placement

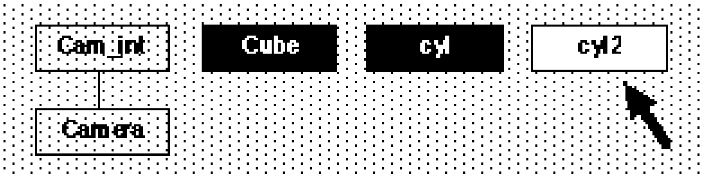
Because our car cannot drive on one wheel, we need to prepare three more. We will do so by duplicating and moving the completed wheel.

After confirming that OBJ mode is set, perform the following operation:

```
     [Duplicate] -> [Immediate]
```

Although it appears that nothing happened on the 3D-view screen, the wheel has been duplicated a glance at the Schematic screen shows the appearance of a newly duplicated object, as shown in the diagram. (Fig 3-47)

Fig 3-47 Schematic Screen



The duplicated object cannot be seen in the normal view screens simply because it appears in the same position as the object being copied.

When an object is duplicated in this manner, the newly duplicated object appears in the selected state.

Click the **[TransZ]** icon. Move the wheel in the negative Z direction and position it in the rear wheel well (Z = -1.1600). (Figs 3-48 and 3-49)

Fig 3-48 Copying and Moving the Wheel

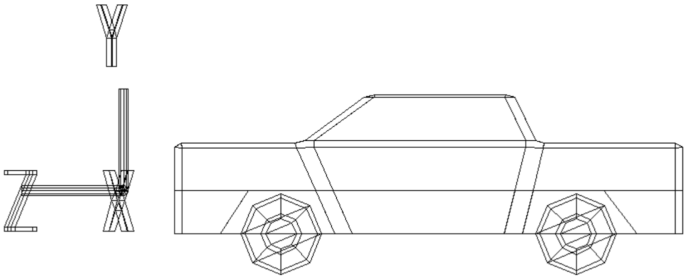
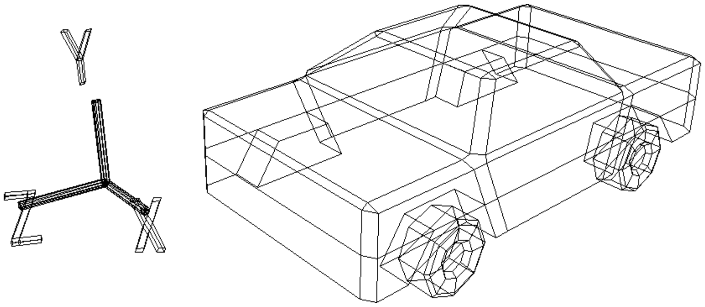


Fig 3-49 Completion of Tires on One Side of Car



We have now completed the wheels on the left half of the car.

We will now create the wheels for the right side of the car; to do so, all we have to do is create two objects that are symmetrical to our existing tires in the YZ plane. SOFTIMAGE is equipped with a useful command, called “Symmetry,” for creating symmetrical shapes.

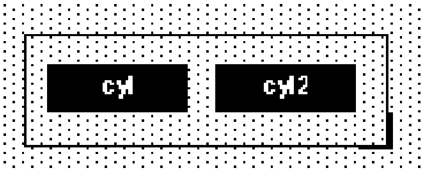
Before executing this command, we must first select the objects that are to be duplicated symmetrically.

Try to select both “cyl” and “cyl2” simultaneously (space bar + left mouse button) on the schematic screen. You find that it is not possible. This is because “Single mode” is currently selected. (**[Single]** under the **[Trans]** icon at the right of the screen is highlighted.)

Selecting multiple objects

To select multiple objects, click **[Multi]** under **[Single]**. Next, drag the mouse so that “cyl” and “cyl2” are both selected. (space bar + left mouse button).

Fig 3-50 Selecting Multiple Objects Together



The selection and de-selection procedure is basically the same as in Single mode.

Now both “cyl” and “cyl2” are selected.

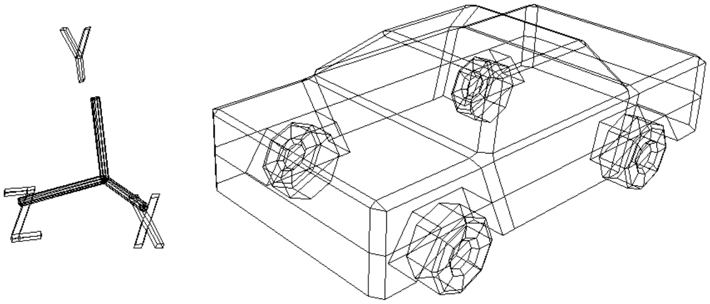
To creak a symmetried shape, select:

```
    [Effect] -> [Symmetry]
```

The “Symmetry” window appears. Because we want to make an object that is symmetrical in the YZ plane, click “YZ plane (x = 0)” and then click “OK.”

“cyl3” and “cyl4” now appear. (Fig 3-41)

Fig 3-51 Completion of Tires on Both Sides of Car



Now return from Multi mode to Single mode. (All objects are de-selected.)

> **Note: If you leave Multi mode in effect, you will perform processes on the multiple objects that are still selected.**

Select “cyl3” and “cyl4” one at a time. RotY should be 180.0000. Since we want to make this state the reference for these objects, perform the following operation for both “cyl3” and “cyl4”:

```
    [Effect] -> [Freeze] -> [Rotation]
```

Incidentally, there is a reason why we have not performed the following operation up to this point:

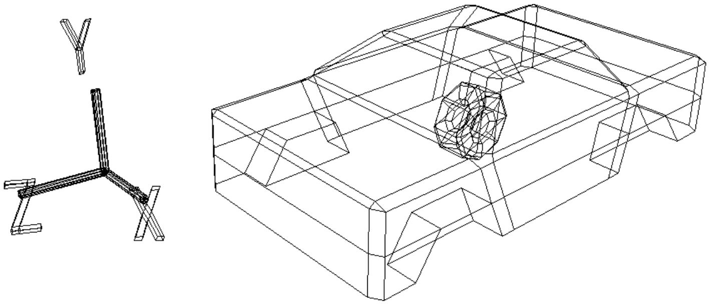
```
    [Effect] -> [Freeze] -> [Translation]
```

The reason is that the values that appear in the **[Trans]** icon when the model is selected are important for programming purposes.

For example, assume that we displaying this model on the Saturn system and that we are making the wheels rotate. In such a case, if the wheel Trans values have been frozen, the origin point for the wheels will be the same as the origin point for the body of the car; as a result, the wheels would rotate around the origin point of the car. To rotate the wheels around their own center axes, it is necessary to display the tires on the Saturn system without freezing the Trans values.

However, if the Trans values are not frozen and this model is displayed on the Saturn system, it will appear as shown in the illustration below. (Fig 5-52)

Fig 5-52 Initial Display on the Saturn System



Therefore, it is to inform the programmers of each of the values that appear in the **[Trans]** icon so that the programmers can move the wheels to the prescribed positions and then make the wheels rotate there (X axis rotation, in this case).

In order to animate models, then, cooperation with the programmers becomes very important.

Finishing Touches for the Model

Creating polygon surfaces

Now we will add the finishing touches to our model.

First, set Multi mode and then select the four objects “cyl,” “cyl2,” “cyl3,” and “cyl4” on the schematic screen. (Press the space bar + left mouse button and then encircle the boxes.)

Execute the following operation:

```
    [Display] -> [Hide] -> [Toggle Selection]
```

All of the wheels are now hidden. (Fig 3-53)

Return from Multi mode back to Single mode, and select “cube” (the body of the car).

Select:

```
    [Info] -> [Selection]
```

and then switch from “Automatic Discontinuity” to “Faceted.”

Fig 3-53 Hiding the Wheels

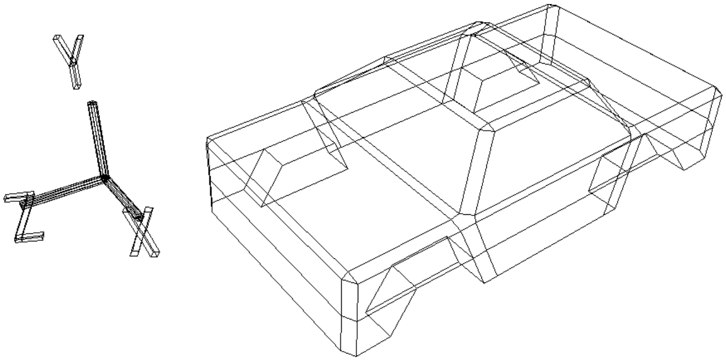
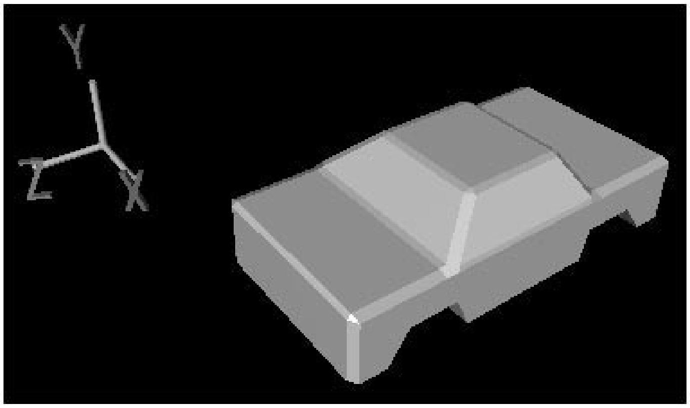


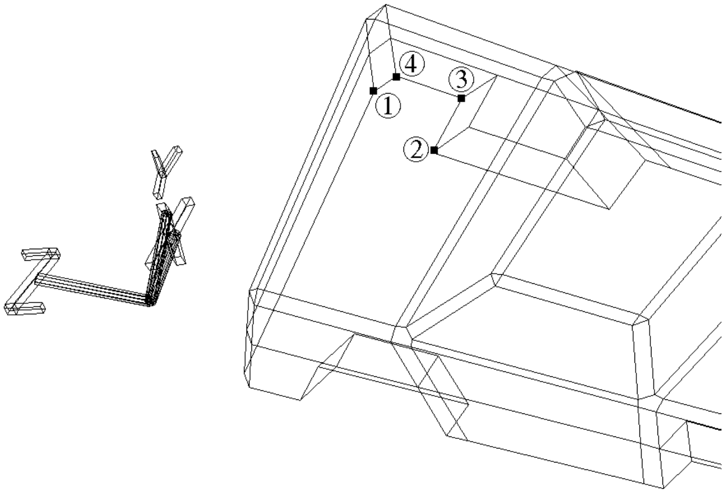
Fig 3-54 Shaded Display



First of all, since the body has no bottom, we will make one.

First, look at the illustration below. (Fig 3-55)

Fig 3-55 Creating a Bottom for the Body



We will create a polygon using the numbered vertices.

Select:

```
[Mesh] -> [Polygon]
```

Use the left mouse button to designate the four vertices in sequence (1, 2, 3, 4).

When the yellow polygon appears, press the center mouse button. This sets the polygon.

Sequence for designating vertices when creating a polygon.

Following these points, fill up the rest of the bottom of the body of the car using:

```
[Mesh] -> [Polygon]
```

When done click the right mouse button and exit polygon creation mode. The completed bottom should look like the illustration below. (Fig 3-56)

Note on the sequence of selection of vertices when creating a polygon

Basically, when creating a polygon, the vertices should be designated in the counterclockwise direction. Doing so will create a polygon in which the normal vector points towards you. If the sequence is reversed, a "bad edge orientation" error will result, and the program will not allow you to designate the vertices.

Fig 3-56 Adding a Bottom to the Car

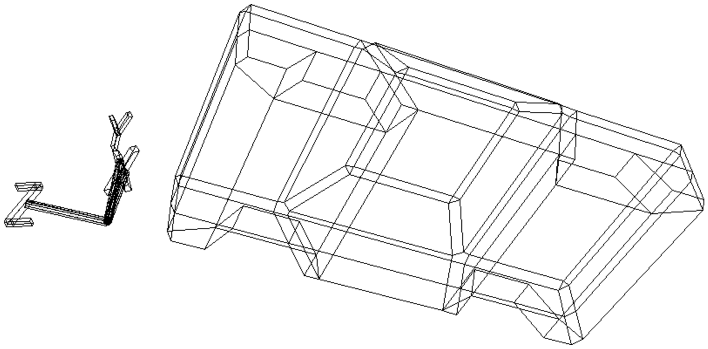
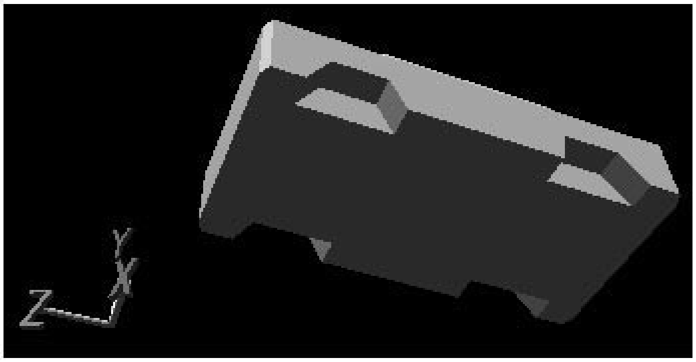


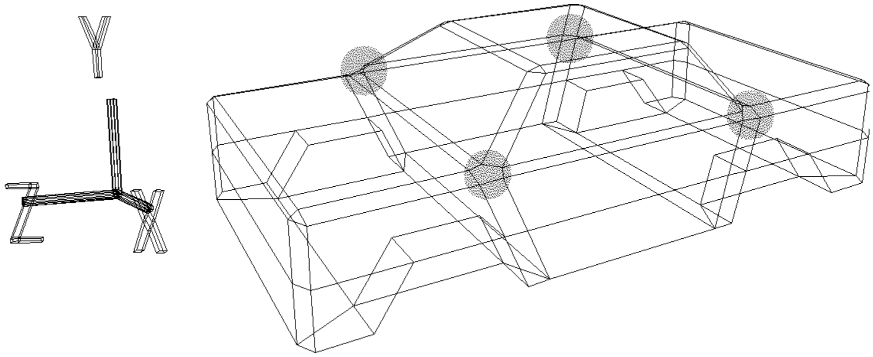
Fig 3-57 Shaded Display



Dividing polygons

Because the Saturn system cannot handle polygons with five or more vertices, such polygons must be divided.

Fig 3-58 Polygons with Five Vertices

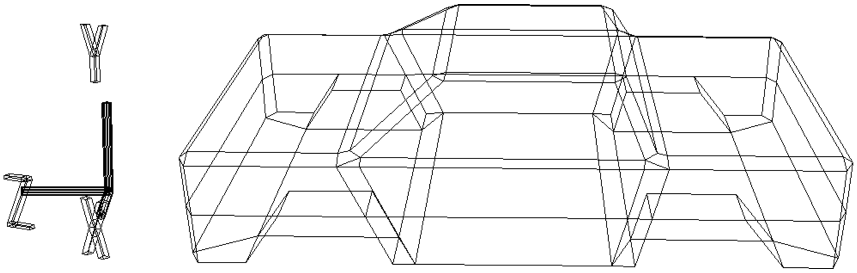


First, we will divide the polygons with five vertices shown in the above diagram (the shaded portions) each into two polygons, one with three vertices and one with four, by drawing in edges. Execute the following operation:

```
     [Mesh] -> [Edge] -> left mouse button (Add one edge)
```

and draw in edges as shown in the diagram. (Fig 3-59)

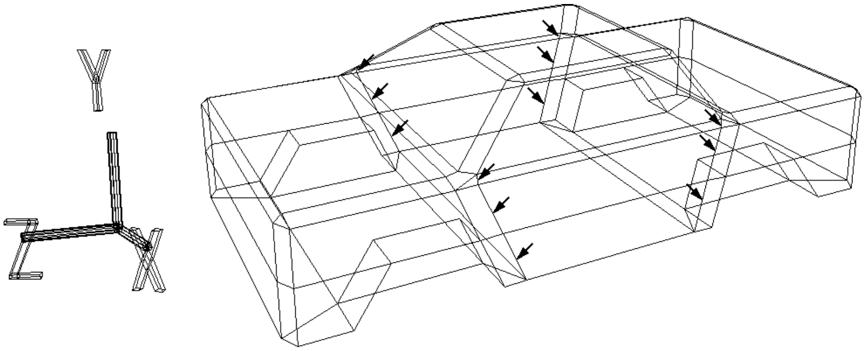
Fig 3-59 Dividing the Polygons with Five Vertices



Deleting polygons

Next we will delete the unnecessary polygons.
Look at the following illustration. (Fig 3-60)

Fig 3-60 Edges to Be Deleted



Delete the edges indicated in the illustration by using the following operation:

```
     [Mesh] -> [Edge] -> right mouse button (Remove edge)
```

(A total of 12 edges are to be deleted.)
After deleting the edges, remove the vertices that were left behind by using:

```
     [Mesh] -> [Vertex] -> right mouse button (Remove vertex)
```

The resulting object should appear as shown in the illustration below. (Figs 3-61 and 3-62)

Fig 3-61 After Removal of Unnecessary Polygons

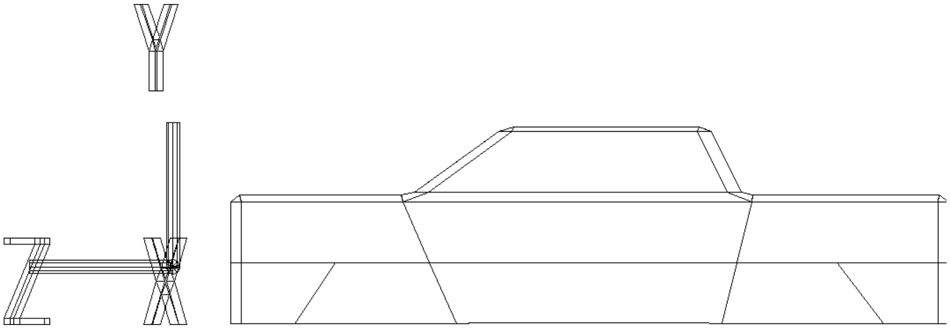
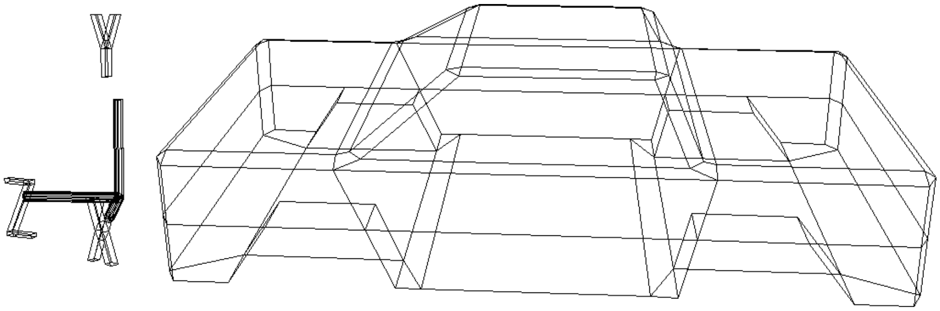


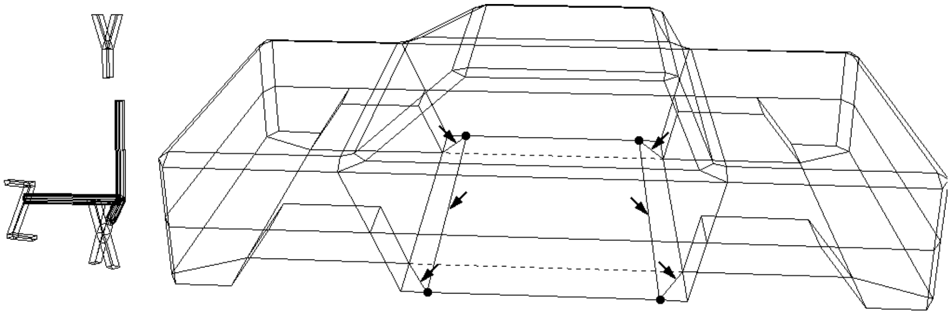
Fig 3-62 Removing the Vertices Left Behind after Removal of Edges



Note: If an edge is removed unintentionally, instead of drawing the edge back in, use the Undo function (“U” key + left mouse button).

As a result of all these changes, other unnecessary edges have been created. Look at Fig 3-63 below.

Fig 3-63 Edges to Be Deleted on the Bottom of the Car



First, delete the six edges indicated

```
     [Mesh] -> [Edge] -> right mouse button
```

Next, draw in edges where indicated by the dotted lines

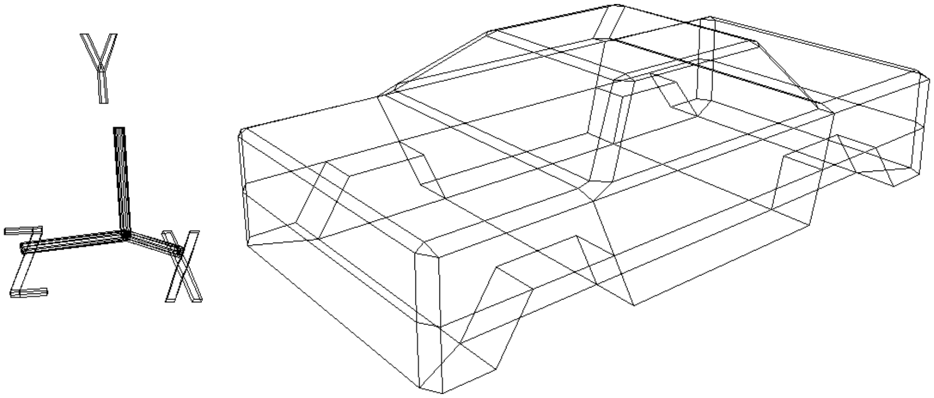
```
     [Mesh] -> [Edge] -> left mouse button
```

Finally, remove the four vertices left behind

```
     [Mesh] -> [Vertex] -> right mouse button
```

Four polygons have been eliminated. The results should appear as shown in Fig 3-64 below.

Fig 3-64 After Deletion of Edges



Adding details to the body

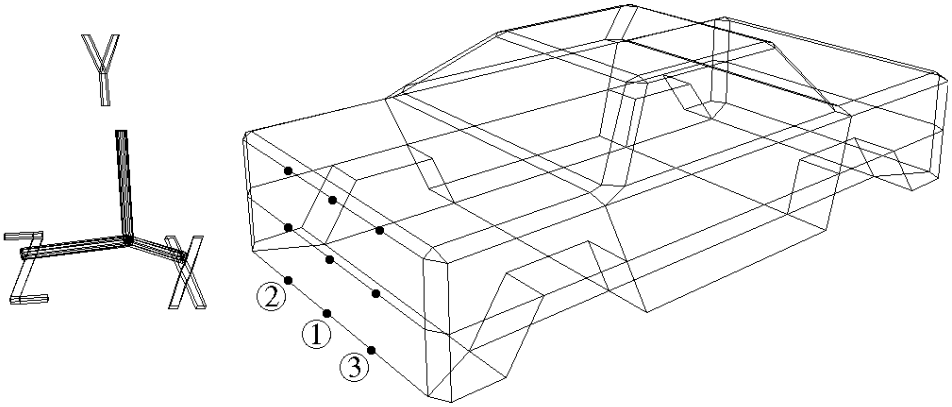
Now we will make our car look more like a real car.

Using the following operation:

```
    [Mesh] -> [Vertex] -> center mouse button (Add middle vertex)
```

add vertices to divide the entire car into four equal parts along the X axis, following the diagram below as a guide. (Fig 3-65) However, note that no vertices are to be added to the bottom of the car.

Fig 3-65 Adding Points to Divide the Car into Four Equal Parts Along the X Axis

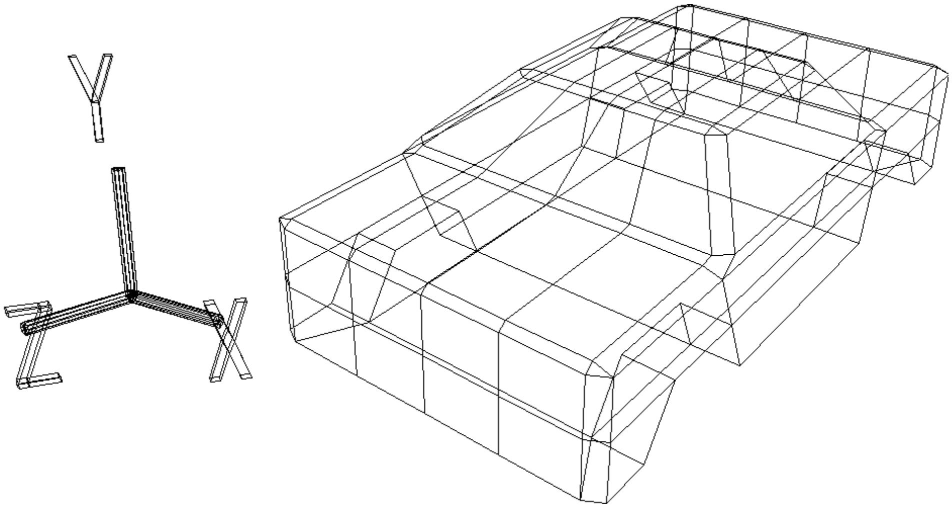


Use:

```
    [Mesh] -> [Edge] -> left mouse button (Add one edge)
```

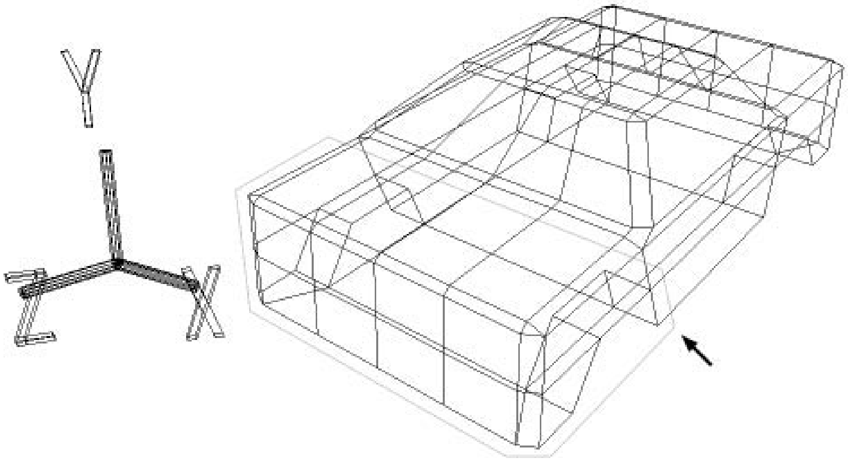
to connect all of the vertices. The final result should appear as shown in Fig 3-66 below.

Fig 3-66 Result When Car Is Divided into Four Equal Parts Along the X Axis



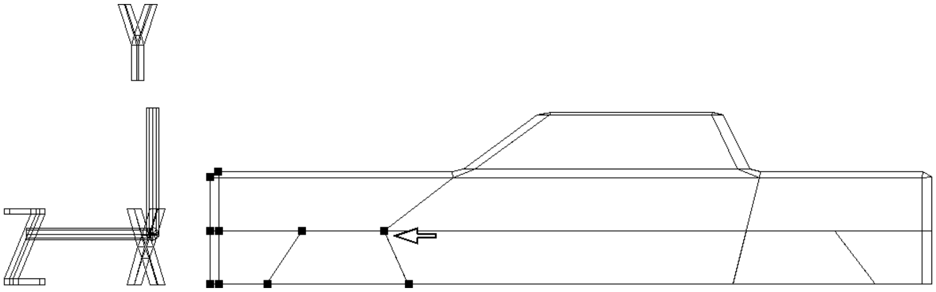
Tag all of the vertices enclosed in the dotted line below. (Fig 3-67) (Hold down the “T” key and left mouse button and drag the mouse to enclose the points.)

Fig 3-67 Tagging the Front Portion of the Car



After confirming that TAG mode is on, select **[TransZ]** and move the tagged points an appropriate amount in the positive Z direction. (Fig 3-68)

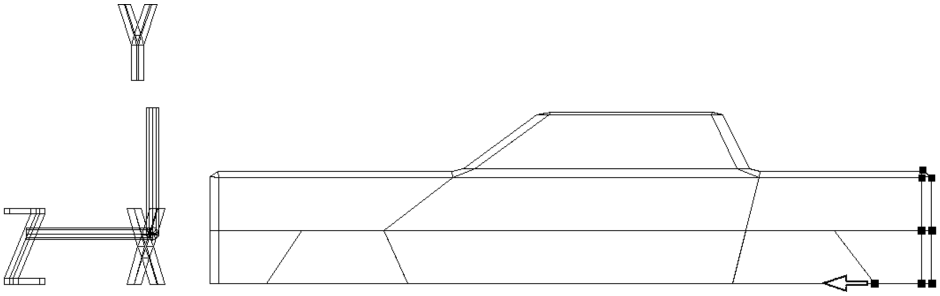
Fig 3-68 Moving the Front Portion of the Car in the Positive Z Direction



After moving the tagged points, release them. (Hold down the “T” key and right mouse button and drag the mouse to enclose the points.)

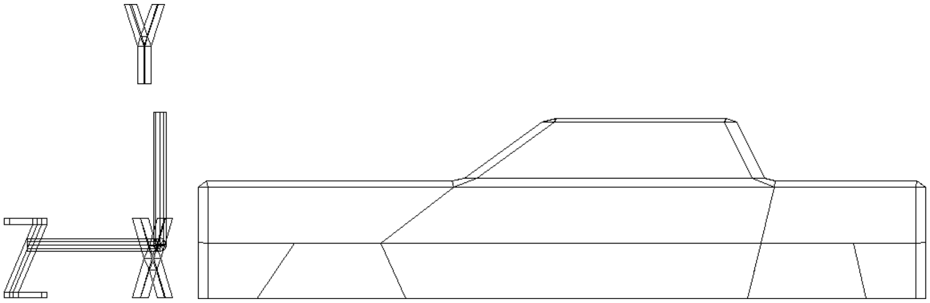
Now tag the points shown in Fig 3-69 below.

Fig 3-69 Tagging the Rear Portion of the Car



After confirming that TAG mode is on, select **[TransZ]** and move the tagged points an appropriate amount in the positive Z direction. (Fig 3-70)

Fig 3-70 Moving the Rear Portion of the Car in the Positive Z Direction



After moving the tagged points, release them.

Next, add middle vertices to the hood of the car by using:

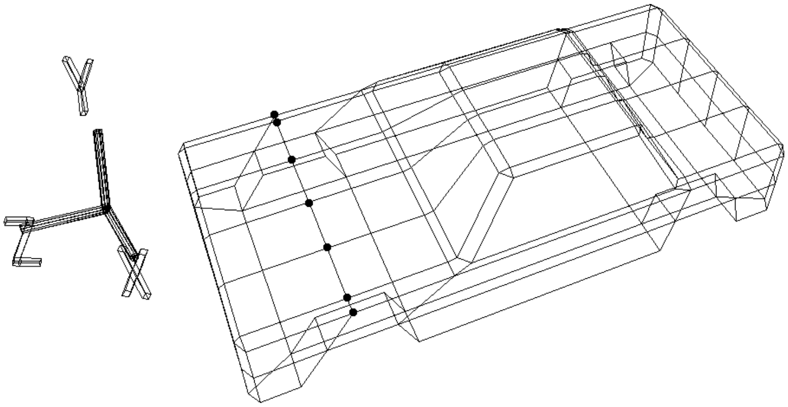
```
     [Mesh] -> [Vertex] -> center mouse button (Add middle vertex)
```

(Add a total of seven middle vertices.) Then connect those vertices by using:

```
     [Mesh] -> [Edge] -> left mouse button (Add one edge)
```

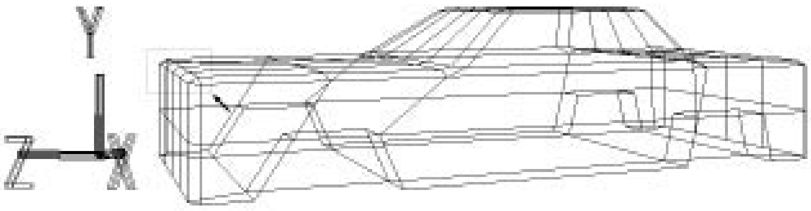
Positioning the vertices as shown in the diagram below prevents the creation of any polygons with five vertices. (Fig 3-71)

Fig 3-71 Adding Detail to the Hood



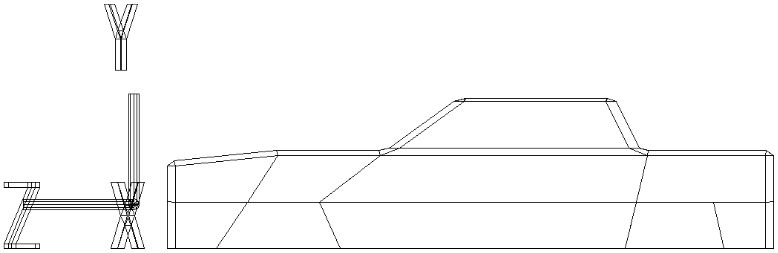
Tag all twelve vertices enclosed by the dotted line in Fig 3-72 below. (Press “T” key + left mouse button and enclose.)

Fig 3-72 Tagging the Front Part of the Hood



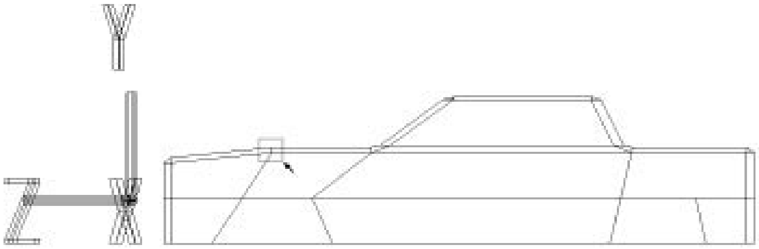
Select **[TransY]** and move the tagged points in the negative Y direction. (Fig 3-73)

Fig 3-73 Lowering the Front Portion of the Hood



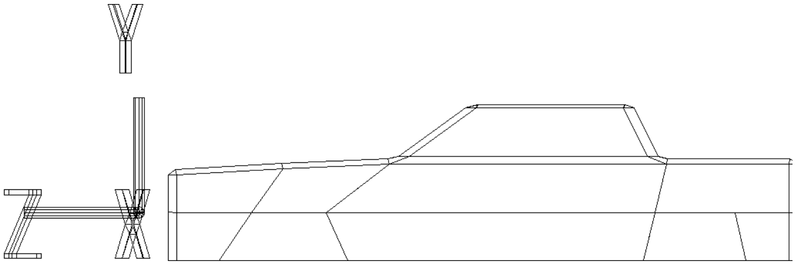
Release the tags, and tag the seven vertices in the middle of the hood. (Fig 3-74)

Fig 3-74 Tagging the Middle Part of the Hood



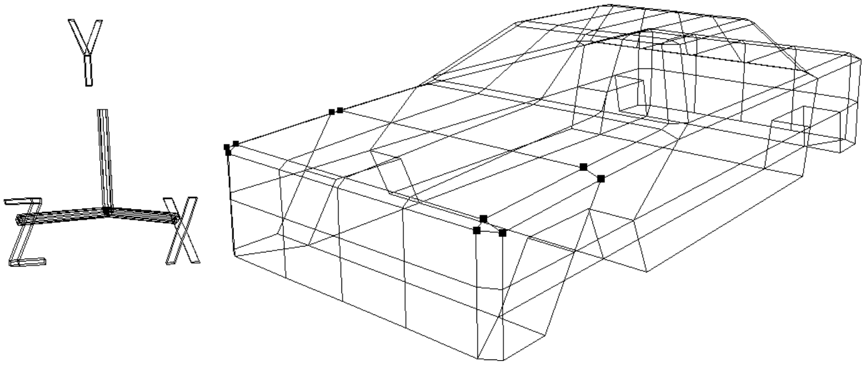
Select **[TransY]** and move the tagged points slightly in the negative Y direction. (Fig 3-75)

Fig 3-75 Lowering the Middle Portion of the Hood



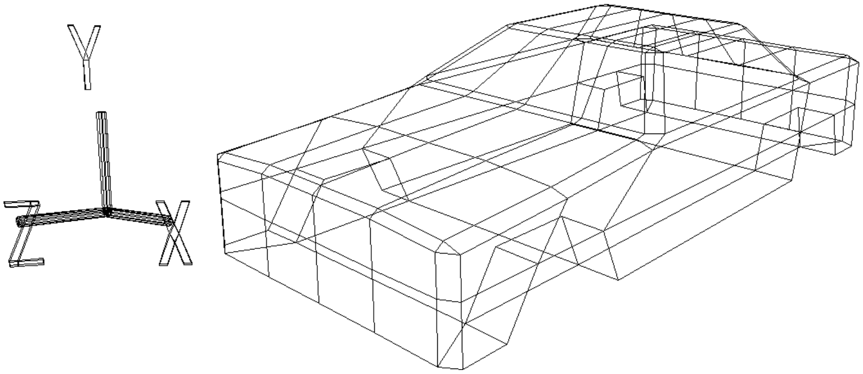
Release the tags and tag the points shown in Fig 3-76 below. (A total of ten vertices, on both sides of the front and center parts of the hood.)

Fig 3-76 Tagging Vertices on Both Sides of the Front and Center Portion of the Hood



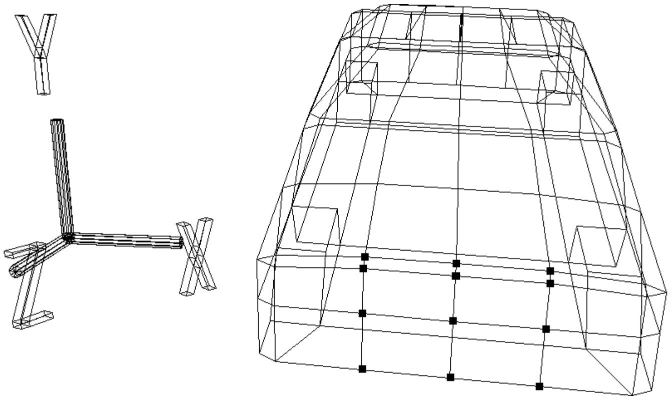
Select **[TransY]** and move the tagged points in the negative Y direction. (Fig 3-77)

Fig 3-77 Lowering the Sides of the Front and Middle Portions of the Hood



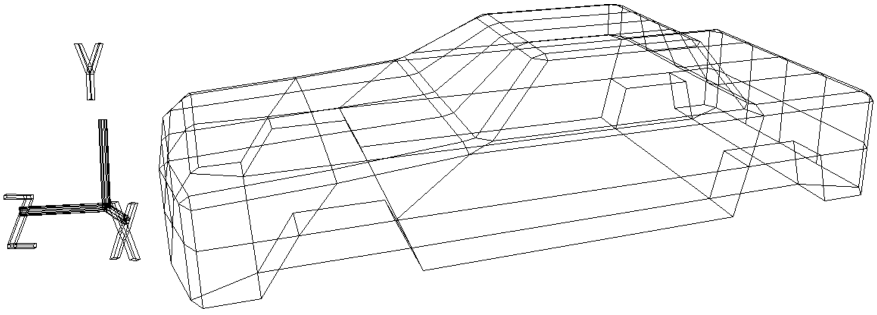
Release the tags, and then tag the 12 points at the center portion of the front end. (Fig 3-78)

Fig 3-78 Tagging the Center Portion of the Front End



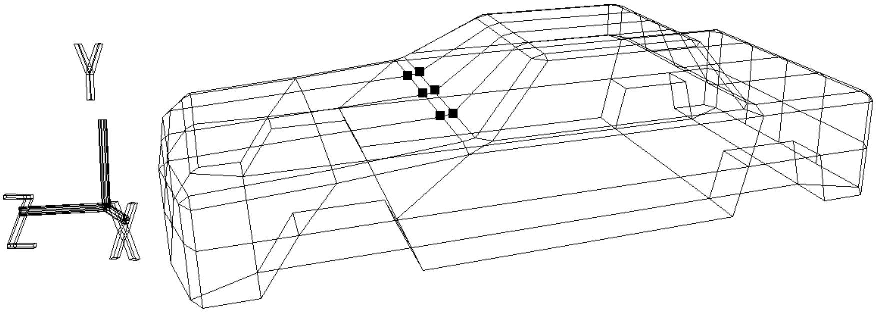
Select **[TransZ]** and move the tagged points a suitable amount in the positive Z direction. (Fig 3-79)

Fig 3-79 Extending the Center Portion of the Front End



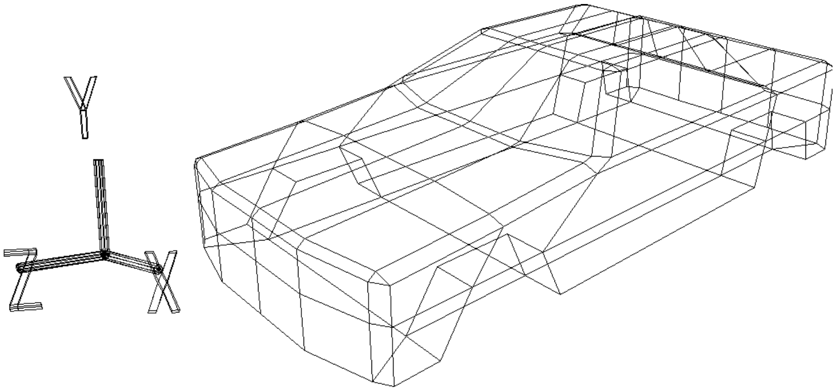
Release the tags, and lastly, tag the points shown in Fig 3-80. (The six points at the center of the bottom of the frame around the windshield.)

Fig 3-80 Tagging the Center of the Bottom of the Frame Around the Windshield



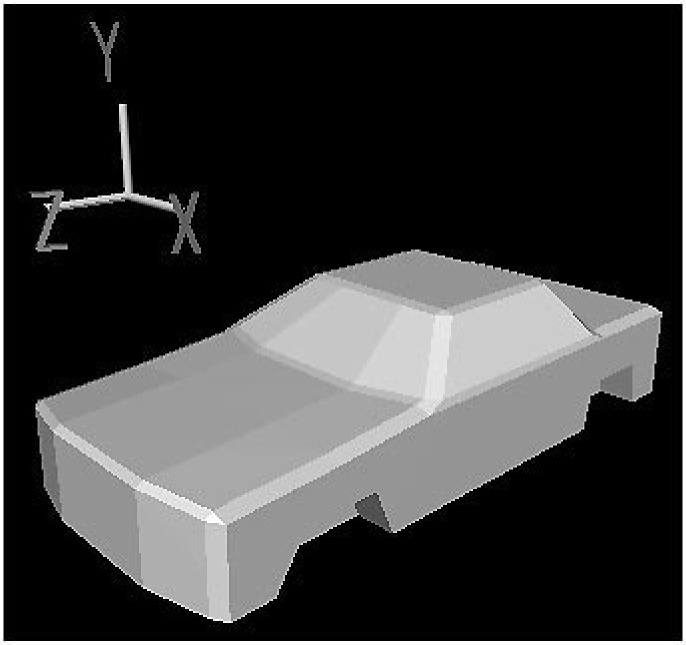
Select **[TransZ]** and move the tagged points a suitable amount in the positive Z direction. (Fig 3-81)

Fig 3-81 Extending the Center of the Bottom of the Frame Around the Windshield



Our model is now complete for all intents and purposes. (Fig 3-82)

Fig 3-82 Completed Body



If you wish, you can use the techniques that you have learned up to this point to add bumpers, etc.

Positioning the wheels

In order to position the wheels, it is first necessary to de-select the car. (Space bar and left mouse button)

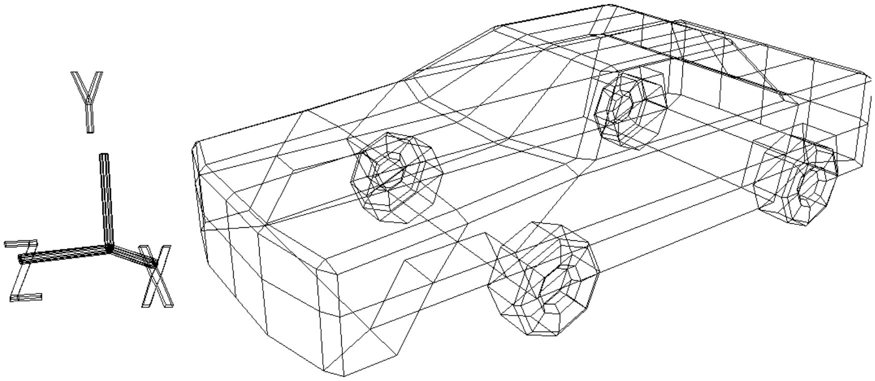
Change the mode from “Single” to “Multi.”

Now select all four hidden wheels (“cyl” to “cyl4”) and display them by using the following operation:

```
     [Display] -> [Hide] -> [Toggle Selection]
```

The figure should then appear as shown in Fig 3-83 below.

Fig 3-83 Wheels Are Out of Position



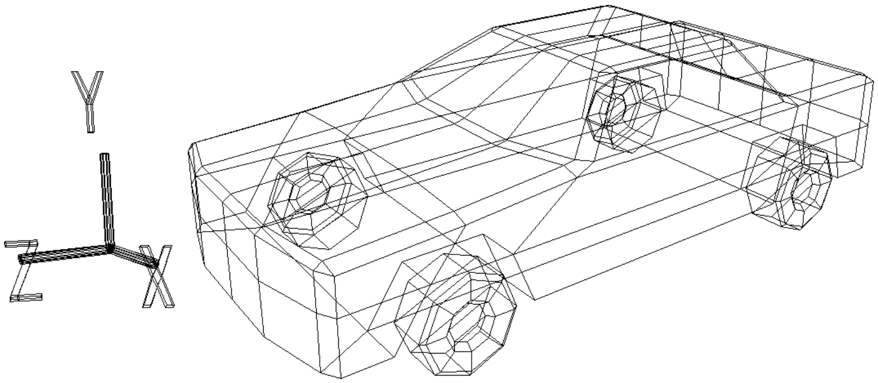
Because the wheels are out of position, we will reposition them.

First, de-select all objects. Next, select the front two wheels. (Multi mode must be set.)

Switch from TAG mode to OBJ mode, select **[TransZ]**, and while watching the Right-view window, move the two wheels in the positive Z direction.

Next, select just the two rear wheels and move them in the positive Z direction. When this is done, return from Multi mode to Single mode. The result should appear as shown in Fig 3-84 below.

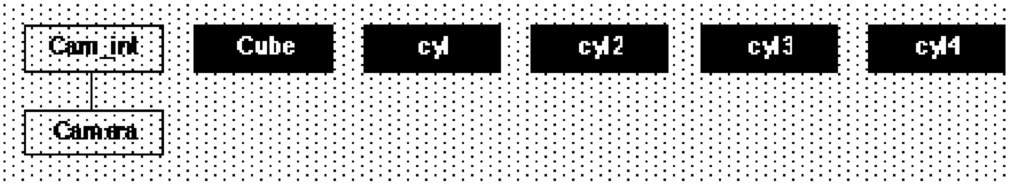
Fig 3-84 Positioning the Wheels



Combining the car and wheels into a single object (parent-child structure)

Look at the Schematic screen. (Fig 3-85)

Fig 3-85 Schematic Screen before Creating the Parent-Child Structure



At present, five objects exist, but since the wheels are really part of the car, we want to be able to handle all of these objects as one object. This is accomplished through a frequently used feature of SOFTIMAGE, the parent-child structure.

Before creating the parent-child structure, select the car (space bar + left mouse button). Then use the following to change the name of the car object from “cube” to “SATURN_CAR”:

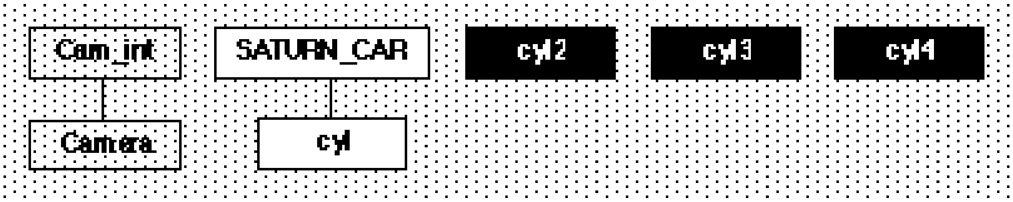
```
[Info] -> [Selection]
```

Now we will create the parent-child structure.

At present, only the car should be selected; with only the car selected, click **[Parent]** (located second from the bottom on the right side of the screen).

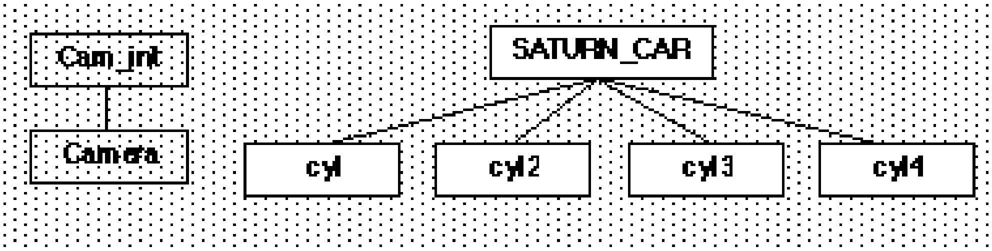
Next, click “cyl” with the left mouse button. The screen should now appear as shown below. (Fig 3-86)

Fig 3-86 Establishing Parent-Child Relationship between “SATURN_CAR” and “cyl”



In the same manner, click “cyl2,” “cyl3,” and “cyl4” with the left mouse button. The resulting Schematic screen should now appear as shown below. (Fig 3-87)

Fig 3-87 Schematic Screen after Creating Parent-Child Structure



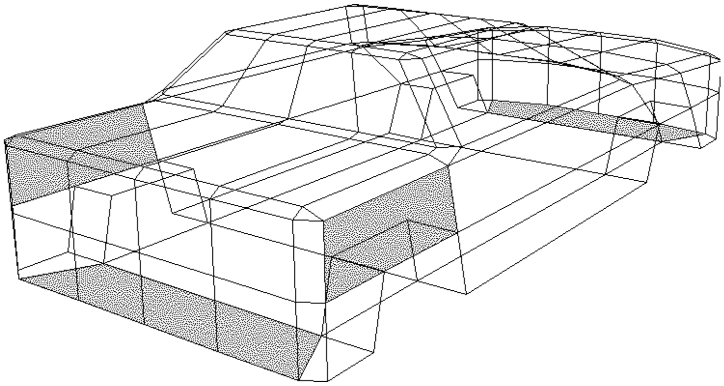
Once the structure is completed, click the right mouse button. **[Parent]** should no longer be highlighted. If Parent mode is left on, you will end up accidentally putting a large number of objects into a parent-child relationship, so always be sure to exit Parent mode.

Final check

Although our work is now practically complete, we will make a final check of the shape.

The first problem is the existence of polygons with five vertices. The presence of such polygons will prevent the data from passing through the converter for the Saturn system. An examination of our model reveals that there are four such polygons. The following illustration reveals their positions. (Fig 3-88)

Fig 3-88 Polygons with Five or More Vertices

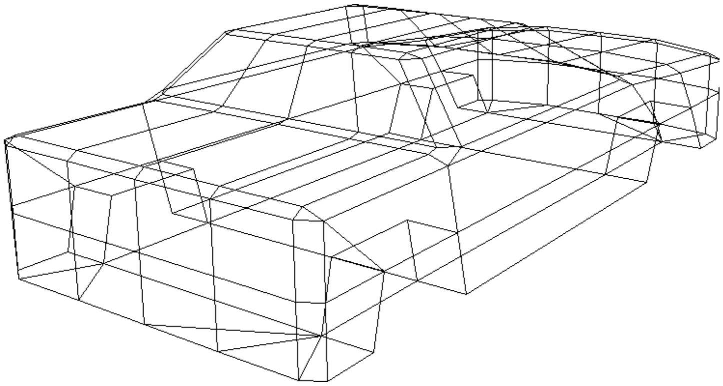


They are all located on the body of the car. (For clarity’s sake, the wheels are hidden in the illustration.)

We will add edges to these polygons to create polygons with three or four vertices.

The result should appear as shown in the following illustration. (Fig 3-89)

Fig 3-89 Dividing the Polygons with Five or More Vertices



The car is now complete!

Do not forget to save the model. Display the wheels, and then execute the following:

```
    [Save] -> [Selected Models]
```

There are still places where polygons could be safely eliminated form this car. Try to see how many you can eliminate.

4

Designer’s Tutorial

Coloring the Model

The process of coloring the model is called, “material assignment.” This chapter explains the material assignment process.

We will practice by using the TV monitor that we created in Chapter 2.

*** In this manual, “[]” will be used to indicate a menu command, and “[]” will be used to indicate a submenu command.**

Preparation before coloring

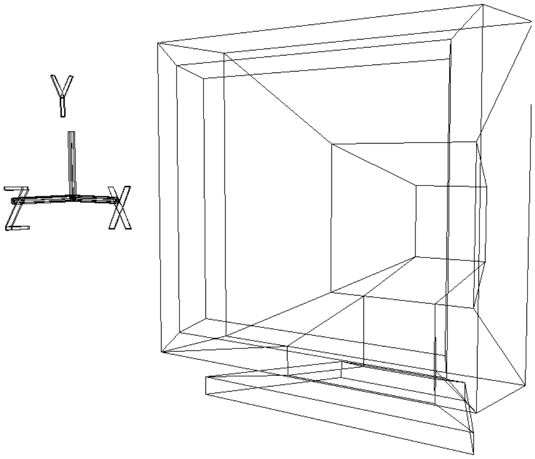
Use:

```
    [Get] -> [Element]
```

to load the TV monitor that we constructed Chapter 2. (Fig 4-1)

Once it is loaded, select the TV (space bar + left mouse button).

Fig 4-1 TV Monitor Produced in Chapter 2



In order to color the object, we must change the mode from “Model” to “Matter.”

Either click on the area where “Matter” is displayed on the top portion of the screen, or else press the shortcut key F5. The color bar at the top of the screen changes from purple to blue. Preparations for coloring the object are now complete.

> **Note: In SOFTIMAGE 3D (version 3.0 or later), "Matter" mode has been changed from the F5 key to the F4 key.**

Material assignment

The task of applying color to the model basically consists of the following three tasks:

1) Tagging all of the vertices surrounding the polygon to which color is to be applied

2) Highlighting the specified polygons in pink

3) Assigning the colors

Now we will begin the process of assigning colors to the TV monitor. Note that when modeling of an object is completed, the object has no colors.

Select:

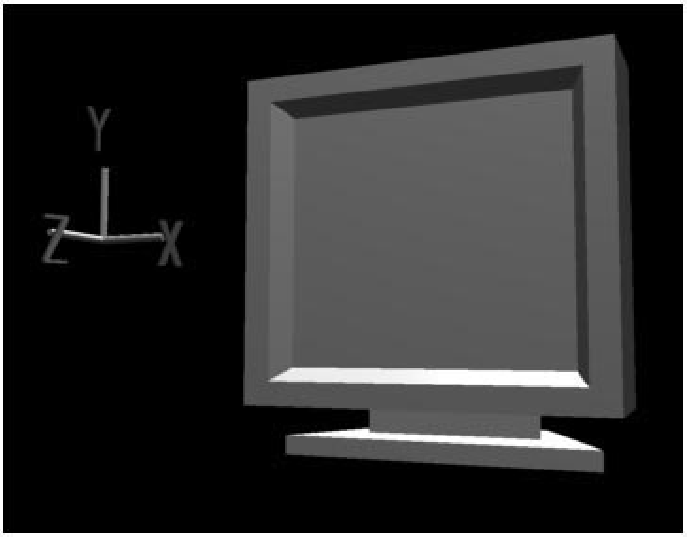
```
    [Polygon] -> [Current Material]
```

If any part of the object already had a color assigned to it, those parts would now be highlighted in pink, but since our model currently has no colors, the following message should appear at the bottom of the screen:

```
    “Warning: *Selected model has no material.”
```

Note that if you change the display method in the Perspective window from wire frame to shaded, the object is shown in a silver color, but this is only done to show the object; do not mistake this for the existence of color. (Fig 4-2)

Fig 4-2 Shaded Display before Color Is Added



Apply color to entire object

First, we will apply color to the object as a whole (in other words, to all of the polygons).

Tag all of the vertices by pressing the “T” key and the left mouse button and then dragging the mouse to enclose the entire object. All vertices are now tagged.

Next, select:

```
[Polygon] -> [Select Mode by tag vert]
```

Note: Once this function is selected after SOFTIMAGE is started up, it remains in effect until you quit SOFTIMAGE (in Matter mode only, however).

At this point, place the cursor inside any window and click the left mouse button. When you do so, the entire object is highlighted in pink.

In this state, select:

```
[Polygon] -> [Assign New Material]
```

The “Material Editor” window opens.

First, the “Shading Model” item is set to its default setting, “Phong.” change this to “Lambert.”

Note: Always use “Lambert” whenever adding color to objects to be used in the Saturn system.

Next, we will add color to the selected polygons.

The values for the color we will add (a dark blue) are:

```
R: 0.510, G: 0.540, B: 0.690
```

First, click the center mouse button in the field where “0.700” is displayed next to “R” and input “0.51”. After inputting the value, be sure to press the Return key.

In the same manner, input “0.54” for “G” and “0.69” for “B”.

The “Diffuse” color should now appear to be a dark blue.

Next, we will bring the "Diffuse" and "Ambient" values into agreement by using method 1 or 2 below.

1) Click the left mouse button in the text field where “Ambient” is displayed. The clicked field becomes a double box; when the RGB values are all 0.500, simply input the same values that were input when color was added for “Diffuse.”
2) If “Ambient” already has a double-box, click either the center or right mouse button in the “Diffuse” box (where the color is displayed); the same color should be copied to “Ambient.” (This method is recommended, since it is faster.)

Note: In the Saturn system the "Diffuse" and "Ambient" values must be identied.

Next, we will assign a name.

For "Name", we will use three letters that represent the attributes of the polygons. We will assign the letters in the sequence: [Plane], [Sort], [Mesh].

1) The [Place] setting

[Plane] sets whether the polygon is single sided or double sided.

- Single sided (Single_Plane): S
- Double sided (Dual_Plane): D

2) The [Sort] setting

[Sort] sets the Z_Sort representative point.

- Nearest point (Sort_MIN): N (Near)
- Center point (Sort_CEN): C (Center)
- Farthest point (Sort_MAX): F (Far)

3) The [Mesh] setting

[Mesh] sets whether or not to make the polygon into a mesh so that it is semi-transparent.

- Make semi-transparent (MESHon): O
- Do not make semi-transparent (MESHoff): N

Accordingly, while a variety of combinations are possible, such as SNN, DCO, SCN, DFN, etc., here we will use “SNN.”

Input “SNN” in upper-case letters in the Name field.

Note: The converter will read this three-character name to determine the polygon attributes for display in the Saturn system. Therefore, it is very important to assign this name carefully.

Note: Identical material names cannot exist in SOFTIMAGE. If the same material name is specified agein, a number is automatically added after the three characters (for example, "SNN2").
In other words, if you assign the name “SNN” (as an example) to some of the polygons in an object displayed on the screen, you cannot use the name “SNN” for another polygon; note, however, that the names “SNN”, “SNN1”, and “SNN2” are all regarded as different names. The converter ignores any numbers that follow the three letters, so “SNN1” and “SNN6” are handled in the same manner.

After assigning the name, click “Accept” in the lower right corner of the screen.

Applying color to the monitor screen frame

Now we will apply color to a small portion of the monitor.

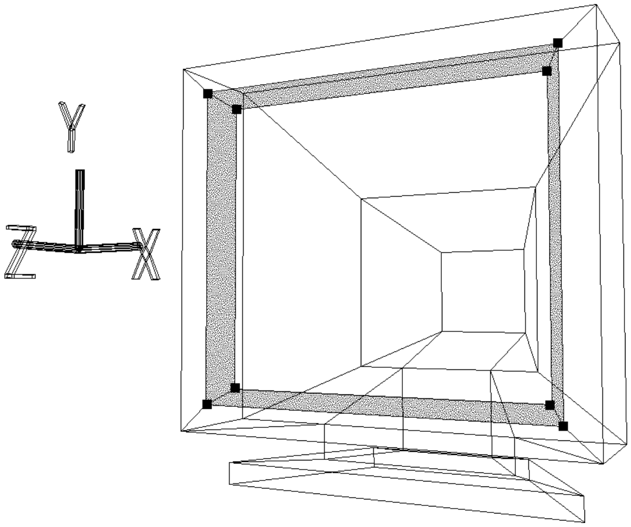
Presently, the entire object is highlighted in pink, so we will first de-select the object. Place the cursor in any window and press the center mouse button. The pink highlighting disappears. (If the highlighting does not disappears, re-select **[Polygon]** -> [Select Mode by tag vert] and then try again.)

Next, release all of the tagged vertices ("T" key + center mouse button and drag to enclose the vertices).

Now we will highlight the monitor screen frame.

First, tag all of the vertices on the screen frame (eight points) ("T" key + left mouse button and drag to enclose the vertices). (Fig 4-3)

Fig 4-3 Selecting the Monitor Screen Frame



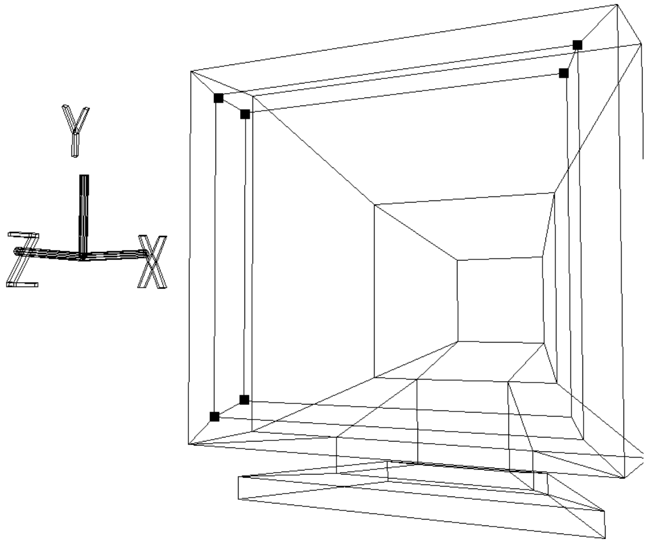
Place the cursor in any window and press the left mouse button.

Note that not only the screen frame but the screen itself is highlighted. If you look closely, you can see that by tagging the entire frame we have also tagged all of the vertices of the polygon that makes up the screen. This problem can be worked around by highlighting the frame in two parts.

First, undo the failed highlight operation ("U" key + left mouse button).

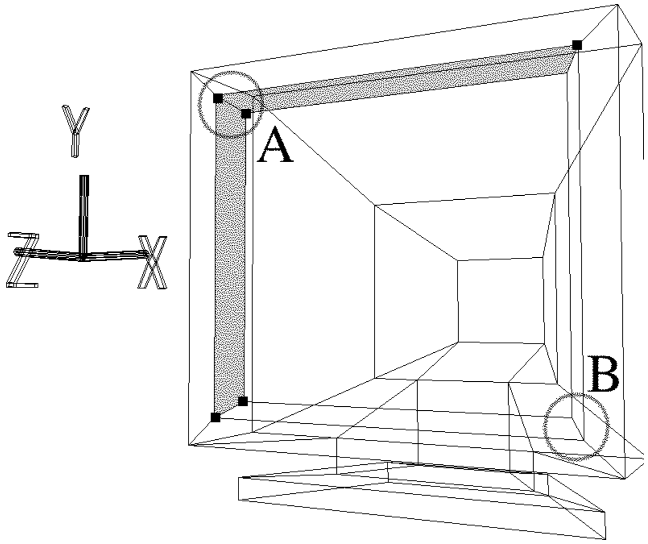
Next, tag the six vertices shown in Fig 4-4 below.

Fig 4-4 Selecting the Screen Frame in Parts (Part 1)



Place the cursor in the window and click the left mouse button. The object should be highlighted as shown in Fig 4-5.

Fig 4-5 Selecting the Screen Frame in Parts (Part 1)



In this state, release the two tags indicated by "A" ("T" key + center mouse button).

Next, tag the two vertices indicated by "B".

Then place the cursor inside the window again and click the left mouse button.

Now the screen frame should be highlighted.

After highlighting the frame, release the tags. The only object that is highlighted should be the screen frame.

Select:

```
     [Polygon] -> [Assign New Material]
```

to assign a new color. The settings in this window should be as follows:

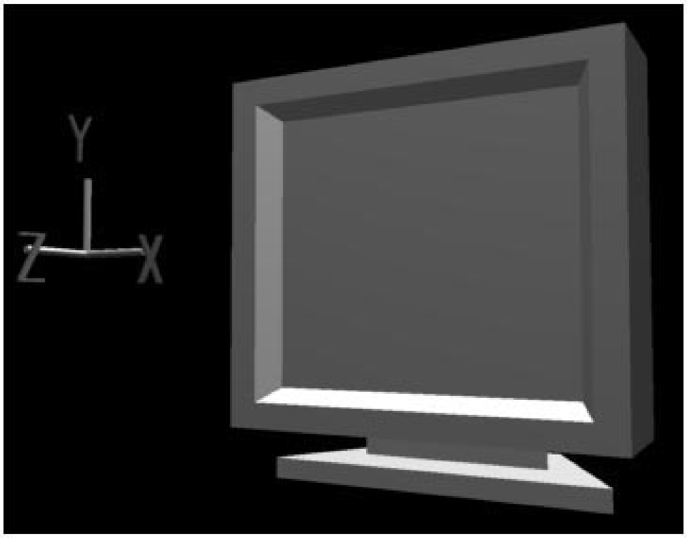
1) Change “Phong” to “Lambert.”
2) Input R: 0.78, G: 0.78, B: 0.78.
3) Set the same values for “Diffuse” and “Ambient.”
4) It is OK to specify the name as “SNN”.

Only when using the “Assign New Material” function, a different name is automatically assigned when you specify a name that is already in use. For example, in the current case, the name will probably be changed to “SNN2”. (However, if you are renaming an object with a name that has already been used once, a warning message will appear and ask you to change the new name.)

> **Note: To rename a colored polygon, select the polygon so that it is highlighted in pink, and then click "Material". When the Material Editor opens, you can change the name and color value of the polygon.**

After all of the input is complete, click “Accept.”

Fig 4-6 Shaded Display after Assigning a Color to the Screen Frame



Next, we will release the highlighting of the screen frame by clicking the center mouse button.

However, doing so does not release the highlighting. The reason is because that function is effective only for polygons surrounded by tagged vertices, and therefore is not applicable here. Because it would be extra work to tag the vertices again and then de-select them, we will use another function:

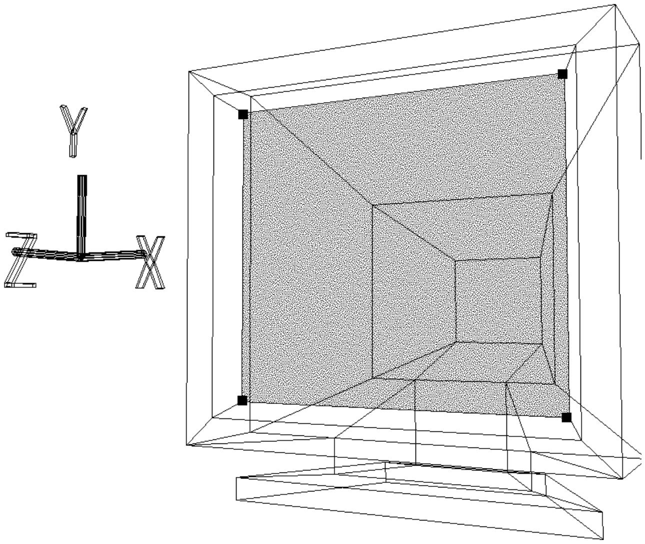
```
     [Polygon] -> [Unselect all]
```

The highlighting should now be released.

Coloring the monitor screen

Tag the points indicated in Fig 4-7 below and highlight the polygon that makes up the screen.

Fig 4-7 Selecting the Monitor Screen



Next, select:

```
     [Polygon] -> [Assign New Material]
```

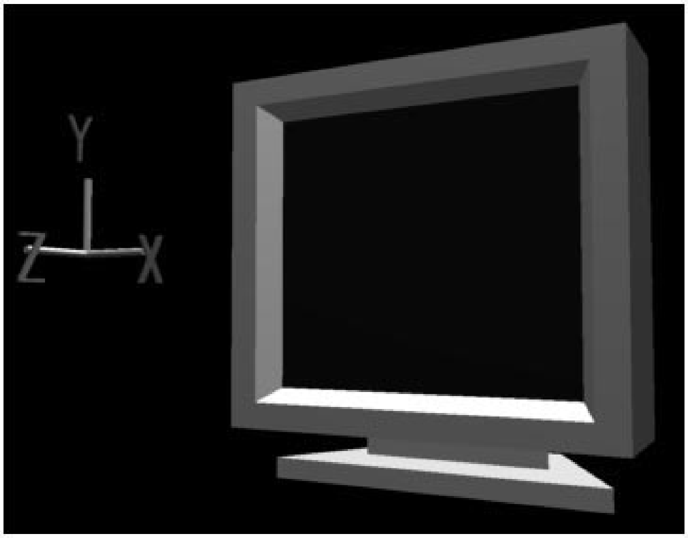
The settings in this window should be as follows:

1) Change “Phong” to “Lambert.”
2) Input R: 0.06, G: 0.06, B: 0.06.
3) Set the same values for “Diffuse” and “Ambient.”
4) It is OK to specify the name as “SNN”.

After the settings are complete, click “Accept.”

Now release the highlighting and the tags.

Fig 4-8 Shaded Display after Coloring the Monitor Screen



Lastly, save your work:

```
     [Save] -> [Selected Models]
```

You have now completed coloring training using the TV monitor.

Supplement: Color Setting Chart Used by the Saturn System

When setting a polygon color for use in the Saturn system, set each of the RGB values to values shown in the chart below.

Table 4-1 Color Setting Chart used by the Saturn System

00	0.00	08	0.24	16	0.48	24	0.72
01	0.03	09	0.27	17	0.51	25	0.75
02	0.06	10	0.30	18	0.54	26	0.78
03	0.09	11	0.33	19	0.57	27	0.87
04	0.12	12	0.36	20	0.60	28	0.90
05	0.15	13	0.42	21	0.63	29	0.90
06	0.18	14	0.42	22	0.66	30	0.93
07	0.21	15	0.45	23	0.69	31	1.00

5

Designer’s Tutorial

Useful Techniques

This chapter describes useful techniques to employ when working with the SOFTIMAGE software.

*** In this manual, “[]” will be used to indicate a menu command, and “▯” will be used to indicate a submenu command.**

Merge and Clean Up (Using Left-Right Symmetry in Modeling)

Here we will introduce a technique that is useful for creating models that have left-right symmetry.

It is likely that you will have many opportunities to create symmetrical models, but it is possible to create only half of the model versus the plane of symmetry (the XY, YZ, or XZ plane) and then use the **[Effect]** -> [Symmetry] function to create the other half.

By working with only half the mode, the number of vertices you have to work with is reduced, reducing the number of mistakes and making the work proceed faster; in addition, wire frame objects are easier to see since there is less clutter on the screen.

Although the TV monitor and the car that we created in the chapters on modeling training were produced without using this method of creating only half of the object, which method you use is strictly a matter of personal preference.

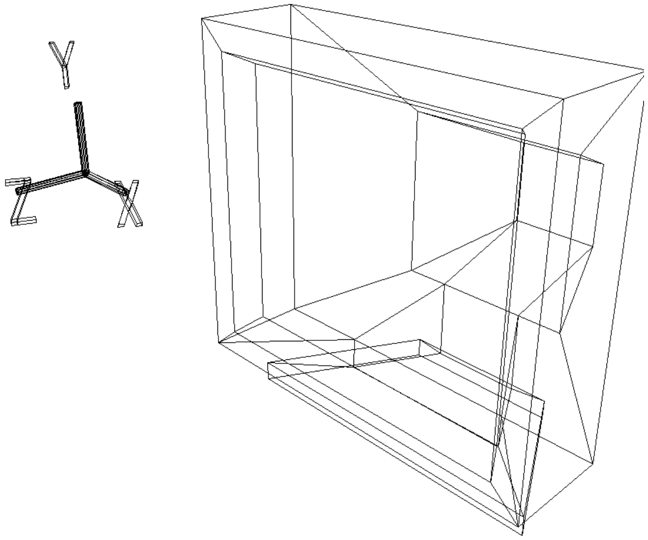
Step 1: Loading the model

Set the mode to "Model," and load the TV monitor model (SATURN_TV_SET) that we created in Chapter 2:

```
    [Get] -> [Element] -> [MODELS]
```

After the object is loaded, it should appear as shown in Fig 5-1.

Fig 5-1 TV Monitor Created in Chapter 2



After loading the object, press the space bar and the left mouse button to select the object.

Step 2: During center lines

```
    [Effect] -> [Subdivision]
```

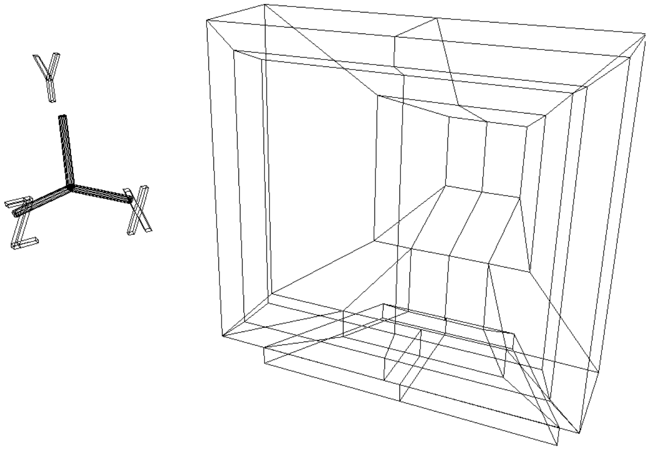
When the "Mesh Subdivision" window appears, input:

```
    X: 1, Y: 0, Z: 0
```

and click "OK."

After doing so, a line is drawn through the object at X = 0. (Fig 5-2)

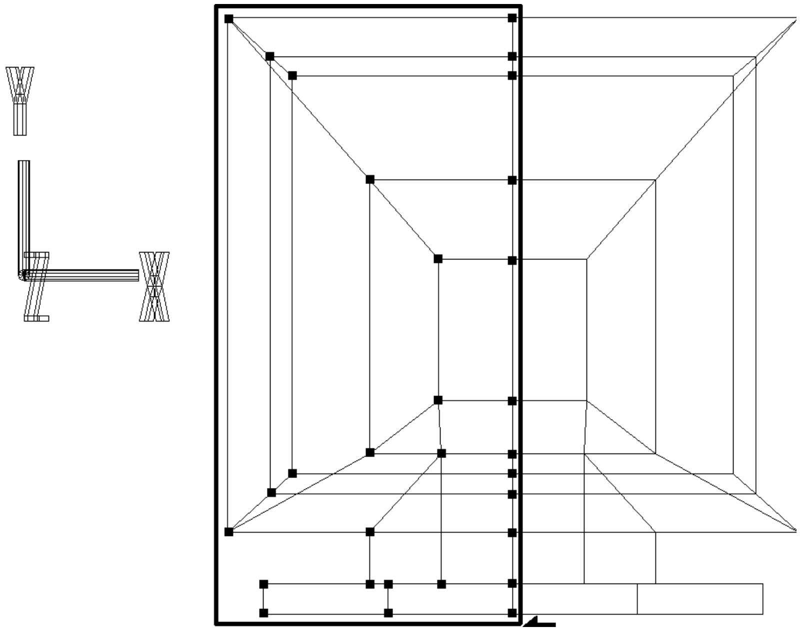
Fig 5-2 Drawing a Line to Divide the TV Monitor into Left and Right Halves



Step 3: Deleting the left half

Now switch from OBJ mode to TAG mode and tag all of the points indicated in Fig 5-3. (Press the “T” key and the left mouse button and then drag the mouse to enclose the points.)

Fig 5-3 Tagging Half of the TV Monitor

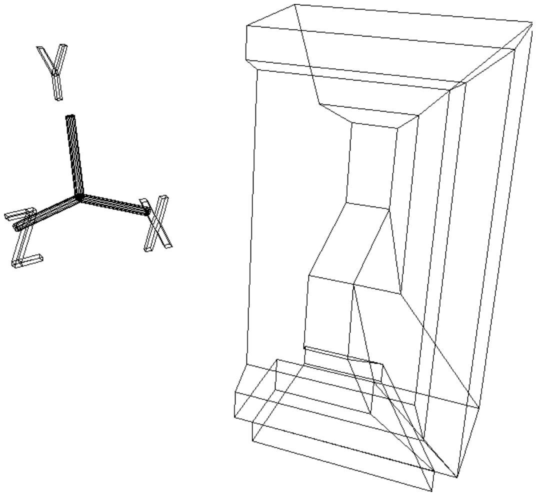


After confirming that TAG mode is still in effect, execute the following operation:

```
[Delete] -> [Selection]
```

As a result of this operation, the left half (the portion where X < 0) of the TV monitor should have disappeared. Release all of the remaining tags. (Press the “T” key and the center mouse button and then drag the mouse to enclose the points.)

Fig 5-4 Deleting Half the TV Monitor



We will now explain how to create an entire object, starting form the point where we have just finished creating half of the object.

Step 4: Executing [Symmetry]

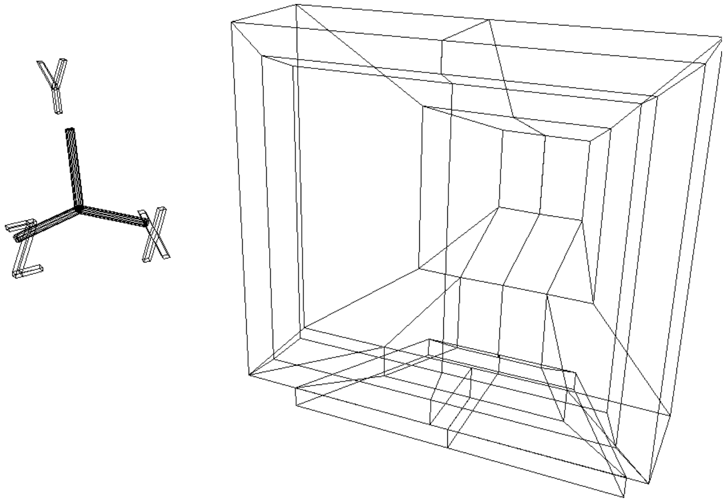
First, set the mode to OBJ mode.

After confirming that the half-TV monitor model is selected, select:

```
[Effect] -> [Symmetry]
```

Because we want to create an object that is symmetrical versus the YZ plane, select “YZ plane” and then click “OK.” The result should appear as shown in Fig 5-5 below.

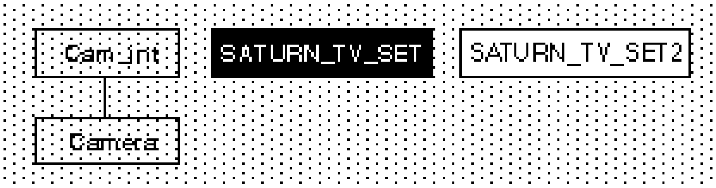
Fig 5-5 After Executing the Symmetry Function



The Schematic screen should appear as shown below.

(For details on the Schematic screen, refer to chapter 3.)

Fig 5-6 Schematic Screen



In the current state, although the display shows a single TV monitor, it actually consists of two objects. Because the handing of two objects is more difficult for programming, we will combine the two objects into a single object.

Step 5: Combining two objects into one

Change the select mode from “Single” to “Multi.” (There is a box for this purpose on the right side of the screen.)

Next, select the “SATURN_TV_SET” (space bar + left mouse button or drag mouse to enclose.)

Now the two models should both be selected. At this point, select:

```
    **[Effect]** -> [Merge]
```

The “Merge” window appears.

Click “OK” without checking either of the two check boxes. The wire frame display will flash momentarily, but otherwise no change will be visible in the object display. But a glance at the Schematic screen will reveal that a new model, called “bmerge”, has been created.

The Merge function creates one new object out of existing multiple objects.

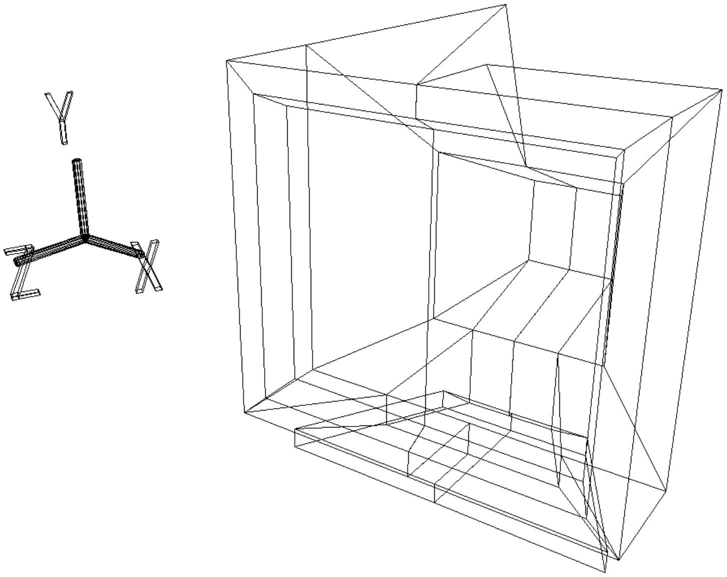
In order to view the newly created object “bmerge”, we will hide the other two objects.

Although it is possible, as was done in chapter 3, to select each object to be hidden and then select **[Display]** **->** [Hide] **->** [Toggle Selection], in the present situation, where only “bmerge” is shown to be selected on the Schematic screen, select **[Display]** **->** [Hide] **->** [Unselected]; this will hide everything except for “bmerge”.

Now we will modify the model “bmerge”.

Although the object looks as if it is completely finished, look at Fig 5-7 below.

Fig 5-7 Pairs of Vertices Overlap on the Dividing Line



Pressing the “M” key and any of the mouse buttons, pick one of the vertices on the line that divided the monitor in half and drag the vertex. In actuality, each “vertex” on that line is a pair of vertices in the exact same position.

After moving the vertex by dragging it, use the Undo function to return it (“U” key + left mouse button).

Step 6: Combining overlapping vertices into one vertex

Our next task is to combine each of those pairs of overlapping vertices into single vertices.

Select:

```
    [Effect] -> [Cleanup]
```

When the “Mesh Cleanup” window appears, check the checkboxes for “Merge near points if distance less than” and “Merge unconnected vertices” (items 1 and 3 from the top of the list).

After confirming that the value set for the “Merge near points if distance less than” condition is “0.001”, click “OK.”

Now try to drag one of the vertices on the line that divided the monitor in half by pressing the “M” key and any of the mouse buttons, as before. It should be apparent that the two points have been merged into one.

Combinng overlapping vertices into one (Cleanup)

Multiple vertices that coexist in the same point are difficult to work with when modeling an object. In such a case, use the “Cleanup” function as explained above to merge the multiple vertices into one.

Step 7: Completing the TV Monitor

Now delete the center dividing line by executing the following operation:

```
    [Mesh] -> [Edge] + right mouse button (Remove edge)
```

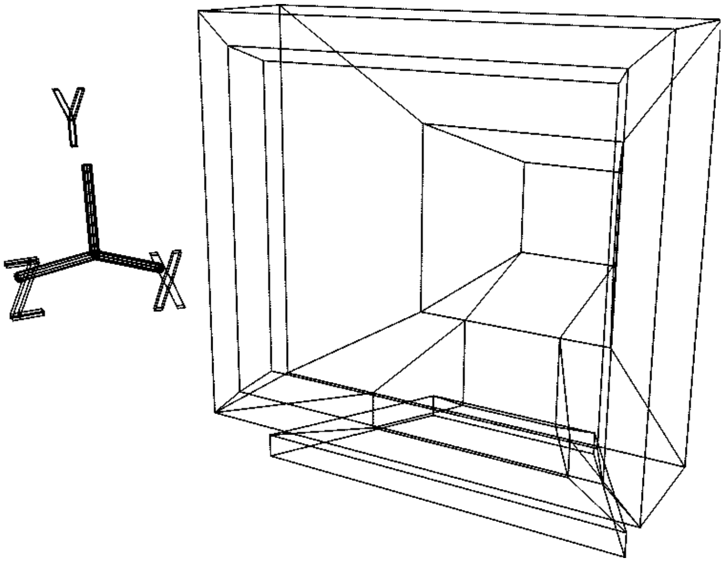
Then remove the vertices that were left behind by using either:

1) **[Mesh]** -> [Vertex] + right mouse button (Remove vertex)

   or:

2) **[Effect] -**> [Cleanup] (Simply click “OK” without checking any of the checkboxes.)

Fig 5-8 Completed TV Monitor



The TV monitor is now complete.

When modeling objects, it is useful to remember that it is sometimes easier to create half an object and then duplicate that half to make the whole object.

Magnet Function (Point-to-Point Attraction Function)

In this section we will introduce the Magnet function, a useful modeling tool that pulls points together.

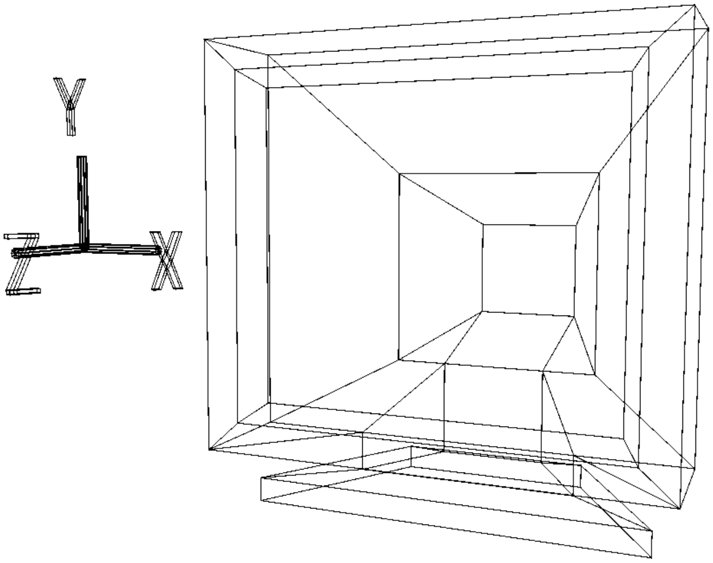
Step 1: Loading the model

First, we need to prepare in order to use the Magnet function by loading the TV monitor model (SATURN_TV_SET) that we created in chapter 2.

```
    [Get] -> [Element] -> [MODELS]
```

After loading, the model should appear as shown below. (Fig 5-9)

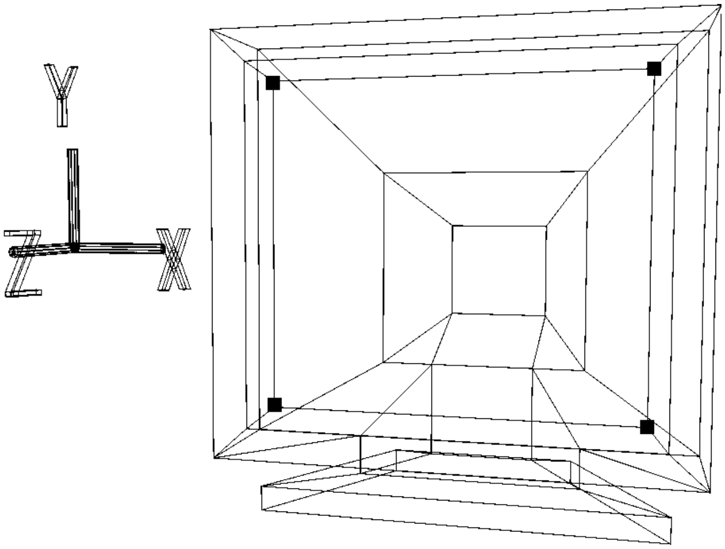
Fig 5-9 TV Monitor Preparation



Step 2: Deleting the polygon corresponding to the screen

Change the mode from “OBJ” to “TAG” and then tag the points shown in Fig 5-10 below.

Fig 5-10 Tags

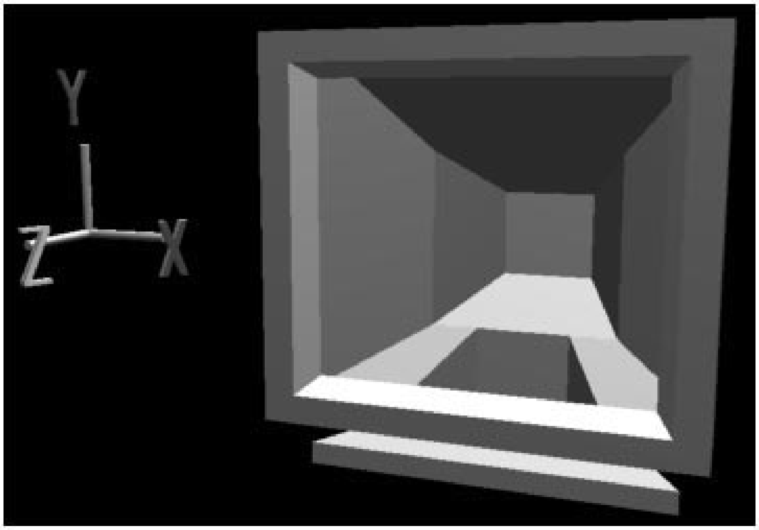


Next, select:

```
     [Delete] -> [Selection]
```

(Do not release the tags yet.) Now the (one) polygon corresponding to the screen of the monitor should have disappeared. (Fig 5-11)

Fig 5-11 Deleting the Polygon Corresponding to the Screen



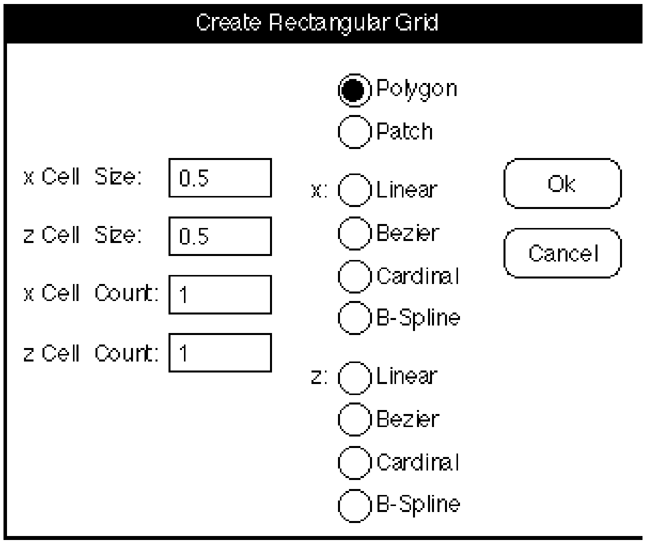
Step 3: Getting one polygon

Next, select:

```
    [Get] -> [Primitive] -> [Grid]
```

The “Create Rectangular Grid” window appears. (Fig 5-12)

Fig 5-12 “Create Rectangular Grid” Setting Screen



Create Rectangular Grid

● Polygon
○ Patch

x Cell Size: 0.5
z Cell Size: 0.5
x Cell Count: 1
z Cell Count: 1

x: ○ Linear ○ Bezier ○ Cardinal ○ B-Spline

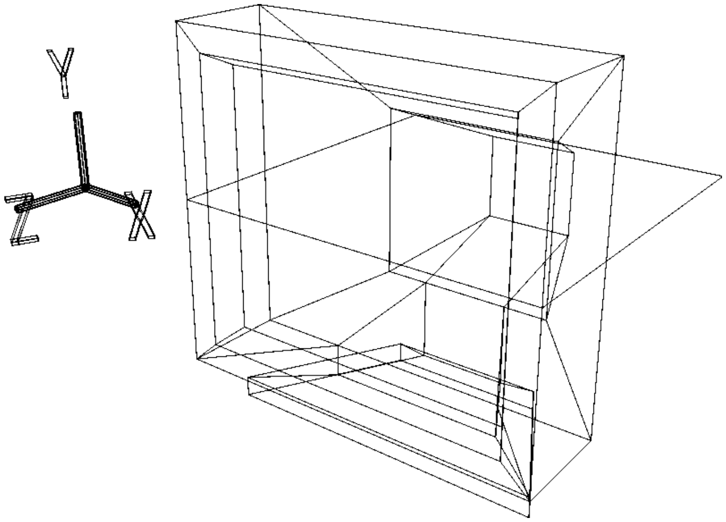
z: ○ Linear ○ Bezier ○ Cardinal ○ B-Spline

Input “0.5” for the X cell size, “0.5” for the Z cell size, “1” for the X cell count, and “1” for the Z cell count.

Make sure that “Polygon” is checked, and then click “OK.”

The object view should now appear as shown in Fig 5-13 below.

Fig 5-13 Creating One Polygon



A single square polygon has appeared

Getting a polygon

From now on, when you want to create a single polygon, use: [Get] -> [Primitive] -> [Grid].

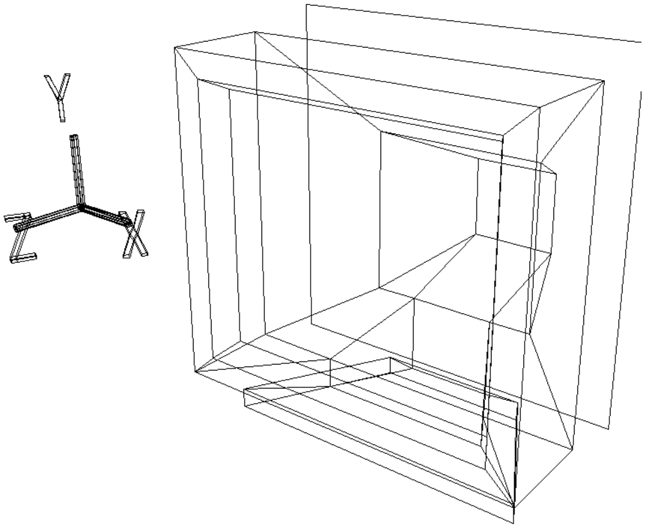
Step 4: Rotating a polygon

At this point, the single polygon should be selected. Select OBJ mode and then click on the corner triangle in the “Rot” icon. When the numeric input window appears, input the following values:

```
     X: 90, Y: 0, Z: 0
```

and then click “Set.” The selected polygon rotates as shown below. (Fig 5-14)

Fig 5-14 Rotating the Single Polygon



Because we want to set this state as the reference, execute the following operation:

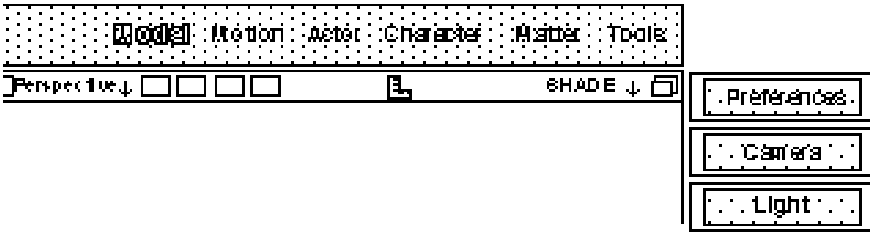
```
     [Effect] -> [Freeze] -> [Rotation]
```

Step 5: Setting the Magnet function

Next, we will cover the hole in our TV monitor exactly with this new polygon. First, we will set the Magnet function.

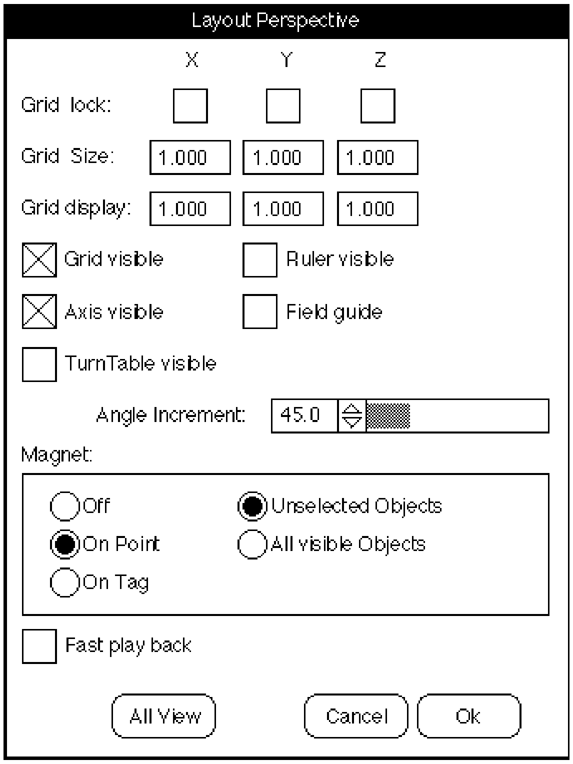
There is an icon shaped like a ruler in the bar at the top of the Perspective window. (Fig 5-15)

Fig 5-15 Ruler-shaped Icon



Click on the ruler and the “Layout Perspective” window shown below appears. (Fig 5-16)

Fig 5-16 Layout Perspective Setting Screen



Layout Perspective

	X	Y	Z
Grid lock:	□	□	□
Grid Size:	1.000	1.000	1.000
Grid display:	1.000	1.000	1.000

☒ Grid visible □ Ruler visible

☒ Axis visible □ Field guide

□ TurnTable visible

Angle Increment: 45.0

Magnet:

○ Off ● Unselected Objects

● On Point ○ All visible Objects

○ On Tag

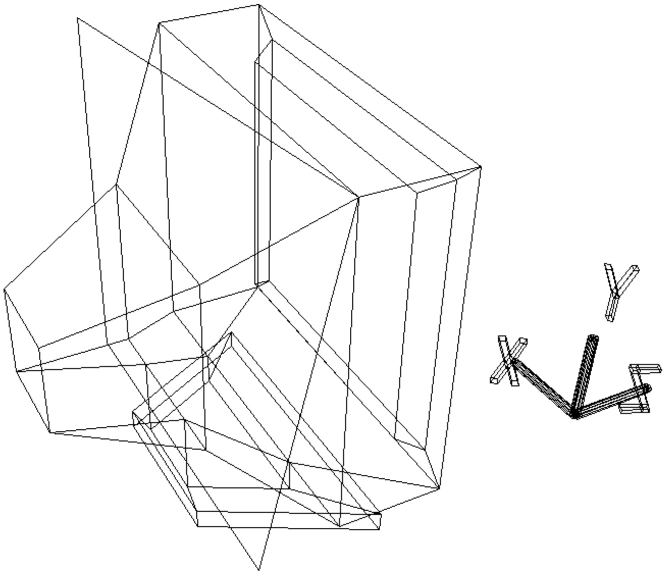
□ Fast play back

One of the items in this window is labelled “Magnet.”

Although in the initial settings the “Off” option is selected, at this point we want to select “On Point.” After confirming that “Unselected Objects” in the right-hand column is selected, click “OK.”

In the screen where the settings were made, press the “M” key and any of the mouse buttons and click on one of the vertices of the polygon. The point will move as shown in Fig 5-17.

Fig 5-17 point Movement Caused by the “M” Key



After trying this function once as above, use the Undo function (“U” key + left mouse button) to return the polygon to its previous shape.

The Magnet function

In short, the Magnet function causes the point that is clicked on to adhere to a certain point. It is important to note that this function only works in the window that it is set in.

"On Point" and "On Tag"

The difference between “On Point” and “On Tag” is that when “On Point” is selected, the point that is clicked on adheres to another point, but when “On Tag” is selected, the point that is clicked on adheres to a tagged point.

"Unselected Objects" and "All visible Objects"

“Unselected Objects” means that the point that is clicked adheres to a point on an object that is not currently selected (the TV monitor, in our case), while “All Visible Objects” would cause the point to adhere to a point on any visible object. In our current sample, the clicked point could adhere not only to a point on the TV monitor, but also to another point on the polygon, even though it is currently selected.

Now, because we left the vertices around the TV monitor screen tagged, we will specify “On Tag,” and because we only want the polygon to adhere to the TV, which is not selected, we will specify “Unselected Objects.”

Step 6: Using the Magnet function on a polygon

Press the space bar and the left mouse button to re-select the TV monitor, and make sure that the tagged vertices are still tagged. After confirming that they are, select the single polygon again.

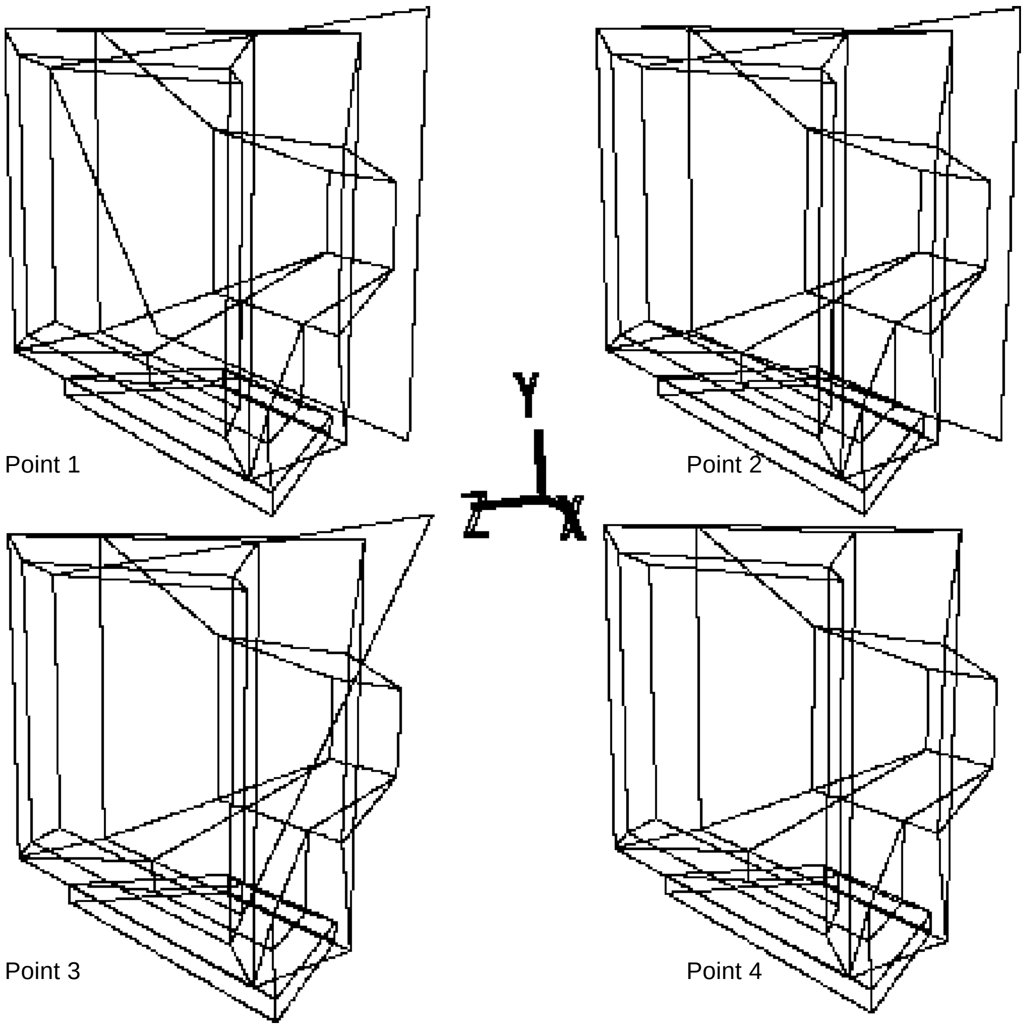
Next, we will move the four vertices of the polygon.

When you click on a vertex with the “M” key and any mouse button, the vertex that was picked will initially adhere to the closest eligible point in the screen, but since that is not always the point that you want the vertex to adhere to, do not release the mouse button right away; instead, move the mouse around until the vertex adheres to the desired point and then release the mouse button.

If two points should adhere to the same point accidentally when you release the mouse button, execute the Undo function (“U” key + left mouse button) as soon as possible.

The following Fig 5-18 show the sequence until all of the points are connected.

Fig 5-18 Moving Points 1 to 4



Now the polygon has been properly placed where the monitor screen would be.

Normal vector orientation

At this stage, there is one item you need to be aware of concerning the direction of normal vectors.

The normal vectors determine the front and back of an object. You can view the normal vectors by selecting:

```
[Show] -> [Normal]
```

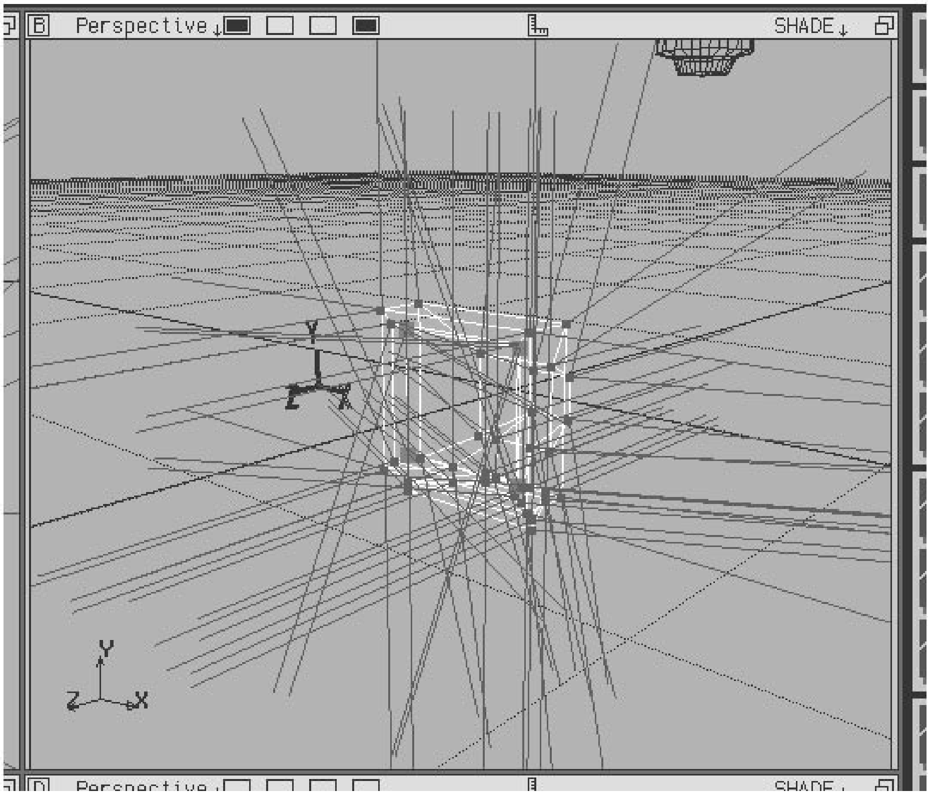
(“Normal” here refers to “normal vectors,” and not to “the opposite of abnormal.”)

Select the TV monitor and then select:

```
[Show] -> [Normal]
```

The normal vectors display should appear as shown below. (Fig 5-19)

Fig 5-19 Directions of Normal Vectors



The lines emanating from the TV monitor are the normal vectors.

Because the direction that the normal vector points in is treated as the front direction for the polygon in question, in the case of most objects, the normal vectors will typically be emanating from the object to the outside. It is important to remember that in a case (such as with the magnet function) where two objects are being brought together, if the orientation of their normal vectors do not match, the object may not be displayed properly (incorrect shading, etc.) after the data is transferred to the programmers. In the example that we just completed, the normal vectors should all be pointing out.

Adjusting the direction of a normal vector

The direction of the normal vector depends on how the polygon which appeared in parallel with the XZ plane, was raised up by **[Get]** -> [Primitive] -> [grid]. If the polygon was rotated -90° instead of +90°, the normal vector will point in the opposite direction.

If the normal vector is pointing in the opposite direction, select:

```
[Effect] -> [Inverse]
```

This will reverse the direction of the normal vector.

After confirming that the normal vector is pointing in the proper direction, select **[Show]** -> [Normal] again to erase the normal vector lines.

If just the screen of the TV monitor is kept as a separate object, it would be possible, for example, to create the appearance of a video image being displayed on the monitor by inserting one after another individual polygons with different textures applied in place of the screen polygon.

Dividing a Polygon When an Edge Cannot be Drawn

When attempting to divide a polygon with five or more vertices into polygons with three or four vertices, it is not uncommon to be unable to draw an edge using **[Mesh]** -> [Edge].

In such instances, the following error message is displayed:

```
    “Error: *Cannot create an edge that intersects existing edges.”
```

This phenomenon often occurs when the polygon to be divided is twisted.

In those cases where you want to connect two points with a line in any way possible, what do you do? An example of a solution is shown below.

Preparations (creating a polygon)

Select:

```
    [Get] -> [Primitive] -> [Grid]
```

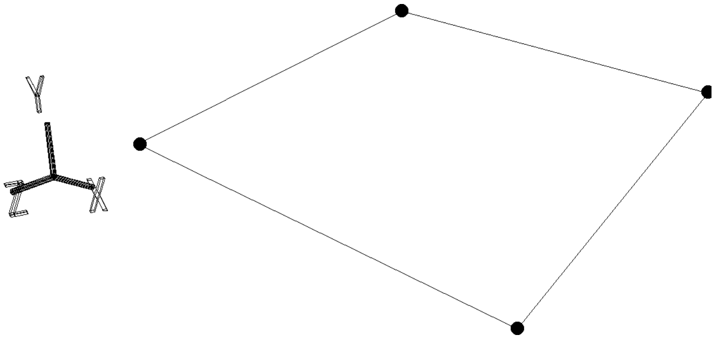
When the window appears, set the size as follows:

X cell size: 1.0
Z cell size: 1.0
X cell count: 1
Z cell count: 1

Check the “Polygon” item, and then click “OK.”

A single polygon like the one shown below appears. (Fig 5-20)

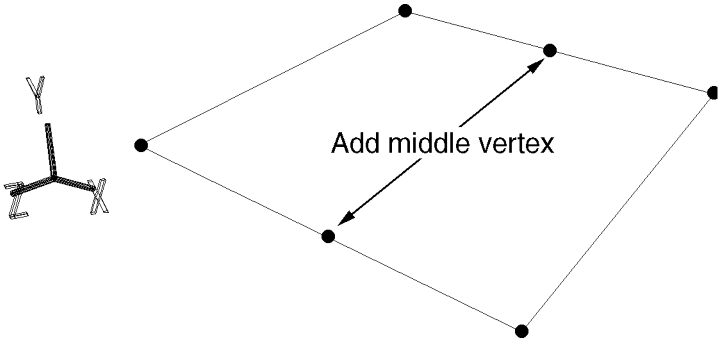
Fig 5-20 Preparations (creating a twisted polygon)



Add middle vertices as shown in the illustration below by using:

```
    [Mesh] -> [Vertex] -> middle mouse button (Add middle vertex)
```

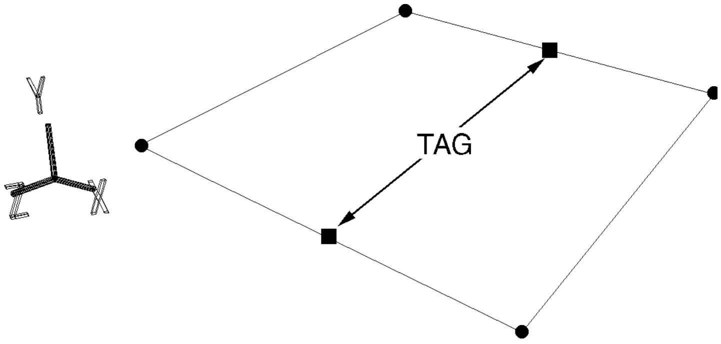
Fig 5-21 Adding Middle Vertices



Next, change the mode from OBJ to TAG. (Click directly on the window in the lower right corner of the screen.)

Now tag the points indicated in the diagram. (Fig 5-22) (Press the "T" key and the left mouse button and drag the mouse to enclose the points.)

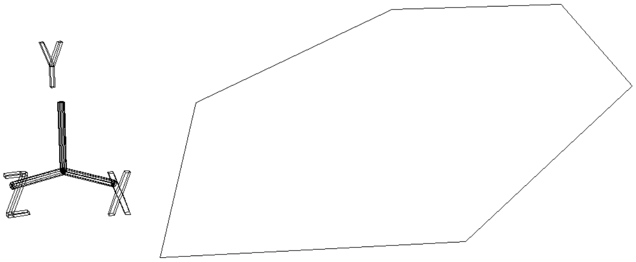
Fig 5-22 Tagging Points



Now click on the corner triangle in the Scale icon to open the numeric value input window. Input the values X: 1, Y: 1, and Z: 2, and then click "Add." (Note that you do not click "Set" in this instance.)

The polygon now appears as shown below. (Fig 5-23)

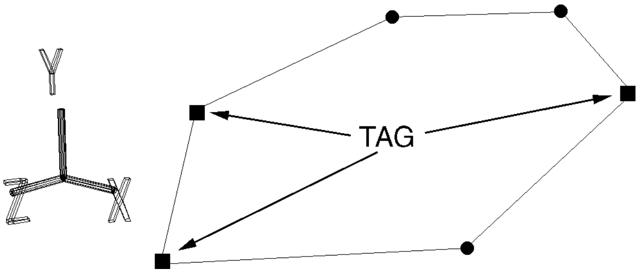
Fig 5-23 Changing the Shape of a Single Polygon



Release the tags. (Press the "T" key and the center mouse button and drag the mouse to enclose the points.)

Next, with the mode still set to TAG, tag the vertices indicated in Fig 5-24.

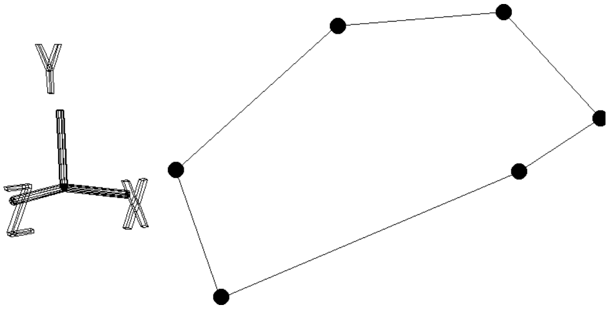
Fig 5-24 Tagging Vertices



Now click on the corner triangle in the Trans icon to open the numeric value input window. Input the values X: 0, Y: -0.2, and Z: 0, and then click "Add." (Note that you do not click "Set" in this instance.)

The polygon now appears as shown below. (Fig 5-25)

Fig 5-25 Completion of Twisted Polygon



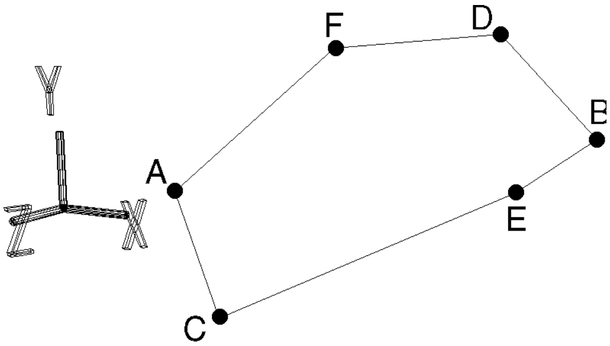
Release the tags. (Press the “T” key and the center mouse button and drag the mouse to enclose the points.)

We now have a twisted polygon. We will begin to experiment with it.

Connect vertex A and vertex B in Fig 5-26 below by using **[Mesh]** -> [Edge] -> left mouse button.

(For the sake of convenience as we continue, we have labeled all of the other vertices, as well.)

Fig 5-26 A and B Cannot Be Connected Immediately



The two points, however, are not connected; instead, an error message appears:

“Error: *Can not create an edge that intersects existing edges.”

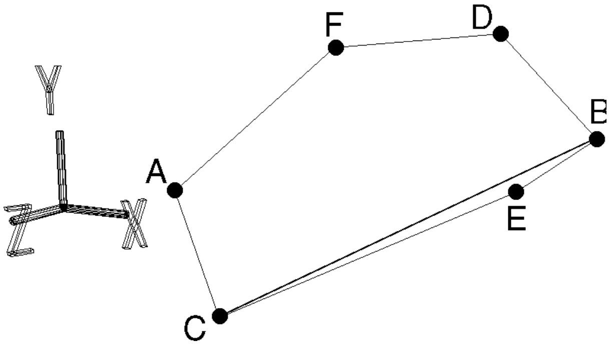
What should you do if you want to connect A and B no matter what?

See sloutions 1 and 2, which follow.

Solution 1: Create a triangle at the edge first

Connect B and C with an edge as shown in Fig 5-27 below. (These two points can be connected in this polygon.)

Fig 5-27 Connect B and C First



Now, if points A and B, which could not previously be connected, are clicked by using **[Mesh] -** > [Edge] -> left mouse button, they can be connected.

Now use **[Mesh]** -> [Edge] -> right mouse button to delete the edge connecting B and C.

By first creating a triangle that includes one of the target vertices (in this case, either A or B), it becomes possible to draw an edge that previously could not be drawn.

If creating one triangle does not solve the problem, try creating additional triangles at the edges.

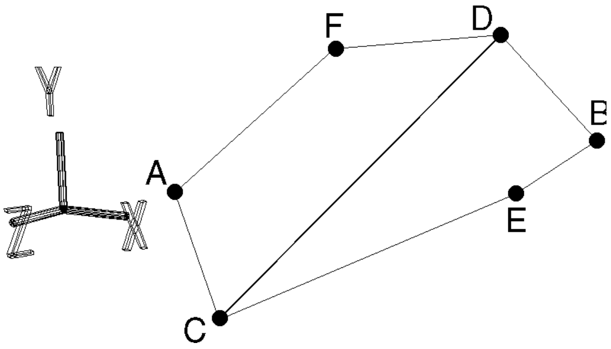
If doing so still does not allow the desired edge to be drawn, try the following method.

Solution 2: Starting from Two Points that Are Not the Target Points

First connect two points that are not the target points.

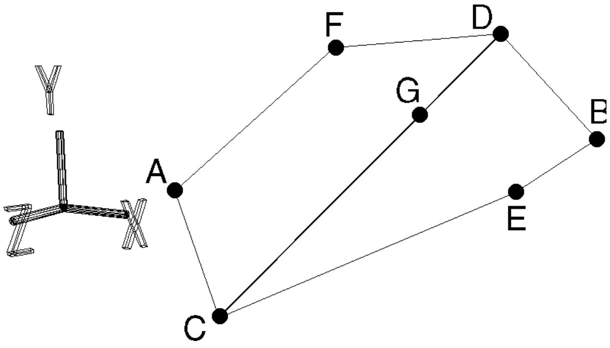
In the case of our polygon, there are a number of possible combinations. We will connect C and D in our example. (Fig 5-28)

Fig 5-28 Connecting Points C and D



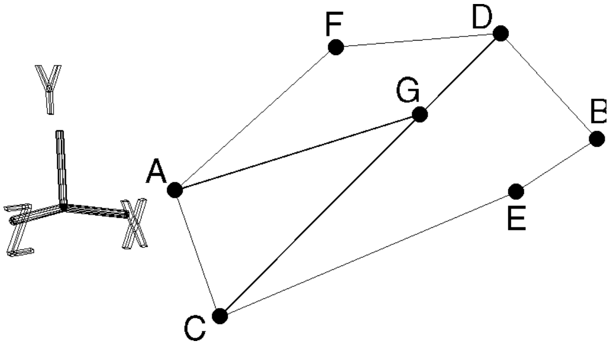
Using **[Mesh]** -> [Vertex] -> left mouse button, add a vertex (point G) on the edge between C and D. (Fig 5-29)

Fig 5-29 Adding Point G



Now connect A and G.

Fig 5-30 Connecting A and G

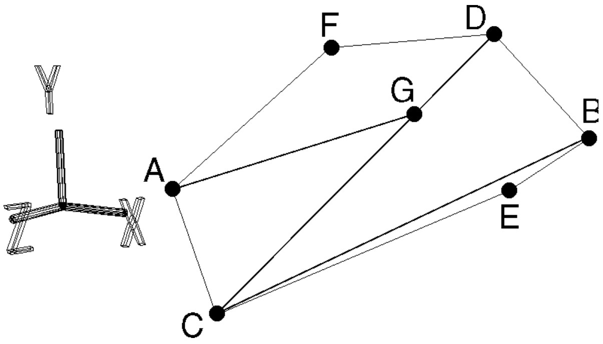


If we could simply connect G and B we would almost be done, but in this polygon we cannot draw an edge between G and B.

At this point, recall the method used in solution 1.

First, we create a triangle by connecting B and C. (Fig 5-31)

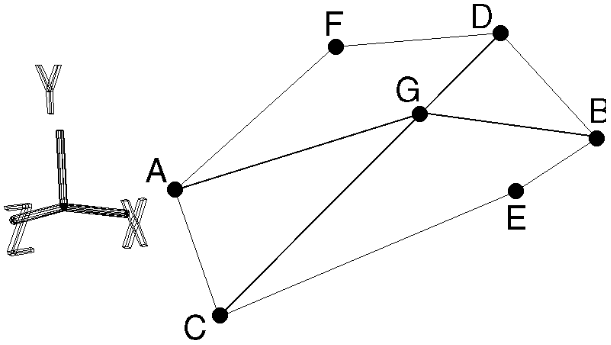
Fig 5-31 Connecting B and C



Now we are able to drawn an edge between G and B.

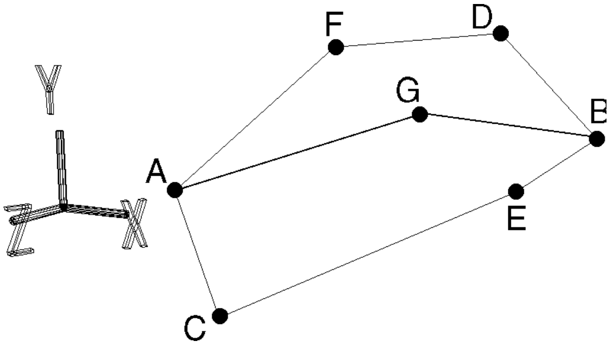
After connecting B and G, use **[Mesh]** -> [Edge] -> right mouse button (Remove edge) to delete the edge between B and C. (Fig 5-32)

Fig 5-32 Connecting G and B, and Deleting Edge between B and C



Now use **[Mesh]** -> [Edge] -> right mouse button (Remove edge) to remove the edges between C and G and between G and D. (Fig 5-33)

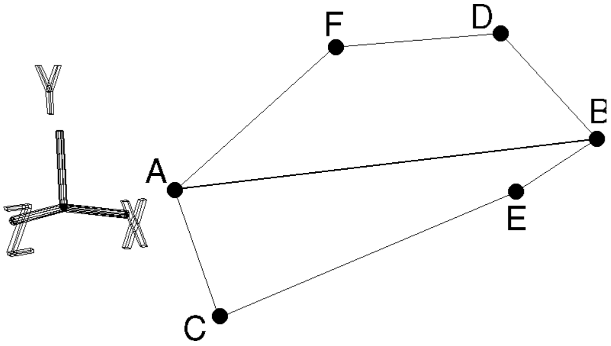
Fig 5-33 Deleting the Edges between C and G and G and D



Now for the finishing touch.

Use **[Mesh]** -> [Vertex] -> right mouse button (Remove vertex) to delete point G. (Fig 5-34)

Fig 5-34 Deleting Point G



Use these methods to try to connect other vertices that cannot be connected in the normal manner.

Sound Tutorial

The SEGA Saturn Sound tutorial has been designed in order to provide the knowledge needed by sound designers for sound development work for the SEGA Saturn system.

This chapter is written so that, as long as you have experience with using Macintoshes, you will be able to play music on the SEGA Saturn system, even if you are not well-versed in DTM (desktop music).

This manual covers the sound development task up to the point where you use the “SEGA Sound Tools” to create sound data files for use on the Sega Saturn system.

In order to play back songs in an actual game by using sound data files, it is necessary from within the program to either use the sound functions in the SEGA Graphics Library (SGL) or to use the direct sound control commands.

For details on the sound control commands, refer to the “Saturn Sound Driver System Interface.”

Table of Contents

Table of Figures and Tables

Figures

Table

1

Sound Tutorial

Preparing the Development Environment

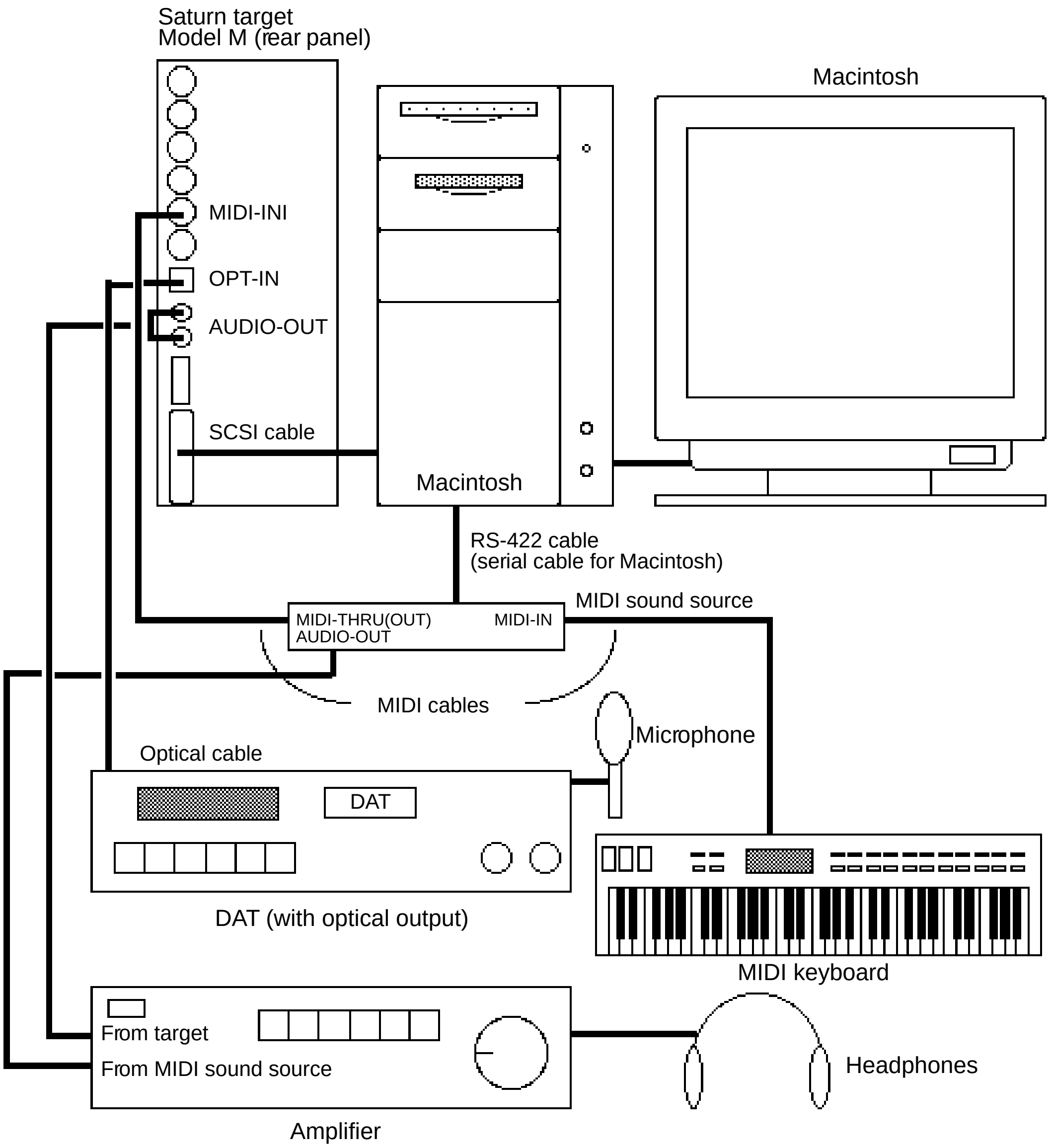
This chapter describes the hardware configuration required in order to use the SEGA Sound Tools.

A Macintosh is required for sound development work.

The hardware configuration required in order to use the SEGA Sound Tools is depicted below.

Note that the configuration will differ somewhat if you are using a commercial tool, such as AUDIOMEDIA II; the differences in the hardware configurations are outside the scope of this tutorial.

Fig 1-1 Hardware Configuration when Using the SEGA Sound Tools



Notes on Hardware Preparation

1) Although songs can be created without a MIDI sound source, the job becomes much more difficult. The use of a MIDI sound source is highly recommended.
2) If the MIDI sound source does not have a connector for the Macintosh, use a MIDI interface.
3) In addition to a DAT deck, an MD or CD player can also be connected to the digital input.

Sound Tutorial

Creating Music

This chapter describes the procedure for creating music by using the SEGA Sound Tools, and also provides cautionary notes regarding the use of the tools.

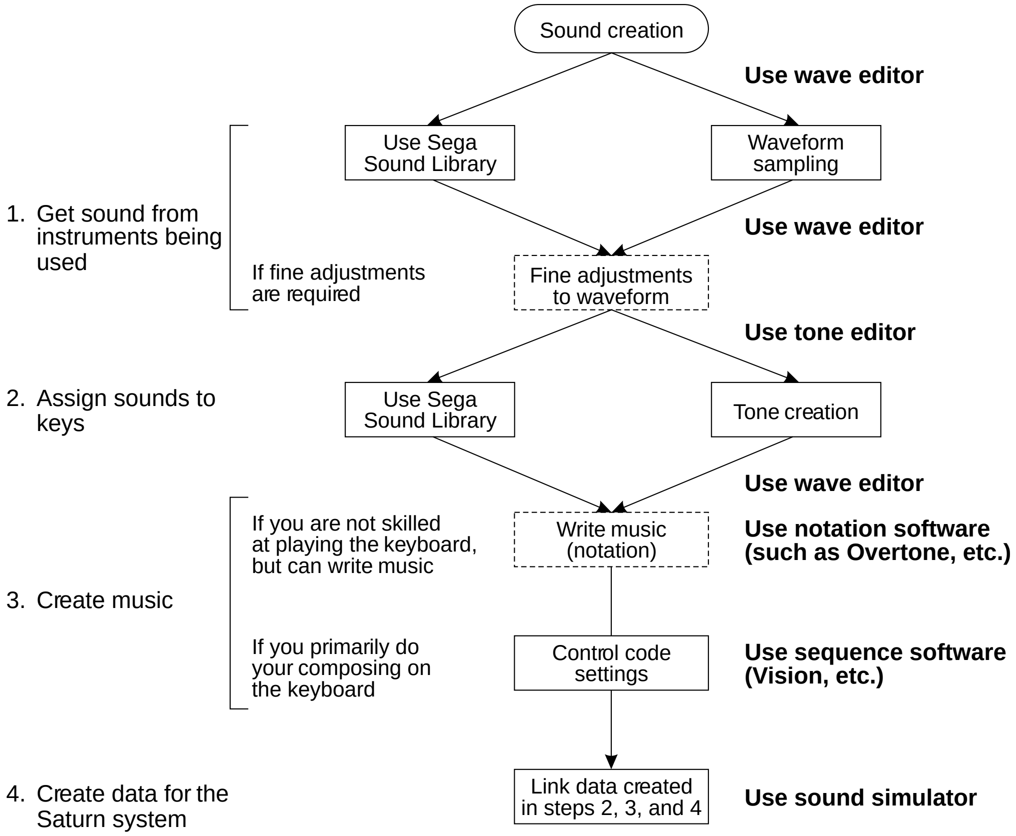
Although this chapter does not specifically discuss the creation of sound effects, the same procedure that is used to create music is also used to create sound effects.

Although the large number of specialized terms may seem confusing initially, this chapter really only describes the basic editing methods. Do not hesitate to experiment freely.

Flow of Sound Creation Work

The flow of sound creation work for the SEGA Saturn system when using the SEGA Sound Tools is illustrated below. In this flow of work, sound can be created even if you do not have a MIDI sound source.

Fig 2-1 Flow of Sound Creation Work



Sound creation
Use wave editor
Use Sega Sound Library
Waveform sampling
1. Get sound from instruments being used
Use wave editor
If fine adjustments are required
Fine adjustments to waveform
Use tone editor
2. Assign sounds to keys
Use Sega Sound Library
Tone creation
Use wave editor
If you are not skilled at playing the keyboard, but can write music
Write music (notation)
Use notation software (such as Overtone, etc.)
3. Create music
If you primarily do your composing on the keyboard
Control code settings
Use sequence software (Vision, etc.)
4. Create data for the Saturn system
Link data created in steps 2, 3, and 4
Use sound simulator

* The "Sega Sound Library" is a product of Invision Co.
* "Overtone" and "Vision" are products of OPCODE SYSTEM INC.
* The wave editor and tone editor are tools provided by Sega.

Music creation tools

1) The SEGA Sound Tools do not include software for creating music (a sequencer, etc.). Use third-party software.
2) Step 1 can be accomplished using third-party software. Select whatever software you are comfortable with.
3) when using only notation software, use a program that has MIDI event (at a minimum, controllers and programs) editing capabilities.

Sampling Sound from Instruments

The only difference between the Saturn target when the power has just been turned on and the MIDI sound source is that the target has no tone data; otherwise, they can be considered to be roughly equivalent.

At this point, we will use the wave editor to get, in the form of waveforms, the sounds that are to be handled by the target. Because the sounds provided in the SEGA Sound Library consume a large amount of storage space, other tasks such as reducing the size of the library for use in an actual game also become necessary.

However, until you become familiar with the handling of sound in the SEGA Saturn system, you should continue to use this library as is.

Now, we will actually “get” a sound.

This process is called “sampling,” and by using the wave editor in the SEGA Sound Tools it is possible to directly output the sound from the target.

The sound sampling procedure is described below.

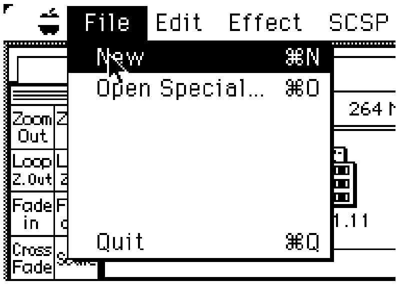
1) Wave editor startup

Start up the wave editor.

2) New file creation

Select “New” under the “File” menu.

Fig 2-2 Creating a New File

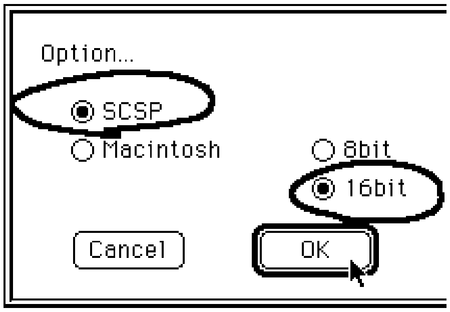


3) Target module settings

Set the conditions for sampling from the target.

Because the sound is to be produced by the target, select “SCSP”. Also select “16bit” for sampling the sound. After selecting these options, click “OK”.

Fig 2-3 Target Module Settings



Option...

● SCSP

○ Macintosh

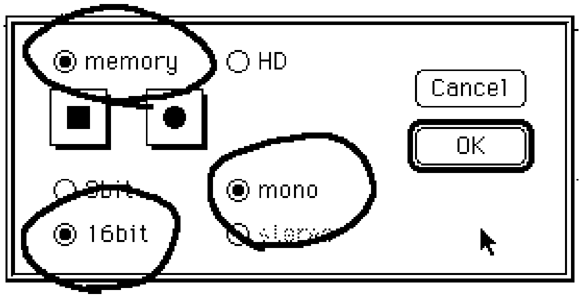
○ 8bit

● 16bit

4) Sampling settings

If the sound to be sampled is less than 10 seconds in duration, select “memory”; otherwise, select “HD”. As shown in the illustration, select “16bit”; also select “mono”, since only monaural sampling is possible. After selecting these options, click “OK”.

Fig 2-4 Sampling Settings



● memory ○ HD

○ 8bit

● 16bit

● mono

○ stereo

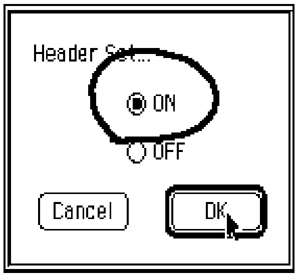
When “HD” has been selected

If “HD” was selected, a file is created after the sampling process, and it is necessary for you to re-open that file.

Therefore, if using the wave editor, it is best to make every effort to keep the sound of the size down to an extent that allows “memory” to be selected.

If “HD” was selected, the following screen appears. Normally, select “ON”, and then click “OK”.

Fig 2-5 HD Settings



Header Set...

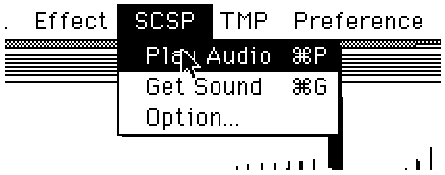
● ON

○ OFF

5) Generating the sound

Select “Play Audio”.

Fig 2-6 Selecting “Play Audio”

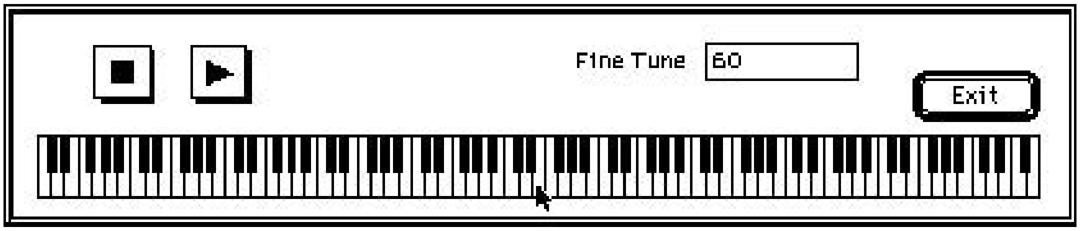


Once “Play Audio” is selected, the keyboard screen appears. This screen is used to play the sampled waveform.

However, because the primary purpose of this task is waveform editing, clicking the keys gently or firmly does not change the volume.

The volume settings are made by the tone editor.

Fig 2-7 Keyboard Screen


Fine Tune 60

Clicking a key in the key keyboard with the mouse causes the target to emit the corresponding tone. In addition, clicking the playback button generates the basic key tone, and clicking the stop button stops the tone.

6) Basic editing

Cutting, copying and pasting are performed just as with regular word processing software by selecting the appropriate commands from the “Edit” menu.

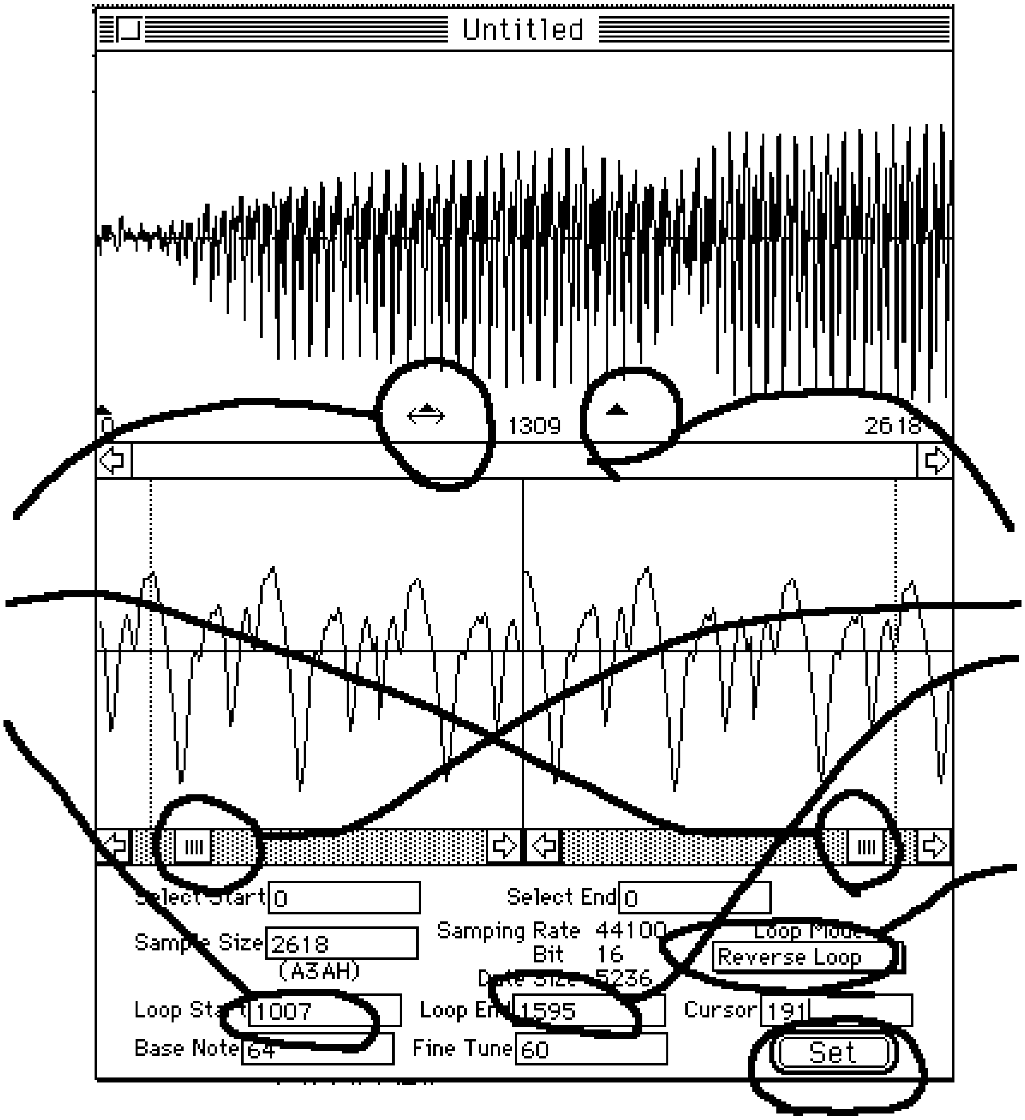
The only minor difference is that in the case of pasting and cutting, it is possible to select whether or not to overwrite the selected portion and whether or not to close up the space left behind by the cut portion. Otherwise, these operations are practically identical with their word processing counterparts.

7) Creating a loop

Creating a loop makes it possible to repeat the sound within the range designated as the loop; this makes it possible to reduce the amount of data required for a waveform.

The following illustration shows an example of setting up a loop. After the settings have been made, click “Set”.

Fig 2-8 Loop Settings



Select Start 0
Select End 0
Sample Size 2618 (A3AH)
Samping Rate 44100
Bit 16
Data Size 5236
Loop Mode Reverse Loop
Loop Start 1007
Loop End 1595
Cursor 191
Base Note 64
Fine Tune 60

Loop starting position

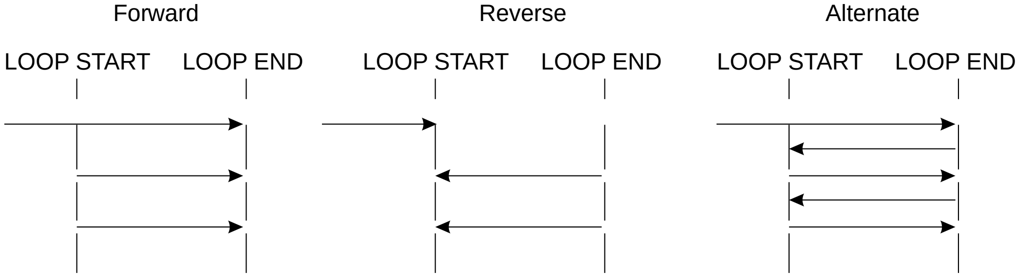
Loop ending position

Loop setting pop-up menu

If there is a little popping noise that is audible at the end of the loop, move the loop position slightly. Use the space key to move the scroll bar slowly in the direction indicated by the arrow while listening to the music.

A loop can be one of the following three types:

Fig 2-9 Loop Modes



8) Setting waveform effects

Since the best way to gain an understanding of these effects is to try them, this section will only provide a few guidelines. Using these effects merely entails changing the numeric values.

Table 2-1 Descriptions of Effects

Resample	11K to 44.1K	Changes the sample count. (If the value is too small, the sound becomes rough.)
Pitch Shift	0 to 127	The higher the value, the faster the speed. (Standard: 60)
Size Shift	Max FFFEh	Changes the size. (Affects all parameters.)
Scale	100%	Adjusts the volume.
Filter LPF HPF	 500 to 16000 Hz 32 to 2200 Hz	 Cuts frequencies higher than the set value. Cuts frequencies lower than the set value.
Compressor Threshold CompressionRatio	 -90 to 0 1 to 90	 The larger the value, the lower the volume. The larger the value, the lower the volume.
Noise Gate Threshold Release Hold	 -90 to 0 0 to 2000 0 to 2000	 Silences the portions that do not reach this value. Time until fade out. Time until fade in.

When adjusting these values, it is best to try to make only slight adjustments, step by step.

Also, always be sure to save your data.

The file that is created as the end result is a Macintosh AIFF (Audio Interface File Format) file.

The wave editor discussed up to this point offers the advantage of permitting confirmation of the sound output directly from the target, if you are used to other waveform editing software on the Macintosh, it is probably most efficient to use that software and then simply use the wave editor to check the final results.

Because there is a large number of sound-related programs available for the Macintosh, feel free to try whatever software you wish.

Assigning Sounds to Keys

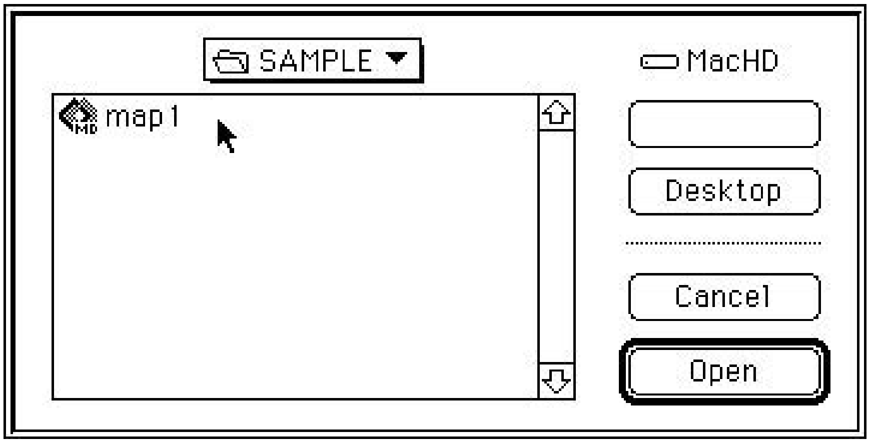
We will now use the waveform that we have created and actually assign sounds to the keyboard.

We will also set the relationship between the intensity with which keys are struck and changes in the sound.

1) Target initialization

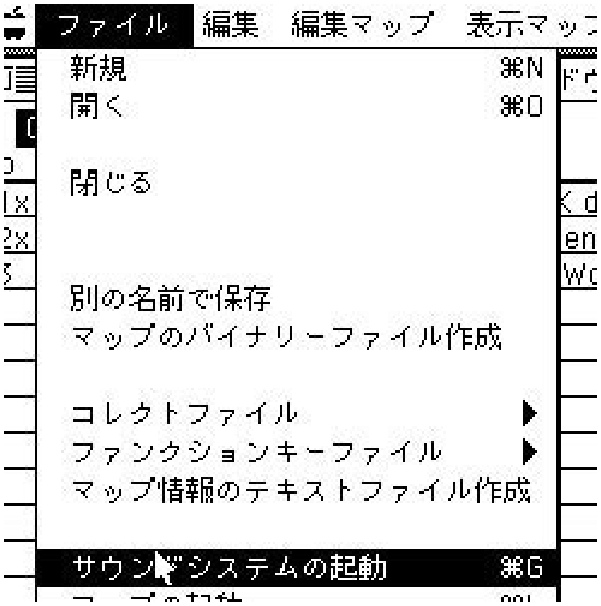
When using the tone editor, it is necessary to initialize the target with the sound simulator. Start up the sound simulator and open the map. In this instance, simply open the sample map file provided with the SEGA Sound tools.

Fig 2-10 Open Map



Next, select “Startup Sound System” from the “File” menu. The sound system starts up.

Fig 2-11 Selecting “Startup Sound System”


ファイル
編集
編集マップ
表示マッ
新規 ⌘N
開く ⌘O
閉じる
別の名前で保存
マップのバイナリーファイル作成
コレクトファイル
ファンクションキーファイル
マップ情報のテキストファイル作成
サウンドシステムの起動 ⌘G

Target initialization is now complete.

2) Tone editor startup

Start up the tone editor.

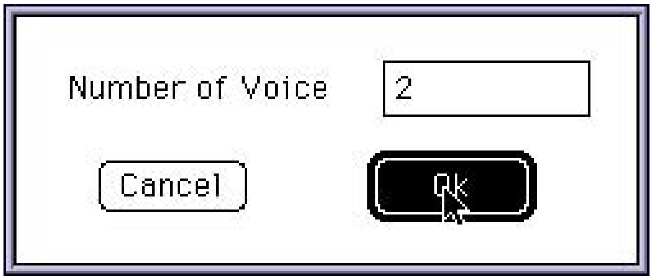
3) Voice data creation

When creating new voice data, the default number of voices is “15”; change this setting to “2”.

The number of voices can be increased or decreased later.

If the sequence data has already been created, it is only necessary to set the number of instruments.

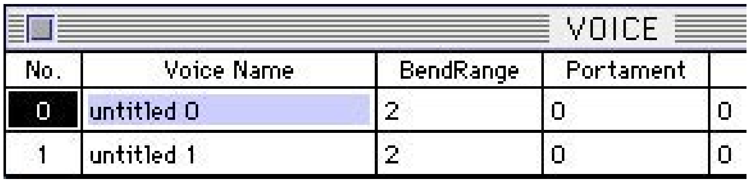
Fig 2-12 Setting the Number of Voices



Number of Voice: 2

Once these settings have been completed, the Voice Window appears.

Fig 2-13 Voice Window



No.	Voice Name	BendRange	Portament	
0	untitled 0	2	0	0
1	untitled 1	2	0	0

This window shows voice names and numbers.

Because it is confusing if the name that appears in pop-up menus when making settings later is “untitled,” rename the voice with the name of the instrument, etc.

Next, we will set each of the tones.

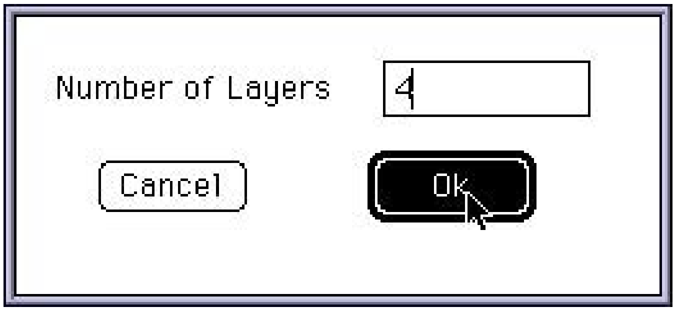
Click on a number at the left. A window will appear, asking for the number of layers; set the number to “4”.

The number of layers sets the number of sound waveforms to be assigned to a given range of keys.

Although assigning each individual waveform to each individual key would yield exactly the same sound, that approach would consume too much memory.

Therefore, although reducing the waveform size without harming the sound quality and then determining the number of waveforms to be used is a difficult task, it is most important. Attempt it several times in order to make sure that the best results are achieved.

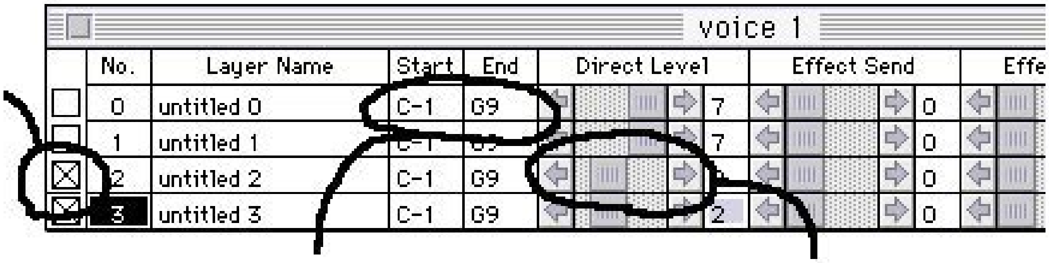
Fig 2-14 Setting the Number of Layers



Number of Layers: 4

The Layer Window now appears.

Fig 2-15 Layer Window



	No.	Layer Name	Start	End	Direct Level	Effect Send	Effe
□	0	untitled 0	C-1	G9	7	0	
□	1	untitled 1	C-1	G9	7	0	
☒	2	untitled 2	C-1	G9		0	
☒	3	untitled 3	C-1	G9	2	0	

Check this box when using the waveform as an FM carrier wave.

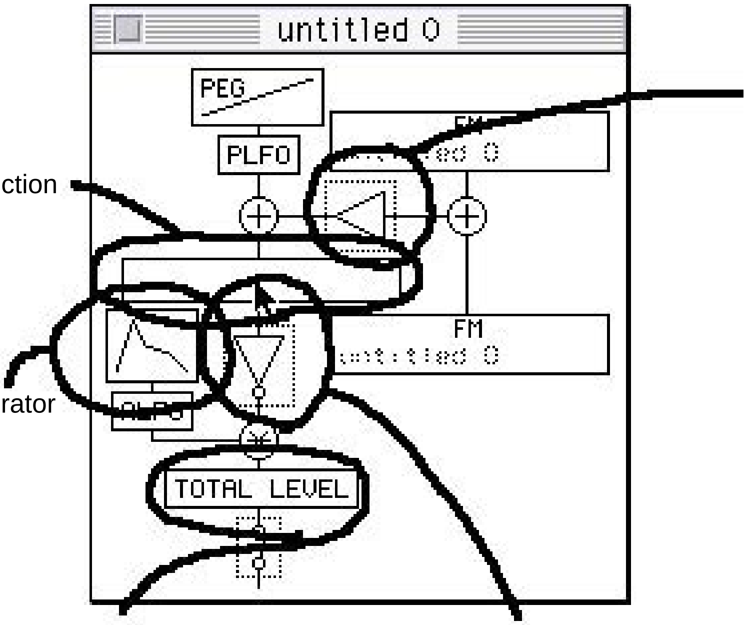
Range of key positions to which the waveform is assigned.

Think of this simply as the volume.

3) Layer data creation

The various settings can be made by double-clicking within each frame.

Fig 2-16 Setting the Layer Data



FM application settings

AIFF file selection

Envelope generator settings

Velocity selection, total level settings

Waveform loop method and basic key setting

If there are any changes made to an AIFF file while that file is selected, either select another AIFF file and then reselect the first one, or else change the file name and select the new file.

Note that unless one of these options is executed, the changed file is not read into the tone editor.

Next, adjust each of the settings while checking the results with the keyboard. Those points that require particular attention when changing settings are described next.

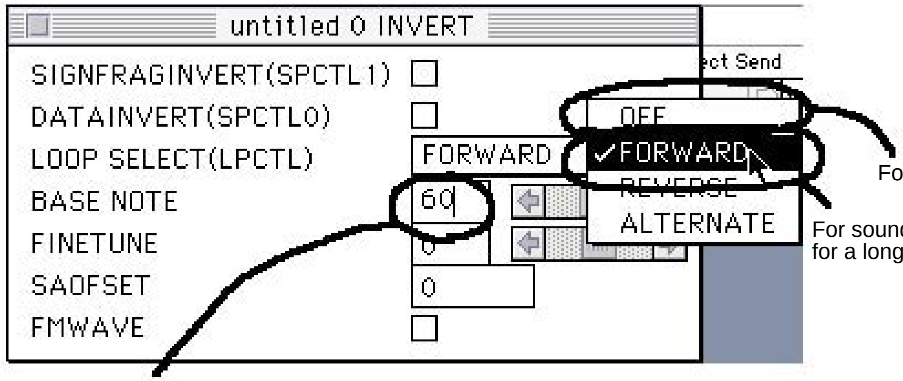
When changing various settings, it is best to use the settings of existing sounds in the SEGA Sound Library as a guide.

For further details, refer to references concerning DTM.

Waveform information settings

If you are using third-party waveform editing software, pay careful attention to the waveform loop method and the setting of the basic key.

Fig 2-17 Setting Waveform Information



untitled 0 INVERT

SIGNFRAGINVERT(SPCTL1) □

DATAINVERT(SPCTL0) □

LOOP SELECT(LPCTL) FORWARD

BASE NOTE 60

FINETUNE 0

SAOFSET 0

FMWAVE □

For "once-only" sounds

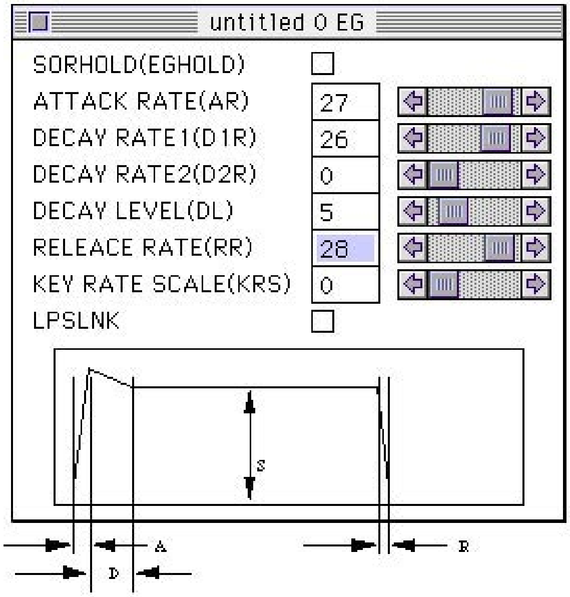
For sounds that continue
for a long time, such as a flute

Number of the basic key for the waveform being set

Envelope Generator (EG)

When an actual musical instrument plays a note, the volume attenuates and the tone changes as time passes from the moment when the note is first played. The envelope generator (EG) sets these changes that occur with the passage of time.

Fig 2-18 Setting the Envelope Generator (EG)



untitled 0 EG

SORHOLD(EGHOLD)	□
ATTACK RATE(AR)	27
DECAY RATE1(D1R)	26
DECAY RATE2(D2R)	0
DECAY LEVEL(DL)	5
RELEACE RATE(RR)	28
KEY RATE SCALE(KRS)	0
LPSLNK	□

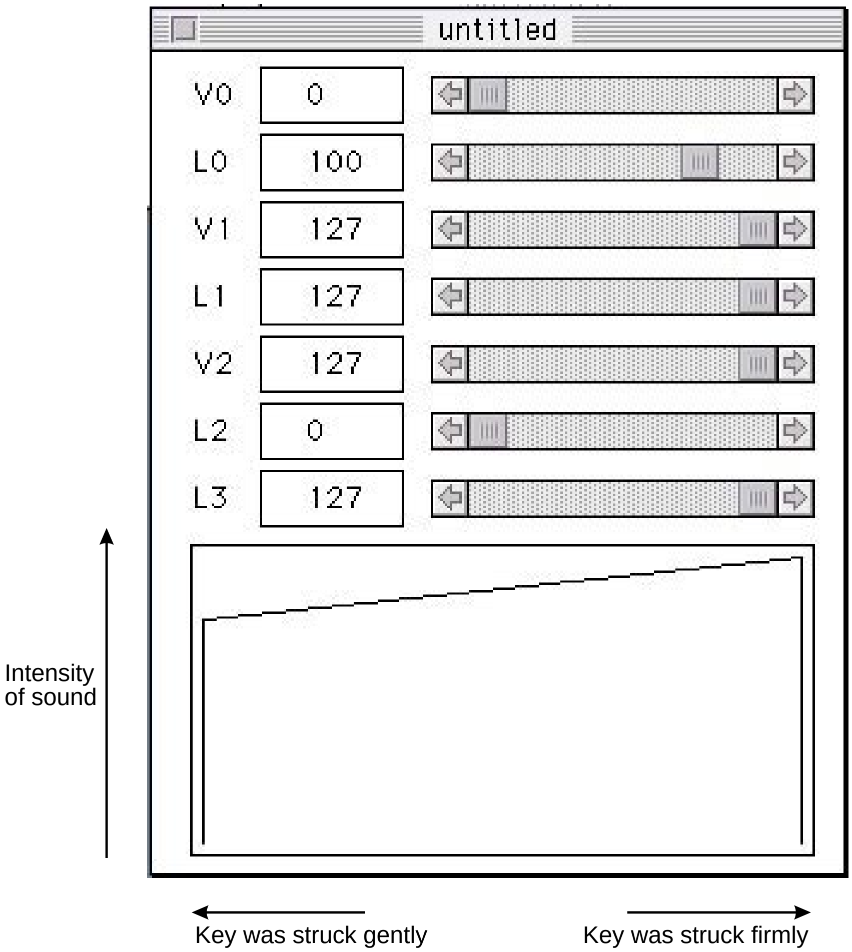
A: Time that elapses from the initiation of the sound until it reaches its maximum volume
D: Time that elapses as the volume attenuates from its maximum down to its continuing volume
S: Time that the sound continues while the key is held down
R: Time until the sound disappears once the key is released

Velocity

The velocity, which is the speed with which the keys are struck, can be set to one of 127 levels. This setting effects changes in volume due to strong or gentle playing.

The standard sound settings are roughly those shown in the illustration below.

Fig 2-19 Setting the Velocity



V0 0
L0 100
V1 127
L1 127
V2 127
L2 0
L3 127

DSP Program Creation

In addition to sounds that it plays through its internal sound source, the Saturn system can also use its internal DSP to apply effects to sound effects or sounds from a CD. This section describes how to create a DSP program for this purpose.

However, because it is possible to produce sound even without a DSP program, you can skip this section if you will be producing sounds without any added effects.

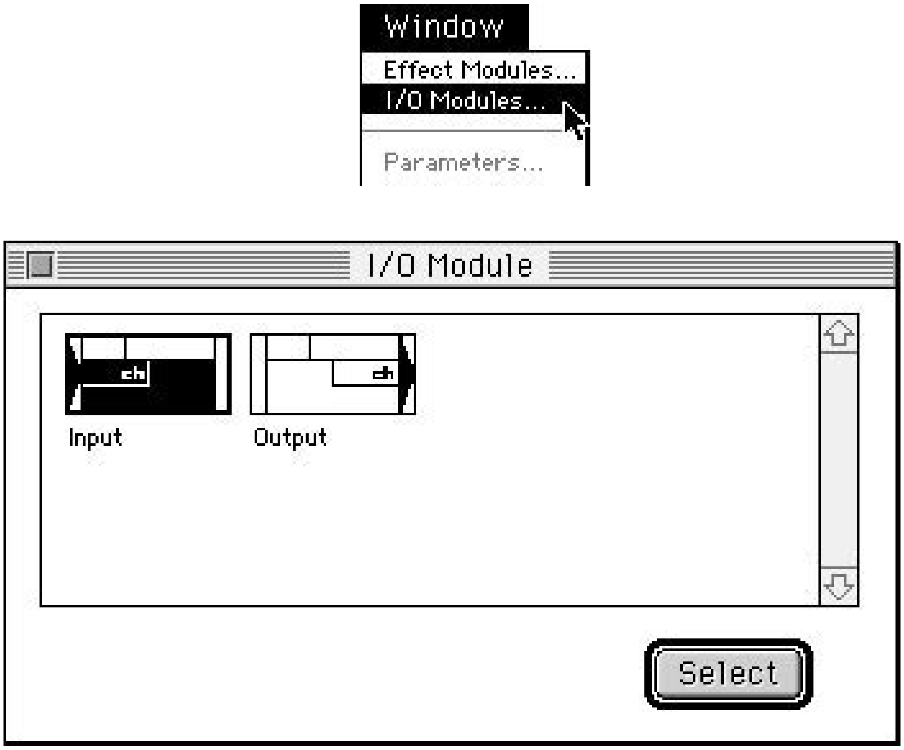
1) DSP Linker startup

First, double-click the DSP Linker in order to start it up. When creating a new file, select "New" from the "File" menu and name the file. The Algorithm Editing Window then opens, and the extension ".YLI" is automatically added to the file name.

2) Arrangement of DSP input/output modules

If "I/O Modules" is selected from the "Window" menu, the I/O Module Window opens.

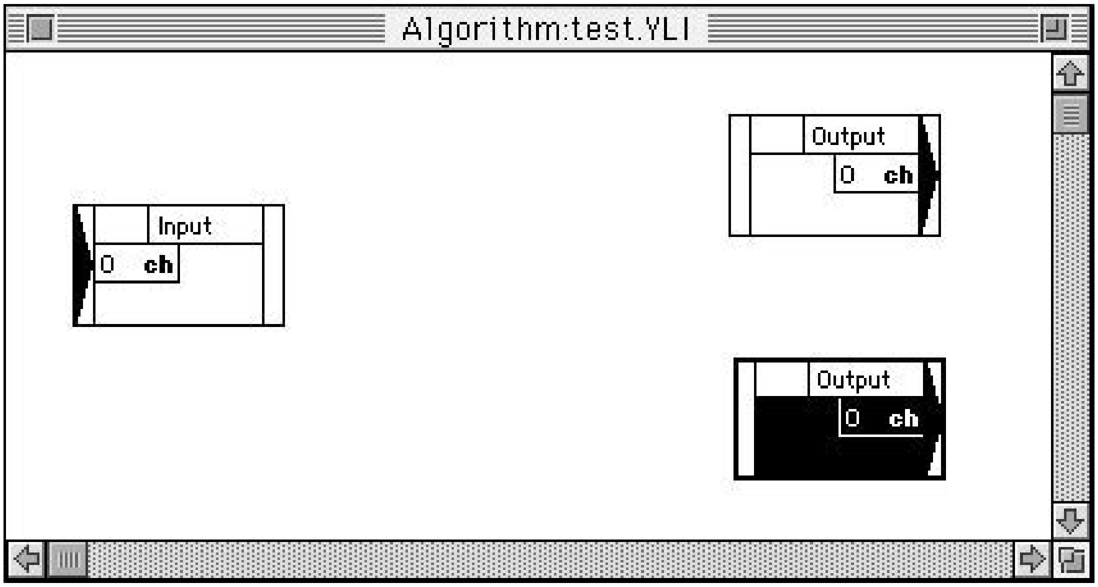
Fig 2-20 I/O Module Window



Either double-click on the “Input” (input to the DSP) module or the “Output” (output from the DSP) in the I/O Module Window, or else click on them once and then click the “Select” button. The modules are then copied into the Algorithm Editing Window. As an example, we are going to add a reverb effect; therefore, we will copy one “Input” module and two “Output” modules.

Position the modules in the window so that they do not overlap and can be easily seen.

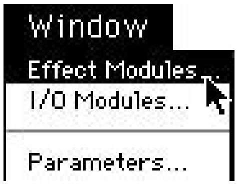
Fig 2-21 Arrangement of DSP I/O Modules

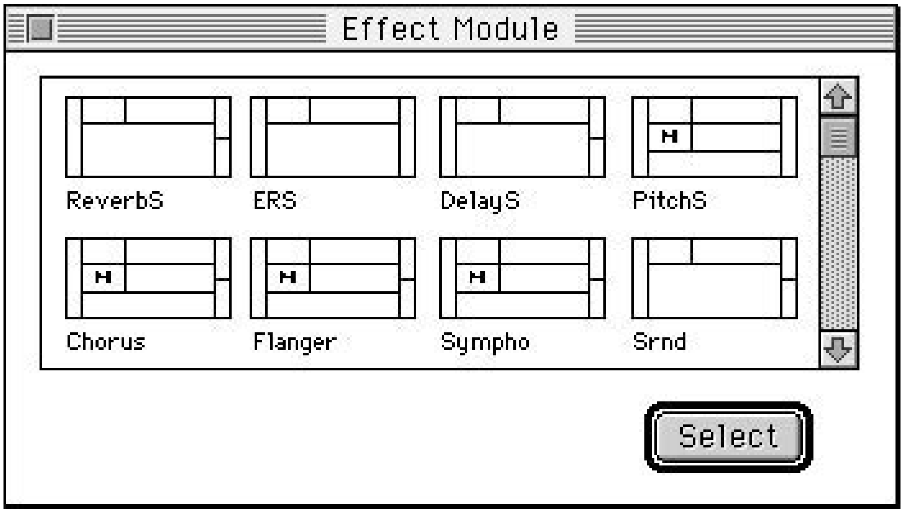


3) Arrangement of effect modules

Select “Effect Modules” from the “Window” menu; the Effect Module Window opens.

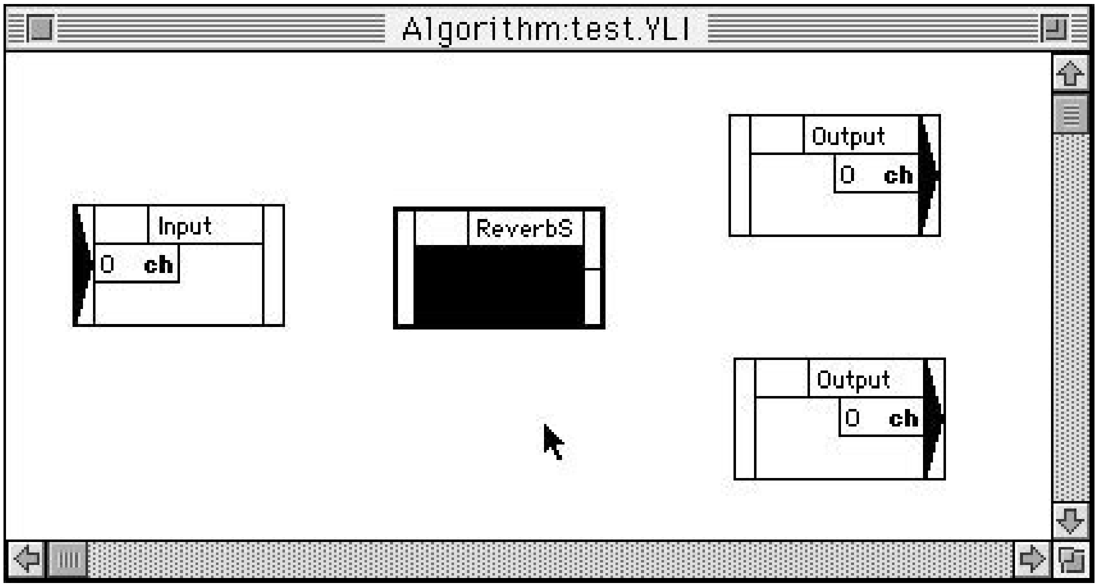
Fig 2-22 Effect Module Window





Select the desired effect from this window; it will be copied to the Algorithm Editing Window in the same manner as the input and output modules.

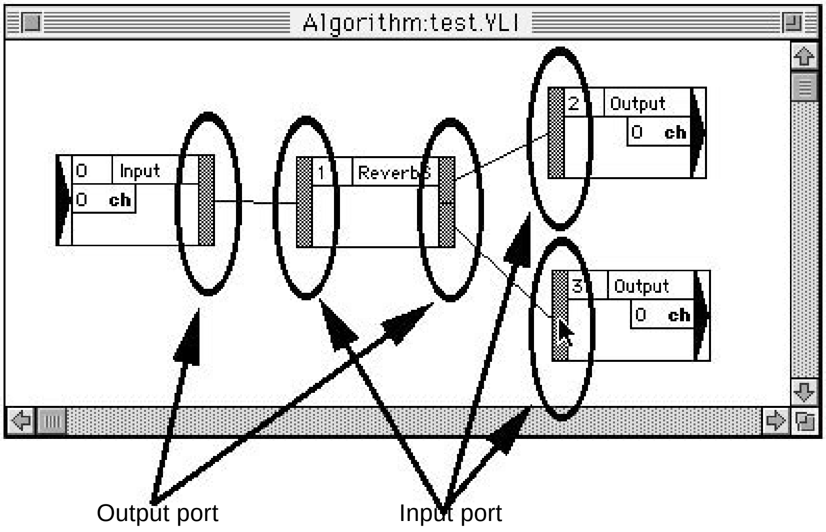
Fig 2-23 Effect Module Arrangement



4) Connecting the modules

In order to determine the flow of the sound data among the modules, it is necessary to connect the modules. First, click on the output port of a module and then click on the input port of the next module; a straight line is then drawn, indicating the connection between the modules.

Fig 2-24 Connecting the Modules

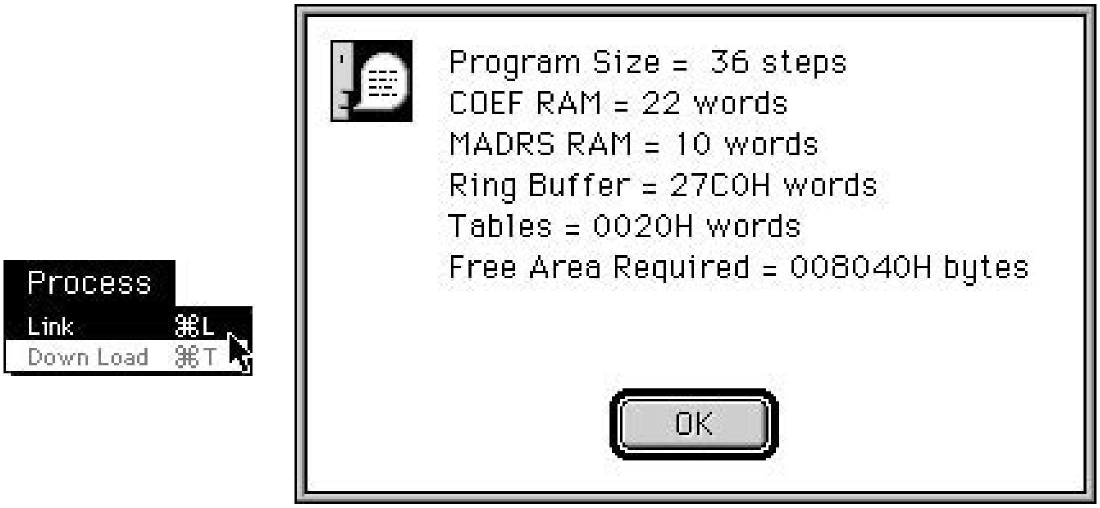


This defines the path by which the sound data flows from the input module through the effect modules (more than one can be used) and then out to the output modules.

5) Linking

After connecting the modules, select “Link” from the “Process” menu to link together the effect algorithm that you have created. If the linking operation is completed successfully, the “Link Results Information” dialog box is displayed. This dialog box displays information on the usage of DSP-related hardware resources.

Fig 2-25 “Link Results Information” Dialog Box



Program Size = 36 steps
COEF RAM = 22 words
MADRS RAM = 10 words
Ring Buffer = 27C0H words
Tables = 0020H words
Free Area Required = 008040H bytes

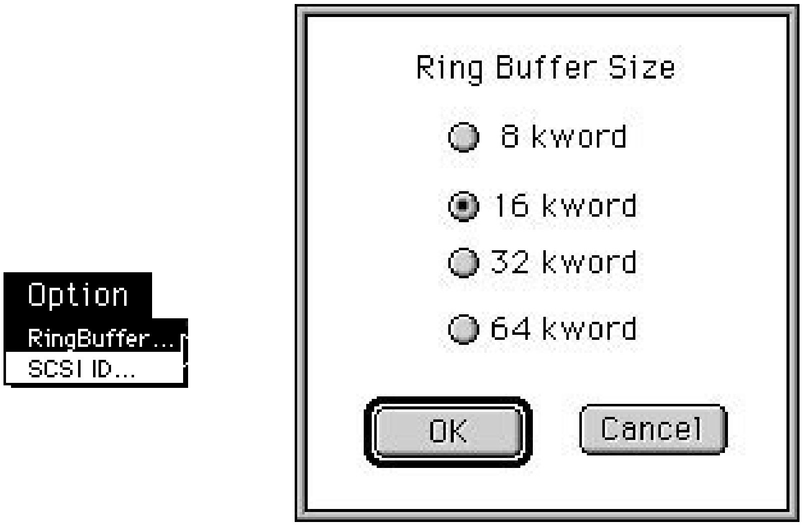
The value shown for “Free Area Required” in this “Link Results Information” dialog box is the size of the DSP work RAM allocated in the map.

When the DSP work RAM is set in the sound simulator, the starting address is given in units of 2000h. If an attempt is made to specify an address using a smaller unit, the address is automatically moved back to an address at the proper interval.

Processing when the “Ring buffer too small” message appears

Sometimes a link attempt fails and the message “Ring buffer too small” appears. In this event, select “Ring Buffer” from the “Option” menu and increase the size of the ring buffer. (The larger the ring buffer, the larger the DSP work RAM area that must be allocated in the map.)

Fig 2-26 Selecting the Ring Buffer Size



Ring Buffer Size

○ 8 kword

● 16 kword

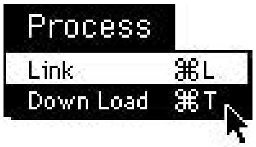
○ 32 kword

○ 64 kword

6) Downloading

After the linking process is completed, select “Download” from the “Process” menu. This command downloads the effect algorithm that has been created to the target (development board) so that the DSP can function.

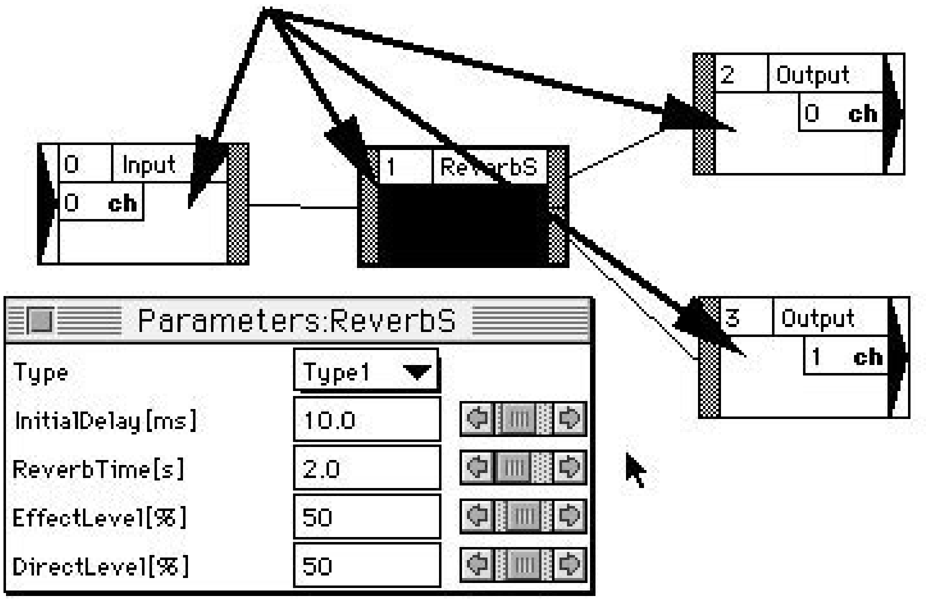
Fig 2-27 Downloading to the Target



7) Editing the effect parameters

To open the Parameter Editing Window, either double-click on the white space (the portion where no text appears) in a given module in the Algorithm Editing Window, or else select a module and then select “Parameters” from the “Window” menu.

Fig 2-28 Editing the Reverb Module



Select this portion and double click

Type: Type1

InitialDelay[ms]: 10.0

ReverbTime[s]: 2.0

EffectLevel[%]: 50

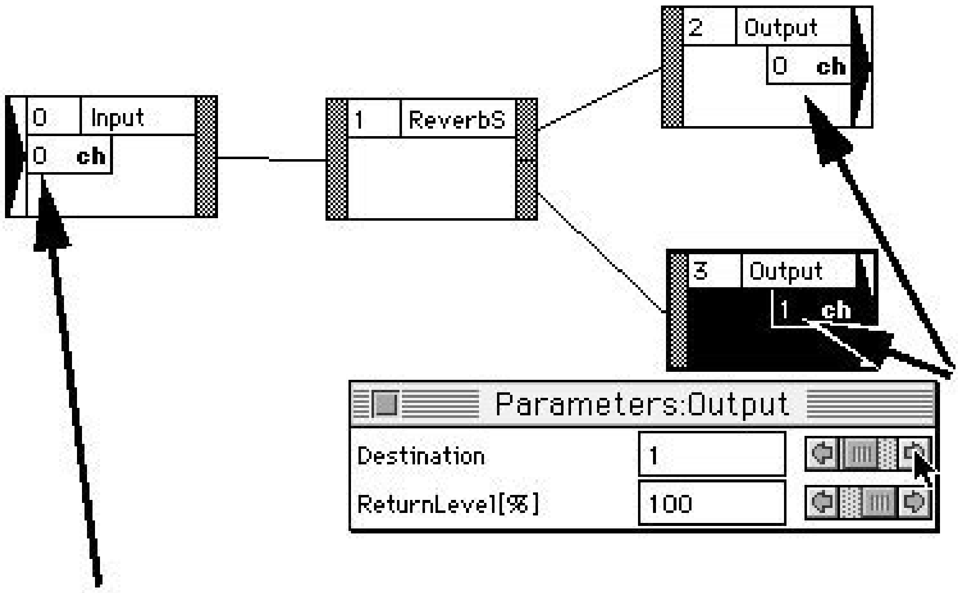
DirectLevel[%]: 50

It is possible to make precise changes to the effect parameters by changing the values in the Parameter Editing Window. This task can be performed in real time while listening to the actual music or sound effect. Note, however, that making frequent use of the sliders while playing back a sequence can cause problems involving the SCSI interface.

Prepare two output modules for effects, such as reverb, that you want to give a stereo feel. This can be accomplished by assigning different outlets and then switching them between left and right.

The channel (“ch”) shown for each output module corresponds to the channels in the Mixer Window of the tone editor. The channel in the input modules corresponds to the “Effect Select” for each layer in the tone editor.

Fig 2-29 Editing the Input and Output Modules



Destination 1

ReturnLevel[%] 100

Corresponds to mixer

Corresponds to layer “Effect Select”

8) Saving the file

At this stage, the effect algorithm that has been created exists only in the memory of the target, and has not yet been saved as a file. To save the effect algorithm after it has been completed or even while still working on it, select “Save” from the “File” menu.

When the effect algorithm is saved, four files are created with the extensions “.YLI”, “.EXL”, “.LRI”, and “.EXB”.

To again open the file that was saved last, open the file with the “.YLI” extension.

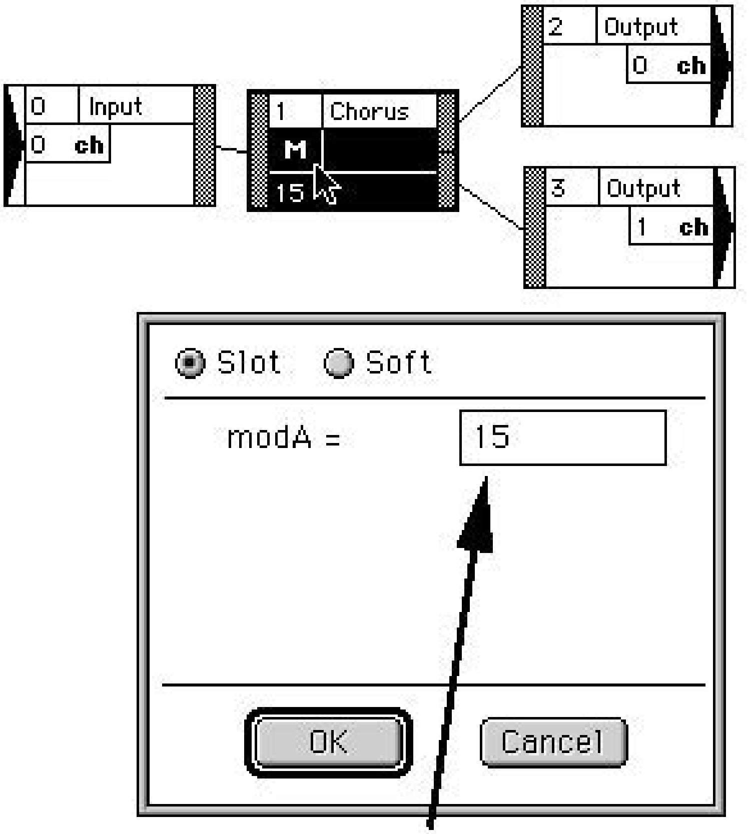
The file that is to be actually incorporated into the map and passed to the main programmer is the file with the “.EXB” extension.

9) Modulation-type effects

Modulation-type effects, such as chorus and autopan cannot be linked unless the modulator input buffer number (the DSP input buffer number) is specified.

Clicking on the “M” opens the modulator input buffer setting dialog box.

Fig 2-30 Modulation-type Effects



● Slot ○ Soft

modA = 15

Modulator input buffer number (DSP input buffer number)

Of the “Slot” and “Soft” buttons, always select “Slot”.

Incorporate the modulation voices found in the DSP tool folder, such as “VoiceForAutoPan” and “VoiceForModulations”, into the tone bank to be used.

Make sure that the voice DSP input buffer number (Effect Select) and the modulator input buffer number are the same. (Initially, “15” is selected for these voices.)

When using these effects, it is necessary to set the modulation voice so that it is on. Insert the data for turning this voice on into the sequence data. (Because the direct level is “0”, it will not produce sound as such.)

Adjust the modulation speed by adjusting the voice interval.

Creating Music

What we have created up to this point is only sound; now we must use those sounds to create music.

However, the SEGA Sound Tools do not include software for creating musical scores or music data.

Software that creates musical scores is typically known as sequencer software; this software records the playing of a MIDI instrument, such as a keyboard, and stores the music data.

There is also notation software, which displays sheet music and allows the user to input notes in a manner similar to a word processor.

The sequencer software can store the music data in SMF format (Standard MIDI Format).

For the Saturn system, store music data in the SMF type 1 format.

For details, refer to the manual provided with your software.

Before creating music, some points regarding the music itself should be noted; always be sure to discuss the points listed below with the game programmer.

Notes concerning the music itself

- When using the fade-out function

  If sounds that have a long duration are generated before the fade-out function is applied, the volume of those sounds does not change as long as those sounds continue, so that only those sounds do not fade out and simply linger behind.

- When using loops

  When playing music that contains loop information, if the music tempo is changed, the tempo at the start of the loop returns to the default value.

Now we will commence with the task of creating music.

Music creation (including sound effects) is handled in terms of the individual “part” (called a “track”) for each instrument. When creating an SMF file, information called a “MIDI event” must be inserted according to the following procedure into tracks which contain musical note information, with at least a one-clock delay.

1) Insert No. 0 for control code 0 at the start of the track.

Although in the case of the Saturn system no problems result whether this code is inserted or not, it is best to insert it since the control numbers 32 to 63 that are used later are provided in order to improve the precision that originally was only from 0 to 31.

2) Next, insert control code 32.

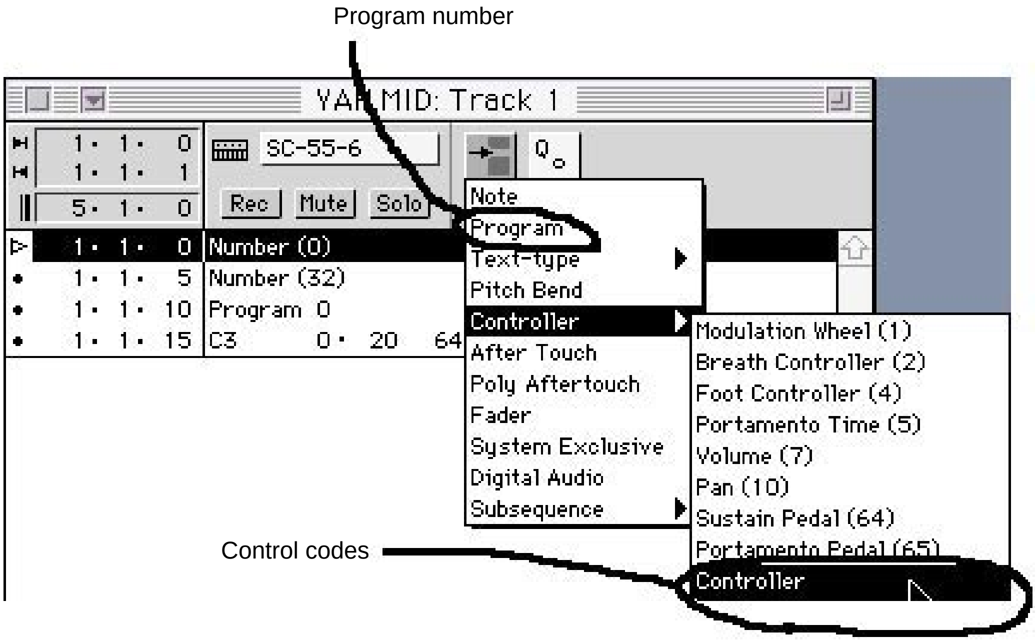
This parameter is the tone bank number (from 0 to 15) used by this music (sound effect). The tone bank number is set when the sound simulator map is created. (Refer to item 4 in section 2-6, “Map creation.”)

3) Next, insert the program number.

Insert the number (from 0 to 127) of the tone (starting from the beginning of the tone bank set by item 2 above) to be used by the track.

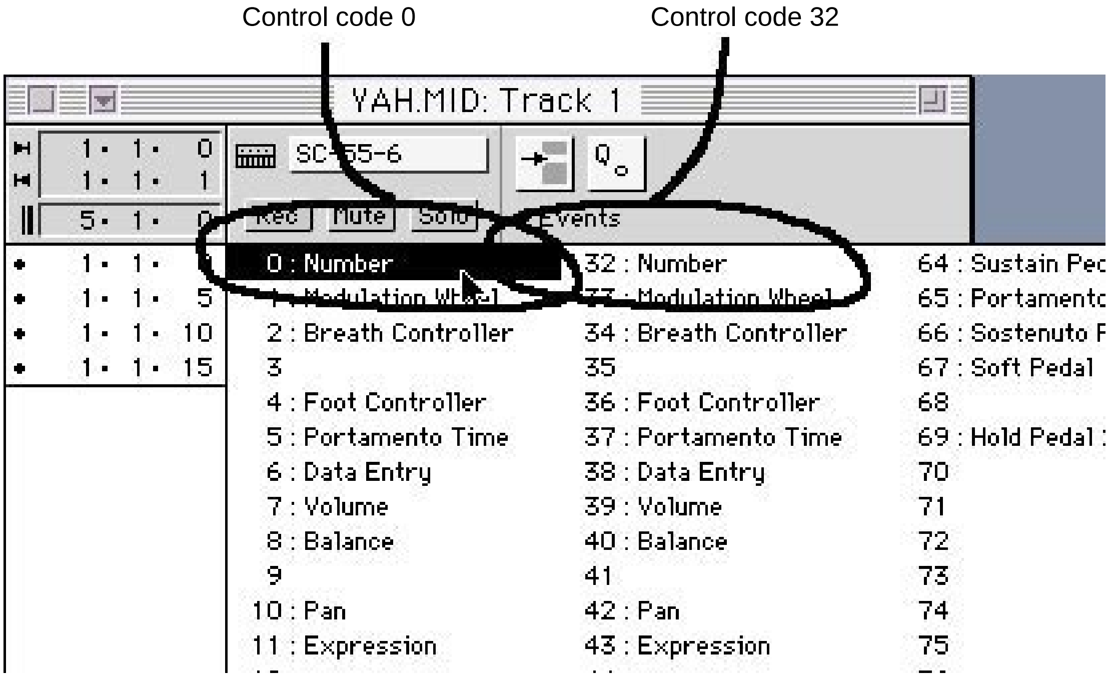
Although the example shown below is taken from VisionAV, it is fundamentally the same as other sequencer software.

Fig 2-31 Inserting Control codes Using VisionAV



For the control codes, click the mouse on the position of the control code that was inserted (as shown below) and set 0 and 32.

Fig 2-32 Control Code Setting



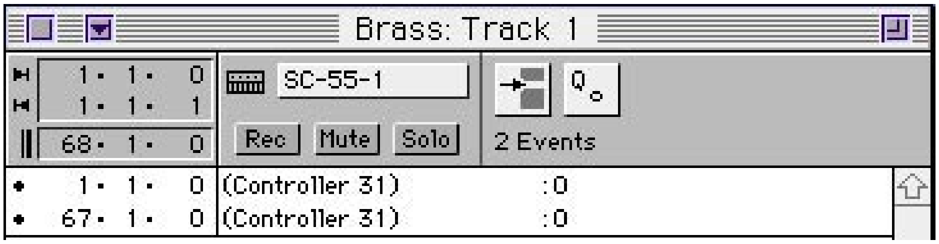
In some software, there is no pop-up menu; instead, you position the mouse over the parentheses and click the mouse to increase or decrease the number.

To make music loop for use as background music, etc., it is possible to insert No. 0 for control code 31 at the start and end of the loop.

Because it is only necessary to insert the loop information in one track, creating a track that is used solely to hold the loop information makes the data easier to understand if examined later.

The following is such an example.

Fig 2-33 Example of a Track for Loop Information



```
 1· 1·  0
 1· 1·  1
68· 1·  0
```

```
•  1· 1·  0 (Controller 31)        :0
• 67· 1·  0 (Controller 31)        :0
```

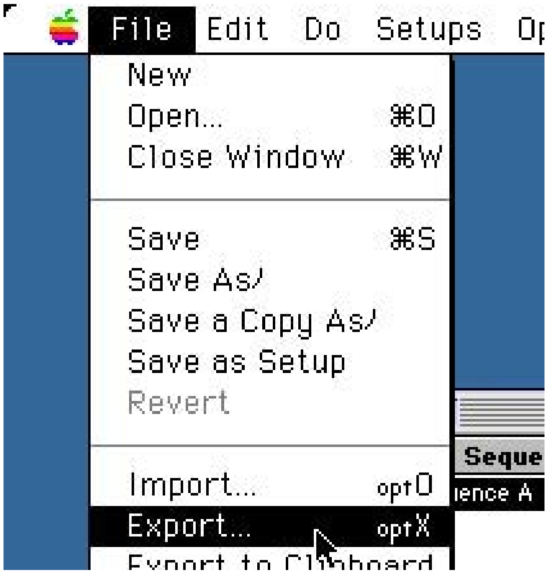
The method for inserting MIDI events is exactly the same as the method shown in the example for inserting control codes.

Save

Save the file in SMF file multitrack format.

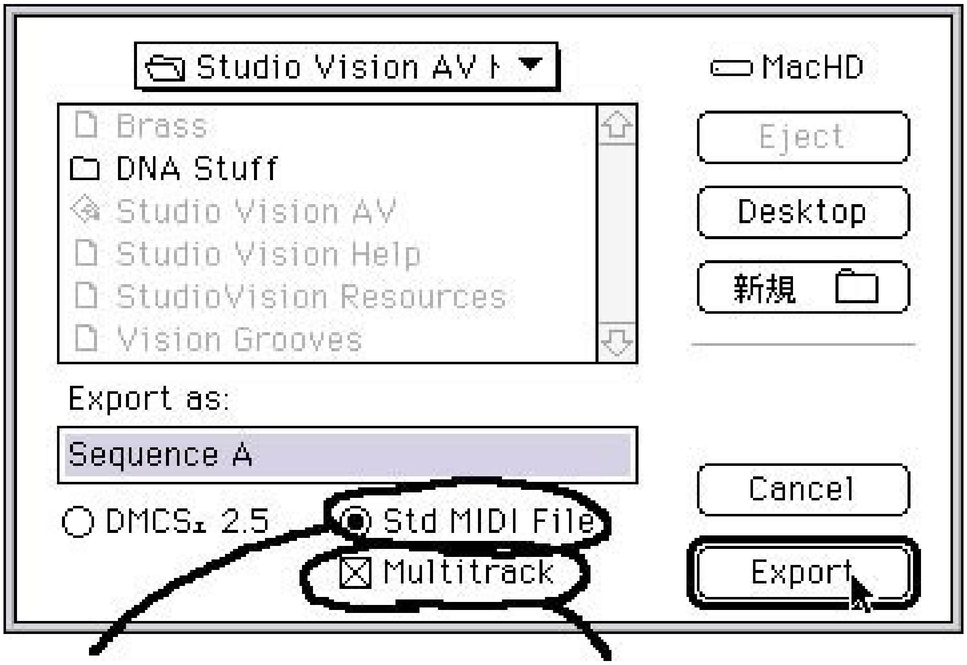
First, select “Export” from the “File” menu.

Fig 2-34 Save File (Export)



Next, the following screen appears; specify “Std MIDI File” (SMF) and “Multitrack” (type 1 format).

Fig 2-35 File Save (Export) Operation Settings



Export as: Sequence A

○ DMCSɪ 2.5 ● Std MIDI File

☒ Multitrack

SMF selection

Multitrack (type 1 format) selection

Creating Music Data for the Saturn System

Lastly, we will link together all of the data that we have created up to this point and test play the music on the target. This procedure is described below.

1) Sound simulator startup

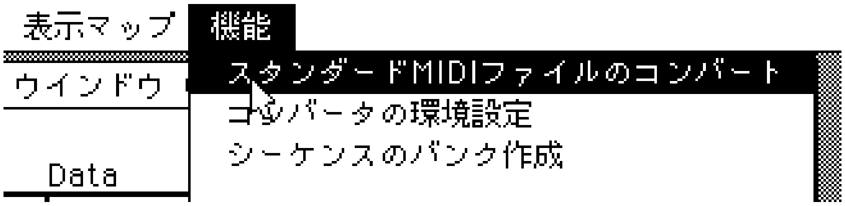
Start up the sound simulator.

2) SMF file conversion

Convert the music data that was created into data for the Saturn system.

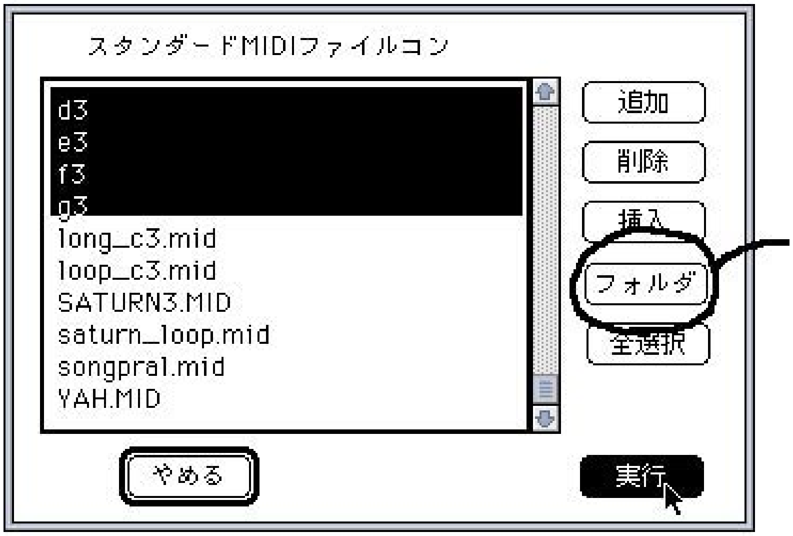
First, select “Standard MIDI File Conversion” from the “Function” menu.

Fig 2-36 Selecting “Standard MIDI File Conversion”



Using the “Add”, “Insert”, and “Folder” buttons, add the SMF files created in section 2-4, “Creating Music,” to the list, and then click the “Execute” button to convert the data.

Fig 2-37 SMF File Conversion



d3
e3
f3
g3
long_c3.mid
loop_c3.mid
SATURN3.MID
saturn_loop.mid
songpral.mid
YAH.MID

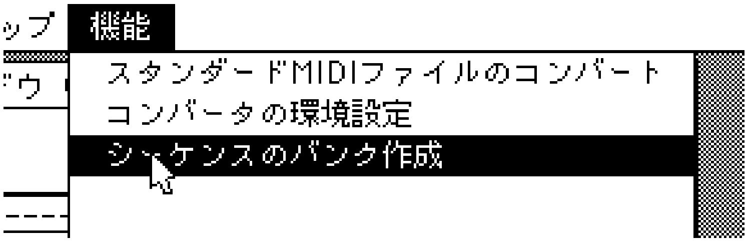
Selecting any file in the folder containing the files to be converted causes all SMF files in that folder to be selected.

* Multiple selection possible

3) Creating the sequence data

The files that were converted in step 2 are named “[original file name].CNV”. Select “Sequence Bank Creation” from the “Function” menu.

Fig 2-38 Selecting “Sequence Bank Creation”



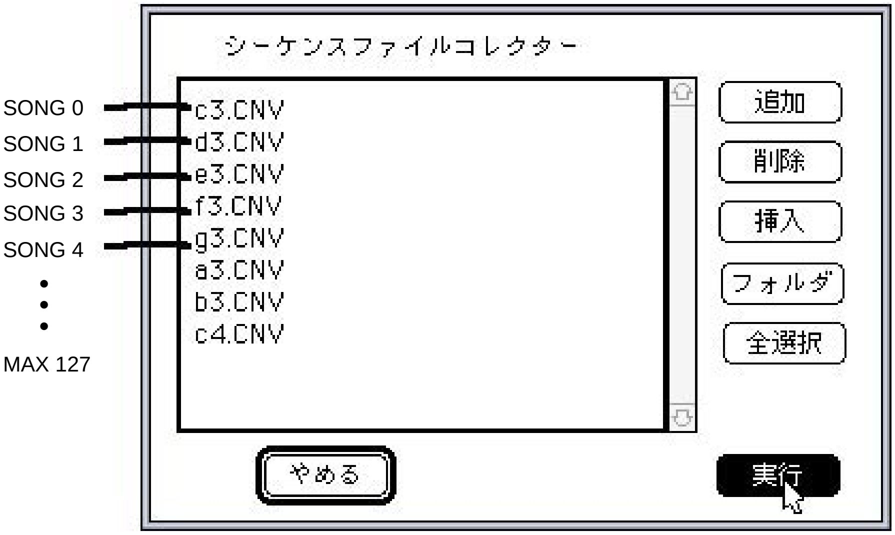
The files “[original file name].CNV”, which contain the converted data created in step 2, are grouped together as the sequence data.

At this point, the SONG numbers are assigned, starting from the top with 0, 1, 2, 3, ...

These SONG numbers are important, since they are used to specify the corresponding music for playback.

Fig 2-39 Sequence File Collector Screen

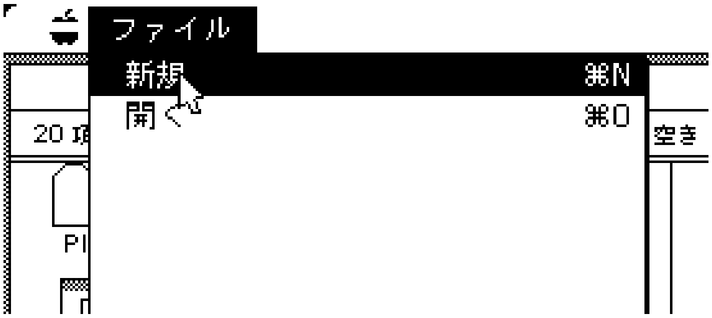
The SONG numbers are in sequence, starting from the top.



4) Map creation

Select “New” to create a new file.

Fig 2-40 Creating a New Map File

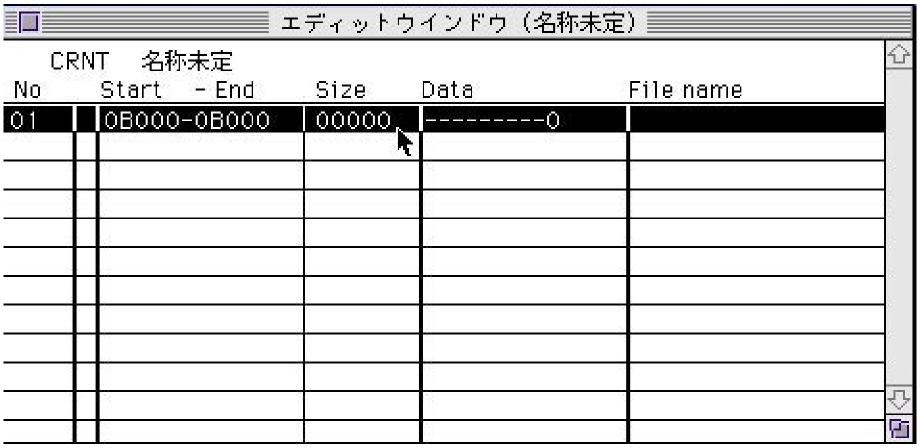


One file can store information on 128 maps.

When a file is newly created, map 0 is displayed as the editing map.

Create the information needed to group all of the tone data and music data together.

Fig 2-41 Map Editing Window


エディットウインドウ（名称未定）

CRNT 名称未定

No	Start - End	Size	Data	File name
01	0B000-0B000	00000	---------0	

Double-click on the portion of the list for which data is set in the Editing Window.

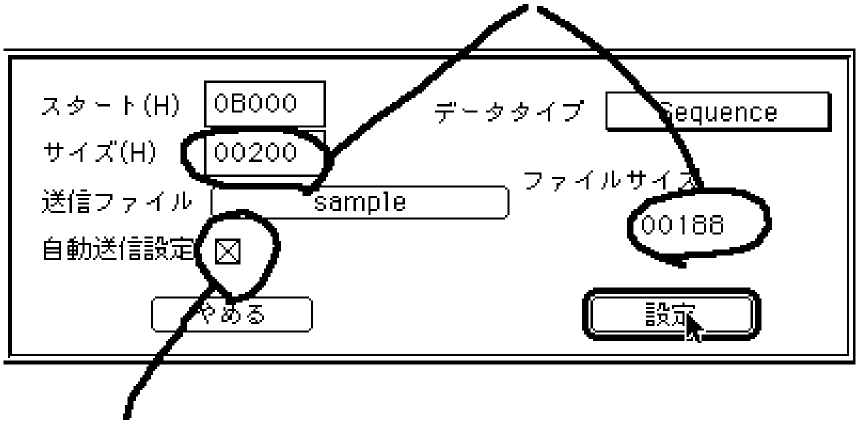
Because a newly created map contains only one element of data, use “New Data” from the “Edit” menu to add the missing data.

In this way, the information needed to group all of the tone data and music data together is created.

Set the data on the screen shown in Fig 2-42 To select the data type, click in the field to the right of “Data type”; when the pop-up menu shown in Fig 2-43 appears, select the desired data type

Fig 2-42 Data Editing Window

Set the size according to the file size



スタート(H) 0B000

サイズ(H) 00200

送信ファイル sample

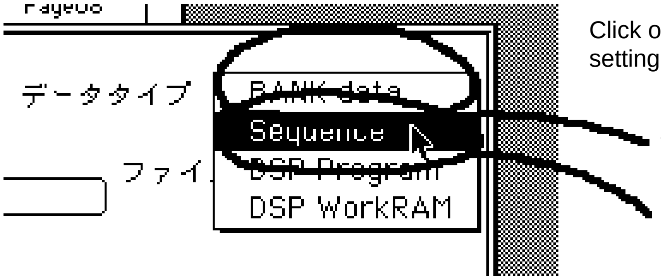
自動送信設定 ☒

データタイプ Sequence

ファイルサイズ 00188

Data is loaded when "Load map" from the "File" menu is executed, and when the file is opened.

Fig 2-43 Setting the Data Type



Click on the list to display the file setting dialog box.

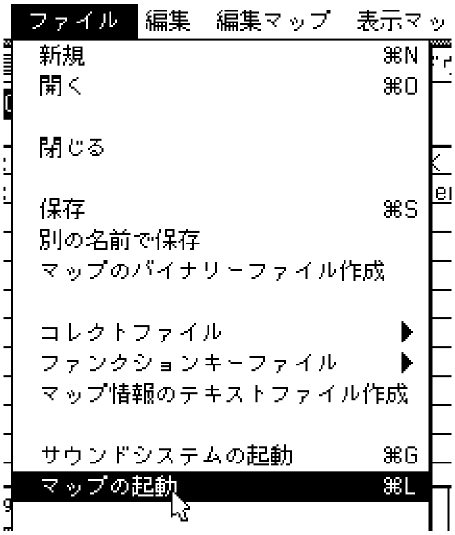
Tone data

Music data

5) Loading data

Select “Startup Map” and transfer the data to the target.

Fig 2-44 Selecting “Map startup”

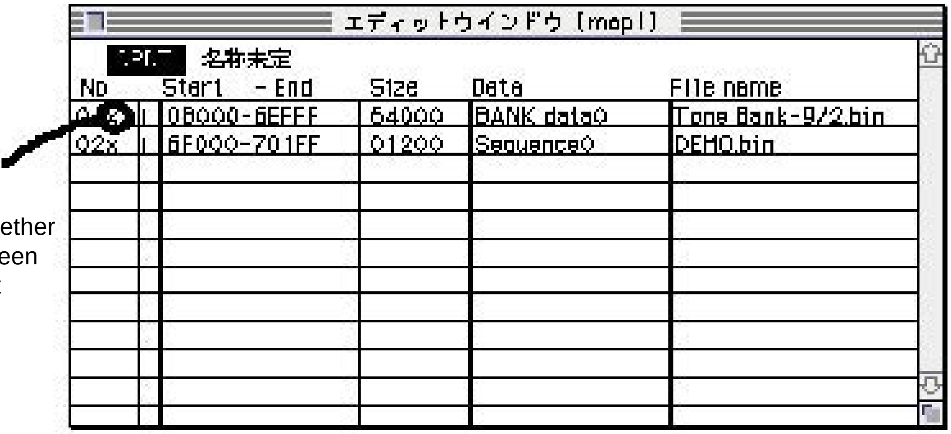


ファイル
編集
編集マップ
表示マッ
新規 ⌘N
開く ⌘O
閉じる
保存 ⌘S
別の名前で保存
マップのバイナリーファイル作成
コレクトファイル
ファンクションキーファイル
マップ情報のテキストファイル作成
サウンドシステムの起動 ⌘G
マップの起動 ⌘L

At this point, the if the sound system has not yet been started up, select “Startup Sound System” from the “File” menu and start up the sound system.

Now confirm the following point in the Edit Map Window:

Fig 2-45 Edit Map Window



エディットウインドウ [map1]

名称未定

No		Start - End	Size	Data	File name
0[illegible]	|	0B000-6EFFF	64000	BANK data0	Tone Bank-9/2.bin
02x	|	6F000-701FF	01200	Sequence0	DEMO.bin

Check mark indicating whether the file has been loaded or not

8) Music playback

Select “Sound Simulator” from the “Function” menu; the sound simulator screen appears.

Fig 2-46 Selecting “Sound Simulator”

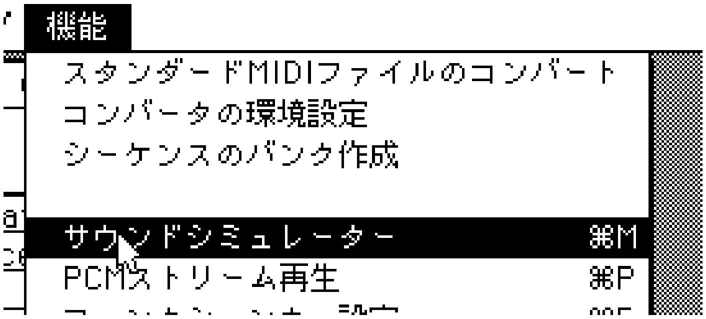
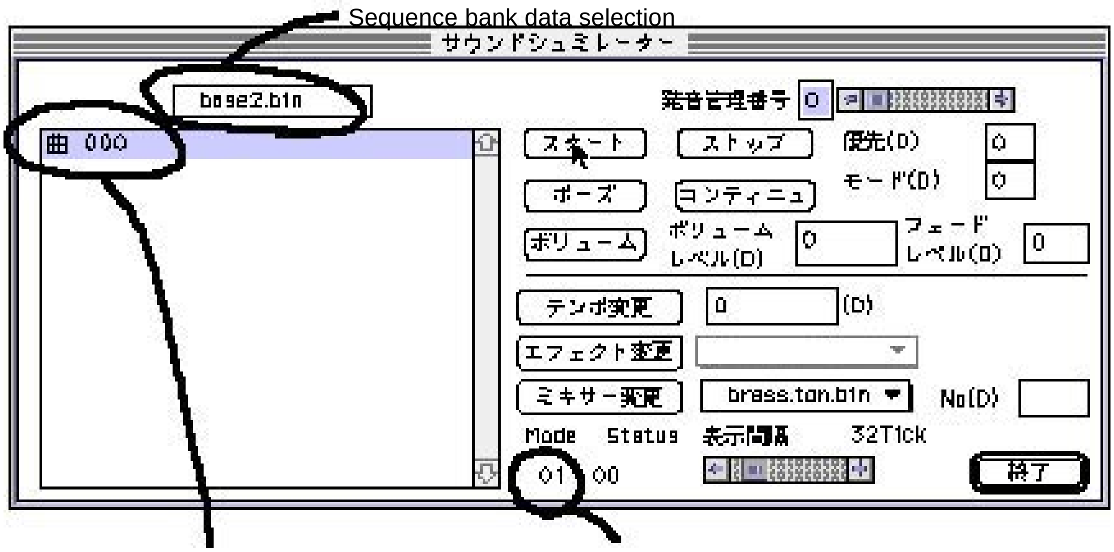


Fig 2-47 Sound Simulator Screen



Sequence bank data selection

Select SONG number of music to be played

“01” is displayed while music is being played

The Start button starts playback, and the Stop button stops playback.

If the sound is not as intended, use the appropriate software to correct the data, relink the data and then run the simulator again.

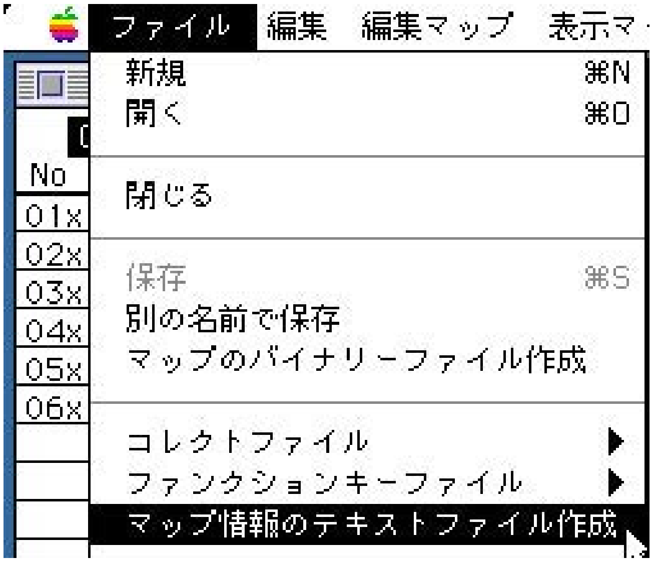
Note on map data size

When the target is a sound box, such a device has more memory available for storing sound data than the Saturn system; therefore, be sure that the last data in the map that is the final product does not go beyond address 7FFFFH.
Note that because addresses at 78000H and above are allocated for PCM playback in the SGL sound-related functions, be sure that the last data in the map does not go beyond address 77FFFH if the SGL is used along with PCM stream playback.

7) Binary map file creation

Select “Create Text File of Map Data” to create the map data file for the Saturn system.

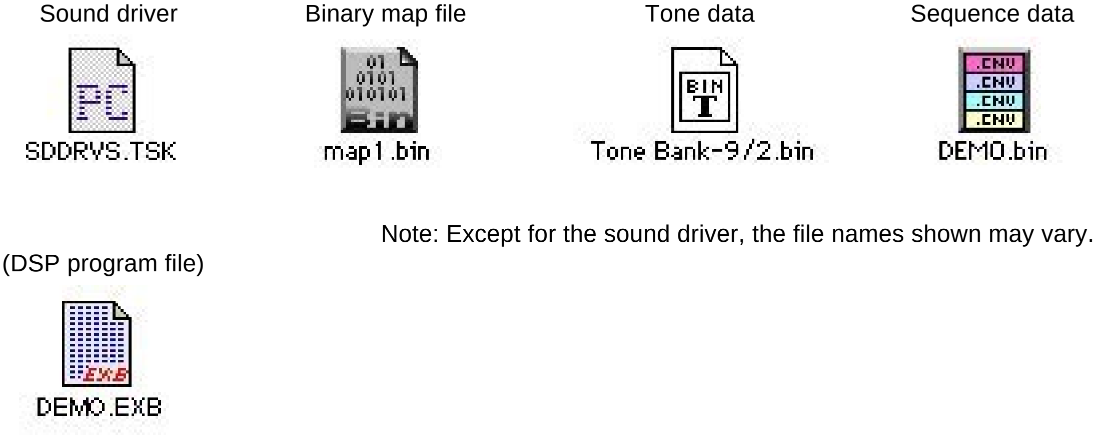
Fig 2-48 Selecting “Create Text File of Map Data”



The music data is now complete. The minimum data required to actually use the sound in the Saturn system is the binary data for the tone files used in the map, the sequence data, the binary map file, and the sound driver file.

In addition, if the DSP is to be used, the DSP program file is also needed.

Fig 2-49 Music Data Files to Be Passed to the Programmers

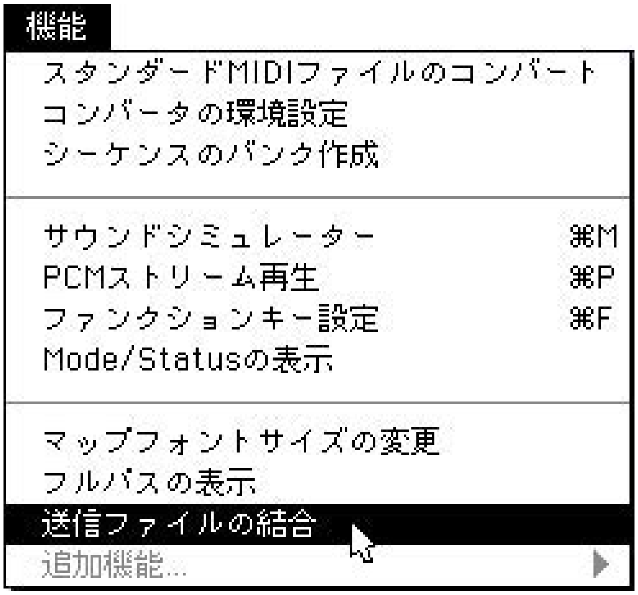


Note: Except for the sound driver, the file names shown may vary.

If the data in one map will all fit in the memory of the 68000 sound CPU, the game program can be simplified by creating a dump file that links together the tone data and sequence data in that one map.

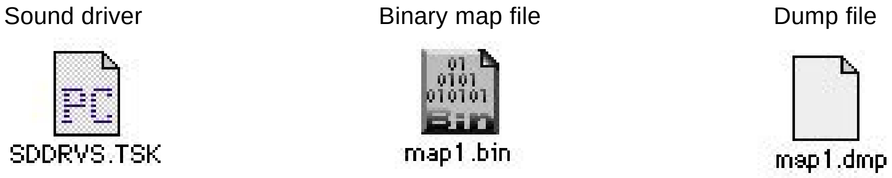
While the data is loaded, select “Link Transmission Files” in the “Function” menu in order to create the dump file.

Fig 2-50 Selecting “Link Transmission Files”



Aside from this file, the other files required by the game are just the sound driver file and the map file.

Fig 2-51 Music Data Files to Be Passed to the Programmers (When Using a Dump File)



Note: Except for the sound driver, the file names shown may vary.

Now all that is necessary is to incorporate the music into the game and play the music. For details on how to incorporate the sound data into the game program, refer to chapter 2, “Sound Data,” in “Transferring Data.”

Transferring Data

This manual explains the procedure for transferring design data, created by the designers, to the programmers. Because this chapter also discusses the various data formats, it should serve as a reference when transferring data.

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Figures

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1

Transferring Data

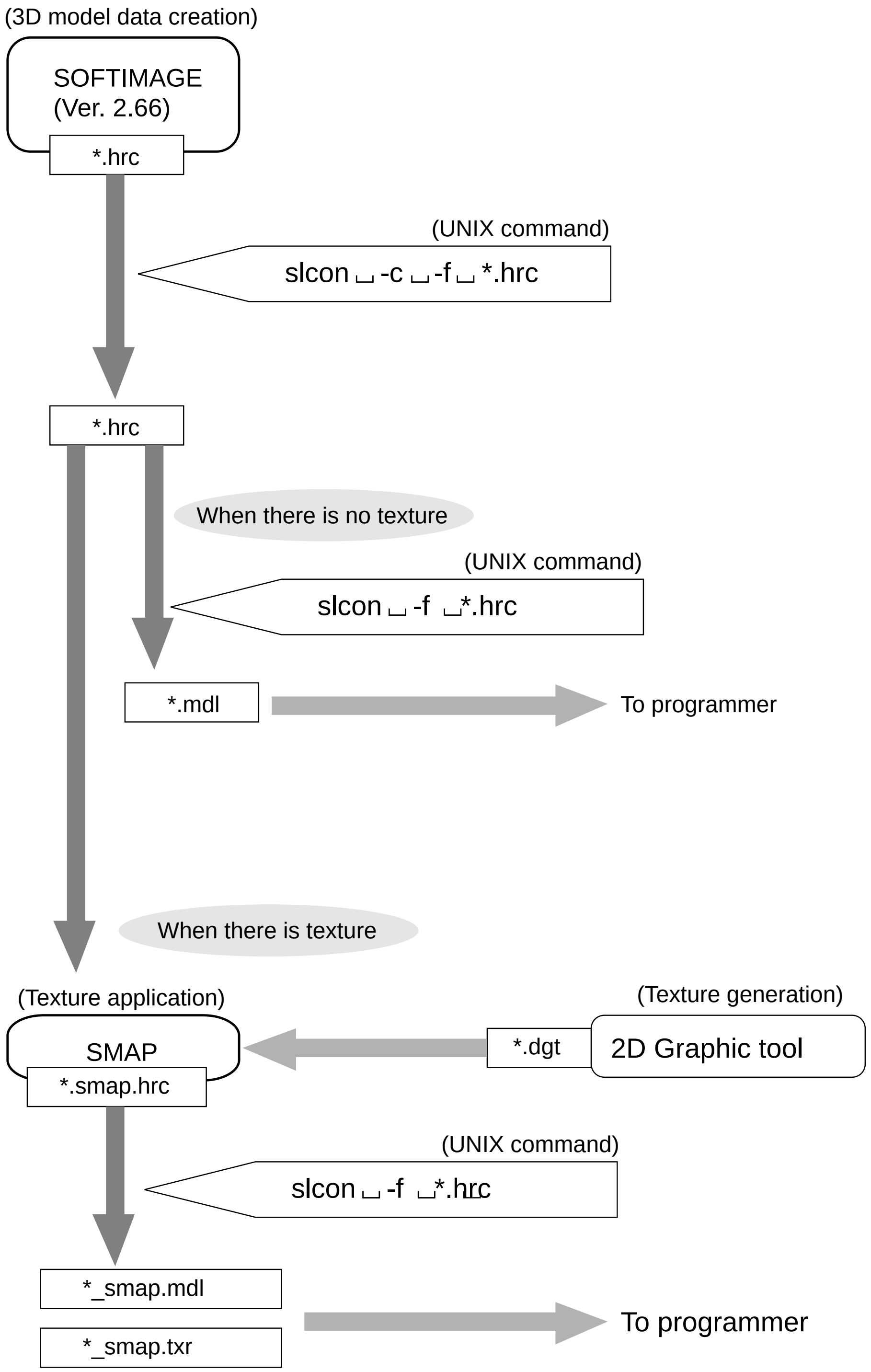
Design Data

This chapter explains the method for transferring 3D model data created by the designers, including data for 3D models with textures, to the programmers so that they can incorporate the data into the software. This chapter also explains the workings of the data that is required in order to add textures to 3D model data.

Flow of Data

3D model data generated by SOFTIMAGE is passed to the programmers according to the flow chart shown below.

Fig 1-1 Flow of Data



```
slcon ␣ -c ␣ -f ␣ *.hrc
```

```
slcon ␣ -f  ␣*.hrc
```

```
slcon ␣ -f  ␣*.hrc
```

SOFTIMAGE Data Conversion/Checking

Using for an example the data for the TV monitor that was created in the Designer’s Tutorial, this section will explain in concrete terms the procedure for converting data, processing it, and then transferring it.

Data check

Open a UNIX shell and input:

```
cd STUDY/MODELS (return)
```

The path name should now be displayed:

```
[(home directory)/STUDY/MODELS]
```

At this point, input “ls (return)”. The list should show “SATURN_TV_SET.1-0.hrc”.

Note: Because this shows the version, the number indicated may not be “1-0”; as long as the name is as shown above, there is no problem.

At this point, input:

```
cp SATURN_TV_SET.?-0.hrc~/check (return)
```

(Substitute the appropriate version number for the question mark (“?”).

Note: The “~” symbol is located above the TAB key, and represents the home directory. This symbol is very useful, and is used often.

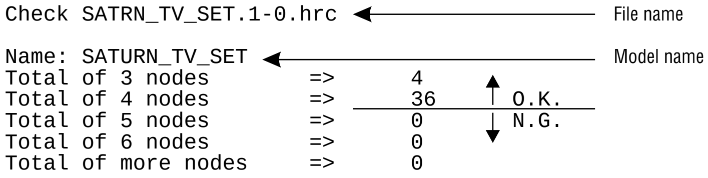
Open another UNIX shell and input:

```
cd CHECK (return)
```

and then input “ls (return)”. Confirm that “SATURN_TV_SET.1-0.hrc” exists in the CHECK directory. After confirming that there are no other “.hrc” files aside from this one in the directory, input:

```
slcon -c -f (return)
```

The following information is then displayed.



```
Check SATRN_TV_SET.1-0.hrc

Name: SATURN_TV_SET
Total of 3 nodes        =>      4
Total of 4 nodes        =>      36
Total of 5 nodes        =>      0
Total of 6 nodes        =>      0
Total of more nodes     =>      0
```

The models that can be output to Saturn are only those models with numbers only next to “Total of 3 nodes” or “Total of 4 nodes”; there can be no numbers next to “Total of 5 nodes” or more.

Note: Textures can be applied only to those models that meet the above conditions.

When performing the next step, use the SMAP-generated file “set_smap.hrc” if a texture is to be applied to the mode, or use the file “saturn_tv_set.hrc” (mentioned previously) if textures are not to be applied.

Conversion to the Format Used for Transfer to the Programmers

Next, we will use the UNIX command "slcon" to convert a "sample.hrc" or "sample_smap.hrc" file to a format that can be passed to the programmers.

Assuming that the following is true:

File format when texture has not been applied: sample.hrc

File format when texture has been applied: sample_smap.hrc

then when:

```
slcon -f sample.hrc (return)
```

is input, then a file of the format:

```
sample.mdl
```

will be created if the original data was an "sample.hrc" file (no texture applied), and files of the formats:

```
sample_smap.mdl
sample_smap.txr
```

will be created if the original data was an "sample_smap.hrc" file (texture applied).

Copy the output files to the directory specified by the programmers.

2

Transferring Data

Sound Data

This chapter explains the basic information that the sound designers must know concerning data formats and work procedures when transferring sound data to the programmers for incorporation into SGL-based software.

Data Types

All sound data created on the Macintosh is stored in binary files that can be divided into two types:

- Data files for background music and sequences
- Data files for PCM stream playback

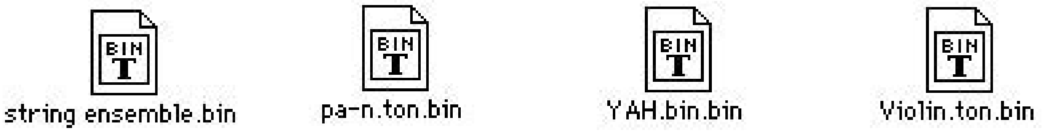
Background music and sequence data

Tone bank data

This is tone data used for music and sound effects.

This data is created by the tone editor provided with the Sega Sound Tools.

Fig 2-1 Examples of Tone Bank Data Files



The number of files required is the number that will be used in the map.

Inform the programmers of the sequence in which the files are used in the map.

Sequence data

This is music and sound effect data.

This data is created with the sound simulator provided with the Sega Sound Tools.

Fig 2-2 Examples of Sequence Data Files

The number of files required is the number that will be used in the map.

Inform the programmers of the sequence in which the files are used in the map.

DSP program

This is the effect module program.

This program is created by the DSP Linker provided with the Sega Sound Tools.

Fig 2-3 Example of a DSP Program File

The DSP program file is not needed if no effects are used..

Inform the programmers of the sequence in which the files are used in the map.

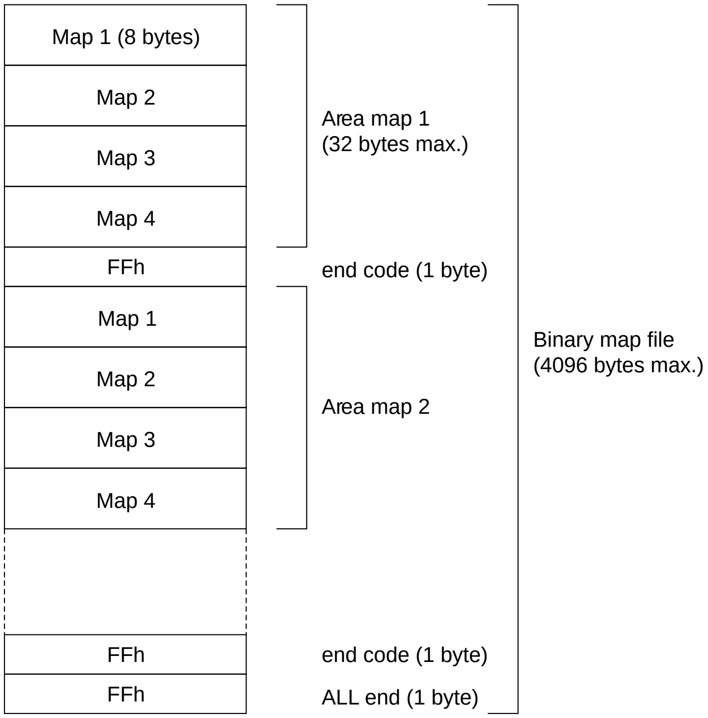
Binary map file

The binary map file shows the load addresses in the 68000 sound CPU memory for the three types of files described above and also the work areas used by DSP programs.

This file is loaded at address A000 in the 68000 memory.

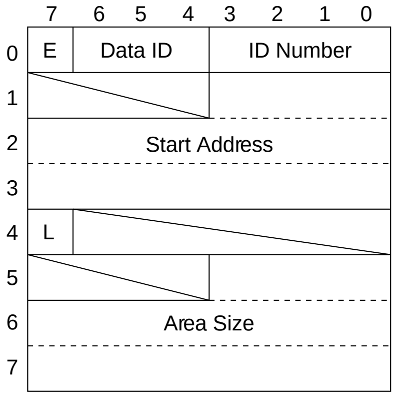
The map can consist of up to 4096 bytes and can hold a maximum of 128 area maps. One area map can contain up to 32 bytes of map information.

Fig 2-4 Structure of a Binary Map File



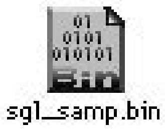
The bit image of each map (maps 1 to 4) is shown below.

Fig 2-5 Map Bit Image



E	0: Contains data 1: Does not contain data
Data ID	0: tone bank data 1: Sequence data 2: DSP program 3: DSP work RAM
ID Number	0 to 15: Data ID number
L	0: Data not yet transferred 1: Data has been transferred

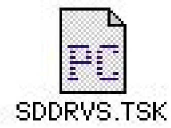
Fig 2-6 Example of a Binary Map File



Sound driver

In order to make sure the versions are the same, it is safest to pass the sound driver provided with the Macintosh tools on to the programmers.

Fig 2-7 Sound Driver



Dump data file

The dump data file is a dump of memory with the files described above in items 1 to 3 loaded into memory, from B000h to the last map data.

(However if the last data is the DSP work RAM, the dump ends with the second to last data.) In cases where there is no need to partially load only essential banks and it is possible to load all of the map data at one time, using the dump data file eliminates the need for loading the files described in 1 to 3 one at a time. As a result, mistakes in the sequence in which data is loaded are eliminated, and programming work is simplified.

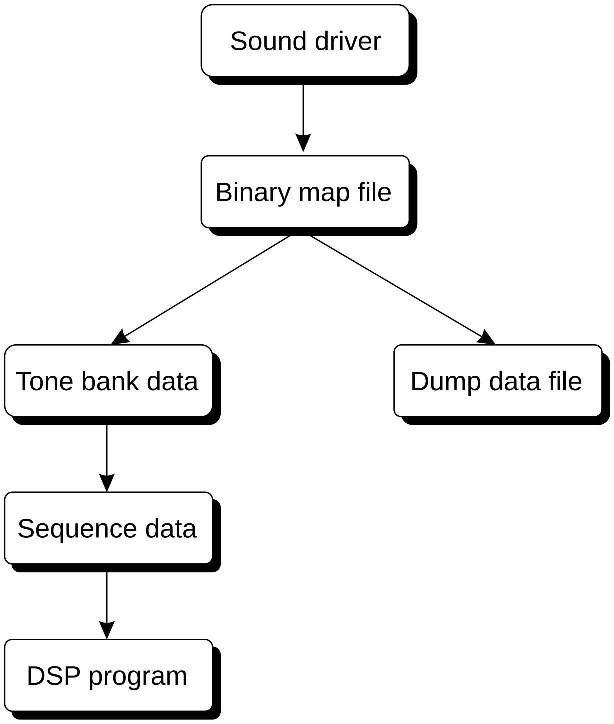
The dump data file is created by the sound simulator provided with the Sega Sound Tools.

Fig 2-8 Example of a Dump Data File

The diagram below shows the background music and sequence files that need to be transferred to the programmers. Transfer either of the following groups of files to the programmers.

1. Sound driver, binary map file, dump data file (includes the tone bank data, sequence data, and DSP program)
2. Sound driver, binary map file, tone bank data, sequence data, and DSP program

Fig 2-9 Background Music and Sequence Files Being Transferred to the Programmers

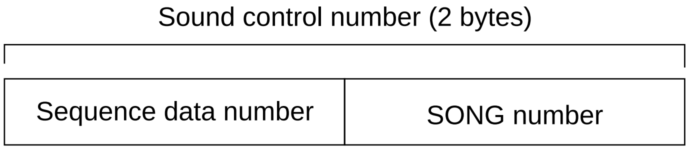


Relaying sound control numbers

The programmers use the sound control numbers to play music and sound effects in the SGL.

The sound control number is a combination of the sequence data number and the SONG number from the sound simulator. Therefore, when transferring the files to the programmers, the sound designer must inform the programmers of what numbers to use to produce what sounds.

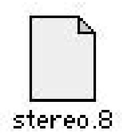
Fig 2-10 Sound Control Number Being Transferred to the Programmers



PCM stream playback data

This is the PCM data used in the SGL.

Fig 2-11 Example of a PCM Data File



PCM data files are created by the sound simulator provided with the Sega Sound Tools.

The sound designer should provide the following information when passing this type of file to the programmers.

Table 2-1 Information on PCM Data Files Being Transferred to the Programmers

File name	Sound	Stereo	Bits	Pitch	Comments
stereo.8	“10 years too early”	Stereo	8	7800	Shifts left and right
mono.16	“OK”	Monaural	16	7180	
stereo.16	“Oooo”	Stereo	16	7F00	Flows from right to left

Incorporating the Data

In order to incorporate the sound data files described up to this point into a program that uses the SGL, it is necessary to convert the various individual binary data files into array data that can be handled in C.

A sample script for performing this task in a UNIX environment is shown below.
Here we will use “sed” of “GNU”.

Script name [binary file name] [array name] > [output file name]

```
#!/bin/csh -f
echo "char $2[] = {"
od -hv $1 | cut -s -d " " -f2- | gsed 's/¥(..¥)¥(..¥) */0x¥1,0x¥2,/g'
echo "};"
```

Because ANSI functions can be easily used in C, create a script in C if your development environment is PC-based.
The data is now in a form that can be incorporated into the application software. From this point on, it can be treated in the same manner as any other data.

3

Transferring Data

Writing CD-ROMs

This chapter describes the method for writing user-written games to CD-ROMs.

Flow of Work

CD-ROMs are created in the PC DOS English mode environment. As a result, file names are subject to DOS restrictions, which means they are limited to 8 characters + 3 characters.

In order to write a user-written game to a CD-ROM, it is necessary to prepare a binary-format IP, program, and data.

The basic flow of the CD-ROM creation process is shown in Fig 3-1. The files that are required for CD-ROM creation are shown in Fig 3-2.

Fig 3-1 Flow of the CD-ROM Creation Process

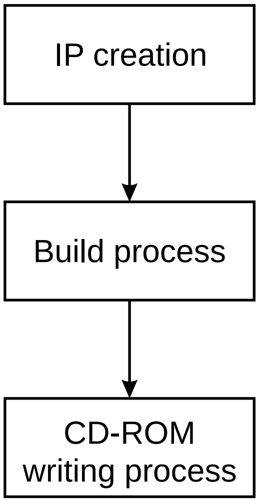
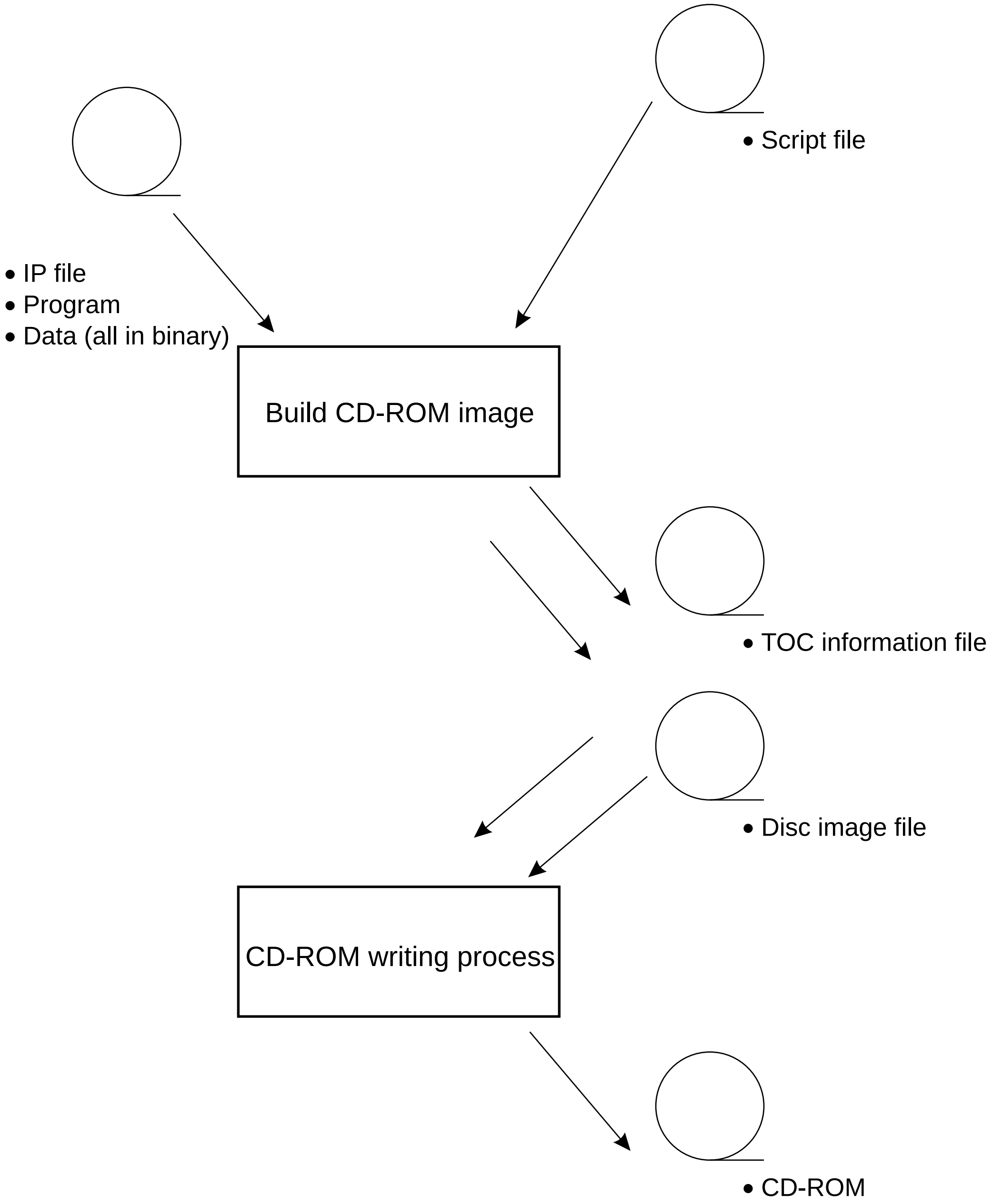


Fig 3-2 Flow of the CD-ROM Creation Process and Files



IP Creation

What is the “IP”?

The IP is written in the system area of the CD-ROM disc, and is used when the application uses the Saturn boot system. The IP is required on all CD-ROM program discs. (It is not required on data discs.)

Details on the IP are provided in “Disc Format Standards and Boot System” in the Programmer’s Guide.

IP configuration

The IP consists of the boot code and the application initial program.

The boot code consists of an ID code for the game name, a security code supplied by Sega, and an area code.

The application initial program is positioned immediately after the area code, and is executed immediately after the area code is executed. Thereafter, the program proceeds under the control of the application.

Table 3-1   IP Configuration

Structure			Size	Remarks
IP	Boot Code	System ID	100H	Game name, product number, version, etc.
		Security Code	D00H	Security code
		Area Code	20H to 100H	Area code
	Aplication Initial Program		20H to 71E0h	Initial program, file system, etc.

Details on how to create the IP are provided in “Boot System” in the Programmer’s Guide.

Build

The build process is preprocessing that is performed in order to write all of the binary format files prepared by the user (IP, program, data, etc.) onto the CD-ROM. The build process creates the TOC information files and disc image files that are required in order to write the CD-ROM.

The build procedure is described below.

1) Prepare the files to be written to the CD-ROM

Prepare all files that are to be written to the CD-ROM on the PC hard disk. The file positions do not matter, since they will be specified in the script. The file names must be no more than eight characters plus a period and a three-character extension, for a total of twelve characters. The CDDA files must be arranged in Intel format. If the file is in Motorola format, perform byte swapping. (“SWAP.EXE” is available as a byte swapping program for DOS.)

2) Allocate the work area

Prepare a work area for creating the CD-ROM disc image. A space equal to the total file size is required. All subsequent file creation and execution work is performed in this area. (Change the current directory.)

3) Determine the project name

Keep the name to eight characters or less, since it will be used as the body of the MS-DOS file names. Here, we will use “sample” as an example.

4) Create the script file

Referring to sample program 1 (Listing 3-1), use a suitable editor to create a script file. For the file name, use the project name with the extension “.scr” added. (“sample.scr” in our example.)

Create the script file in the directory where the VCDBUILD command (which creates the disc configuration information file and the disc image file) will be executed.

5) Create the disc configuration information file and the disc image file

Initiate the pre-processing program “vcdbuild.exe”.

Regarding the parameter, specify “vcdbuild sample” in our example.

As a result of the execution of this command, the disc configuration information file and the disc image file are created (as “sample.rti” and “sample.dsk” in the current example.)

6) Create the TOC file

Initiate the TOC file generation program “vcdmktoc.exe”. Supply the body of the RTI file name (i.e., the project name) as the parameter: “vcdmktoc sample”.

The TOC file (“sample.toc” in the example) is created as a result of the execution of this command.

List 3-1 Sample Program 1 (Creating the Script File “sample.scr”)

```
Disc sample.dsk
        Session CDROM
                LeadIn  MODE1
                EndLeadIn
                SystemArea  e:\ip.bin

                Track MODE1
                        Volume ISO9660 sample.pvd                Specification of the volume descriptor
                                PrimaryVolume 0:2:16             The characters appearing in bold repre
                                EndPrimaryVolume                 Basic volume descriptor
                        EndVolume

                        File ASAMPLE.BIN
                                FileSource e:\mode1\asample.bin  These four lines correspond to one fil
                                EndFileSource
                        EndFile
                        File SAMPLE1.BIN
                                FileSource e:\mode1\sample1.bin
                                EndFileSource
                        EndFile
                        File SAMPLE2.BIN
                                FileSource e:\mode1\sample2.bin
                                EndFileSource
                        EndFile
                                .....                            If there are additional files, add the

                Track CDDA
                        Pause 150                                These five lines represent one CDDA tr
                        FileSource e:\cdda\samp_cd1.dat
                        EndFileSource
                EndTrack
                Track CDDA
                        Pause 150
                        FileSource e:\cdda\samp_cd2.dat
                        EndFileSource
                EndTrack
                Track CDDA
                        Pause 150
                        FileSource e:\cdda\samp_cd3.dat
                        EndFileSource
                EndTrack
                                .....                            If there are additional tracks, add th

                LeadOut CDDA                                     The CDDA specification cannot be omitt
                        Empty   500
                EndLeadOut
        EndSession
EndDisc
```

Writing the CD-ROM

Load the CD-ROM in the CD writer and input the following CD writer command to initiate the writing process: “segacdw.exe”

The parameters are described below:

```
segacdw [-s#][-i#][-t] project name
```

-s: Specifies the writing speed.
Specify one of the following:
1: normal speed; 2: double speed; 4: quadruple speed.

-i: Specify the SCSI ID number of the CD writer.
The default ID is “5”.

-t: Write in test mode.
In test mode, the data is not written to an actual CD-ROM.

For example, the parameters could be specified in the following manner:

```
“segacdw -s 2 sample”
```

In this case, the project named “sample” is written at normal speed by the CD writer with SCSI ID number 5.

It is best to write the data once in test mode before performing the actual writing operation and then, if there are no errors, proceeding with the actual writing operation.

To execute test mode, specify (for example) the following:

```
segacdw -s 2 -t sample
```

4

Transferring Data

Data Structure

This chapter explains the model data handled by the SEGA Saturn system, how material names are used, and the structure of texture data.

Usage of Model Data

The “model data” referred to here is a collection of three types of data: three-dimensional (x, y, and z) coordinate point data, data on the polygons formed by four of those points, and the polygon attribute data.

Assuming a hypothetical model name of “label”, the general formats for these data types are shown below:

Point data

```
POINT point_label[]={
        POStoFIXED(x,y,z),
        POStoFIXED(x,y,z),
        POStoFIXED(x,y,z),
        POStoFIXED(x,y,z),
            ..............
        };
```

POINT: Point data

x, y, z: Floating-point coordinate values

The point data is indexed 0, 1, 2, and 3, in sequence from the top.

Polygon data

```
POLYGON polyfon_label[]={
        NORMAL(x,y,z),
        VERTICES(0,1,2,3),

        NORMAL(x,y,z),
        VERTICES(0,1,2,3),
            ..............
        };
```

NORMAL: Normal vector

x, y, z: Floating-point coordinate values

VERTICES: Point data for the four vertices that form the polygon

In the case of a triangle, the last point is repeated so that the polygon still has “four” vertices.

Example: In the case where the polygon has four corners:

```
VERTICES(0,1,2,3)
```

Example: In the case where the polygon has three corners:

```
VERTICES(0,1,2,2)
```

Attribute data

```
ATTR attribute_label[]={
        ATTRIBUTE(Plane,Sort,Texture,Color,Gouraud,Mode,Command,Option),
            .......           ......   .....   ......   .....   ......
        };
```

ATTR: Attribute

Plane: Attribute determining whether front/back determination is made or not

Sort: Representative point for Z sort

Texture: Texture name (No.)

Color: Color data

Gouraud: Gouraud shading attribute

Mode: Graphics mode

Command: Polygon and texture statuses

Option: Optional functions

The attributes consist of the eight parameters indicated above. The symbols actually output by those parameters and their meanings are explained below.

[Plane]

Single_Plane:	Backside determination made
Dual_Plane:	Backside determination not made

[Sort]

SORT_MIN:	Closest point
SORT_CEN:	Mid-point
SORT_MAX:	Farthest point

[Texture]

No_Texture:	Polygon
texture name:	Texture (macro indicating the texture data)

For details, refer to "Texture Data Usage."

[Color]

No_Palet:	Texture
C_RGB(r, g, b):	Color data for a polygon

*** “r,” “g,” and “b” stand for red, green, and blue, and represent decimal values from 0 to 31.**

[Gouraud]

No_Gouraud	No gouraud shading

[Mode]

MESHon:	Mesh on
MESHoff:	Mesh off

[Command]

SprHflip:	Flip sprite horizontally
SprVflip:	Flip sprite vertically
SprHVflip:	Flip sprite horizontally and vertically
SprNoflip:	Do not flip sprite
SprPolygon:	Polygon
SprPolyLine:	Polyline

[Option]

NoOption:	No options

Of the above parameters, plane, sort, and mode are obtained through the specification of the material name described on the next page.

[MODE]

Group	Macro	Description
1	No_Windows	Accept no window restrictions (default)
	Window_In	Display inside window
	Window_Out	Display outside window
2	MESHoff	Normal display (default)
	MESHon	Display with mesh
3	ECdis	Disable EndCode
	ECenb	Enable EndCode (default)
4	SPdis	Display clear pixels (default)
	SPenb	Do not display clear pixels
5	CL16Bnk	16-color color bank mode (default)
	CL16Look	16-color look-up table mode
	CL64Bnk	64-color color bank mode
	CL128Bnk	128-color color bank mode
	CL256Bnk	256-color color bank mode
	CL32KRGB	32,768-color RGB mode
6	CL_Replace	Overwrite (standard) mode (default)
	CL_Shadow	Shadow mode
	CL_Half	Half-bright mode
	CL_Trans	Semi-transparent mode
	CL_Gourand	Gouraud shading mode

[Dir]

Macro	Description
sprNoflip	Display texture normally
sprHflip	Flip texture horizontally
sprVflip	Flip texture vertically
sprHVflip	Flip texture vertically and horizontally
sprPolygon	Display polygon
sprPolyLine	Display polyline
sprLine	Display straight line using first two points

[Option]

Macro	Description
UseLight	Calculate light source
UseClip	Do not display vertices outside of the screen
UsePalette	Indicates that the polygon color is palette format

Of the above parameters, "Plane", "Sort", and "Mode" are obtained by specifying them in the material name described in the next item.

Data structure

```
PDATA pdata_label={
                        point_label,n1,
                        point_label,n2,
                        attribute_label
        };
```

Object data structure

```
        OBJECT          object_label={
                        pdata_label,
                        TRANSLATION(x,y,z),
                        ROTATION(x,y,z),
                        SCALING(x,y,z)
                        object_child,
                        object_sibling,
        };
```

Material Name Usage

Each letter of the material name has meaning. That information is reflected directly in the attribute data. The method is shown below.

In general the name consists of three letters, representing the following attributes in order:

[Plane][Sort][Mesh] (“[]” represents one letter; a material name is represented by three letters, such as "SSN")

The possible attributes for each letter are:

[Plane]

S: Single_Plane

D: Dual_Plane

[Sort]

N: SORT_MIN

C: SORT_CEN

F: SORT_MAX

[Mesh]

O: MESHon

N: MESHoff

Example: If the material name is “SCN”, the attribute data is as follows:

```
ATTRIBUTE (Single_Plane, SORT_CEN, No_Texture, C_RGB(r,g,b),
No_Gouraud, MESHoff, sprNoFlip, NoOption)
```

Texture Data Usage

Texture data is necessary when textures are used. The texture name for the attribute “Texture” is based on this data.

Assuming a texture DGT file named “sample.dgt”:

```
        TEXTBL(sample,hsize,vsize);

        TEXDAT sample[]={
                rgb,rgb,rgb,rgb,rgb,rgb,rgb,rgb,
                rgb,rgb,rgb,rgb,rgb,rgb,rgb,rgb,
                ............................
        };
```

TEXTBL: Texture table
sample: Indicates the label for the texture data (the file name)
hsize, vsize: Texture size ("hsize" is always a multiple of "8")
bgr: Individual pixel of texture data

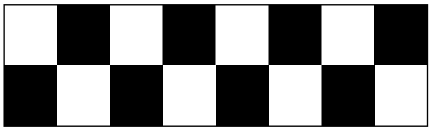
Each of the three primary colors is represented by five bits, ranging in decimal value from 0 to 31.

The data format is as shown below:

	B					G					R				
1	4	3	2	1	0	4	3	2	1	0	4	3	2	1	0

Example: Assume that a graphic data file named “sample.dgt” is a texture consisting of an 8 × 2 black and white checker pattern.

Fig 4-1 Checker Pattern Texture



The texture data for this texture would be as shown below:

```
TEXTBL(sample,8,2);

TEXDAT sample[]={
                0xffff,0x8000,0xffff,0x8000,0xffff,0x8000,0xffff,0x8000,

                0x8000,0xffff,0x8000,0xffff,0x8000,0xffff,0x8000,0xffff
                };
```

The attribute data for the polygon with the material name “SCN” on which this texture is applied is as follows:

```
ATTRIBUTE (Single_Plane, SORT_CEN, SAMPLE, No_Palet, No_Gouraud,
MESHoff, sprNoFlip, NoOption)
```

Note:
For textures, the Saturn hardware requires that the horizontal size be a multiple of eight.