

PlayStation Specifications

- psx-spx

None

None

None

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1. Home

This is a conversion/edition of Martin "nocash" Korth's Playstation specs document originally hosted at <https://problemkaputt.de/psx-spx.htm>. See <https://github.com/psx-spx/psx-spx.github.io#readme> for more details.

You can also download this website as a [single-page pdf](#).

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2. Memory Map

Memory Map

KUSEG	KSEG0	KSEG1		
00000000h	80000000h	A0000000h	2048K	Main RAM (first 64K reserved for BIOS)
1F000000h	9F000000h	BF000000h	8192K	Expansion Region 1 (ROM/RAM)
1F800000h	9F800000h	--	1K	Scratchpad (D-Cache used as Fast RAM)
1F801000h	9F801000h	BF801000h	8K	I/O Ports
1F802000h	9F802000h	BF802000h	8K	Expansion Region 2 (I/O Ports)
1FA00000h	9FA00000h	BFA00000h	2048K	Expansion Region 3 (SRAM BIOS region for DTL cards)
1FC00000h	9FC00000h	BFC00000h	512K	BIOS ROM (Kernel) (4096K max)
	FFFE0000h (in KSEG2)		0.5K	Internal CPU control registers (Cache Control)

Additionally, there are a number of memory mirrors.

Additional Memory (not mapped to the CPU bus)

1024K	VRAM (Framebuffers, Textures, Palettes) (with 2KB Texture Cache)
512K	Sound RAM (Capture Buffers, ADPCM Data, Reverb Workspace)
0.5K	CDROM controller RAM (see CDROM Test commands)
16.5K	CDROM controller ROM (Firmware and Bootstrap for MC68HC05 cpu)
32K	CDROM Buffer (IC303) (32Kx8) (BUG: only two sectors accessible?)
128K	External Memory Card(s) (EEPROMs)

KUSEG,KSEG0,KSEG1,KSEG2 Memory Regions

Address	Name	i-Cache	Write-Queue
00000000h	KUSEG	Yes	Yes
80000000h	KSEG0	Yes	Yes
A0000000h	KSEG1	No	No
C0000000h	KSEG2	(No code)	No

Kernel Memory: KSEG1 is the normal physical memory (uncached), KSEG0 is a mirror thereof (but with cache enabled). KSEG2 is usually intended to contain virtual kernel memory, but in the PSX it's containing Cache Control hardware registers.

User Memory: KUSEG is intended to contain 2GB virtual memory (on extended MIPS processors), the PSX doesn't support virtual memory, and KUSEG simply contains a mirror of KSEG0/KSEG1 (in the first 512MB) (trying to access memory in the remaining 1.5GB causes an exception).

i-Cache

The i-Cache can hold 4096 bytes, or 1024 instructions.

It is only active in the cached regions (KUSEG and KSEG0).

There are reportedly some restrictions... not sure there... eventually it is using the LSBs of the address as cache-line number... so, for example, it couldn't simultaneously memorize opcodes at BOTH address 80001234h, AND at address 800F1234h (?)

Scratchpad

MIPS CPUs usually have a d-Cache, but, in the PSX, Sony has assigned it as what's referenced as the "Scratchpad", mapped to a fixed memory location at 1F800000h.. 1F8003FFh, ie. it's used as Fast RAM, rather than as cache.

There \<might> be a way to disable that behavior (via Port FFFE0130h or so), but, the Kernel is accessing I/O ports via KUSEG, so activating Data Cache would cause the Kernel to access cached I/O ports.

The purpose of the scratchpad is to have a more flexible cache system available to the programmer. Neither the kernel nor the Sony libraries will try to make use of it, so it is therefore completely up for grabs to the programmer. A good example would be if you were to write a piece of code that's doing a lot of CRC computation, to use the 1KB scratchpad to initially load the CRC lookup tables, which incidentally, is exactly 1KB large. Doing this will relieve SDRAM page changes overhead while reading the data to checksum linearly, while also keeping the whole CRC code in the i-Cache, hence being more optimal than what you'd get with an automatic d-Cache system.

Memory Mirrors

As described above, the 512Mbyte KUSEG, KSEG0, and KSEG1 regions are mirrors of each other. Additional mirrors within these 512MB regions are:

```
2MB RAM can be mirrored to the first 8MB (strangely, enabled by default)
512K BIOS ROM can be mirrored to the last 4MB (disabled by default)
Expansion hardware (if any) may be mirrored within expansion region
The seven DMA Control Registers at 1F8010x8h are mirrored to 1F8010xCh
```

The size of the RAM, BIOS, Expansion regions can be configured by software, for Expansion Region it's also possible to change base address, see:

[Memory Control](#)

The Scratchpad is mirrored only in KUSEG and KSEG0, but not in KSEG1.

Memory Exceptions

```

Memory Error -----> Misalignments
    (and probably also KSEG access in User mode)
Bus Error     -----> Unused Memory Regions (including Gaps in I/O Region)
    (unless RAM/BIOS/Expansion mirrors are mapped to "unused" area)

```

Write queue

The MIPS CPU has a 4-words deep pass-through write queue, in order to relieve some bus contention when writing to memory. If reading the same memory location that just got written into the write queue, it will first be flushed before being read back from memory. It is important to realize that the write queue's mechanism is only viable for normal memory attached to the main CPU, and that any hardware register state machine will get messed up by it.

The typical example is the typical JEDEC standard to access flash, which usually does the following sequence to read the ID of a flash chip:

```

base[0xAAA] = 0xAA;
base[0x555] = 0x55;
base[0xAAA] = 0x90;
uint8_t mnfcstrID = base[0x000];
uint8_t deviceId = base[0x002];

```

In this example above, if `base` is located in a memory segment that has the write queue enabled, even if the low level assembly code will do the first 3 stores before doing 2 loads, the physical signals sent to that device through the CPU bus will be seen in the sequence:

```

store(0xaaa, 0xaa)
load(0x000)
store(0x555, 0x55)
load(0x002)
store(0xaaa, 0x90)

```

Therefore, using KSEG1 that disables the write queue is the only way to ensure that the operations are done in the proper way.

The above is valid for most of the hardware connected to the main CPU, such as the CDROM controller, exp1, exp2, the SPU, or the GPU. Therefore, using BF80180xh to access the CDROM registers is more correct than using 1F80180xh.

It is noteworthy that the Sony code will still incorrectly use KUSEG as the memory map for all hardware registers, and they then spend a lot of time writing 4 dummy values somewhere, in order to ensure the write queue has been flushed.

The SN debugger in contrast is properly using the KSEG1 memory map for all the hardware registers, nullifying the need to flush the write queue when accessing it.

It's also noteworthy that doing ANY KSEG1 access (read OR write) will automatically stall the CPU in order to flush the whole write queue before proceeding with the operation. Therefore, all BIOS ROM operations will naturally and effectively have the write queue disabled, as this code requires the CPU to read from KSEG1 constantly.

This also means that if using KUSEG for the hardware registers, another method to flush the write queue, albeit potentially slightly less efficient, would be to simply read the first byte located at BFC00000h. The latter is what is effectively described as the official method to flush the write queue in the MIPS handbook. This could be potentially useful to flush the write queue all at once, instead of flushing it word by word.

More Memory Info

For Info on Exception vectors, Unused/Garbage memory locations, I/O Ports, Expansion ROM Headers, and Memory Waitstate Control, etc. see:

[I/O Map](#)

[Memory Control](#)

[EXP1 Expansion ROM Header](#)

[BIOS Memory Map](#)

[BIOS Memory Allocation](#)

[COP0 - Exception Handling](#)

[Unpredictable Things](#)

3. I/O Map

Expansion Region 1

```
1F000000h 80000h Expansion Region (default 512 Kbytes, max 8 MBytes)
1F000000h 100h Expansion ROM Header (IDs and Entrypoints)
```

Scratchpad

```
1F800000h 400h Scratchpad (1K Fast RAM) (Data Cache mapped to fixed address)
```

Memory Control 1

1F801000h 4	Expansion 1 Base Address (usually 1F000000h)
1F801004h 4	Expansion 2 Base Address (usually 1F802000h)
1F801008h 4	Expansion 1 Delay/Size (usually 0013243Fh; 512Kbytes 8bit-bus)
1F80100Ch 4	Expansion 3 Delay/Size (usually 00003022h; 1 byte)
1F801010h 4	BIOS ROM Delay/Size (usually 0013243Fh; 512Kbytes 8bit-bus)
1F801014h 4	SPU_DELAY Delay/Size (usually 200931E1h)
1F801018h 4	CDROM_DELAY Delay/Size (usually 00020843h or 00020943h)
1F80101Ch 4	Expansion 2 Delay/Size (usually 00070777h; 128-bytes 8bit-bus)
1F801020h 4	COM_DELAY / COMMON_DELAY (00031125h or 0000132Ch or 00001325h)

Peripheral I/O Ports

1F801040h 1/4	JOY_DATA Joypad/Memory Card Data (R/W)
1F801044h 4	JOY_STAT Joypad/Memory Card Status (R)
1F801048h 2	JOY_MODE Joypad/Memory Card Mode (R/W)
1F80104Ah 2	JOY_CTRL Joypad/Memory Card Control (R/W)
1F80104Eh 2	JOY_BAUD Joypad/Memory Card Baudrate (R/W)
1F801050h 1/4	SIO_DATA Serial Port Data (R/W)
1F801054h 4	SIO_STAT Serial Port Status (R)
1F801058h 2	SIO_MODE Serial Port Mode (R/W)
1F80105Ah 2	SIO_CTRL Serial Port Control (R/W)
1F80105Ch 2	SIO_MISC Serial Port Internal Register (R/W)
1F80105Eh 2	SIO_BAUD Serial Port Baudrate (R/W)

Memory Control 2

```
1F801060h 4/2 RAM_SIZE (usually 00000B88h; 2MB RAM mirrored in first 8MB)
```

Interrupt Control

1F801070h 2	I_STAT - Interrupt status register
1F801074h 2	I_MASK - Interrupt mask register

DMA Registers

1F80108xh	DMA0 channel 0 - MDECin
1F80109xh	DMA1 channel 1 - MDECout
1F8010Axh	DMA2 channel 2 - GPU (lists + image data)
1F8010Bxh	DMA3 channel 3 - CDROM
1F8010Cxh	DMA4 channel 4 - SPU
1F8010Dxh	DMA5 channel 5 - PIO (Expansion Port)
1F8010Exh	DMA6 channel 6 - OTC (reverse clear OT) (GPU related)
1F8010F0h	DPCR - DMA Control register
1F8010F4h	DICR - DMA Interrupt register
1F8010F8h	unknown
1F8010FCCh	unknown

Timers (aka Root counters)

1F80110xh	Timer 0 Dotclock
1F80111xh	Timer 1 Horizontal Retrace
1F80112xh	Timer 2 1/8 system clock

CDROM Registers (Address.Read/Write.Index)

1F801800h.x.x	1	CD Index/Status Register (Bit0-1 R/W, Bit2-7 Read Only)
1F801801h.R.x	1	CD Response Fifo (R) (usually with Index1)
1F801802h.R.x	1/2	CD Data Fifo - 8bit/16bit (R) (usually with Index0..1)
1F801803h.R.0	1	CD Interrupt Enable Register (R)
1F801803h.R.1	1	CD Interrupt Flag Register (R/W)
1F801803h.R.2	1	CD Interrupt Enable Register (R) (Mirror)
1F801803h.R.3	1	CD Interrupt Flag Register (R/W) (Mirror)
1F801801h.W.0	1	CD Command Register (W)
1F801802h.W.0	1	CD Parameter Fifo (W)
1F801803h.W.0	1	CD Request Register (W)
1F801801h.W.1	1	Unknown/unused
1F801802h.W.1	1	CD Interrupt Enable Register (W)
1F801803h.W.1	1	CD Interrupt Flag Register (R/W)
1F801801h.W.2	1	Unknown/unused
1F801802h.W.2	1	CD Audio Volume for Left-CD-Out to Left-SPU-Input (W)
1F801803h.W.2	1	CD Audio Volume for Left-CD-Out to Right-SPU-Input (W)
1F801801h.W.3	1	CD Audio Volume for Right-CD-Out to Right-SPU-Input (W)
1F801802h.W.3	1	CD Audio Volume for Right-CD-Out to Left-SPU-Input (W)
1F801803h.W.3	1	CD Audio Volume Apply Changes (by writing bit5=1)

GPU Registers

1F801810h.Write 4	GPO Send GPO Commands/Packets (Rendering and VRAM Access)
1F801814h.Write 4	GP1 Send GP1 Commands (Display Control)
1F801810h.Read 4	GPUREAD Read responses to GPO(C0h) and GP1(10h) commands
1F801814h.Read 4	GPUSTAT Read GPU Status Register

MDEC Registers

1F801820h.Write 4	MDEC Command/Parameter Register (W)
1F801820h.Read 4	MDEC Data/Response Register (R)
1F801824h.Write 4	MDEC Control/Reset Register (W)
1F801824h.Read 4	MDEC Status Register (R)

SPU Voice 0..23 Registers

1F801C00h+N*10h 4	Voice 0..23 Volume Left/Right
1F801C04h+N*10h 2	Voice 0..23 ADPCM Sample Rate
1F801C06h+N*10h 2	Voice 0..23 ADPCM Start Address
1F801C08h+N*10h 4	Voice 0..23 ADSR Attack/Decay/Sustain/Release
1F801C0Ch+N*10h 2	Voice 0..23 ADSR Current Volume
1F801C0Eh+N*10h 2	Voice 0..23 ADPCM Repeat Address

SPU Control Registers

1F801D80h 4	Main Volume Left/Right
1F801D84h 4	Reverb Output Volume Left/Right
1F801D88h 4	Voice 0..23 Key ON (Start Attack/Decay/Sustain) (W)
1F801D8Ch 4	Voice 0..23 Key OFF (Start Release) (W)
1F801D90h 4	Voice 0..23 Channel FM (pitch lfo) mode (R/W)
1F801D94h 4	Voice 0..23 Channel Noise mode (R/W)
1F801D98h 4	Voice 0..23 Channel Reverb mode (R/W)
1F801D9Ch 4	Voice 0..23 Channel ON/OFF (status) (R)
1F801DA0h 2	Unknown? (R) or (W)
1F801DA2h 2	Sound RAM Reverb Work Area Start Address
1F801DA4h 2	Sound RAM IRQ Address
1F801DA6h 2	Sound RAM Data Transfer Address
1F801DA8h 2	Sound RAM Data Transfer Fifo
1F801DAAh 2	SPU Control Register (SPUCNT)
1F801DACH 2	Sound RAM Data Transfer Control
1F801DAEh 2	SPU Status Register (SPUSTAT) (R)
1F801DB0h 4	CD Volume Left/Right
1F801DB4h 4	Extern Volume Left/Right
1F801DB8h 4	Current Main Volume Left/Right
1F801DBCh 4	Unknown? (R/W)

SPU Reverb Configuration Area

```

1F801DC0h 2 dAPF1 Reverb APF Offset 1
1F801DC2h 2 dAPF2 Reverb APF Offset 2
1F801DC4h 2 vIIR Reverb Reflection Volume 1
1F801DC6h 2 vCOMB1 Reverb Comb Volume 1
1F801DC8h 2 vCOMB2 Reverb Comb Volume 2
1F801DCAh 2 vCOMB3 Reverb Comb Volume 3
1F801DCCh 2 vCOMB4 Reverb Comb Volume 4
1F801DCEh 2 vWALL Reverb Reflection Volume 2
1F801DD0h 2 vAPF1 Reverb APF Volume 1
1F801DD2h 2 vAPF2 Reverb APF Volume 2
1F801DD4h 4 mSAME Reverb Same Side Reflection Address 1 Left/Right
1F801DD8h 4 mCOMB1 Reverb Comb Address 1 Left/Right
1F801DDCh 4 mCOMB2 Reverb Comb Address 2 Left/Right
1F801DE0h 4 dSAME Reverb Same Side Reflection Address 2 Left/Right
1F801DE4h 4 mDIFF Reverb Different Side Reflection Address 1 Left/Right
1F801DE8h 4 mCOMB3 Reverb Comb Address 3 Left/Right
1F801DECh 4 mCOMB4 Reverb Comb Address 4 Left/Right
1F801DF0h 4 dDIFF Reverb Different Side Reflection Address 2 Left/Right
1F801DF4h 4 mAPF1 Reverb APF Address 1 Left/Right
1F801DF8h 4 mAPF2 Reverb APF Address 2 Left/Right
1F801DFCh 4 vIN Reverb Input Volume Left/Right

```

SPU Internal Registers

```

1F801E00h+N*04h 4 Voice 0..23 Current Volume Left/Right
1F801E60h      20h Unknown? (R/W)
1F801E80h      180h Unknown? (Read: FFh-filled) (Unused or Write only?)

```

Expansion Region 2 (default 128 bytes, max 8 KBytes)

```
1F802000h      80h Expansion Region (8bit data bus, crashes on 16bit access?)
```

Expansion Region 2 - Dual Serial Port (for TTY Debug Terminal)

```

1F802020h/1st    DUART Mode Register 1.A (R/W)
1F802020h/2nd    DUART Mode Register 2.A (R/W)
1F802021h/Read   DUART Status Register A (R)
1F802021h/Write  DUART Clock Select Register A (W)
1F802022h/Read   DUART Toggle Baud Rate Generator Test Mode (Read=Strobe)
1F802022h/Write  DUART Command Register A (W)
1F802023h/Read   DUART Rx Holding Register A (FIFO) (R)
1F802023h/Write  DUART Tx Holding Register A (W)
1F802024h/Read   DUART Input Port Change Register (R)
1F802024h/Write  DUART Aux. Control Register (W)
1F802025h/Read   DUART Interrupt Status Register (R)
1F802025h/Write  DUART Interrupt Mask Register (W)

```

1F802026h/Read	DUART Counter/Timer Current Value, Upper/Bit15-8 (R)
1F802026h/Write	DUART Counter/Timer Reload Value, Upper/Bit15-8 (W)
1F802027h/Read	DUART Counter/Timer Current Value, Lower/Bit7-0 (R)
1F802027h/Write	DUART Counter/Timer Reload Value, Lower/Bit7-0 (W)
1F802028h/1st	DUART Mode Register 1.B (R/W)
1F802028h/2nd	DUART Mode Register 2.B (R/W)
1F802029h/Read	DUART Status Register B (R)
1F802029h/Write	DUART Clock Select Register B (W)
1F80202Ah/Read	DUART Toggle 1X/16X Test Mode (Read=Strobe)
1F80202Ah/Write	DUART Command Register B (W)
1F80202Bh/Read	DUART Rx Holding Register B (FIFO) (R)
1F80202Bh/Write	DUART Tx Holding Register B (W)
1F80202Ch/None	DUART Reserved Register (neither R nor W)
1F80202Dh/Read	DUART Input Port (R)
1F80202Dh/Write	DUART Output Port Configuration Register (W)
1F80202Eh/Read	DUART Start Counter Command (Read=Strobe)
1F80202Eh/Write	DUART Set Output Port Bits Command (Set means Out=LOW)
1F80202Fh/Read	DUART Stop Counter Command (Read=Strobe)
1F80202Fh/Write	DUART Reset Output Port Bits Command (Reset means Out=HIGH)

Expansion Region 2 - Int/Dip/Post

1F802000h 1 DTL-H2000: ATCONS STAT (R)
 1F802002h 1 DTL-H2000: ATCONS DATA (R and W)
 1F802004h 2 DTL-H2000: Whatever 16bit data ?
 1F802030h 1/4 DTL-H2000: Secondary IRQ10 Flags
 1F802032h 1 DTL-H2000: Whatever IRQ Control ?
 1F802040h 1 DTL-H2000: Bootmode "Dip switches" (R)
 1F802041h 1 PSX: POST (external 7 segment display, indicate BIOS boot status)
 1F802042h 1 DTL-H2000: POST/LED (similar to POST) (other addr, 2-digit wide)
 1F802070h 1 PS2: POST2 (similar to POST, but PS2 BIOS uses this address)

Expansion Region 2 - Nocash Emulation Expansion

1F802060h Emu-Expansion ID1 "E" (R)
 1F802061h Emu-Expansion ID2 "X" (R)
 1F802062h Emu-Expansion ID3 "P" (R)
 1F802063h Emu-Expansion Version (01h) (R)
 1F802064h Emu-Expansion Enable1 "O" (R/W)
 1F802065h Emu-Expansion Enable2 "N" (R/W)
 1F802066h Emu-Expansion Halt (R)
 1F802067h Emu-Expansion Turbo Mode Flags (R/W)

Expansion Region 3 (default 1 byte, max 2 MBytes)

1FA00000h - Not used by BIOS or any PSX games
 1FA00000h - POST3 (similar to POST, but PS2 BIOS uses this address)

BIOS Region (default 512 Kbytes, max 4 MBytes)

1FC00000h 80000h BIOS ROM (512Kbytes) (Reset Entrypoint at BFC00000h)

Memory Control 3 (Cache Control)

FFFE0130h 4 Cache Control

Coprocessor Registers

COP0 System Control Coprocessor - 32 registers (not all used)

COP1 N/A

COP2 Geometry Transformation Engine (GTE) - 64 registers (most are used)

COP3 N/A

4. Graphics Processing Unit (GPU)

The GPU can render Polygons, Lines, or Rectangles to the Drawing Buffer, and sends the Display Buffer to the Television Set. Polygons are useful for 3D graphics (or rotated/scaled 2D graphics), Rectangles are useful for 2D graphics and Text output.

[GPU I/O Ports, DMA Channels, Commands, VRAM](#)

[GPU Render Polygon Commands](#)

[GPU Render Line Commands](#)

[GPU Render Rectangle Commands](#)

[GPU Rendering Attributes](#)

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[GPU Other Commands](#)

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[GPU Status Register](#)

[GPU Versions](#)

[GPU Depth Ordering](#)

[GPU Video Memory \(VRAM\)](#)

[GPU Texture Caching](#)

[GPU Timings](#)

[GPU \(MISC\)](#)

4.1 GPU I/O Ports, DMA Channels, Commands, VRAM

GPU I/O Ports (1F801810h and 1F801814h in Read/Write Directions)

Port	Name	Expl.
1F801810h-Write	GP0	Send GP0 Commands/Packets (Rendering and VRAM Access)
1F801814h-Write	GP1	Send GP1 Commands (Display Control) (and DMA Control)
1F801810h-Read	GPUREAD	Receive responses to GP0(C0h) and GP1(10h) commands
1F801814h-Read	GPUSTAT	Receive GPU Status Register

It (=GP0 only?) has a 64-byte (16-word) command FIFO buffer.

Optionally, Port 1F801810h (Read/Write) can be also accessed via DMA2.

The communication between the CPU and the GPU is a 32-bits data-only bus called the VBUS. Aside from address line 2 being connected, in order to make the difference

between port 0 and 1, there are no other address line between the two chips.
Thus the GPU can be seen as a blackbox that executes 32 bits commands.

GPU Timers / Synchronization

Most of the Timers are bound to GPU timings, see

[Timers](#)

[Interrupts](#)

GPU-related DMA Channels (DMA2 and DMA6)

Channel	Recommended for
DMA2 in Linked Mode	- Sending rendering commands ;GP0(20h..7Fh,E1h..E6h)
DMA2 in Continuous Mode	- VRAM transfers to/from GPU ;GP0(A0h,C0h)
DMA6	- Initializing the Link List ;Main RAM

Note: Before using DMA2, set up the DMA Direction in GP1(04h).

DMA2 is equivalent to accessing Port 1F801810h (GP0/GPUREAD) by software.

DMA6 just initializes data in Main RAM (not physically connected to the GPU).

GPU Command Summary

While it is probably more simple for the MIPS software to see GPU commands as a collection of bytes, the GPU will only see 32 bits words being sent to it. Therefore, while the Sony libraries will fill up structures to send to the GPU using byte-level granularity, it is much more simple to see these as bitmasks from the GPU's point of view.

So when processing commands on GP0, the GPU will first inspect the top 3 bits of the 32 bits command being sent. Depending on the value of these 3 bits, further decoding of the other bits can be done.

Commands sent to GP1 are more simple in nature to decode.

Top 3 bits of a GP0 command:

0 (000)	Misc commands
1 (001)	Polygon primitive
2 (010)	Line primitive
3 (011)	Rectangle primitive
4 (100)	VRAM-to-VRAM blit
5 (101)	CPU-to-VRAM blit
6 (110)	VRAM-to-CPU blit
7 (111)	Environment commands

Some GP0 commands require additional parameters, which are written (following the initial command) as further 32bit values to GP0. The execution of the command starts when all parameters have been received (or, in case of Polygon/Line commands, when the first 3/2 vertices have been received).

The astute reader will realize that there are shared bits between primitives, such as the gouraud shading flag.

Unlike all the others, the environment commands are more clear to be seen as a single 8 bits command, therefore the rest of the document will refer to them by their full 8 bits value.

Clear Cache

1st Command	(01000000h)
-------------	-------------

The GPU has a small texture cache, in order to reduce VRAM access. This command flushes it, when mutating the VRAM, similar to how the CPU i-cache must be flushed after writing new code and before executing it.

Note that it is possible to abuse the texture cache by changing pixels in VRAM that the GPU loaded in its cache, therefore creating weird drawing effects, but this is only seen in some demos, and never in actual games.

Quick Rectangle Fill

1st Color+Command	(02BbGgRrh)	;24bit RGB value (see note)
2nd Top Left Corner	(YyyyXxxxh)	;Xpos counted in halfwords, steps of 10h
3rd Width+Height	(YsizXsizh)	;Xsiz counted in halfwords, steps of 10h

Fills the area in the frame buffer with the value in RGB. Horizontally the filling is done in 16-pixel (32-bytes) units (see below masking/rounding).

The "Color" parameter is a 24bit RGB value, however, the actual fill data is 16bit: The hardware automatically converts the 24bit RGB value to 15bit RGB (with bit15=0).

Fill is NOT affected by the Mask settings (acts as if Mask.Bit0,1 are both zero).

This command is typically used to do a quick clear, as it'll be faster to run than an equivalent Rectangle command.

VRAM Overview / VRAM Addressing

VRAM is 1MByte (not mapped to the CPU bus) (it can be read/written only via I/O or DMA). The memory is used for:

```
Framebuffer(s)      ;Usually 2 buffers (Drawing Area, and Display Area)
Texture Page(s)    ;Required when using Textures
Texture Palette(s) ;Required when using 4bit/8bit Textures
```

The 1MByte VRAM is organized as 512 lines of 2048 bytes. It is accessed via coordinates, ranging from (0,0)=Upper-Left to (N,511)=Lower-Right.

Unit = 4bit 8bit 16bit 24bit Halfwords		Unit = Lines
Width = 4096 2048 1024 682.66 1024		Height = 512

The horizontal coordinates are addressing memory in 4bit/8bit/16bit/24bit/halfword units (depending on what data formats you are using) (or a mixup thereof, eg. a halfword-base address, plus a 4bit texture coordinate).

4.2 GPU Render Polygon Commands

When the upper 3 bits of the first GP0 command are set to 1 (001), then the command can be decoded using the following bitfield:

bit number	value	meaning
31-29	001	polygon render
28	1/0	gouraud / flat shading
27	1/0	4 / 3 vertices
26	1	textured / untextured
25	1/0	semi transparent / solid
24	0	texture blending
23-0	rgb	first color value.

Subsequent data sent to GP0 to complete this command will be the vertex data for the command. The meaning and count of these words will be altered by the initial flags sent in the first command.

If doing flat rendering, no further color will be sent. If doing gouraud shading, there will be one more color per vertex sent, and the initial color will be the one for vertex 0.

If doing 3 or 4 vertices rendering, this will affect the total number of vertex sent.

If doing textured rendering, each vertex sent will also have a U/V texture coordinate attached to it, as well as a CLUT index.

So each vertex data can be seen as the following set of words:

Color	xxBBGGRR	- optional, only present for gouraud shading
Vertex	YYYYXXXX	- required, two signed 16 bits values
UV	ClutUUUV	- optional, only present for textured polygons

The Clut index is only relevant for the first vertex seen in the stream of data. Any further Clut index ought to be set to 0.

So for example, a solid flat blue triangle of coordinate (10, 20), (30, 40), (50, 60) will be drawn using the following draw call data:

```
200000FF
00100020
00300040
00500060
```

And a quad with gouraud shading texture-blend will have the following structure:

```
2CR1G1B1
Yyy1Xxx1
ClutU1V1
00R2G2B2
Yyy2Xxx2
0000U2V2
00R3G3B3
Yyy3Xxx3
0000U3V3
00R4G4B4
Yyy4Xxx4
0000U4V4
```

Some combination of these flags can be seen as nonsense however, but it's important to realize that the GPU will still process them properly. For instance, specifying gouraud shading without texture blending will force the user to send the colors for each vertex to satisfy the GPU's state machine, without them being actually used for the rendering.

Notes

Polygons are displayed up to \<excluding> their lower-right coordinates.

Four-point polygons are internally processed as two Three-point polygons, the first consisting of Vertices 1,2,3, and the second of Vertices 2,3,4.

Within the Three-point polygons, the ordering of the vertices is don't care at the GPU side (a front-back check, based on clockwise or anti-clockwise ordering, can be implemented at the GTE side).

Dither enable (in Texpage command) affects ONLY polygons that do use Gouraud Shading or Texture Blending.

4.3 GPU Render Line Commands

When the upper 3 bits of the first GPO command are set to 2 (010), then the command can be decoded using the following bitfield:

bit number	value	meaning
31-29	010	line render
28	1/0	gouraud / flat shading
27	1/0	polyline / single line
25	1/0	semi transparent / solid
23-0	rgb	first color value.

So each vertex can be seen as the following list of words:

Color	xxBBGGRR	- optional, only present for gouraud shading
Vertex	YYYYXXXX	- required, two signed 16 bits values

When polyline mode is active, at least two vertices must be sent to the GPU. The vertex list is terminated by the bits 12-15 and 28-31 equaling `0x5`, or `(word & 0xF000F000 == 0x50005000)`. The terminator value occurs on the first word of the vertex (i.e. the color word if it's a gouraud shaded).

Note

Lines are displayed up to \<including> their lower-right coordinates (ie. unlike as for polygons, the lower-right coordinate is not excluded).

If dithering is enabled (via Texpage command), then both monochrome and shaded lines are drawn with dithering (this differs from monochrome polygons and monochrome rectangles).

Wire-Frame

Poly-Lines can be used (among others) to create Wire-Frame polygons (by setting the last Vertex equal to Vertex 1).

4.4 GPU Render Rectangle Commands

Rectangles are drawn much faster than polygons. Unlike polygons, gouraud shading is not possible, dithering isn't applied, the rectangle must forcefully have horizontal and vertical edges, textures cannot be rotated or scaled, and, of course, the GPU does render Rectangles as a single entity, without splitting them into two triangles.

The Rectangle command can be decoded using the following bitfield:

bit number	value	meaning
31-29	011	rectangle render
28-27	sss	rectangle size
26	1/0	textured / untextured
25	1/0	semi transparent / solid
23-0	rgb	first color value.

The `size` parameter can be seen as the following enum:

0 (00)	variable size
1 (01)	single pixel (1x1)
2 (10)	8x8 sprite
3 (11)	16x16 sprite

Therefore, the whole draw call can be seen as the following sequence of words:

Color	ccBBGGRR	- command + color; color is ignored when textured
Vertex1	YYYYXXXX	- required, indicates the upper left corner to render
UV	ClutUUUV	- optional, only present for textured rectangles
Vertex2	YYYYXXXX	- optional, bottom right corner for variable sized rectangles

Unlike for Textured-Polygons, the "Texpage" must be set up separately for Rectangles, via GP0(E1h). Width and Height can be up to 1023x511, however, the maximum size of the texture window is 256x256 (so the source data will be repeated when trying to use sizes larger than 256x256).

Texture Origin and X/Y-Flip

Vertex & Texcoord specify the upper-left edge of the rectangle. And, normally, screen coords and texture coords are both incremented during rendering the rectangle pixels. Optionally, X/Y-Flip bits can be set in Texpage.Bit12/13, these bits cause the texture coordinates to be decremented (instead of incremented). The X/Y-Flip bits do affect only Rectangles (not Polygons, nor VRAM Transfers).

Caution: Reportedly, the X/Y-Flip feature isn't supported on old PSX consoles (unknown

which ones exactly, maybe such with PU-7 mainboards, and unknown how to detect flipping support; except of course by reading VRAM).

Note

There are also two VRAM Transfer commands which work similar to GP0(60h) and GP0(65h). Eventually, that commands might be even faster... although not sure if they do use the Texture Cache?

The difference is that VRAM Transfers do not clip to the Drawig Area boundary, do not support fully-transparent nor semi-transparent texture pixels, and do not convert color depths (eg. without 4bit texture to 16bit framebuffer conversion).

4.5 GPU Rendering Attributes

Vertex (Parameter for Polygon, Line, Rectangle commands)

```

0-10  X-coordinate (signed, -1024..+1023)
11-15 Not used (usually sign-extension, but ignored by hardware)
16-26 Y-coordinate (signed, -1024..+1023)
26-31 Not used (usually sign-extension, but ignored by hardware)

```

Size Restriction: The maximum distance between two vertices is 1023 horizontally, and 511 vertically. Polygons and lines that are exceeding that dimensions are NOT rendered. For example, a line from Y1=-300 to Y2=+300 is NOT rendered, a line from Y1=-100 to Y2=+400 is rendered (as far as it is within the drawing area).

If portions of the polygon/line/rectangle are located outside of the drawing area, then the hardware renders only the portion that is inside of the drawing area. Not sure if the hardware is skipping all clipped pixels at once (within a single clock cycle), or if it's (slowly) processing them pixel by pixel?

Color Attribute (Parameter for all Rendering commands, except Raw Texture)

```

0-7    Red    (0..FFh)
8-15   Green  (0..FFh)
16-23  Blue   (0..FFh)
24-31  Command (in first parameter) (don't care in further parameters)

```

Caution: For untextured graphics, 8bit RGB values of FFh are brightest. However, for texture blending, 8bit values of 80h are brightest (values 81h..FFh are "brighter than bright" allowing to make textures about twice as bright as than they were originally

stored in memory; of course the results can't exceed the maximum brightness, ie. the 5bit values written to the framebuffer are saturated to max 1Fh).

Texpage Attribute (Parameter for Textured-Polygons commands)

0-8	Same as GP0(E1h).Bit0-8 (see there)
9-10	Unused (does NOT change GP0(E1h).Bit9-10)
11	Same as GP0(E1h).Bit11 (see there)
12-13	Unused (does NOT change GP0(E1h).Bit12-13)
14-15	Unused (should be 0)

This attribute is used in all Textured-Polygons commands.

Clut Attribute (Color Lookup Table, aka Palette)

This attribute is used in all Textured Polygon/Rectangle commands. Of course, it's relevant only for 4bit/8bit textures (don't care for 15bit textures).

0-5	X coordinate X/16 (ie. in 16-halfword steps)
6-14	Y coordinate 0-511 (ie. in 1-line steps)
15	Unknown/unused (should be 0)

Specifies the location of the CLUT data within VRAM.

GP0(E1h) - Draw Mode setting (aka "Texpage")

0-3	Texture page X Base	(N*64) (ie. in 64-halfword steps)	;GPUSTAT.0-3
4	Texture page Y Base	(N*256) (ie. 0 or 256)	;GPUSTAT.4
5-6	Semi Transparency	(0=B/2+F/2, 1=B+F, 2=B-F, 3=B+F/4)	;GPUSTAT.5-6
7-8	Texture page colors	(0=4bit, 1=8bit, 2=15bit, 3=Reserved)	;GPUSTAT.7-8
9	Dither 24bit to 15bit	(0=Off/strip LSBs, 1=Dither Enabled)	;GPUSTAT.9
10	Drawing to display area	(0=Prohibited, 1=Allowed)	;GPUSTAT.10
11	Texture Disable	(0=Normal, 1=Disable if GP1(09h).Bit0=1)	;GPUSTAT.15 (Above might be chipselect for (absent) second VRAM chip?)
12	Textured Rectangle X-Flip	(BIOS does set this bit on power-up...?)	
13	Textured Rectangle Y-Flip	(BIOS does set it equal to GPUSTAT.13...?)	
14-23	Not used	(should be 0)	
24-31	Command	(E1h)	

The GP0(E1h) command is required only for Lines, Rectangle, and Untextured-Polygons (for Textured-Polygons, the data is specified in form of the Texpage attribute; except that, Bit9-10 can be changed only via GP0(E1h), not via the Texpage attribute).

Texture page colors setting 3 (reserved) is same as setting 2 (15bit).

Note: GP0(00h) seems to be often inserted between Texpage and Rectangle commands,

maybe it acts as a NOP, which may be required between that commands, for timing reasons...?

GP0(E2h) - Texture Window setting

```

0-4    Texture window Mask X  (in 8 pixel steps)
5-9    Texture window Mask Y  (in 8 pixel steps)
10-14  Texture window Offset X (in 8 pixel steps)
15-19  Texture window Offset Y (in 8 pixel steps)
20-23  Not used (zero)
24-31  Command  (E2h)

```

Mask specifies the bits that are to be manipulated, and Offset contains the new values for these bits, ie. texture X/Y coordinates are adjusted as so:

```
Texcoord = (Texcoord AND (NOT (Mask*8))) OR ((Offset AND Mask) *8)
```

The area within a texture window is repeated throughout the texture page. The data is not actually stored all over the texture page but the GPU reads the repeated patterns as if they were there.

GP0(E3h) - Set Drawing Area top left (X1,Y1)

GP0(E4h) - Set Drawing Area bottom right (X2,Y2)

```

0-9    X-coordinate (0..1023)
10-18  Y-coordinate (0..511) ;\on Old 160pin GPU (max 1MB VRAM)
19-23  Not used (zero)      ;/
10-19  Y-coordinate (0..1023) ;\on New 208pin GPU (max 2MB VRAM)
20-23  Not used (zero)      ;/(retail consoles have only 1MB though)
24-31  Command  (Exh)

```

Sets the drawing area corners. The Render commands GP0(20h..7Fh) are automatically clipping any pixels that are outside of this region.

GP0(E5h) - Set Drawing Offset (X,Y)

```

0-10   X-offset (-1024..+1023) (usually within X1,X2 of Drawing Area)
11-21   Y-offset (-1024..+1023) (usually within Y1,Y2 of Drawing Area)
22-23   Not used (zero)
24-31   Command  (E5h)

```

If you have configured the GTE to produce vertices with coordinate "0,0" being located in the center of the drawing area, then the Drawing Offset must be " $X1+(X2-X1)/2$, $Y1+(Y2-Y1)/2$ ". Or, if coordinate "0,0" shall be the upper-left of the Drawing Area, then Drawing Offset should be " $X1, Y1$ ". Where $X1, Y1, X2, Y2$ are the values defined with GP0(E3h-E4h).

GP0(E6h) - Mask Bit Setting

0	Set mask while drawing (0=TextureBit15, 1=ForceBit15=1)	;GPUSTAT.11
1	Check mask before draw (0=Draw Always, 1=Draw if Bit15=0)	;GPUSTAT.12
2-23	Not used (zero)	
24-31	Command (E6h)	

When bit0 is off, the upper bit of the data written to the framebuffer is equal to bit15 of the texture color (ie. it is set for colors that are marked as "semi-transparent") (for untextured polygons, bit15 is set to zero).

When bit1 is on, any (old) pixels in the framebuffer with bit15=1 are write-protected, and cannot be overwritten by (new) rendering commands.

The mask setting affects all rendering commands, as well as CPU-to-VRAM and VRAM-to-VRAM transfer commands (where it acts on the separate halfwords, ie. as for 15bit textures). However, Mask does NOT affect the Fill-VRAM command.

This setting is used in games such as Metal Gear Solid and Silent Hill.

Note

GP0(E3h..E5h) do not take up space in the FIFO, so they are probably executed immediately (even if there're still other commands in the FIFO). Best use them only if you are sure that the FIFO is empty (otherwise the new Drawing Area settings might accidentally affect older Rendering Commands in the FIFO).

4.6 GPU Memory Transfer Commands

The next three commands being described are when the high 3 bits are set to the values 4 (100), 5 (101), and 6 (110). For them, the remaining 29 bits are ignored, and can be set to any arbitrary value.

VRAM to VRAM blitting - command 4 (100)

1st	Command	
2nd	Source Coord (YyyyXxxxh)	;Xpos counted in halfwords

```

3rd Destination Coord (YyyyXxxxxh) ;Xpos counted in halfwords
4th Width+Height      (YsizXsizh) ;Xsiz counted in halfwords

```

Copies data within framebuffer. The transfer is affected by Mask setting.

CPU to VRAM blitting - command 5 (101)

```

1st Command
2nd Destination Coord (YyyyXxxxxh) ;Xpos counted in halfwords
3rd Width+Height      (YsizXsizh) ;Xsiz counted in halfwords
... Data             (...)      <--- usually transferred via DMA

```

Transfers data from CPU to frame buffer. If the number of halfwords to be sent is odd, an extra halfword should be sent, as packets consist of 32bits words. The transfer is affected by Mask setting.

VRAM to CPU blitting - command 6 (110)

```

1st Command          ; \
2nd Source Coord    (YyyyXxxxxh) ; write to GP0 port (as usually)
3rd Width+Height    (YsizXsizh) ;/
... Data             (...)      ;<--- read from GPUREAD port (or via DMA)

```

Transfers data from frame buffer to CPU. Wait for bit27 of the status register to be set before reading the image data. When the number of halfwords is odd, an extra halfword is added at the end, as packets consist of 32bits words.

Masking and Rounding for FILL Command parameters

```

Xpos=(Xpos AND 3F0h)           ;range 0..3F0h, in steps of 10h
Ypos=(Ypos AND 1FFh)           ;range 0..1FFh
Xsiz=((Xsiz AND 3FFh)+0Fh) AND (NOT 0Fh) ;range 0..400h, in steps of 10h
Ysiz=((Ysiz AND 1FFh))         ;range 0..1FFh

```

Fill does NOT occur when Xsiz=0 or Ysiz=0 (unlike as for Copy commands). Xsiz=400h works only indirectly: Param=400h is handled as Xsiz=0, however, Param=3F1h..3FFh is rounded-up and handled as Xsiz=400h.

Note that because of the height (Ysiz) masking, a maximum of 511 rows can be filled in a single command. Calling a fill with a full VRAM height of 512 rows will be ineffective as the height will be masked to 0.

Masking for COPY Commands parameters

```

Xpos=(Xpos AND 3FFh) ; range 0..3FFh
Ypos=(Ypos AND 1FFh) ; range 0..1FFh
Xsiz=((Xsiz-1) AND 3FFh)+1 ; range 1..400h
Ysiz=((Ysiz-1) AND 1FFh)+1 ; range 1..200h

```

Parameters are just clipped to 10bit/9bit range, the only special case is that Size=0 is handled as Size=max.

Notes

The coordinates for the above VRAM transfer commands are absolute framebuffer addresses (not relative to Draw Offset, and not clipped to Draw Area). Non-DMA transfers seem to be working at any time, but GPU-DMA Transfers seem to be working ONLY during V-Blank (outside of V-Blank, portions of the data appear to be skipped, and the following words arrive at wrong addresses), unknown if it's possible to change that by whatever configuration settings...? That problem appears ONLY for continuous DMA aka VRAM transfers (linked-list DMA aka Ordering Table works even outside V-Blank).

Wrapping

If the Source/Dest starting points plus the width/height value exceed the 1024x512 pixel VRAM size, then the Copy/Fill operations wrap to the opposite memory edge (without any carry-out from X to Y, nor from Y to X).

4.7 GPU Other Commands

GP0(1Fh) - Interrupt Request (IRQ1)

1st Command	(Cc000000h)	;GPUSTAT.24
-------------	-------------	-------------

Requests IRQ1. Can be acknowledged via GP1(02h). This feature is rarely used.

Note: The command is used by Blaze'n'Blade, but the game doesn't have IRQ1 enabled, and the written value (1F801810h) looks more like an I/O address, rather than like a command, so not sure if it's done intentionally, or if it is just a bug.

GP0(03h) - Unknown?

Unknown. Doesn't seem to be used by any games. Unlike the "NOP" commands, GP0(03h) does take up space in FIFO, so it is apparently not a NOP.

GP0(00h) - NOP (?)

This command doesn't take up space in the FIFO (eg. even if a VRAM-to-VRAM transfer is still busy, one can send dozens of GP0(00h) commands, without the command FIFO becoming full. So, either the command is ignored (or, if it has a function, it is executed immediately, even while the transfer is busy).

...

GP0(00h) unknown, used with parameter = 08A16Ch... or rather 08FDBCh ... the written value seems to be a bios/ram memory address, anded with 00FFFFFFh... maybe a bios bug?

GP0(00h) seems to be often inserted between Texpage and Rectangle commands, maybe it acts as a NOP, which may be required between that commands, for timing reasons...?

GP0(04h..1Eh,E0h,E7h..EFh) - Mirrors of GP0(00h) - NOP (?)

Like GP0(00h), these commands don't take up space in the FIFO. So, maybe, they are same as GP0(00h), however, the Drawing Area/Offset commands GP0(E3h..E5h) don't take up FIFO space either, so not taking up FIFO space doesn't necessarily mean that the command has no function.

4.8 GPU Display Control Commands (GP1)

GP1 Display Control Commands are sent by writing the 8bit Command number (MSBs), and 24bit parameter (LSBs) to Port 1F801814h. Unlike GP0 commands, GP1 commands are passed directly to the GPU (ie. they can be sent even when the FIFO is full).

GP1(00h) - Reset GPU

0-23 Not used (zero)

Resets the GPU to the following values:

GP1(01h)	;clear fifo
GP1(02h)	;ack irq (0)
GP1(03h)	;display off (1)

```

GP1(04h)      ;dma off (0)
GP1(05h)      ;display address (0)
GP1(06h)      ;display x1,x2 (x1=200h, x2=200h+256*10)
GP1(07h)      ;display y1,y2 (y1=010h, y2=010h+240)
GP1(08h)      ;display mode 320x200 NTSC (0)
GP0(E1h..E6h) ;rendering attributes (0)

```

Accordingly, GPUSTAT becomes 14802000h. The x1,y1 values are too small, ie. the upper-left edge isn't visible. Note that GP1(09h) is NOT affected by the reset command.

GP1(01h) - Reset Command Buffer

```
0-23 Not used (zero)
```

Resets the command buffer and CLUT cache.

GP1(02h) - Acknowledge GPU Interrupt (IRQ1)

```
0-23 Not used (zero) ;GPUSTAT.24
```

Resets the IRQ flag in GPUSTAT.24. The flag can be set via GP0(1Fh).

GP1(03h) - Display Enable

```

0      Display On/Off   (0=On, 1=Off) ;GPUSTAT.23
1-23  Not used (zero)

```

Turns display on/off. "Note that a turned off screen still gives the flicker of NTSC on a PAL screen if NTSC mode is selected."

The "Off" settings displays a black picture (and still sends /SYNC signals to the television set). (Unknown if it still generates vblank IRQs though?)

GP1(04h) - DMA Direction / Data Request

```

0-1  DMA Direction (0=Off, 1=FIFO, 2=CPUtoGP0, 3=GPUREADtoCPU) ;GPUSTAT.29-30
2-23 Not used (zero)

```

Notes: Manually sending/reading data by software (non-DMA) is ALWAYS possible, regardless of the GP1(04h) setting. The GP1(04h) setting does affect the meaning of GPUSTAT.25.

Display start/end

Specifies where the display area is positioned on the screen, and how much data gets sent to the screen. The screen sizes of the display area are valid only if the horizontal/vertical start/end values are default. By changing these you can get bigger/smaller display screens. On most TV's there is some black around the edge, which can be utilised by setting the start of the screen earlier and the end later. The size of the pixels is NOT changed with these settings, the GPU simply sends more data to the screen. Some monitors/TVs have a smaller display area and the extended size might not be visible on those sets. "(Mine is capable of about 330 pixels horizontal, and 272 vertical in 320*240 mode)"

GP1(05h) - Start of Display area (in VRAM)

0-9 X (0-1023)	(halfword address in VRAM)	(relative to begin of VRAM)
10-18 Y (0-511)	(scanline number in VRAM)	(relative to begin of VRAM)
19-23 Not used (zero)		

Upper/left Display source address in VRAM. The size and target position on screen is set via Display Range registers; target=X1,Y2; size=(X2-X1/cycles_per_pix), (Y2-Y1).

GP1(06h) - Horizontal Display range (on Screen)

0-11 X1 (260h+0)	;12bit	; \counted in video clock units,
12-23 X2 (260h+320*8)	;12bit	; /relative to HSYNC

Specifies the horizontal range within which the display area is displayed. For resolutions other than 320 pixels it may be necessary to fine adjust the value to obtain an exact match (eg. $X2 = X1 + \text{pixels} * \text{cycles_per_pix}$).

The number of displayed pixels per line is " $((X2-X1)/\text{cycles_per_pix})+2$ " AND NOT 3" (ie. the hardware is rounding the width up/down to a multiple of 4 pixels).

Most games are using a width equal to the horizontal resolution (ie. 256, 320, 368, 512, 640 pixels). A few games are using slightly smaller widths (probably due to programming bugs). Pandemonium 2 is using a bigger "overscan" width (ensuring an intact picture without borders even on mis-calibrated TV sets).

The 260h value is the first visible pixel on normal TV Sets, this value is used by MOST NTSC games, and SOME PAL games (see below notes on Mis-Centered PAL games).

Video clock unit used depends on console region, regardless of NTSC/PAL video mode set by GP1(08h).3; see section on [nominal video clocks](#) for values.

GP1(07h) - Vertical Display range (on Screen)

```

0-9   Y1 (NTSC=88h-(240/2), (PAL=A3h-(288/2)) ;\scanline numbers on screen,
10-19 Y2 (NTSC=88h+(240/2), (PAL=A3h+(288/2)) ;/relative to VSYNC
20-23 Not used (zero)

```

Specifies the vertical range within which the display area is displayed. The number of lines is Y2-Y1 (unlike as for the width, there's no rounding applied to the height). If Y2 is set to a much too large value, then the hardware stops to generate vblank interrupts (IRQ0). The 88h/A3h values are the middle-scanlines on normal TV Sets, these values are used by MOST NTSC games, and SOME PAL games (see below notes on Mis-Centered PAL games).

The 240/288 values are for fullscreen pictures. Many NTSC games display 240 lines, but on most analog television sets, only 224 lines are visible (8 lines of overscan on top and 8 lines of overscan on bottom). Many PAL games display only 256 lines (underscan with black borders).

Some games such as Chrono Cross will occasionally adjust these values to create a screen shake effect, so proper emulation of this command is necessary for those particular cases.

GP1(08h) - Display mode

```

0-1   Horizontal Resolution 1    (0=256, 1=320, 2=512, 3=640) ;GPUSTAT.17-18
2     Vertical Resolution       (0=240, 1=480, when Bit5=1)   ;GPUSTAT.19
3     Video Mode                (0=NTSC/60Hz, 1=PAL/50Hz)   ;GPUSTAT.20
4     Display Area Color Depth (0=15bit, 1=24bit)           ;GPUSTAT.21
5     Vertical Interlace        (0=Off, 1=On)                 ;GPUSTAT.22
6     Horizontal Resolution 2   (0=256/320/512/640, 1=368)  ;GPUSTAT.16
7     "Reverseflag"            (0=Normal, 1=Distorted)        ;GPUSTAT.14
8-23  Not used (zero)

```

Note: Interlace must be enabled to see all lines in 480-lines mode (interlace is causing ugly flickering, so a non-interlaced low resolution image is typically having better quality than a high resolution interlaced image, a pretty bad example are the intro screens shown by the BIOS). The Display Area Color Depth does NOT affect the Drawing Area (the Drawing Area is \<always> 15bit).

When the "Reverseflag" is set, the display scrolls down 2 lines or so, and colored regions are getting somehow hatched/distorted, but black and white regions are still looking okay. Don't know what that's good for? Probably relates to PAL/NTSC-Color Clock vs PSX-Dot Clock mismatches: Bit7=0 causes Flimmering errors (errors at different locations in each frame), and Bit7=1 causes Static errors (errors at same locations in all frames)?

GP1(10h) - Get GPU Info

GP1(11h..1Fh) - Mirrors of GP1(10h), Get GPU Info

After sending the command, the result can be read (immediately) from GPUREAD register (there's no NOP or other delay required) (namely GPUSTAT.Bit27 is used only for VRAM-Reads, but NOT for GPU-Info-Reads, so do not try to wait for that flag).

```
0-23  Select Information which is to be retrieved (via following GPUREAD)
```

On Old 180pin GPUs, following values can be selected:

```
00h-01h = Returns Nothing (old value in GPUREAD remains unchanged)
02h      = Read Texture Window setting ;GP0(E2h) ;20bit/MSBs=Nothing
03h      = Read Draw area top left    ;GP0(E3h) ;19bit/MSBs=Nothing
04h      = Read Draw area bottom right ;GP0(E4h) ;19bit/MSBs=Nothing
05h      = Read Draw offset        ;GP0(E5h) ;22bit
06h-07h = Returns Nothing (old value in GPUREAD remains unchanged)
08h-FFFFFh = Mirrors of 00h..07h
```

On New 208pin GPUs, following values can be selected:

```
00h-01h = Returns Nothing (old value in GPUREAD remains unchanged)
02h      = Read Texture Window setting ;GP0(E2h) ;20bit/MSBs=Nothing
03h      = Read Draw area top left    ;GP0(E3h) ;20bit/MSBs=Nothing
04h      = Read Draw area bottom right ;GP0(E4h) ;20bit/MSBs=Nothing
05h      = Read Draw offset        ;GP0(E5h) ;22bit
06h      = Returns Nothing (old value in GPUREAD remains unchanged)
07h      = Read GPU Type (usually 2) ;see "GPU Versions" chapter
08h      = Unknown (Returns 00000000h) (lightgun on some GPUs?)
09h-0Fh = Returns Nothing (old value in GPUREAD remains unchanged)
10h-FFFFFh = Mirrors of 00h..0Fh
```

The selected data is latched in GPUREAD, the same/latched value can be read multiple times, but, the latch isn't automatically updated when changing GP0 registers.

GP1(09h) - New Texture Disable

```
0      Texture Disable (0=Normal, 1=Allow Disable via GP0(E1h).11) ;GPUSTAT.15
1-23  Unknown (seems to have no effect)
```

This feature seems to be intended for debugging purposes (most released games do contain program code for disabling textures, but do never execute it).

GP1(09h) seems to be supported only on New GPUs. Old GPUs don't support it all, and there seem to be some Special/Prototype GPUs that use GP1(20h) instead of GP1(09h).

GP1(20h) - Special/Prototype Texture Disable

```
0-23 Unknown (501h=Texture Enable, 504h=Texture Disable, or so?)
```

Seems to be used only on whatever arcade/prototype GPUs. New GPUs are using GP1(09h) instead of GP1(20h).

GP1(0Bh) - Unknown/Internal?

```
0-10 Unknown (GPU crashes after a while when set to 274h..7FFh)
11-23 Unknown (seems to have no effect)
```

The register doesn't seem to be used by any games.

GP1(0Ah..0Ch..0Fh,21h..3Fh) - N/A

Not used?

GP1(40h..FFh) - N/A (Mirrors)

Mirrors of GP1(00h..3Fh).

Mis-Centered PAL Games (wrong GP1(06h)/GP1(07h) settings)

NTSC games are typically well centered (using X1=260h, and Y1/Y2=88h+/-N). PAL games should be centered as X1=260h, and Y1/Y2=A3h+/-N) - these values would be looking well on a Philips Philetta TV Set, and do also match up with other common picture positions (eg. as used by Nintendo's SNES console). However, most PAL games are using completely different "random" centering values (maybe caused by different developers trying to match the centering to the different TV Sets) (although it looks more as if the PAL developers just went amok: Many PAL games are even using different centerings for their Intro, Movie, and actual Game sequences). In result, most PAL games are looking like crap when playing them on a real PSX. For PSX emulators it may be recommended to ignore the GP1(06h)/GP1(07h) centering, and instead, apply auto-centering to PAL games. For PAL game developers, it may be recommended to add a screen centering option (as

found in Tomb Raider 3, for example). Unknown if this is really required... or if X1=260h, and Y1/Y2=A3h+/-N would work fine on most or all PAL TV Sets?

4.9 GPU Status Register

1F801814h - GPUSTAT - GPU Status Register (R)

0-3	Texture page X Base	(N*64)	;GP0(E1h).0-3
4	Texture page Y Base	(N*256) (ie. 0 or 256)	;GP0(E1h).4
5-6	Semi Transparency	(0=B/2+F/2, 1=B+F, 2=B-F, 3=B+F/4)	;GP0(E1h).5-6
7-8	Texture page colors	(0=4bit, 1=8bit, 2=15bit, 3=Reserved)	GP0(E1h).7-8
9	Dither 24bit to 15bit	(0=Off/strip LSBs, 1=Dither Enabled)	;GP0(E1h).9
10	Drawing to display area	(0=Prohibited, 1=Allowed)	;GP0(E1h).10
11	Set Mask-bit when drawing pixels	(0=No, 1=Yes/Mask)	;GP0(E6h).0
12	Draw Pixels	(0=Always, 1=Not to Masked areas)	;GP0(E6h).1
13	Interlace Field	(or, always 1 when GP1(08h).5=0)	
14	"Reverseflag"	(0=Normal, 1=Distorted)	;GP1(08h).7
15	Texture Disable	(0=Normal, 1=Disable Textures)	;GP0(E1h).11
16	Horizontal Resolution 2	(0=256/320/512/640, 1=368)	;GP1(08h).6
17-18	Horizontal Resolution 1	(0=256, 1=320, 2=512, 3=640)	;GP1(08h).0-1
19	Vertical Resolution	(0=240, 1=480, when Bit22=1)	;GP1(08h).2
20	Video Mode	(0=NTSC/60Hz, 1=PAL/50Hz)	;GP1(08h).3
21	Display Area Color Depth	(0=15bit, 1=24bit)	;GP1(08h).4
22	Vertical Interlace	(0=Off, 1=On)	;GP1(08h).5
23	Display Enable	(0=Enabled, 1=Disabled)	;GP1(03h).0
24	Interrupt Request (IRQ1)	(0=Off, 1=IRQ)	;GP0(1Fh)/GP1(02h)
25	DMA / Data Request, meaning depends on GP1(04h)	DMA Direction: When GP1(04h)=0 ---> Always zero (0) When GP1(04h)=1 ---> FIFO State (0=Full, 1=Not Full) When GP1(04h)=2 ---> Same as GPUSTAT.28 When GP1(04h)=3 ---> Same as GPUSTAT.27	
26	Ready to receive Cmd Word	(0=No, 1=Ready)	;GP0(...);via GP0
27	Ready to send VRAM to CPU	(0=No, 1=Ready)	;GP0(C0h);via GPUREAD
28	Ready to receive DMA Block	(0=No, 1=Ready)	;GP0(...);via GP0
29-30	DMA Direction	(0=Off, 1=?, 2=CPUtoGP0, 3=GPUREADtoCPU)	;GP1(04h).0-1
31	Drawing even/odd lines in interlace mode	(0=Even or Vblank, 1=Odd)	

In 480-lines mode, bit31 changes per frame. And in 240-lines mode, the bit changes per scanline. The bit is always zero during Vblank (vertical retrace and upper/lower screen border).

Note

Further GPU status information can be retrieved via GP1(10h) and GP0(C0h).

Ready Bits

Bit28: Normally, this bit gets cleared when the command execution is busy (ie. once when the command and all of its parameters are received), however, for Polygon and Line Rendering commands, the bit gets cleared immediately after receiving the command word (ie. before receiving the vertex parameters). The bit is used as DMA request in DMA Mode 2, accordingly, the DMA would probably hang if the Polygon/Line parameters are transferred in a separate DMA block (ie. the DMA probably starts ONLY on command words).

Bit27: Gets set after sending GP0(C0h) and its parameters, and stays set until all data words are received; used as DMA request in DMA Mode 3.

Bit26: Gets set when the GPU wants to receive a command. If the bit is cleared, then the GPU does either want to receive data, or it is busy with a command execution (and doesn't want to receive anything).

Bit25: This is the DMA Request bit, however, the bit is also useful for non-DMA transfers, especially in the FIFO State mode.

4.10 GPU Versions

Summary of GPU Differences

Differences...	Old 160pin GPU	New 208pin GPU
GPU Chip	CXD8514Q	CXD8561Q/BQ/CQ/CXD9500Q
Mainboard	EARLY-PU-8 and below	LATE-PU-8 and up
Memory Type	Dual-ported VRAM	Normal DRAM
GPUSTAT.13 when interlace=off	always 0	always 1
GPUSTAT.14	always 0	reverseflag
GPUSTAT.15	always 0	texture_disable
GP1(10h:index3..4)	19bit (1MB VRAM)	20bit (2MB VRAM)
GP1(10h:index7)	N/A	00000002h version
GP1(10h:index8)	mirror of index0	00000000h zero
GP1(10h:index9..F)	mirror of index1..7	N/A
GP1(20h)	whatever? used for detecting old gpu	
GP0(E1h).bit12/13	without x/y-flip	with x/y-flip
GP0(03h)	N/A (no stored in fifo)	unknown/unused command
Shaded Textures	((color/8)*texel)/2	(color*texel)/16
GP0(02h) FillVram	xpos.bit0-3=0Fh=bugged	xpos.bit0-3=ignored
dma-to-vram:	doesn't work with blksiz>10h (new gpu works with blksiz=8C0h!)	
dma-to-vram:	MAYBE also needs extra software-handshake to confirm DMA done?	
320*224 pix = 11800h pix = 8C00h words		
GP0(80h) VramToVram	works	Freeze on large moves?

Shaded Textures

The Old GPU crops 8:8:8 bit gouraud shading color to 5:5:5 bit before multiplying it with the texture color, resulting in rather poor graphics. For example, the snow scene in the first level of Tomb Raider I looks a lot smoother on New GPUs.

The cropped colors are looking a bit as if dithering would be disabled (although, technically dithering works fine, but due to the crippled color input, it's always using the same dither pattern per 8 intensities, instead of using 8 different dither patterns).

Memory/Rendering Timings

The Old GPU uses two Dual-ported VRAM chips (each with two 16bit databusses, one for CPU/DMA/rendering access, and one for output to the video DAC). The New GPU uses a normal DRAM chip (with single 32bit databus).

The exact timing differences are unknown, but the different memory types should result in quite different timings:

The Old GPU might perform better on non-32bit aligned accesses, and on memory accesses performed simultaneously with DAC output.

On the other hand, the New GPU's DRAM seems to be faster in some cases (for example, during Vblank, it's fast enough to perform DMA's with blksiz>10h, which exceeds the GPU's FIFO size, and causes lost data on Old GPUs).

X/Y-Flip and 2MB Video RAM

The X/Y-flipping feature may be used by arcade games (provided that the arcade board is fitted with New GPUs). The flipping feature does also work on retail consoles with New GPUs, but PSX games should never use that feature (for maintaining compatibility with older PSX consoles).

2Mbyte Video RAM is used on some arcade boards. Whilst PSX retail consoles are always containing only 1MByte RAM, so the feature cannot be used even if the console contains a New GPU. There's one special case: Some PSone consoles are actually fitted with 2MB chips (maybe because smaller chips haven't been in production anymore), but the chips are wired so that only half of the memory is accessible (the extra memory could be theoretically unlocked with some minimal hardware modification).

GPU Detection (and optional texture disable)

Below is slightly customized GPU Detection function taken from Perfect Assassin (the index7 latching works ONLY on New GPUs, whilst old GPUs would leave the latched value

unchanged; as a workaround, the index4 latching is used to ensure that the latch won't contain 000002h on old GPUs, assuming that index4 is never set to 000002h).

```
[1F801814h]=10000004h      ;GP1(10h).index4 (latch draw area bottom right)
[1F801814h]=10000007h      ;GP1(10h).index7 (latch GPU version, if any)
if ([1F801810h] AND 00FFFFFFh)=00000002h then goto @@gpu_v2
[1F801810h]=([1F801814h] AND 3FFFh) OR E1001000h ;change GPUSTAT via GP0(E1h)
dummy=[1F801810h]           ;dummy read (unknown purpose)
if ([1F801814h] AND 00001000h) then goto @@gpu_v1 else goto @@gpu_v0
;---
@@gpu_v0: ;Old 160pin GPU (EARLY-PU-8)
return 0
;---
@@gpu_v1: ;unknown GPU type, maybe some custom arcade/prototype version ?
if want_tex_dis then [1F801814h]=20000504h ;GP1(20h)
return 1
;---
@@gpu_v2: ;New 208pin GPU (LATE-PU-8 and up)
if want_tex_dis then [1F801814h]=09000001h ;GP1(09h)
return 2
```

GP0(02h) FillVram

The FillVram command does normally ignore the lower 4bit of the x-coordinate (and software should always set those bits to zero). However, if the 4bits are all set, then the Old GPU does write each 2nd pixel to wrong memory address. For example, a 32x4 pixel fill produces following results for x=0..1Fh:

0h	10h	20h	30h	40h
# #####	# #####	# #####	# #####	# #####
# #####	# #####	# #####	# #####	# #####
# #####	# #####	# #####	# #####	# #####
# # # # #	# # # # #	# # # # #	# # # # #	# \x=00h..0Eh
# # # # #	# # # # #	# # # # #	# # # # #	; and, x=0Fh
# # # # #	# # # # #	# # # # #	# # # # #	; on NEW GPU
# # # # #	# # # # #	# # # # #	# # # # #	;/
# # # # #	# # # # #	# # # # #	# # # # #	;\
# # # # #	# # # # #	# # # # #	# # # # #	; x=0Fh
# # # # #	# # # # #	# # # # #	# # # # #	; on OLD GPU
# # # # #	# # # # #	# # # # #	# # # # #	;/
# #####	# #####	# #####	# #####	\x=10h..1Eh
# #####	# #####	# #####	# #####	; and, x=1Fh
# #####	# #####	# #####	# #####	; on NEW GPU
# #####	# #####	# #####	# #####	;/
# # # # #	# # # # #	# # # # #	# # # # #	;\
# # # # #	# # # # #	# # # # #	# # # # #	; x=1Fh
# # # # #	# # # # #	# # # # #	# # # # #	; on OLD GPU
# # # # #	# # # # #	# # # # #	# # # # #	;/

Arcade GPUs

Some arcade boards are using normal retail GPUs, however, there are also two special non-retail 208pin GPUs which seem to be solely used on arcade boards:

```
IC21 - 208pin - "SONY CXD8538Q" ; seen on GP-11 (namco System 11) boards
IC103 - 208pin - "SONY CXD8654Q" ; seen on GP-15 (namco System 12) boards
```

The exact differences to retail GPUs are unknown. One of the special GPUs is said to use entirely different command numbers for rendering commands (maybe some old prototype variant, or maybe some protection against cloning arcade boards with retail chips).

4.11 GPU Depth Ordering

Absent Depth Buffer

The PlayStation's GPU stores only RGB colors in the framebuffer (ie. unlike modern 3D processors, it's NOT buffering Depth values; leaving apart the Mask bit, which could be considered as a tiny 1bit "Depth" or "Priority" value). In fact, the GPU supports only X,Y coordinates, and it's totally unaware of Z coordinates. So, when rendering a polygon, the hardware CANNOT determine which of the new pixels are in front/behind of the old pixels in the buffer.

Simple Ordering

The rendering simply takes place in the ordering as the data is sent to the GPU (ie. the most distant objects should be sent first). For 2D graphics, it's fairly easy follow that order (eg. even multi-layer 2D graphics can be using DMA2-continuous mode).

Depth Ordering Table (OT)

For 3D graphics, the ordering of the polygons may change more or less randomly (eg. when rotating/moving the camera). To solve that problem, the whole rendering data is usually first stored in a Depth Ordering Table (OT) in Main RAM, and, once when all polygons have been stored in the OT, the OT is sent to the GPU via "DMA2-linked-list" mode.

Initializing an empty OT (via DMA6)

DMA channel 6 can be used to set up an empty linked list, in which each entry points to the previous:

DPCR - enable bits	;Example=x8xxxxxxh
D6_MADR - pointer to the LAST table entry	;Example=8012300Ch
D6_BCR - number of list entries	;Example=00000004h
D6_CHCR - control bits (should be 11000002h)	;Example=11000002h

Each entry has a size of 00h words (upper 8bit), and a pointer to the previous entry (lower 24bit). With the above Example values, the generated table would look like so:

[8012300h]=00FFFFFFh	;1st entry, points to end code (xxFFFFFFh)
[80123004h]=00123000h	;2nd entry, points to 1st entry
[80123008h]=00123004h	;3rd entry, points to 2nd entry
[8012300Ch]=00123008h	;last entry, points to 3rd entry (table entrypoint)

Inserting Entries (Passing GTE data to the OT) (by software)

The GTE commands AVSZ3 and AVSZ4 can be used to calculate the Average Z coordinates of a polygon (based on its three or four Z coordinates). The result is returned as a 16bit Z value in GTE register OTZ, the commands do also allow to divide the result, to make it less than 16bit (the full 16bit would require an OT of 256KBytes - for the EMPTY table, which would be a waste of memory, and which would slowdown the DMA2/DMA6 operations) (on the other hand, a smaller table means less depth resolution).

[PacketAddr+0] = [8012300h+OTZ*4] + (N SHL 24)	<--internal link chain
[PacketAddr+4..N*4] = GP0 Command(s) and Parameters	<--data (send to GP0)
[8012300h+OTZ*4] = PacketAddr AND FFFFFFFh	<--internal link chain

If there's been already an entry (at the same OTZ index), then the new polygon will be processed first (ie. it will appear "behind" of the old entry).

Not sure if the packet size must be limited to max N=16 words (ie. as for the DMA2-continuous block size) (due to GP0 FIFO size limits)?

Sending the OT to the CPU (via DMA2-linked-list mode)

```

1 - Wait until GPU is ready to receive commands ;GPUSTAT.28
2 - Enable DMA channel 2 ;DPCR
3 - Set GPU to DMA cpu->gpu mode ;[GP1]=04000002h aka GP1(04h)
3 - Set D2_MADR to the start of the list ;(LAST Entry) ;Example=80123010h

```

```

4 - Set D2_BCR to zero           ;(length unused, end at END-CODE)
5 - Set D2_CHCR to link mode, mem->GPU and dma enable   ;=01000401h

```

4.12 GPU Video Memory (VRAM)

Framebuffer

The framebuffer contains the image that is to be output to the Television Set. The GPU supports 10 resolutions, with 16bit or 24bit per pixel.

Resolution	16bit	24bit		Resolution	16bit	24bit
256x240	120Kbytes	180Kbytes		256x480	240Kbytes	360Kbytes
320x240	150Kbytes	225Kbytes		320x480	300Kbytes	450Kbytes
368x240	xx0Kbytes	xx0Kbytes		368x480	xx0Kbytes	xx0Kbytes
512x240	240Kbytes	360Kbytes		512x480	480Kbytes	720Kbytes
640x240	300Kbytes	450Kbytes		640x480	600Kbytes	900Kbytes

Note: In most cases, you'll need TWO framebuffers (one being displayed, and used as rendering target) (unless you are able to draw the whole new image during vblank, or unless when using single-layer 2D graphics). So, resolutions that occupy more than 512K would exceed the available 1MB VRAM when using 2 buffers. Also, high resolutions mean higher rendering load, and less texture memory.

```

<B> 15bit Direct Display (default) (works with polygons, lines, rectangles)</B>
    0-4  Red      (0..31)
    5-9  Green    (0..31)
   10-14 Blue    (0..31)
   15   Mask flag (0=Normal, 1=Do not allow to overwrite this pixel)
<B> 24bit Direct Display (works ONLY with direct vram transfers)</B>
    0-7  Red      (0..255)
    8-15 Green    (0..255)
   16-23 Blue    (0..255)

```

Note: The 24bit pixels occupy 3 bytes (not 4 bytes with unused MSBs), so each 6 bytes contain two 24bit pixels. The 24bit display mode works only with VRAM transfer commands like GP0(A0h); the rendering commands GP0(20h..7Fh) cannot output 24bit data. Ie. 24bit mode is used mostly for MDEC videos (and some 2D games like Heart of Darkness).

Texture Bitmaps

A texture is an image put on a polygon or sprite. The data of a texture can be stored in 3 different modes:

```
<B> 16bit Texture (Direct Color) ; (One 256x256 page = 128Kbytes)</B>
 0-4 Red      (0..31)    ;\Color 0000h      = Fully-Transparent
 5-9 Green     (0..31)    ; Color 0001h..7FFFh = Non-Transparent
 10-14 Blue    (0..31)    ; Color 8000h..FFFFh = Semi-Transparent (*)
 15 Semi Transparency Flag ;/(*) or Non-Transparent for opaque commands

<B> 8bit Texture (256 Color Palette) ; (One 256x256 page = 64Kbytes)</B>
 0-7 Palette index for 1st pixel (left)
 8-15 Palette index for 2nd pixel (right)

<B> 4bit Texture (16 Color Palette) ; (One 256x256 page = 32Kbytes)</B>
 0-3 Palette index for 1st pixel (left)
 4-7 Palette index for 2nd pixel (middle/left)
 8-11 Palette index for 3rd pixel (middle/right)
 12-15 Palette index for 4th pixel (right)
```

A Texture Page is a 256x256 texel region in VRAM (the Polygon rendering commands are using Texcoords with 8bit X,Y coordinates, so polygons cannot use textures bigger than 256x256) (the Rectangle rendering commands with width/height parameters could theoretically use larger textures, but the hardware clips their texture coordinates to 8bit, too).

The GP0(E2h) Texture Window (aka Texture Repeat) command can be used to reduce the texture size to less than 256x256 texels.

The Texture Pages can be located in the frame buffer on X multiples of 64 halfwords and Y multiples of 256 lines.

Texture Palettes - CLUT (Color Lookup Table)

The clut is a the table where the colors are stored for the image data in the CLUT modes. The pixels of those images are used as indexes to this table. The clut is arranged in the frame buffer as a 256x1 image for the 8bit clut mode, and a 16x1 image for the 4bit clut mode.

```
0-4 Red      (0..31)    ;\Color 0000h      = Fully-Transparent
 5-9 Green     (0..31)    ; Color 0001h..7FFFh = Non-Transparent
 10-14 Blue    (0..31)    ; Color 8000h..FFFFh = Semi-Transparent (*)
 15 Semi Transparency Flag ;/(*) or Non-Transparent for opaque commands
```

The clut data can be arranged in the frame buffer at X multiples of 16 (X=0,16,32,48,etc) and anywhere in the Y range of 0-511.

Texture Color Black Limitations

On the PSX, texture color 0000h is fully-transparent, that means textures cannot contain Black pixels. However, in some cases, Color 8000h (Black with semi-transparent flag) can be used, depending on the rendering command:

```
opaque command, eg. GP0(24h)      --> 8000h = Non-Transparent Black
semi-transp command, eg. GP0(26h)  --> 8000h = Semi-Transparent Black
```

So, with semi-transparent rendering commands, it isn't possible to use Non-Transparent Black pixels in textures, the only workaround is to use colors like 0001h (dark red) or 0400h (dark blue). However, due to the PSX's rather steeply increasing intensity ramp, these colors are clearly visible to be brighter than black.

RGB Intensity Notes

The Playstations RGB values aren't linear to normal RGB values (as used on PCs). The min/max values are of course the same, but the medium values differ:

Intensity	PC	PSX
Minimum	0	0
Medium (circa)	16	8
Maximum	31	31

Ie. on the PSX, the intensity increases steeply from 0 to 15, and less steeply from 16 to 31.

4.13 GPU Texture Caching

The GPU has 2 Kbyte Texture Cache

There is also a CLUT cache that is preserved between GPU drawing commands. The CLUT cache is invalidated when different CLUT index values are used or when GP0(01h) is issued. It is unknown if the CLUT cache overlaps or is shared with the Texture Cache.

If polygons with texture are displayed, the GPU needs to read these from the frame buffer. This slows down the drawing process, and as a result the number of polygons that can be drawn in a given timespan. To speed up this process the GPU is equipped with a texture cache, so a given piece of texture needs not to be read multiple times in succession.

The texture cache size depends on the color mode used for the textures.

In 4 bit CLUT mode it has a size of 64x64, in 8 bit CLUT it's 32x64 and in 15bitDirect is

32x32. A general speed up can be achieved by setting up textures according to these sizes. For further speed gain a more precise knowledge of how the cache works is necessary.

Cache blocks

The texture page is divided into non-overlapping cache blocks, each of a unit size according to color mode. These cache blocks are tiled within the texture page.

cache			
block			
0	1	2	..
..			

Cache entries

Each cache block is divided into 256 cache entries, which are numbered sequentially, and are 8 bytes wide. So a cache entry holds 16 4bit clut pixels 8 8bit clut pixels, or 4 15bitdirect pixels.

4bit and 8bit clut:				15bitdirect:							
0	1	2	3	0	1	2	3	4	5	6	7
4	5	6	7	8	9	a	b	c	d	e	f
8	9	..	10	11	..						
c	..	18	..								
..		..									

The cache can hold only one cache entry by the same number, so if f.e. a piece of texture spans multiple cache blocks and it has data on entry 9 of block 1, but also on entry 9 of block 2, these cannot be in the cache at once.

4.14 GPU Timings

Nominal Video Clock

```
NTSC video clock = 53.693175 MHz
PAL video clock = 53.203425 MHz
```

Consoles will always use the video clock for its region, regardless of the GPU being configured in NTSC or PAL output mode, because an NTSC console lacks a PAL reference clock and vice versa. Without modifications for an additional oscillator for the other region, consoles may experience drift over time when playing content from a different video region. See vertical refresh rates below.

Vertical Video Timings

```
263 scanlines per field for NTSC non-interlaced
262.5 scanlines per field for NTSC interlaced
```

```
314 scanlines per field for PAL non-interlaced
312.5 scanlines per field for PAL interlaced
```

Horizontal blanking and vertical blanking signals occur on the video output side as expected for NTSC/PAL signals. These are not necessarily the same as the timer/interrupt HBLANK and VBLANK.

Vertical Refresh Rates

```
NTSC mode on NTSC video clock
Interlaced: 59.940 Hz
Non-interlaced: 59.826 Hz
```

```
PAL mode on PAL video clock
Interlaced: 50.000 Hz
Non-interlaced: 49.761 Hz
```

```
NTSC mode on PAL video clock
Interlaced: 59.393 Hz
Non-interlaced: 59.280 Hz
```

```
PAL mode on NTSC video clock
Interlaced: 50.460 Hz
Non-interlaced: 50.219 Hz
```

For emulation purposes, it's recommended to use an NTSC video clock when running NTSC content (or in NTSC mode) and a PAL clock when running PAL content (or in PAL mode).

TODO: Derivations for vertical refresh rates; horizontal timing notes

Nocash's original GPU Timings notes:

Video Clock

The PSone/PAL video clock is the cpu clock multiplied by 11/7.

```
CPU Clock      = 33.868800MHz (44100Hz*300h)
Video Clock   = 53.222400MHz (44100Hz*300h*11/7)
```

For other PSX/PSone PAL/NTSC variants, see:

[Pinouts - CLK Pinouts](#)

Vertical Timings

```
PAL: 314 scanlines per frame (13Ah)
NTSC: 263 scanlines per frame (107h)
```

Timer1 can use the hblank signal as input, allowing to count scanlines (unless the display is configured to 0 pixels width, which would cause an endless hblank). The hblank signal is generated even during vertical blanking/retrace.

Horizontal Timings

```
PAL: 3406 video cycles per scanline (or 3406.1 or so?)
NTSC: 3413 video cycles per scanline (or 3413.6 or so?)
```

Dotclocks:

```
PSX.256-pix Dotclock = 5.322240MHz (44100Hz*300h*11/7/10)
PSX.320-pix Dotclock = 6.652800MHz (44100Hz*300h*11/7/8)
PSX.368-pix Dotclock = 7.603200MHz (44100Hz*300h*11/7/7)
PSX.512-pix Dotclock = 10.644480MHz (44100Hz*300h*11/7/5)
PSX.640-pix Dotclock = 13.305600MHz (44100Hz*300h*11/7/4)
Namco GunCon 385-pix = 8.000000MHz (from 8.00MHz on lightgun PCB)
```

Dots per scanline are, depending on horizontal resolution, and on PAL/NTSC:

320pix/PAL: 3406/8 = 425.75 dots	320pix/NTSC: 3413/8 = 426.625 dots
640pix/PAL: 3406/4 = 851.5 dots	640pix/NTSC: 3413/4 = 853.25 dots
256pix/PAL: 3406/10 = 340.6 dots	256pix/NTSC: 3413/10 = 341.3 dots
512pix/PAL: 3406/5 = 681.2 dots	512pix/NTSC: 3413/5 = 682.6 dots
368pix/PAL: 3406/7 = 486.5714 dots	368pix/NTSC: 3413/7 = 487.5714 dots

Timer0 can use the dotclock as input, however, the Timer0 input "ignores" the fractional portions (in most cases, the values are rounded down, ie. with 340.6 dots/line, the timer increments only 340 times/line; the only value that is rounded up is 425.75 dots/line) (for example, due to the rounding, the timer isn't running exactly twice as fast in 512pix/PAL mode than in 256pix/PAL mode). The dotclock signal is generated even during horizontal/vertical blanking/retrace.

Frame Rates

PAL: 53.222400MHz/314/3406 = ca. 49.76 Hz (ie. almost 50Hz)
NTSC: 53.222400MHz/263/3413 = ca. 59.29 Hz (ie. almost 60Hz)

Note

Above values include "hidden" dots and scanlines (during horizontal and vertical blanking/retrace).

4.15 GPU (MISC)

GP0(20h..7Fh) - Render Command Bits

0-23 Color for (first) Vertex	(Not for Raw-Texture)
24 Texture Mode (0=Blended, 1=Raw)	(Textured-Polygon/Rect only)
25 Semi Transparency (0=Off, 1=On)	(All Render Types)
26 Texture Mapping (0=Off, 1=On)	(Polygon/Rectangle only)
27-28 Rect Size (0=Var, 1=1x1, 2=8x8, 3=16x16)	(Rectangle only)
27 Num Vertices (0=Triple, 1=Quad)	(Polygon only)
27 Num Lines (0=Single, 1=Poly)	(Line only)
28 Shading (0=Flat, 1=Gouroud)	(Polygon/Line only)
29-31 Primitive Type (1=Polygon, 2=Line, 3=Rectangle)	

Perspective (in-)correct Rendering

The PSX doesn't support perspective correct rendering: Assume a polygon to be rotated so that its right half becomes more distant to the camera, and its left half becomes closer. Due to the GTE's perspective division, the right half should appear smaller than the left half.

The GPU supports only linear interpolations for rendering - that is correct concerning the X and Y screen coordinates (which are still linear to each other, even after perspective division, since both are divided by the same value).

However, texture coordinates (and Gouraud shaded colors) are NOT linear to the screen coordinates, and so, the linear interpolated PSX graphics are often looking rather distorted, that especially for textures that contain straight lines. For color shading the problem is less obvious (since shading is kinda blurry anyways).

Perspective correct Rendering

For perspective correct rendering, the polygon's Z-coordinates would be needed to be passed from the GTE to the GPU, and, the GPU would then need to use that Z-coordinates to "undo" the perspective division for each pixel (that'd require some additional memory, and especially a powerful division unit, which isn't implemented in the hardware).

As a workaround, you can try to reduce the size of your polygons (the interpolation errors increase in the center region of larger polygons). Reducing the size would be only required for polygons that occupy a larger screen region (which may vary depending on the distance to the camera).

Ie. you may check the size AFTER perspective division, if it's too large, then break it into smaller parts (using the original coordinates, NOT the screen coordinates), and then pass the fragments to the GTE another time.

Again, perspective correction would be relevant only for certain textures (not for randomly dithered textures like sand, water, fire, grass, and not for untextured polygons, and of course not for 2D graphics, so you may exclude those from size reduction).

24bit RGB to 15bit RGB Dithering (enabled in Texpage attribute)

For dithering, VRAM is broken to 4x4 pixel blocks, depending on the location in that 4x4 pixel region, the corresponding dither offset is added to the 8bit R/G/B values, the result

is saturated to +00h..+FFh, and then divided by 8, resulting in the final 5bit R/G/B values.

```
-4  +0  -3  +1 ;\dither offsets for first two scanlines
+2  -2  +3  -1 ;/
-3  +1  -4  +0 ;\dither offsets for next two scanlines
+3  -1  +2  -2 ;/(same as above, but shifted two pixels horizontally)
```

POLYGONs (triangles/quads) are dithered ONLY if they do use gouraud shading or texture blending.

LINEs are dithered (no matter if they are mono or do use gouraud shading).

RECTs are NOT dithered (no matter if they do use texture blending).

Shading information

"Texture RGB values control the brightness of the individual colors (\$00-\$7f). A value of \$80 in a color will take the former value as data." (What...? probably means the "double brightness" effect... or does it want to tell that ALL colors of 80h..FFh have only single brightness.. rather than reaching double brightness at FFh...?)

Shading

The GPU has a shading function, which will scale the color of a primitive to a specified brightness. There are 2 shading modes: Flat shading, and gouraud shading. Flat shading is the mode in which one brightness value is specified for the entire primitive. In Gouraud shading mode, a different brightness value can be given for each vertex of a primitive, and the brightness between these points is automatically interpolated.

Semi Transparency

When semi transparency is set for a pixel, the GPU first reads the pixel it wants to write to, and then calculates the color it will write from the 2 pixels according to the semitransparency mode selected. Processing speed is lower in this mode because additional reading and calculating are necessary. There are 4 semitransparency modes in the GPU.

```
B=Back (the old pixel read from the image in the frame buffer)
F=Front (the new halftransparent pixel)
* 0.5 x B + 0.5 x F ;aka B/2+F/2
* 1.0 x B + 1.0 x F ;aka B+F
* 1.0 x B - 1.0 x F ;aka B-F
* 1.0 x B +0.25 x F ;aka B+F/4
```

Draw to display enable

This will enable/disable any drawing to the area that is currently displayed. Not sure yet WHY one should want to disable that?

Also not sure HOW and IF it works... the SIZE of the display area is implied by the screen size - which is horizontally counted in CLOCK CYCLES, so, to obtain the size in PIXELS, the hardware would require to divide that value by the number of cycles per pixel, depending on the current resolution...?

5. Geometry Transformation Engine (GTE)

[GTE Overview](#)

[GTE Registers](#)

[GTE Saturation](#)

[GTE Opcode Summary](#)

[GTE Coordinate Calculation Commands](#)

[GTE General Purpose Calculation Commands](#)

[GTE Color Calculation Commands](#)

[GTE Division Inaccuracy](#)

5.1 GTE Overview

GTE Operation

The GTE doesn't have any memory or I/O ports mapped to the CPU memory bus, instead, it's solely accessed via coprocessor opcodes:

```

mov  cop0r12,rt      ;-enable/disable COP2 (GTE) via COP0 status register
mov  cop2r0-63,rt    ;\write parameters to GTE registers
mov  cop2r0-31,[rs+imm] ;/
mov  cop2cmd,imm25   ;-issue GTE command
mov  rt,cop2r0-63   ;\read results from GTE registers
mov  [rs+imm],cop2r0-31 ;/
jt   cop2flg,dest    ;-jump never ;\implemented (no exception), but,
jf   cop2flg,dest    ;-jump always ;/flag seems to be always "false"

```

GTE (memory-?) load and store instructions have a delay of 2 instructions, for any GTE commands or operations accessing that register. Any? That's wrong!

GTE instructions and functions should not be used in

- Delay slots of jumps and branches
- Event handlers or interrupts (sounds like nonsense?) (need push/pop though)

If an instruction that reads a GTE register or a GTE command is executed before the current GTE command is finished, the CPU will hold until the instruction has finished. The number of cycles each GTE instruction takes is shown in the command list.

GTE Command Encoding (COP2 imm25 opcodes)

```

31-25 Must be 0100101b for "COP2 imm25" instructions
20-24 Fake GTE Command Number (00h..1Fh) (ignored by hardware)
19      sf - Shift Fraction in IR registers (0=No fraction, 1=12bit fraction)
17-18 MVMVA Multiply Matrix   (0=Rotation. 1=Light, 2=Color, 3=Reserved)
15-16 MVMVA Multiply Vector   (0=V0, 1=V1, 2=V2, 3=IR/long)
13-14 MVMVA Translation Vector (0=TR, 1=BK, 2=FC/Bugged, 3=None)
11-12 Always zero           (ignored by hardware)
10      lm - Saturate IR1,IR2,IR3 result (0=To -8000h..+7FFFh, 1=To 0..+7FFFh)
6-9     Always zero           (ignored by hardware)
0-5     Real GTE Command Number (00h..3Fh) (used by hardware)

```

The MVMVA bits are used only by the MVMVA opcode (the bits are zero for all other opcodes).

The "sf" and "lm" bits are usually fixed (either set, or cleared, depending on the command) (for MVMVA, the bits are variable) (also, "sf" can be changed for some commands like SQR) (although they are usually fixed for most other opcodes, changing them might have some effect on some/all opcodes)?

GTE Data Register Summary (cop2r0-31)

cop2r0-1	3xS16 VXY0,VZ0	Vector 0 (X,Y,Z)
cop2r2-3	3xS16 VXY1,VZ1	Vector 1 (X,Y,Z)
cop2r4-5	3xS16 VXY2,VZ2	Vector 2 (X,Y,Z)
cop2r6	4xU8 RGBC	Color/code value
cop2r7	1xU16 OTZ	Average Z value (for Ordering Table)
cop2r8	1xS16 IRO	16bit Accumulator (Interpolate)
cop2r9-11	3xS16 IR1,IR2,IR3	16bit Accumulator (Vector)
cop2r12-15	6xS16 SXY0,SXY1,SXY2,SXY3	Screen XY-coordinate FIFO (3 stages)
cop2r16-19	4xU16 SZ0,SZ1,SZ2,SZ3	Screen Z-coordinate FIFO (4 stages)
cop2r20-22	12xU8 RGB0,RGB1,RGB2	Color CRGB-code/color FIFO (3 stages)
cop2r23	4xU8 (RES1)	Prohibited
cop2r24	1xS32 MAC0	32bit Maths Accumulators (Value)
cop2r25-27	3xS32 MAC1,MAC2,MAC3	32bit Maths Accumulators (Vector)
cop2r28-29	1xU15 IRGB,ORGB	Convert RGB Color (48bit vs 15bit)
cop2r30-31	2xS32 LZCS,LZCR	Count Leading-Zeroes/Ones (sign bits)

GTE Control Register Summary (cop2r32-63)

cop2r32-36	9xS16 RT11RT12,...,RT33	Rotation matrix (3x3)	;cnt0-4
cop2r37-39	3x 32 TRX,TRY,TRZ	Translation vector (X,Y,Z)	;cnt5-7
cop2r40-44	9xS16 L11L12,...,L33	Light source matrix (3x3)	;cnt8-12
cop2r45-47	3x 32 RBK,GBK,BBK	Background color (R,G,B)	;cnt13-15
cop2r48-52	9xS16 LR1LR2,...,LB3	Light color matrix source (3x3)	;cnt16-20
cop2r53-55	3x 32 RFC,GFC,BFC	Far color (R,G,B)	;cnt21-23
cop2r56-57	2x 32 OFX,OFY	Screen offset (X,Y)	;cnt24-25

cop2r58	BuggyU16 H	Projection plane distance. ;cnt26
cop2r59	S16 DQA	Depth queing parameter A (coeff) ;cnt27
cop2r60	32 DQB	Depth queing parameter B (offset);cnt28
cop2r61-62	2xS16 ZSF3,ZSF4	Average Z scale factors ;cnt29-30
cop2r63	U20 FLAG	Returns any calculation errors ;cnt31

5.2 GTE Registers

Note in some functions format is different from the one that's given here.

Matrix Registers

Rotation matrix (RT)	Light matrix (LLM)	Light Color matrix (LCM)
cop2r32.lsbs=RT11	cop2r40.lsbs=L11	cop2r48.lsbs=LR1
cop2r32.msbs=RT12	cop2r40.msbs=L12	cop2r48.msbs=LR2
cop2r33.lsbs=RT13	cop2r41.lsbs=L13	cop2r49.lsbs=LR3
cop2r33.msbs=RT21	cop2r41.msbs=L21	cop2r49.msbs=LG1
cop2r34.lsbs=RT22	cop2r42.lsbs=L22	cop2r50.lsbs=LG2
cop2r34.msbs=RT23	cop2r42.msbs=L23	cop2r50.msbs=LG3
cop2r35.lsbs=RT31	cop2r43.lsbs=L31	cop2r51.lsbs=LB1
cop2r35.msbs=RT32	cop2r43.msbs=L32	cop2r51.msbs=LB2
cop2r36 =RT33	cop2r44 =L33	cop2r52 =LB3

Each element is 16bit (1bit sign, 3bit integer, 12bit fraction). Reading the last elements (RT33,L33,LB3) returns the 16bit value sign-expanded to 32bit.

Translation Vector (TR) (Input, R/W?)

cop2r37 (cnt5)	- TRX	- Translation vector X (R/W?)
cop2r38 (cnt6)	- TRY	- Translation vector Y (R/W?)
cop2r39 (cnt7)	- TRZ	- Translation vector Z (R/W?)

Each element is 32bit (1bit sign, 31bit integer).

Used only for MVMVA, RTPS, RTPT commands.

Background Color (BK) (Input?, R/W?)

cop2r45 (cnt13)	- RBK	- Background color red component
cop2r46 (cnt14)	- GBK	- Background color green component
cop2r47 (cnt15)	- BBK	- Background color blue component

Each element is 32bit (1bit sign, 19bit integer, 12bit fraction).

Far Color (FC) (Input?) (R/W?)

```

cop2r53 (cnt21) - RFC - Far color red component
cop2r54 (cnt22) - GFC - Far color green component
cop2r55 (cnt23) - BFC - Far color blue component

```

Each element is 32bit (1bit sign, 27bit integer, 4bit fraction).

Screen Offset and Distance (Input, R/W?)

```

cop2r56 (cnt24) - OFX - Screen offset X
cop2r57 (cnt25) - OFY - Screen offset Y
cop2r58 (cnt26) - H - Projection plane distance
cop2r59 (cnt27) - DQA - Depth queing parameter A. (coeff.)
cop2r60 (cnt28) - DQB - Depth queing parameter B. (offset.)

```

The X and Y values are each 32bit (1bit sign, 15bit integer, 16bit fraction).

The H value is 16bit unsigned (0bit sign, 16bit integer, 0bit fraction). BUG: When reading the H register, the hardware does accidentally \<sign-expand> the \<unsigned> 16bit value (ie. values +8000h..+FFFFh are returned as FFFF8000h..FFFFFFFh) (this bug applies only to "mov rd,cop2r58" opcodes; the actual calculations via RTPS/RTPT opcodes are working okay).

The DQA value is only 16bit (1bit sign, 7bit integer, 8bit fraction).

The DQB value is 32bit (1bit sign, 7bit integer, 24bit? fraction).

Used only for RTPS/RTPT commands.

Average Z Registers (ZSF3/ZSF4=Input, R/W?) (OTZ=Result, R)

```

cop2r61 (cnt29) ZSF3 | 0|ZSF3 1,3,12| Z3 average scale factor (normally 1/3)
cop2r62 (cnt30) ZSF4 | 0|ZSF4 1,3,12| Z4 average scale factor (normally 1/4)
cop2r7      OTZ (R) | 0|OTZ 0,15, 0| Average Z value (for Ordering Table)

```

Used only for AVSZ3/AVSZ4 commands.

Screen XYZ Coordinate FIFOs

cop2r12 - SXY0	rw SY0 1,15, 0 SX0 1,15, 0	Screen XY fifo (older)
cop2r13 - SXY1	rw SY1 1,15, 0 SX1 1,15, 0	Screen XY fifo (old)
cop2r14 - SXY2	rw SY2 1,15, 0 SX2 1,15, 0	Screen XY fifo (new)
cop2r15 - SXYP	rw SYP 1,15, 0 SXP 1,15, 0	SXY2-mirror with move-on-write
cop2r16 - SZ0	rw SZ0 0,16, 0	Screen Z fifo (oldest)
cop2r17 - SZ1	rw SZ1 0,16, 0	Screen Z fifo (older)
cop2r18 - SZ2	rw SZ2 0,16, 0	Screen Z fifo (old)
cop2r19 - SZ3	rw SZ3 0,16, 0	Screen Z fifo (new)

SX,SY,SZ are used as Output for RTPS/RTPT. Additionally, SX,SY are used as Input for NCLIP, and SZ is used as Input for AVSZ3/AVSZ4.

The SZn Fifo has 4 stages (required for AVSZ4 command), the SXYn Fifo has only 3 stages, and a special mirrored register: SXYP is a mirror of SXY2, the difference is that writing to SXYP moves SXY2/SXY1 to SXY1/SXY0, whilst writing to SXY2 (or any other SXYn or SZn registers) changes only the written register, but doesn't move any other Fifo entries.

16bit Vectors (R/W)

Vector 0 (V0)	Vector 1 (V1)	Vector 2 (V2)	Vector 3 (IR)
cop2r0.lsbs - VX0	cop2r2.lsbs - VX1	cop2r4.lsbs - VX2	cop2r9 - IR1
cop2r0.msbs - VY0	cop2r2.msbs - VY1	cop2r4.msbs - VY2	cop2r10 - IR2
cop2r1 - VZ0	cop2r3 - VZ1	cop2r5 - VZ2	cop2r11 - IR3

All elements are signed 16bit. The IRn and VZn elements occupy a whole 32bit register, reading these registers returns the 16bit value sign-expanded to 32bit. Note: IRn can be also indirectly accessed via IRGB/ORGBC registers.

Color Register and Color FIFO

cop2r6 - RGBC	rw CODE B	G	R	Color/code
cop2r20 - RGB0	rw CD0 B0	G0	R0	Characteristic color fifo.
cop2r21 - RGB1	rw CD1 B1	G1	R1	
cop2r22 - RGB2	rw CD2 B2	G2	R2	
cop2r23 - (RES1)				Prohibited

RES1 seems to be unused... looks like an unused Fifo stage... RES1 is read/write-able... unlike SXYP (for SXYn Fifo) it does not mirror to RGB2, nor does it have a move-on-write function...

Interpolation Factor

```
cop2r8    IRO    rw|Sign      | IRO 1, 3,12 | Intermediate value 0.
```

Used as Output for RTPS/RTPT, and as Input for various commands.

XX...

```
cop2r24  MAC0  rw|MAC0 1,31,0          | Sum of products value 0
```

XX...

cop2r25 MAC1 rw MAC1 1,31,0	Sum of products value 1
cop2r26 MAC2 rw MAC2 1,31,0	Sum of products value 2
cop2r27 MAC3 rw MAC3 1,31,0	Sum of products value 3

cop2r28 - IRGB - Color conversion Input (R/W)

Expands 5:5:5 bit RGB (range 0..1Fh) to 16:16:16 bit RGB (range 0000h..0F80h).

0-4	Red (0..1Fh) (R/W)	;multiplied by 80h, and written to IR1
5-9	Green (0..1Fh) (R/W)	;multiplied by 80h, and written to IR2
10-14	Blue (0..1Fh) (R/W)	;multiplied by 80h, and written to IR3
15-31	Not used (always zero) (Read only)	

After writing to IRGB, the result can be read from IR3 after TWO nop's, and from IR1,IR2 after THREE nop's (for uncached code, ONE nop would work). When using IR1,IR2,IR3 as parameters for GTE commands, similar timing restrictions might apply... depending on when the specific commands use the parameters?

cop2r29 - ORGB - Color conversion Output (R)

Collapses 16:16:16 bit RGB (range 0000h..0F80h) to 5:5:5 bit RGB (range 0..1Fh). Negative values (8000h..FFFFh/80h) are saturated to 00h, large positive values (1000h..7FFFh/80h) are saturated to 1Fh, there are no overflow or saturation flags set in cop2r63 though.

0-4	Red (0..1Fh) (R)	;IR1 divided by 80h, saturated to +00h..+1Fh
5-9	Green (0..1Fh) (R)	;IR2 divided by 80h, saturated to +00h..+1Fh
10-14	Blue (0..1Fh) (R)	;IR3 divided by 80h, saturated to +00h..+1Fh
15-31	Not used (always zero) (Read only)	

Any changes to IR1,IR2,IR3 are reflected to this register (and, actually also to IRGB) (ie. ORGB is simply a read-only mirror of IRGB).

cop2r30 - LZCS - Count Leading Bits Source data (R/W)

cop2r31 - LZCR - Count Leading Bits Result (R)

Reading LZCR returns the leading 0 count of LZCS if LZCS is positive and the leading 1 count of LZCS if LZCS is negative. The results are in range 1..32.

cop2r63 (cnt31) - FLAG - Returns any calculation errors.

See GTE Saturation chapter.

5.3 GTE Saturation

Maths overflows are indicated in FLAG register. In most cases, the result is saturated to MIN/MAX values (except MAC0,MAC1,MAC2,MAC3 which aren't saturated). For IR1,IR2,IR3 many commands allow to select the MIN value via "Im" bit of the GTE opcode (though not all commands, RTPS/RTPT always act as if Im=0).

cop2r63 (cnt31) - FLAG - Returns any calculation errors.

```

31 Error Flag (Bit30..23, and 18..13 ORed together) (Read only)
30 MAC1 Result larger than 43 bits and positive
29 MAC2 Result larger than 43 bits and positive
28 MAC3 Result larger than 43 bits and positive
27 MAC1 Result larger than 43 bits and negative
26 MAC2 Result larger than 43 bits and negative
25 MAC3 Result larger than 43 bits and negative
24 IR1 saturated to +0000h..+7FFFh (lm=1) or to -8000h..+7FFFh (lm=0)
23 IR2 saturated to +0000h..+7FFFh (lm=1) or to -8000h..+7FFFh (lm=0)
22 IR3 saturated to +0000h..+7FFFh (lm=1) or to -8000h..+7FFFh (lm=0)
21 Color-FIFO-R saturated to +00h..+FFh
20 Color-FIFO-G saturated to +00h..+FFh
19 Color-FIFO-B saturated to +00h..+FFh
18 SZ3 or OTZ saturated to +0000h..+FFFFh
17 Divide overflow. RTPS/RTPT division result saturated to max=1FFFFh
16 MAC0 Result larger than 31 bits and positive
15 MAC0 Result larger than 31 bits and negative
14 SX2 saturated to -0400h..+03FFh
13 SY2 saturated to -0400h..+03FFh
12 IR0 saturated to +0000h..+1000h
0-11 Not used (always zero) (Read only)

```

Bit30-12 are read/write-able, ie. they can be set/reset by software, however, that's normally not required - all bits are automatically reset at the begin of a new GTE command.

Bit31 is apparently intended for RTPS/RTPT commands, since it triggers only on flags that are affected by these two commands, but even for that commands it's totally useless since one could as well check if FLAG is nonzero.

Note: Writing 32bit values to 16bit GTE registers by software does not trigger any overflow/saturation flags (and does not do any saturation), eg. writing 12008900h (positive 32bit) to a signed 16bit register sets that register to FFFF8900h (negative 16bit).

5.4 GTE Opcode Summary

GTE Command Summary (sorted by Real Opcode bits) (bit0-5)

Opc	Name	Clk	Expl.
00h	-		N/A (modifies similar registers than RTPS...)
01h	RTPS	15	Perspective Transformation single
0xh	-		N/A
06h	NCLIP	8	Normal clipping
0xh	-		N/A
0Ch	OP(sf)	6	Outer product of 2 vectors
0xh	-		N/A
10h	DPCS	8	Depth Cueing single
11h	INTPL	8	Interpolation of a vector and far color vector
12h	MVMVA	8	Multiply vector by matrix and add vector (see below)
13h	NCDS	19	Normal color depth cue single vector
14h	CDP	13	Color Depth Que
15h	-		N/A
16h	NCDT	44	Normal color depth cue triple vectors
1xh	-		N/A
1Bh	NCCS	17	Normal Color Color single vector
1Ch	CC	11	Color Color
1Dh	-		N/A
1Eh	NCS	14	Normal color single
1Fh	-		N/A
20h	NCT	30	Normal color triple
2xh	-		N/A
28h	SQR(sf)	5	Square of vector IR
29h	DCPL	8	Depth Cue Color light
2Ah	DPCT	17	Depth Cueing triple (should be fake=08h, but isn't)
2xh	-		N/A
2Dh	AVSZ3	5	Average of three Z values
2Eh	AVSZ4	6	Average of four Z values
2Fh	-		N/A
30h	RTPT	23	Perspective Transformation triple
3xh	-		N/A

3Dh	GPF(sf)5	General purpose interpolation
3Eh	GPL(sf)5	General purpose interpolation with base
3Fh	NCCT 39	Normal Color Color triple vector

Unknown if/what happens when using the "N/A" opcodes?

GTE Command Summary (sorted by Fake Opcode bits) (bit20-24)

The fake opcode number in bit20-24 has absolutely no effect on the hardware, it seems to be solely used to (or not to) confuse developers. Having the opcodes sorted by their fake numbers gives a more or less well arranged list:

Fake	Name	Clk	Expl.
00h	-		N/A
01h	RTPS	15	Perspective Transformation single
02h	RTPT	23	Perspective Transformation triple
03h	-		N/A
04h	MVMVA	8	Multiply vector by matrix and add vector (see below)
05h	-		N/A
06h	DCPL	8	Depth Cue Color light
07h	DPCS	8	Depth Cueing single
08h	DPCT	17	Depth Cueing triple (should be fake=08h, but isn't)
09h	INTPL	8	Interpolation of a vector and far color vector
0Ah	SQR(sf)5		Square of vector IR
0Bh	-		N/A
0Ch	NCS	14	Normal color single
0Dh	NCT	30	Normal color triple
0Eh	NCDS	19	Normal color depth cue single vector
0Fh	NCDT	44	Normal color depth cue triple vectors
10h	NCCS	17	Normal Color Color single vector
11h	NCCT	39	Normal Color Color triple vector
12h	CDP	13	Color Depth Que
13h	CC	11	Color Color
14h	NCLIP	8	Normal clipping
15h	AVSZ3	5	Average of three Z values
16h	AVSZ4	6	Average of four Z values
17h	OP(sf)	6	Outer product of 2 vectors
18h	-		N/A
19h	GPF(sf)5		General purpose interpolation
1Ah	GPL(sf)5		General purpose interpolation with base
1Bh	-		N/A
1Ch	-		N/A
1Dh	-		N/A
1Eh	-		N/A
1Fh	-		N/A

For the sort-effect, DCPT should use fake=08h, but Sony seems to have accidentally numbered it fake=0Fh in their devkit (giving it the same fake number as for NCDT). Also,

"Wipeout 2097" accidentally uses 0140006h (fake=01h and distorted bit18) instead of 1400006h (fake=14h) for NCLIP.

Additional Functions

The LZCS/LZCR registers offer a Count-Leading-Zeroes/Leading-Ones function.

The IRGB/ORGB registers allow to convert between 48bit and 15bit RGB colors.

These registers work without needing to send any COP2 commands. However, unlike for commands (which do automatically halt the CPU when needed), one must insert dummy opcodes between writing and reading the registers.

5.5 GTE Coordinate Calculation Commands

COP2 0180001h - 15 Cycles - RTPS - Perspective Transformation (single)

COP2 0280030h - 23 Cycles - RTPT - Perspective Transformation (triple)

RTPS performs final Rotate, translate and perspective transformation on vertex V0. Before writing to the FIFOs, the older entries are moved one stage down. RTPT is same as RTPS, but repeats for V1 and V2. The "sf" bit should be usually set.

```

IR1 = MAC1 = (TRX*1000h + RT11*VX0 + RT12*VY0 + RT13*VZ0) SAR (sf*12)
IR2 = MAC2 = (TRY*1000h + RT21*VX0 + RT22*VY0 + RT23*VZ0) SAR (sf*12)
IR3 = MAC3 = (TRZ*1000h + RT31*VX0 + RT32*VY0 + RT33*VZ0) SAR (sf*12)
SZ3 = MAC3 SAR ((1-sf)*12) ;ScreenZ FIFO 0..+FFFFh
MAC0=(((H*20000h/SZ3)+1)/2)*IR1+OFX, SX2=MAC0/1000h ;ScrX FIFO -400h..+3FFh
MAC0=(((H*20000h/SZ3)+1)/2)*IR2+OFY, SY2=MAC0/1000h ;ScrY FIFO -400h..+3FFh
MAC0=(((H*20000h/SZ3)+1)/2)*DQA+DQB, IR0=MAC0/1000h ;Depth cueing 0..+1000h

```

If the result of the " $((H*20000h/SZ3)+1)/2$ " division is greater than 1FFFFh, then the division result is saturated to +1FFFFh, and the divide overflow bit in the FLAG register gets set; that happens if the vertex is exceeding the "near clip plane", ie. if it is very close to the camera ($SZ3 \leq H/2$), exactly at the camera position ($SZ3=0$), or behind the camera (negative Z coordinates are saturated to $SZ3=0$). For details on the division, see:

[GTE Division Inaccuracy](#)

For "far plane clipping", one can use the SZ3 saturation flag (MaxZ=FFFFh), or the IR3 saturation flag (MaxZ=7FFFh) (eg. used by Wipeout 2097), or one can compare the SZ3 value with any desired MaxZ value by software.

Note: The command does saturate IR1,IR2,IR3 to -8000h..+7FFFh (regardless of Im bit). When using RTP with sf=0, then the IR3 saturation flag (FLAG.22) gets set \<only> if

"MAC3 SAR 12" exceeds -8000h..+7FFFh (although IR3 is saturated when "MAC3" exceeds -8000h..+7FFFh).

COP2 1400006h - 8 Cycles - NCLIP - Normal clipping

```
MAC0 = SX0*SY1 + SX1*SY2 + SX2*SY0 - SX0*SY2 - SX1*SY0 - SX2*SY1
```

The sign of the result indicates whether the polygon coordinates are arranged clockwise or anticlockwise (ie. whether the front side or backside is visible). If the result is zero, then it's neither one (ie. the vertices are all arranged in a straight line). Note: The GPU probably renders straight lines as invisible 0 pixel width lines?

COP2 158002Dh - 5 Cycles - AVSZ3 - Average of three Z values (for Triangles)

COP2 168002Eh - 6 Cycles - AVSZ4 - Average of four Z values (for Quads)

```
MAC0 = ZSF3*(SZ1+SZ2+SZ3)      ; for AVSZ3
MAC0 = ZSF4*(SZ0+SZ1+SZ2+SZ3)  ; for AVSZ4
OTZ  = MAC0/1000h               ; for both (saturated to 0..FFFFh)
```

Adds three or four Z values together and multiplies them by a fixed point value. The result can be used as index in the GPU's Ordering Table (OT).

[GPU Depth Ordering](#)

The scaling factors would be usually ZSF3=N/30h and ZSF4=N/40h, where "N" is the number of entries in the OT (max 10000h). SZn and OTZ are unsigned 16bit values, for whatever reason ZSFn registers are signed 16bit values (negative values would allow a negative result in MAC0, but would saturate OTZ to zero).

5.6 GTE General Purpose Calculation Commands

COP2 0400012h - 8 Cycles - MVMVA(sf,mx,v,cv,lm)

Multiply vector by matrix and vector addition.

```
Mx = matrix specified by mx ;RT/LLM/LCM - Rotation, light or color matrix
Vx = vector specified by v  ;V0, V1, V2, or [IR1,IR2,IR3]
Tx = translation vector specified by cv ;TR or BK or Bugged/FC, or None
```

Calculation:

```

MAC1 = (Tx1*1000h + Mx11*Vx1 + Mx12*Vx2 + Mx13*Vx3) SAR (sf*12)
MAC2 = (Tx2*1000h + Mx21*Vx1 + Mx22*Vx2 + Mx23*Vx3) SAR (sf*12)
MAC3 = (Tx3*1000h + Mx31*Vx1 + Mx32*Vx2 + Mx33*Vx3) SAR (sf*12)
[IR1,IR2,IR3] = [MAC1,MAC2,MAC3]

```

Multiplies a vector with either the rotation matrix, the light matrix or the color matrix and then adds the translation vector or background color vector.

The GTE also allows selection of the far color vector (FC), but this vector is not added correctly by the hardware: The return values are reduced to the last portion of the formula, ie. $MAC1=(Mx13*Vx3)$ SAR (sf*12), and similar for MAC2 and MAC3, nevertheless, some bits in the FLAG register seem to be adjusted as if the full operation would have been executed. Setting Mx=3 selects a garbage matrix (with elements -60h, +60h, IR0, RT13, RT13, RT13, RT22, RT22, RT22).

COP2 0A00428h+sf*80000h - 5 Cycles - SQR(sf) - Square vector

```

[MAC1,MAC2,MAC3] = [IR1*IR1,IR2*IR2,IR3*IR3] SHR (sf*12)
[IR1,IR2,IR3]     = [MAC1,MAC2,MAC3]           ;IR1,IR2,IR3 saturated to max 7FFFh

```

Calculates the square of a vector. The result is, of course, always positive, so the "Im" flag for negative saturation has no effect.

COP2 170000Ch+sf*80000h - 6 Cycles - OP(sf,Im) - Outer product of 2 vectors

```

[MAC1,MAC2,MAC3] = [IR3*D2-IR2*D3, IR1*D3-IR3*D1, IR2*D1-IR1*D2] SAR (sf*12)
[IR1,IR2,IR3]     = [MAC1,MAC2,MAC3]           ;copy result

```

Calculates the outer product of two signed 16bit vectors. Note: D1,D2,D3 are meant to be the RT11,RT22,RT33 elements of the RT matrix "misused" as vector. Im should be usually zero.

LZCS/LZCR registers - ? Cycles - Count-Leading-Zeroes/Leading-Ones

The LZCS/LZCR registers offer a Count-Leading-Zeroes/Leading-Ones function.

5.7 GTE Color Calculation Commands

COP2 0C8041Eh - 14 Cycles - NCS - Normal color (single)

COP2 0D80420h - 30 Cycles - NCT - Normal color (triple)

COP2 108041Bh - 17 Cycles - NCCS - Normal Color Color (single vector)

COP2 118043Fh - 39 Cycles - NCCT - Normal Color Color (triple vector)

COP2 0E80413h - 19 Cycles - NCDS - Normal color depth cue (single vector)

COP2 0F80416h - 44 Cycles - NCDT - Normal color depth cue (triple vectors)

In: V0=Normal vector (for triple variants repeated with V1 and V2), BK=Background color, RGBC=Primary color/code, LLM=Light matrix, LCM=Color matrix, IR0=Interpolation value.

```
[IR1,IR2,IR3] = [MAC1,MAC2,MAC3] = (LLM*V0) SAR (sf*12)
[IR1,IR2,IR3] = [MAC1,MAC2,MAC3] = (BK*1000h + LCM*IR) SAR (sf*12)
[MAC1,MAC2,MAC3] = [R*IR1,G*IR2,B*IR3] SHL 4 ;<--- for NCDx/NCCx
[MAC1,MAC2,MAC3] = MAC+ (FC-MAC)*IR0 ;<--- for NCDx only
[MAC1,MAC2,MAC3] = [MAC1,MAC2,MAC3] SAR (sf*12) ;<--- for NCDx/NCCx
Color FIFO = [MAC1/16,MAC2/16,MAC3/16,CODE], [IR1,IR2,IR3] = [MAC1,MAC2,MAC3]
```

COP2 138041Ch - 11 Cycles - CC(lm=1) - Color Color

COP2 1280414h - 13 Cycles - CDP(...) - Color Depth Que

In: [IR1,IR2,IR3]=Vector, RGBC=Primary color/code, LCM=Color matrix, BK=Background color, and, for CDP, IR0=Interpolation value, FC=Far color.

```
[IR1,IR2,IR3] = [MAC1,MAC2,MAC3] = (BK*1000h + LCM*IR) SAR (sf*12)
[MAC1,MAC2,MAC3] = [R*IR1,G*IR2,B*IR3] SHL 4 ;<--- for CDP only
[MAC1,MAC2,MAC3] = MAC+ (FC-MAC)*IR0
[MAC1,MAC2,MAC3] = [MAC1,MAC2,MAC3] SAR (sf*12)
Color FIFO = [MAC1/16,MAC2/16,MAC3/16,CODE], [IR1,IR2,IR3] = [MAC1,MAC2,MAC3]
```

COP2 0680029h - 8 Cycles - DCPL - Depth Cue Color light**COP2 0780010h - 8 Cycles - DPCS - Depth Cueing (single)****COP2 0x8002Ah - 17 Cycles - DPCT - Depth Cueing (triple)****COP2 0980011h - 8 Cycles - INTPL - Interpolation of a vector and far color**

In: [IR1,IR2,IR3]=Vector, FC=Far Color, IRO=Interpolation value, CODE=MSB of RGBC, and, for DCPL, R,G,B=LSBs of RGBC.

```
[MAC1,MAC2,MAC3] = [R*IR1,G*IR2,B*IR3] SHL 4 ;<--- for DCPL only
[MAC1,MAC2,MAC3] = [IR1,IR2,IR3] SHL 12 ;<--- for INTPL only
[MAC1,MAC2,MAC3] = [R,G,B] SHL 16 ;<--- for DPCS/DPCT
[MAC1,MAC2,MAC3] = MAC+ (FC-MAC)*IRO
[MAC1,MAC2,MAC3] = [MAC1,MAC2,MAC3] SAR (sf*12)
Color FIFO = [MAC1/16,MAC2/16,MAC3/16,CODE], [IR1,IR2,IR3] = [MAC1,MAC2,MAC3]
```

DPCT executes thrice, and reads the R,G,B values from RGB0 (ie. reads from the Bottom of the Color FIFO, instead of from the RGBC register) (the CODE value is kept read from RGBC as usually), so, after DPCT execution, the RGB0,RGB1,RGB2 Fifo entries are modified.

COP2 190003Dh - 5 Cycles - GPF(sf,lm) - General purpose Interpolation**COP2 1A0003Eh - 5 Cycles - GPL(sf,?) - General Interpolation with base**

```
[MAC1,MAC2,MAC3] = [0,0,0] ;<--- for GPF only
[MAC1,MAC2,MAC3] = [MAC1,MAC2,MAC3] SHL (sf*12) ;<--- for GPL only
[MAC1,MAC2,MAC3] = (([IR1,IR2,IR3] * IRO) + [MAC1,MAC2,MAC3]) SAR (sf*12)
Color FIFO = [MAC1/16,MAC2/16,MAC3/16,CODE], [IR1,IR2,IR3] = [MAC1,MAC2,MAC3]
```

Note: Although the SHL in GPL is theoretically undone by the SAR, 44bit overflows can occur internally when sf=1.

Details on "MAC+(FC-MAC)*IRO"

```
[IR1,IR2,IR3] = (([RFC,GFC,BFC] SHL 12) - [MAC1,MAC2,MAC3]) SAR (sf*12)
[MAC1,MAC2,MAC3] = (([IR1,IR2,IR3] * IRO) + [MAC1,MAC2,MAC3])
```

Note: Above "[IR1,IR2,IR3]=(FC-MAC)" is saturated to -8000h..+7FFFh (ie. as if Im=0), anyways, further writes to [IR1,IR2,IR3] (within the same command) are saturated as usually (ie. depening on Im setting).

Details on "(LLM*V0) SAR (sf*12)" and "(BK*1000h + LCM*IR) SAR (sf*12)"

Works like MVMVA command (see there), but with fixed Tx/Vx/Mx parameters, the sf/Im bits can be changed and do affect the results (although normally both bits should be set for use with color matrices).

Notes

The 8bit RGB values written to the top of Color Fifo are the 32bit MACn values divided by 16, and saturated to +00h..+FFh, and of course, the older Fifo entries are moved downwards. Note that, at the GPU side, the meaning of the RGB values depends on whether or not texture blending is used (for untextured polygons FFh is max brightness) (for texture blending FFh is double brightness and 80h is normal brightness).

The 8bit CODE value is intended to contain a GP0(20h..7Fh) Rendering command, allowing to automatically merge the 8bit command number, with the 24bit color value.

The IRGB/ORGB registers allow to convert between 48bit and 15bit RGB colors.

Although the result of the commands in this chapter is written to the Color FIFO, some commands like GPF/GPL may be also used for other purposes (eg. to scale or scale/translate single vertices).

5.8 GTE Division Inaccuracy

GTE Division Inaccuracy (for RTPS/RTPT commands)

Basically, the GTE division does (attempt to) work as so (using 33bit maths):

```
n = ((H*20000h/SZ3)+1)/2
```

alternatly, below would give (almost) the same result (using 32bit maths):

```
n = ((H*10000h+SZ3/2)/SZ3)
```

in both cases, the result is saturated about as so:

```
if n>1FFFFh or division_by_zero then n=1FFFFh, FLAG.Bit17=1, FLAG.Bit31=1
```

However, the real GTE hardware is using a fast, but less accurate division mechanism (based on Unsigned Newton-Raphson (UNR) algorithm):

```

if (H < SZ3*2) then ;check if overflow
    z = count_leading_zeroes(SZ3) ;z=0..0Fh (for 16bit SZ3)
    n = (H SHL z) ;n=0..7FFF8000h
    d = (SZ3 SHL z) ;d=8000h..FFFFh
    u = unr_table[(d-7FC0h) SHR 7] + 101h ;u=200h..101h
    d = ((2000080h - (d * u)) SHR 8) ;d=10000h..0FF01h
    d = ((0000080h + (d * u)) SHR 8) ;d=20000h..10000h
    n = min(1FFFFh, (((n*d) + 8000h) SHR 16)) ;n=0..1FFFFh
else n = 1FFFFh, FLAG.Bit17=1, FLAG.Bit31=1 ;n=1FFFFh plus overflow flag

```

the GTE's unr_table[000h..100h] consists of following values:

```

FFh, FDh, FBh, F9h, F7h, F5h, F3h, F1h, EFh, EEh, ECh, EAh, E8h, E6h, E4h, E3h ; \
E1h, DFh, DDh, DCh, DAh, D8h, D6h, D5h, D3h, D1h, D0h, CEh, CDh, CBh, C9h, C8h ; 00h..3Fh
C6h, C5h, C3h, C1h, C0h, BEh, BDh, BBh, BAh, B8h, B7h, B5h, B4h, B2h, B1h, B0h ;
AEh, ADh, ABh, AAh, A9h, A7h, A6h, A4h, A3h, A2h, A0h, 9Fh, 9Eh, 9Ch, 9Bh, 9Ah ;/
99h, 97h, 96h, 95h, 94h, 92h, 91h, 90h, 8Fh, 8Dh, 8Ch, 8Bh, 8Ah, 89h, 87h, 86h ;\
85h, 84h, 83h, 82h, 81h, 7Fh, 7Eh, 7Dh, 7Ch, 7Bh, 7Ah, 79h, 78h, 77h, 75h, 74h ; 40h..7Fh
73h, 72h, 71h, 70h, 6Fh, 6Eh, 6Dh, 6Ch, 6Bh, 6Ah, 69h, 68h, 67h, 66h, 65h, 64h ;
63h, 62h, 61h, 60h, 5Fh, 5Eh, 5Dh, 5Ch, 5Bh, 5Ah, 59h, 58h, 57h, 56h, 55h ;/
54h, 53h, 53h, 52h, 51h, 50h, 4Fh, 4Eh, 4Dh, 4Ch, 4Bh, 4Ah, 49h, 48h, 48h ;\
47h, 46h, 45h, 44h, 43h, 43h, 42h, 41h, 40h, 3Fh, 3Fh, 3Eh, 3Dh, 3Ch, 3Ch, 3Bh ; 80h..BFh
3Ah, 39h, 39h, 38h, 37h, 36h, 36h, 35h, 34h, 33h, 33h, 32h, 31h, 31h, 30h, 2Fh ;
2Eh, 2Eh, 2Dh, 2Ch, 2Ch, 2Bh, 2Ah, 2Ah, 29h, 28h, 28h, 27h, 26h, 26h, 25h, 24h ;/
24h, 23h, 22h, 22h, 21h, 20h, 20h, 1Fh, 1Eh, 1Eh, 1Dh, 1Dh, 1Ch, 1Bh, 1Bh, 1Ah ;\
19h, 19h, 18h, 18h, 17h, 16h, 16h, 15h, 15h, 14h, 14h, 13h, 12h, 12h, 11h, 11h ; C0h..FFh
10h, 0Fh, 0Fh, 0Eh, 0Eh, 0Dh, 0Dh, 0Ch, 0Ch, 0Bh, 0Ah, 0Ah, 09h, 09h, 08h, 08h ;
07h, 07h, 06h, 06h, 05h, 05h, 04h, 04h, 03h, 03h, 02h, 02h, 01h, 01h, 00h, 00h ;/
00h ;<-- one extra table entry (for "(d-7FC0h)/80h"=100h) ;-100h

```

Above can be generated as "unr_table[i]=min(0,(40000h/(i+100h)+1)/2-101h)". Some special cases: NNNNh/0001h uses a big multiplier (d=20000h), in practice, this can occur only for 0000h/0001h and 0001h/0001h (due to the H<SZ3*2 overflow check). The min(1FFFFh) limit is needed for cases like FE3Fh/7F20h, F015h/780Bh, etc. (these do produce UNR result 20000h, and are saturated to 1FFFFh, but without setting overflow FLAG bits).

6. Macroblock Decoder (MDEC)

The MDEC is a JPEG-style Macroblock Decoder, that can decompress pictures (or a series of pictures, for being displayed as a movie).

[MDEC I/O Ports](#)

[MDEC Commands](#)

[MDEC Decompression](#)

[MDEC Data Format](#)

6.1 MDEC I/O Ports

1F801820h - MDEC0 - MDEC Command/Parameter Register (W)

31-0 Command or Parameters

Used to send command word, followed by parameter words to the MDEC (usually, only the command word is written to this register, and the parameter words are transferred via DMA0).

1F801820h.Read - MDEC Data/Response Register (R)

31-0 Macroblock Data (or Garbage if there's no data available)

The data is always output as a 8x8 pixel bitmap, so, when manually reading from this register and using colored 16x16 pixel macroblocks, the data from four 8x8 blocks must be re-ordered accordingly (usually, the data is received via DMA1, which is doing the re-ordering automatically). For monochrome 8x8 macroblocks, no re-ordering is needed (that works with DMA1 too).

1F801824h - MDEC1 - MDEC Status Register (R)

31	Data-Out Fifo Empty (0=No, 1=Empty)
30	Data-In Fifo Full (0=No, 1=Full, or Last word received)
29	Command Busy (0=Ready, 1=Busy receiving or processing parameters)
28	Data-In Request (set when DMA0 enabled and ready to receive data)
27	Data-Out Request (set when DMA1 enabled and ready to send data)
26-25	Data Output Depth (0=4bit, 1=8bit, 2=24bit, 3=15bit) ;CMD.28-27

```

24  Data Output Signed (0=Unsigned, 1=Signed) ;CMD.26
23  Data Output Bit15 (0=Clear, 1=Set) (for 15bit depth only) ;CMD.25
22-19 Not used (seems to be always zero)
18-16 Current Block (0..3=Y1..Y4, 4=Cr, 5=Cb) (or for mono: always 4=Y)
15-0 Number of Parameter Words remaining minus 1 (FFFFh=None) ;CMD.Bit0-15

```

If there's data in the output fifo, then the Current Block bits are always set to the current output block number (ie. Y1..Y4; or Y for mono) (this information is apparently passed to the DMA1 controller, so that it knows if and how it must re-order the data in RAM). If the output fifo is empty, then the bits indicate the currently processed incoming block (ie. Cr,Cb,Y1..Y4; or Y for mono).

1F801824h - MDEC1 - MDEC Control/Reset Register (W)

```

31  Reset MDEC (0=No change, 1=Abort any command, and set status=80040000h)
30  Enable Data-In Request (0=Disable, 1=Enable DMA0 and Status.bit28)
29  Enable Data-Out Request (0=Disable, 1=Enable DMA1 and Status.bit27)
28-0 Unknown/Not used - usually zero

```

The data requests are required to be enabled for using DMA (and for reading the request status flags by software). The Data-Out request acts a bit strange: It gets set when a block is available, but, it gets cleared after reading the first some words of that block (nethertheless, one can keep reading the whole block, until the fifo-empty flag gets set).

DMA

MDEC decompression uses a lot of DMA channels,

- 1) DMA3 (CDROM) to send compressed data from CDROM to RAM
- 2) DMA0 (MDEC.In) to send compressed data from RAM to MDEC
- 3) DMA1 (MDEC.Out) to send uncompressed macroblocks from MDEC to RAM
- 4) DMA2 (GPU) to send uncompressed macroblocks from RAM to GPU

DMA0 and DMA1 should be usually used with a blocksize of 20h words. If necessary, the parameters for the MDEC(1) command should be padded with FE00h halfwords to match the 20h words (40h halfwords) DMA blocksize.

6.2 MDEC Commands

MDEC(1) - Decode Macroblock(s)

```

31-29 Command (1=decode_macroblock)
28-27 Data Output Depth (0=4bit, 1=8bit, 2=24bit, 3=15bit) ;STAT.26-25
26     Data Output Signed (0=Unsigned, 1=Signed)           ;STAT.24
25     Data Output Bit15 (0=Clear, 1=Set) (for 15bit depth only) ;STAT.23
24-16 Not used (should be zero)
15-0  Number of Parameter Words (size of compressed data)

```

This command is followed by one or more Macroblock parameters (usually, all macroblocks for the whole image are sent at once).

MDEC(2) - Set Quant Table(s)

```

31-29 Command (2=set_iqtab)
28-1  Not used (should be zero) ;Bit25-28 are copied to STAT.23-26 though
0      Color    (0=Luminance only, 1=Luminance and Color)

```

The command word is followed by 64 unsigned parameter bytes for the Luminance Quant Table (used for Y1..Y4), and if Command.Bit0 was set, by another 64 unsigned parameter bytes for the Color Quant Table (used for Cb and Cr).

MDEC(3) - Set Scale Table

```

31-29 Command (3=set_scale)
28-0  Not used (should be zero) ;Bit25-28 are copied to STAT.23-26 though

```

The command is followed by 64 signed halfwords with 14bit fractional part, the values should be usually/always the same values (based on the standard JPEG constants, although, MDEC(3) allows to use other values than that constants).

MDEC(0) - No function

This command has no function. Command bits 25-28 are reflected to Status bits 23-26 as usually. Command bits 0-15 are reflected to Status bits 0-15 (similar as the "number of parameter words" for MDEC(1), but without the "minus 1" effect, and without actually expecting any parameters).

MDEC(4..7) - Invalid

These commands act identical as MDEC(0).

6.3 MDEC Decompression

decode_colored_macroblock ;MDEC(1) command (at 15bpp or 24bpp depth)

```

rl_decode_block(Crblk,src,iq_uv)           ;Cr (low resolution)
rl_decode_block(Cbblk,src,iq_uv)           ;Cb (low resolution)
rl_decode_block(Yblk,src,iq_y), yuv_to_rgb(0,0) ;Y1 (and upper-left Cr,Cb)
rl_decode_block(Yblk,src,iq_y), yuv_to_rgb(0,8) ;Y2 (and upper-right Cr,Cb)
rl_decode_block(Yblk,src,iq_y), yuv_to_rgb(8,0) ;Y3 (and lower-left Cr,Cb)
rl_decode_block(Yblk,src,iq_y), yuv_to_rgb(8,8) ;Y4 (and lower-right Cr,Cb)

```

decode_monochrome_macroblock ;MDEC(1) command (at 4bpp or 8bpp depth)

```

rl_decode_block(Yblk,src,iq_y), y_to_mono      ;Y

```

rl_decode_block(blk,src,qt)

```

for i=0 to 63, blk[i]=0, next i   ;initially zerofill all entries (for skip)
@@skip:
n=[src], src=src+2, k=0          ;get first entry, init dest addr k=0
if n=FE00h then @@skip          ;ignore padding (FE00h as first halfword)
q_scale=(n SHR 10) AND 3Fh       ;contains scale value (not "skip" value)
val=signed10bit(n AND 3FFh)*qt[k] ;calc first value (without q_scale/8) (?)
@@lop:
if q_scale=0 then val=signed10bit(n AND 3FFh)*2    ;special mode without qt[k]
val=minmax(val,-400h,+3FFh)        ;saturate to signed 11bit range
val=val*scalezag[i]               ;<-- for "fast_idct_core" only
if q_scale>0 then blk[zagzig[k]]=val   ;store entry (normal case)
if q_scale=0 then blk[k]=val       ;store entry (special, no zigzag)
n=[src], src=src+2                ;get next entry (or FE00h end code)
k=k+((n SHR 10) AND 3Fh)+1       ;skip zero-filled entries
val=(signed10bit(n AND 3FFh)*qt[k]*q_scale+4)/8 ;calc value for next entry
if k<=63 then jump @@lop         ;should end with n=FE00h (that sets k>63)
idct_core(blk)
return (with "src" address advanced)

```

fast_idct_core(blk) ;fast "idct_core" version

Fast code with only 80 multiplications, works only if the scaletable from MDEC(3) command contains standard values (which is the case for all known PSX games).

```

src=blk, dst=temp_buffer
for pass=0 to 1
    for i=0 to 7
        if src[(1..7)*8+i]=0 then      ;when src[(1..7)*8+i] are all zero:
            dst[i*8+(0..7)]=src[0*8+i] ;quick fill by src[0*8+i]
        else
            z10=src[0*8+i]+src[4*8+i], z11=src[0*8+i]-src[4*8+i]
            z13=src[2*8+i]+src[6*8+i], z12=src[2*8+i]-src[6*8+i]
            z12=(1.414213562*z12)-z13      ;=sqrt(2)
            tmp0=z10+z13, tmp3=z10-z13, tmp1=z11+z12, tmp2=z11-z12
            z13=src[3*8+i]+src[5*8+i], z10=src[3*8+i]-src[5*8+i]
            z11=src[1*8+i]+src[7*8+i], z12=src[1*8+i]-src[7*8+i]
            z5 =(1.847759065*(z12-z10))      ;=sqrt(2)*scalefactor[2]
            tmp7=z11+z13
            tmp6=(2.613125930*(z10))+z5-tmp7 ;=scalefactor[2]*2
            tmp5=(1.414213562*(z11-z13))-tmp6 ;=sqrt(2)
            tmp4=(1.082392200*(z12))-z5+tmp5 ;=sqrt(2)/scalefactor[2]
            dst[i*8+0]=tmp0+tmp7, dst[i*8+7]=tmp0-tmp7
            dst[i*8+1]=tmp1+tmp6, dst[i*8+6]=tmp1-tmp6
            dst[i*8+2]=tmp2+tmp5, dst[i*8+5]=tmp2-tmp5
            dst[i*8+4]=tmp3+tmp4, dst[i*8+3]=tmp3-tmp4
        endif
    next i
    swap(src,dst)
next pass

```

real_idct_core(blk) ;low level "idct_core" version

Low level code with 1024 multiplications, using the scaletable from the MDEC(3) command. Computes dst=src*scaletable (using normal matrix maths, but with "src" being diagonally mirrored, ie. the matrices are processed column by column, instead of row by column), repeated with src/dst exchanged.

```

src=blk, dst=temp_buffer
for pass=0 to 1
    for x=0 to 7
        for y=0 to 7
            sum=0
            for z=0 to 7
                sum=sum+src[y+z*8]*(scaletable[x+z*8]/8)
            next z
            dst[x+y*8]=(sum+0ffffh)/2000h           ;<-- or so?
        next y
    next x

```

```
swap(src,dst)
next pass
```

The "(sum+0fffh)/2000h" part is meant to strip fractional bits, and to round-up the result if the fraction was BIGGER than 0.5. The hardware appears to be working roughly like that, still the results aren't perfect.

Maybe the real hardware is doing further roundings in other places, possibly stripping some fractional bits before summing up "sum", possibly stripping different amounts of bits in the two "pass" cycles, and possibly keeping a final fraction passed on to the y_to_mono stage.

yuv_to_rgb(xx,yy)

```
for y=0 to 7
  for x=0 to 7
    R=[Crblk+((x+xx)/2)+((y+yy)/2)*8], B=[Cblk+((x+xx)/2)+((y+yy)/2)*8]
    G=(-0.3437*B)+(-0.7143*R), R=(1.402*R), B=(1.772*B)
    Y=[Yblk+(x)+(y)*8]
    R=MinMax(-128,127,(Y+R))
    G=MinMax(-128,127,(Y+G))
    B=MinMax(-128,127,(Y+B))
    if unsigned then BGR=BGR xor 808080h ;aka add 128 to the R,G,B values
    dst[(x+xx)+(y+yy)*16]=BGR
  next x
next y
```

Note: The exact fixed point resolution for "yuv_to_rgb" is unknown. And, there's probably also some 9bit limit (similar as in "y_to_mono").

y_to_mono

```
for i=0 to 63
  Y=[Yblk+i]
  Y=Y AND 1FFh ;clip to signed 9bit range
  Y=MinMax(-128,127,Y) ;saturate from 9bit to signed 8bit range
  if unsigned then Y=Y xor 80h ;aka add 128 to the Y value
  dst[i]=Y
next i
```

set_iqtab ;MDEC(2) command

```
iqtab_core(iq_y,src), src=src+64 ;luminance quant table
if command_word.bit0=1
  iqtab_core(iq_uv,src), src=src+64 ;color quant table (optional)
endif
```

iqtab_core(iq,src) ;src = 64 unsigned parameter bytes

```
for i=0 to 63, iq[i]=src[i], next i
```

Note: For "fast_idct_core" one could precalc "iq[i]=src[i]*scalezag[i]", but that would conflict with the RLE saturation/rounding steps (though those steps aren't actually required, so a very-fast decoder could omit them).

scalefactor[0..7] = cos((0..7)*90'/8) ;for [1..7]: multiplied by sqrt(2)

```
1.000000000, 1.387039845, 1.306562965, 1.175875602,
1.000000000, 0.785694958, 0.541196100, 0.275899379
```

zigzag[0..63] =

```
0 ,1 ,5 ,6 ,14,15,27,28,
2 ,4 ,7 ,13,16,26,29,42,
3 ,8 ,12,17,25,30,41,43,
9 ,11,18,24,31,40,44,53,
10,19,23,32,39,45,52,54,
20,22,33,38,46,51,55,60,
21,34,37,47,50,56,59,61,
35,36,48,49,57,58,62,63
```

scalezag[0..63] (precalculated factors, for "fast_idct_core")

```
for y=0 to 7
  for x=0 to 7
    scalezag[zigzag[x+y*8]] = scalefactor[x] * scalefactor[y] / 8
  next x
next y
```

zagzig[0..63] (reversed zigzag table)

```
for i=0 to 63, zagzig[zigzag[i]]=i, next i
```

set_scale_table: ;MDEC(3) command

This command defines the IDCT scale matrix, which should be usually/always:

```
5A82 5A82 5A82 5A82 5A82 5A82 5A82 5A82
7D8A 6A6D 471C 18F8 E707 B8E3 9592 8275
7641 30FB CF04 89BE 89BE CF04 30FB 7641
```

```
6A6D E707 8275 B8E3 471C 7D8A 18F8 9592
5A82 A57D A57D 5A82 5A82 A57D A57D 5A82
471C 8275 18F8 6A6D 9592 E707 7D8A B8E3
30FB 89BE 7641 CF04 CF04 7641 89BE 30FB
18F8 B8E3 6A6D 8275 7D8A 9592 471C E707
```

Note that the hardware does actually use only the upper 13bit of those 16bit values. The values are chosen like so,

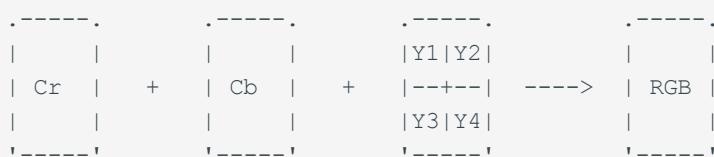
```
+s0 +s0 +s0 +s0 +s0 +s0 +s0 +s0
+s1 +s3 +s5 +s7 -s7 -s5 -s3 -s1
+s2 +s6 -s6 -s2 -s2 -s6 +s6 +s2
+s3 -s7 -s1 -s5 +s5 +s1 +s7 -s3
+s4 -s4 -s4 +s4 +s4 -s4 -s4 +s4
+s5 -s1 +s7 +s3 -s3 -s7 +s1 -s5
+s6 -s2 +s2 -s6 -s6 +s2 -s2 +s6
+s7 -s5 +s3 -s1 +s1 -s3 +s5 -s7
```

whereas, $s0..s7 = \text{scalefactor}[0..7]$, multiplied by $\sqrt{2}$ (ie. by 1.414), and multiplied by 4000h (ie. with 14bit fractional part).

6.4 MDEC Data Format

Colored Macroblocks (16x16 pixels) (in 15bpp or 24bpp depth mode)

Each macroblock consists of six blocks: Two low-resolution blocks with color information (Cr,Cb) and four full-resolution blocks with luminance (grayscale) information (Y1,Y2,Y3,Y4). The color blocks are zoomed from 8x8 to 16x16 pixel size, merged with the luminance blocks, and then converted from YUV to RGB format.



Native PSX files are usually containing vertically arranged Macroblocks (eg. allowing to send them to the GPU as 16x240 portion) (JPEG-style horizontally arranged Macroblocks would require to send the data in 16x16 pixel portions to the GPU) (something like 320x16 won't work, since that'd require to wrap from the bottom of the first macroblock to the top of the next macroblock).

Monochrome Macroblocks (8x8 pixel) (in 4bpp or 8bpp depth mode)

Each macroblock consist of only one block: with luminance (grayscale) information (Y), the data comes out as such (it isn't converted to RGB).

```
.--.      .--.  
| Y |  ----> | Y |  
'--'      '--'
```

The output is an 8x8 bitmap (not 16x16), so it'd be send to the GPU as 8x8 pixel rectangle, or multiple blocks at once as 8x240 pixel rectangle. Since the data isn't RGB, it should be written to Texture memory (and then it can be forwarded to the frame buffer in form of a texture with monochrome 15bit palette with 32 grayscales). Alternately, one could convert the 8bpp image to 24bpp by software (this would allow to use 256 grayscales).

Blocks (8x8 pixels)

An (uncompressed) block consists of 64 values, representing 8x8 pixels. The first (upper-left) value is an absolute value (called "DC" value), the remaining 63 values are relative to the DC value (called "AC" values). After decompression and zig-zag reordering, the data is unfiltered horizontally and vertically (IDCT conversion, ie. the relative "AC" values are converted to absolute "DC" values).

.STR Files

PSX Video files are usually having file extension .STR (for "Streaming").

MDEC vs JPEG

The MDEC data format is very similar to the JPEG file format, the main difference is that JPEG uses Huffman compressed blocks, whilst MDEC uses Run-Length (RL) compressed blocks.

The (uncompressed) blocks are same as in JPEGs, using the same zigzag ordering, AC to DC conversion, and YUV to RGB conversion (ie. the MDEC hardware can be also used to decompress JPEGs, when handling the file header and huffman decompression by software).

Some other differences are that MDEC has only 2 fixed-purpose quant tables, whilst JPEGs \<can> use up to 4 general-purpose quant tables. Also, JPEGs \<can> use other color resolutions than the 8x8 color info for 16x16 pixels. Whereas, JPEGs \<can> do

that stuff, but most standard JPEG files aren't actually using 4 quant tables, nor higher color resolution.

Run-Length compressed Blocks

Within each block the DCT information and RLE compressed data is stored:

```
DCT           ;1 halfword
RLE, RLE, RLE, etc. ;0..63 halfwords
EOB           ;1 halfword
```

DCT (1st value)

DCT data has the quantization factor and the Direct Current (DC) reference.

```
15-10 Q    Quantization factor (6 bits, unsigned)
9-0   DC    Direct Current reference (10 bits, signed)
```

Contains the absolute DC value (the upper-left value of the 8x8 block).

RLE (Run length data, for 2nd through 64th value)

```
15-10 LEN  Number of zero AC values to be inserted (6 bits, unsigned)
9-0   AC    Relative AC value (10 bits, signed)
```

Example: AC values "000h,000h,123h" would be compressed as "(2 shl 10)+123h".

EOB (End Of Block)

Indicates the end of a 8x8 pixel block, causing the rest of the block to be padded with zero AC values.

```
15-0 End-code (Fixed, FE00h)
```

EOB isn't required if the block was already fully defined (up to including blk[63]), however, most games seem to append EOB to all blocks (although it's just acting as dummy/padding value in case of fully defined blocks).

Dummy halfwords

Data is sent in units of words (or, when using DMA, even in units of 32-words), which is making it necessary to send some dummy halfwords (unless the compressed data size

should match up the transfer unit). The value FE00h can be used as dummy value: When FE00h appears at the begin of a new block, or after the end of block, then it is simply ignored by the hardware (if it occurs elsewhere, then it acts as EOB end code, as described above).

7. Sound Processing Unit (SPU)

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7.1 SPU Overview

SPU I/O Port Summary

```

1F801C00h..1F801D7Fh - Voice 0..23 Registers (eight 16bit regs per voice)
1F801D80h..1F801D87h - SPU Control (volume)
1F801D88h..1F801D9Fh - Voice 0..23 Flags (six 1bit flags per voice)
1F801DA2h..1F801DBFh - SPU Control (memory, control, etc.)
1F801DC0h..1F801DFFh - Reverb configuration area
1F801E00h..1F801E5Fh - Voice 0..23 Internal Registers
1F801E60h..1F801E7Fh - Unknown?
1F801E80h..1F801FFFh - Unused?

```

SPU Memory layout (512Kbyte RAM)

```

00000h-003FFh CD Audio left (1Kbyte) ;\CD Audio before Volume processing
00400h-007FFh CD Audio right (1Kbyte) ;/signed 16bit samples at 44.1kHz
00800h-00BFFh Voice 1 mono (1Kbyte) ;\Voice 1 and 3 after ADSR processing
00C00h-00FFFh Voice 3 mono (1Kbyte) ;/signed 16bit samples at 44.1kHz
01000h-xxxxxh ADPCM Samples (first 16bytes usually contain a Sine wave)
xxxxxxh-7FFFFh Reverb work area

```

As shown above, the first 4Kbytes are used as special capture buffers, and, if desired, one can also use the Reverb hardware to capture output from other voice(s).

The SPU memory is not mapped to the CPU bus, it can be accessed only via I/O, or via DMA transfers (DMA4).

Voices

The SPU has 24 hardware voices. These voices can be used to reproduce sample data, noise or can be used as frequency modulator on the next voice. Each voice has its own programmable ADSR envelope filter. The main volume can be programmed independently for left and right output.

Voice Capabilities

All 24 voices are having exactly the same capabilities(?), with the exception that Voice 1 and 3 are having a special Capture feature (see SPU Memory map).

There seems to be no way to produce square waves (without storing a square waveform in memory... although, since SPU RAM isn't connected to the CPU bus, the "useless" DMA for square wave data wouldn't slowdown the CPU bus)?

Additional Sound Inputs

External Audio can be input (from the Expansion Port?), and the CDROM drive can be commanded to playback normal Audio CDs (via Play command), or XA-ADPCM sectors (via Read command), and to pass that data to the SPU.

Unstable and Delayed I/O

The SPU occasionally seems to "miss" I/O writes (not sure if that can be fixed by any Memory Control settings?), a stable workaround is to write all values twice (except of course, Fifo writes). The SPU seems to process written values at 44100Hz rate (so it may take 1/44100 seconds (300h clock cycles) until it has actually realized the new value).

Mono/Stereo Audio Output

The standard PSX Audio cables have separate Left/Right signals, that is good for stereo TVs, but, when using a normal mono TV, only one of the two audio signals (Left or Right) can be connected. PSX programs should thus offer an option to disable stereo effects, and to output an equal volume to both cables.

SPU Bus-Width

The SPU is connected to a 16bit databus. 8bit/16bit/32bit reads and 16bit/32bit writes are implemented. However, 8bit writes are NOT implemented: 8bit writes to ODD addresses are simply ignored (without causing any exceptions), 8bit writes to EVEN addresses are executed as 16bit writes (eg. "movp r1,12345678h, movb [spu_port],r1" will write 5678h instead of 78h).

7.2 SPU ADPCM Samples

The SPU supports only ADPCM compressed samples (uncompressed samples seem to be totally unsupported; leaving apart that one can write uncompressed 16bit PCM samples to the Reverb Buffer, which can be then output at 22050Hz, as long as they aren't overwritten by the hardware).

1F801C06h+N*10h - Voice 0..23 ADPCM Start Address (R/W)

This register holds the sample start address (not the current address, ie. the register doesn't increment during playback).

15-0 Startaddress of sound in Sound buffer (in 8-byte units)

Writing to this register has no effect on the currently playing voice.
The start address is copied to the current address upon Key On.

1F801C0Eh+N*10h - Voice 0..23 ADPCM Repeat Address (R/W)

If the hardware finds an ADPCM header with Loop-Start-Bit, then it copies the current address to the repeat address register.

If the hardware finds an ADPCM header with Loop-Stop-Bit, then it copies the repeat address register setting to the current address; that, \<after> playing the current ADPCM block.

15-0 Address sample loops to at end (in 8-byte units)
--

Normally, repeat works automatically via the above start/stop bits, and software doesn't need to deal with the Repeat Address Register. However, reading from it may be useful to sense if the hardware has reached a start bit, and writing may be also useful in some

cases, eg. to redirect a one-shot sample (with stop-bit, but without any start-bits) to a silent-loop located elsewhere in memory.

Sample Data (SPU-ADPCM)

Samples consist of one or more 16-byte blocks:

00h	Shift/Filter (reportedly same as for CD-XA) (see there)
01h	Flag Bits (see below)
02h	Compressed Data (LSBs=1st Sample, MSBs=2nd Sample)
03h	Compressed Data (LSBs=3rd Sample, MSBs=4th Sample)
04h	Compressed Data (LSBs=5th Sample, MSBs=6th Sample)
...	...
0Fh	Compressed Data (LSBs=27th Sample, MSBs=28th Sample)

Flag Bits (in 2nd byte of ADPCM Header)

0	Loop End (0=No change, 1=Set ENDX flag and Jump to [1F801C0Eh+N*10h])
1	Loop Repeat (0=Force Release and set ADSR Level to Zero; only if Bit0=1)
2	Loop Start (0=No change, 1=Copy current address to [1F801C0Eh+N*10h])
3-7	Unknown (usually 0)

Possible combinations for Bit0-1 are:

Code 0 = Normal	(continue at next 16-byte block)
Code 1 = End+Mute	(jump to Loop-address, set ENDX flag, Release, Env=0000h)
Code 2 = Ignored	(same as Code 0)
Code 3 = End+Repeat	(jump to Loop-address, set ENDX flag)

Looped and One-shot Samples

The Loop Start/End flags in the ADPCM Header allow to play one or more sample block(s) in a loop, that can be either all block(s) endless repeated, or only the last some block(s) of the sample.

There's no way to stop the output, so a one-shot sample must be followed by dummy block (with Loop Start/End flags both set, and all data nibbles set to zero; so that the block gets endless repeated, but doesn't produce any sound).

SPU-ADPCM vs XA-ADPCM

The PSX supports two ADPCM formats: SPU-ADPCM (as described above), and XA-ADPCM. XA-ADPCM is decompressed by the CDROM Controller, and sent directly to the sound mixer, without needing to store the data in SPU RAM, nor needing to use a Voice

channel.

The actual decompression algorithm is the same for both formats. However, the XA nibbles are arranged in different order, and XA uses 2x28 nibbles per block (instead of 2x14), XA blocks can contain mono or stereo data, XA supports only two sample rates, and, XA doesn't support looping.

7.3 SPU ADPCM Pitch

1F801C04h+N*10h - Voice 0..23 ADPCM Sample Rate (R/W) (VxPitch)

```
0-15  Sample rate (0=stop, 4000h=fastest, 4001h..FFFFh=usually same as 4000h)
```

Defines the ADPCM sample rate (1000h = 44100Hz). This register (and PMON) does affect only the ADPCM sample frequency (but not on the Noise frequency, which is defined - and shared for all voices - in the SPUCNT register).

1F801D90h - Voice 0..23 Pitch Modulation Enable Flags (PMON)

Pitch modulation allows to generate "Frequency Sweep" effects by mis-using the amplitude from channel (x-1) as pitch factor for channel (x).

```
0      Unknown... Unused?
1-23   Flags for Voice 1..23 (0=Normal, 1=Modulate by Voice 0..22)
24-31  Not used
```

For example, output a very loud 1Hz sine-wave on channel 4 (with ADSR volume 4000h, and with Left/Right volume=0; unless you actually want to output it to the speaker). Then additionally output a 2kHz sine wave on channel 5 with PMON.Bit5 set. The "2kHz" sound should then repeatedly sweep within 1kHz..3kHz range (or, for a more decent sweep in 1.8kHz..2.2kHz range, drop the ADSR volume of channel 4).

Pitch Counter

The pitch counter is adjusted at 44100Hz rate as follows:

```
Step = VxPitch          ;range +0000h..+FFFFh (0...705.6 kHz)
IF PMON.Bit(x)=1 AND (x>0) ;pitch modulation enable
  Factor = VxOUTX(x-1)    ;range -8000h..+7FFFh (prev voice amplitude)
  Factor = Factor+8000h    ;range +0000h..+FFFFh (factor = 0.00 .. 1.99)
  Step=SignExpand16to32(Step);hardware glitch on VxPitch>7FFFh, make sign
  Step = (Step * Factor) SAR 15 ;range 0..1FFFFh (glitchy if VxPitch>7FFFh)
```

```

Step=Step AND 0000FFFFh      ;hardware glitch on VxPitch>7FFFh, kill sign
IF Step>3FFFh then Step=4000h ;range +0000h..+3FFFh (0.. 176.4kHz)
Counter = Counter + Step

```

Counter.Bit12 and up indicates the current sample (within a ADPCM block). Counter.Bit3..11 are used as 8bit gaussian interpolation index.

Maximum Sound Frequency

The Mixer and DAC supports a 44.1kHz output rate (allowing to produce max 22.1kHz tones). The Reverb unit supports only half the frequency.

The pitch counter supports sample rates up to 176.4kHz. However, exceeding the 44.1kHz limit causes the hardware to skip samples (or actually: to apply incomplete interpolation on the 'skipped' samples).

VxPitch can be theoretically 0..FFFFh (max 705.6kHz), normally 4000h..FFFFh are simply clipped to max=4000h (176.4kHz). Except, 4000h..FFFFh could be used with pitch modulation (as they are multiplied by 0.00..1.99 before clipping; in practice this works only for 4000h..7FFFh; as values 8000h..FFFFh are mistaken as signed values).

4-Point Gaussian Interpolation

Interpolation is applied on the 4 most recent 16bit ADPCM samples (new,old,older,oldest), using bit4-11 of the pitch counter as 8bit interpolation index (i=00h..FFh):

```

out = ((gauss[0FFh-i] * oldest) SAR 15)
out = out + ((gauss[1FFh-i] * older) SAR 15)
out = out + ((gauss[100h+i] * old) SAR 15)
out = out + ((gauss[000h+i] * new) SAR 15)

```

The Gauss table contains the following values (in hex):

```

-001h,-001h,-001h,-001h,-001h,-001h,-001h ;\
-001h,-001h,-001h,-001h,-001h,-001h,-001h ;
0000h,0000h,0000h,0000h,0000h,0000h,0001h ;
0001h,0001h,0001h,0002h,0002h,0002h,0003h ;
0003h,0004h,0004h,0005h,0005h,0006h,0007h ;
0008h,0009h,0009h,000Ah,000Bh,000Ch,000Dh,000Eh ;
000Fh,0010h,0011h,0012h,0013h,0015h,0016h,0018h ; entry
0019h,001Bh,001Ch,001Eh,0020h,0021h,0023h,0025h ; 000h..07Fh
0027h,0029h,002Ch,002Eh,0030h,0033h,0035h,0038h ;
003Ah,003Dh,0040h,0043h,0046h,0049h,004Dh,0050h ;
0054h,0057h,005Bh,005Fh,0063h,0067h,006Bh,006Fh ;
0074h,0078h,007Dh,0082h,0087h,008Ch,0091h,0096h ;
009Ch,00A1h,00A7h,00ADh,00B3h,00BAh,00C0h,00C7h ;
00CDh,00D4h,00DBh,00E3h,00EAh,00F2h,00FAh,0101h ;

```

```

010Ah,0112h,011Bh,0123h,012Ch,0135h,013Fh,0148h ;/
0152h,015Ch,0166h,0171h,017Bh,0186h,0191h,019Ch ;/
01A8h,01B4h,01C0h,01CCh,01D9h,01E5h,01F2h,0200h ;\
020Dh,021Bh,0229h,0237h,0246h,0255h,0264h,0273h ;
0283h,0293h,02A3h,02B4h,02C4h,02D6h,02E7h,02F9h ;
030Bh,031Dh,0330h,0343h,0356h,036Ah,037Eh,0392h ;
03A7h,03BCh,03D1h,03E7h,03FCCh,0413h,042Ah,0441h ;
0458h,0470h,0488h,04A0h,04B9h,04D2h,04ECh,0506h ;
0520h,053Bh,0556h,0572h,058Eh,05AAh,05C7h,05E4h ; entry
0601h,061Fh,063Eh,065Ch,067Ch,069Bh,06BBh,06DCh ; 080h..0FFh
06FDh,071Eh,0740h,0762h,0784h,07A7h,07CBh,07EFh ;
0813h,0838h,085Dh,0883h,08A9h,08D0h,08F7h,091Eh ;
0946h,096Fh,0998h,09C1h,09EBh,0A16h,0A40h,0A6Ch ;
0A98h,0AC4h,0AF1h,0B1Eh,0B4Ch,0B7Ah,0BA9h,0BD8h ;
0C07h,0C38h,0C68h,0C99h,0CCBh,0CFDh,0D30h,0D63h ;
0D97h,0DCBh,0E00h,0E35h,0E6Bh,0EA1h,0ED7h,0F0Fh ;
0F46h,0F7Fh,0FB7h,0FF1h,102Ah,1065h,109Fh,10DBh ;
1116h,1153h,118Fh,11CDh,120Bh,1249h,1288h,12C7h ;/
1307h,1347h,1388h,13C9h,140Bh,144Dh,1490h,14D4h ;\
1517h,155Ch,15A0h,15E6h,162Ch,1672h,16B9h,1700h ;
1747h,1790h,17D8h,1821h,186Bh,18B5h,1900h,194Bh ;
1996h,19E2h,1A2Eh,1A7Bh,1AC8h,1B16h,1B64h,1BB3h ;
1C02h,1C51h,1CA1h,1CF1h,1D42h,1D93h,1DE5h,1E37h ;
1E89h,1EDCh,1F2Fh,1F82h,1FD6h,202Ah,207Fh,20D4h ;
2129h,217Fh,21D5h,222Ch,2282h,22DAh,2331h,2389h ; entry
23E1h,2439h,2492h,24EBh,2545h,259Eh,25F8h,2653h ; 100h..17Fh
26ADh,2708h,2763h,27BEh,281Ah,2876h,28D2h,292Eh ;
298Bh,29E7h,2A44h,2AA1h,2AFFh,2B5Ch,2BBAh,2C18h ;
2C76h,2CD4h,2D33h,2D91h,2DF0h,2E4Fh,2EAEh,2F0Dh ;
2F6Ch,2FCCh,302Bh,308Bh,30EAh,314Ah,31AAh,3209h ;
3269h,32C9h,3329h,3389h,33E9h,3449h,34A9h,3509h ;
3569h,35C9h,3629h,3689h,36E8h,3748h,37A8h,3807h ;
3867h,38C6h,3926h,3985h,39E4h,3A43h,3AA2h,3B00h ;
3B5Fh,3BBDh,3C1Bh,3C79h,3CD7h,3D35h,3D92h,3DEFh ;/
3E4Ch,3EA9h,3F05h,3F62h,3FB Dh,4019h,4074h,40D0h ;\
412Ah,4185h,41DFh,4239h,4292h,42EBh,4344h,439Ch ;
43F4h,444Ch,44A3h,44FAh,4550h,45A6h,45FCh,4651h ;
46A6h,46FAh,474Eh,47A1h,47F4h,4846h,4898h,48E9h ;
493Ah,498Ah,49D9h,4A29h,4A77h,4AC5h,4B13h,4B5Fh ;
4BACh,4BF7h,4C42h,4C8Dh,4CD7h,4D20h,4D68h,4DB0h ;
4DF7h,4E3Eh,4E84h,4EC9h,4F0Eh,4F52h,4F95h,4FD7h ; entry
5019h,505Ah,509Ah,50DAh,5118h,5156h,5194h,51D0h ; 180h..1FFh
520Ch,5247h,5281h,52BAh,52F3h,532Ah,5361h,5397h ;
53CCh,5401h,5434h,5467h,5499h,54CAh,54FAh,5529h ;
5558h,5585h,55B2h,55DEh,5609h,5632h,565Bh,5684h ;
56ABh,56D1h,56F6h,571Bh,573Eh,5761h,5782h,57A3h ;
57C3h,57E2h,57FFh,581Ch,5838h,5853h,586Dh,5886h ;
589Eh,58B5h,58CBh,58E0h,58F4h,5907h,5919h,592Ah ;
593Ah,5949h,5958h,5965h,5971h,597Ch,5986h,598Fh ;
5997h,599Eh,59A4h,59A9h,59ADh,59B0h,59B2h,59B3h ;/

```

The PSX table is a bit different as the SNES table: Values up to 3569h are smaller as on SNES, the remaining values are bigger as on SNES, and the width of the PSX table entries

is 4bit higher as on SNES.

The PSX table is slightly bugged: Theoretically, each four values (`gauss[000h+i]`, `gauss[0FFh-i]`, `gauss[100h+i]`, `gauss[1FFh-i]`) should sum up to `8000h`, but in practice they do sum up to `7F7Fh..7F81h` (fortunately the PSX sum doesn't exceed the `8000h` limit; meaning that the PSX interpolations won't overflow, which has been a hardware glitch on the SNES).

Waveform Examples

```
Incoming ADPCM Data ---> Interpolated Data

|---|---|---|---|---|---| . . . . Nibbles=79797979, Filter=0
|---|---|---|---|---|---| ---> / \ / \ / \ / \ HALF-volume ZIGZAG-wave
|---|---|---|---|---|---| . . . .

|---|---|---|---|---| . . . . Nibbles=77997799, Filter=0
|---|---|---|---|---| ---> / \ / \ FULL-volume SINE-wave
|---|---|---|---|---| . . . .

|---|---|---|---|---| . . . . Nibbles=77779999, Filter=0
|---|---|---|---|---| ---> / \ SQUARE wave (with rounded edges)
|---|---|---|---|---| . . . .

|---|---|---|---|---| . . . . Nibbles=7777CC44, Filter=0
|---|---|---|---|---| ---> / ' ' ' CUSTOM wave-form
|---|---|---|---|---| . . . .

|---|---|---|---|---| \ ! / . \ ! / Nibbles=77DE9HZK, Filter=V
|---|---|---|---|---| ---> - + - + - + - SOLAR STORM wave-form
|---|---|---|---|---| / ! \ ' / ! \ . . . .
```

7.4 SPU Volume and ADSR Generator

1F801C08h+N*10h - Voice 0..23 Attack/Decay/Sustain/Release (ADSR) (32bit)

<u>lower 16bit (at 1F801C08h+N*10h)</u>	
15	Attack Mode (0=Linear, 1=Exponential)
-	Attack Direction (Fixed, always Increase) (until Level 7FFFh)
14-10	Attack Shift (0..1Fh = Fast..Slow)
9-8	Attack Step (0..3 = "+7,+6,+5,+4")
-	Decay Mode (Fixed, always Exponential)
-	Decay Direction (Fixed, always Decrease) (until Sustain Level)
7-4	Decay Shift (0..0Fh = Fast..Slow)
-	Decay Step (Fixed, always "-8")
3-0	Sustain Level (0..0Fh) ;Level=(N+1)*800h
<u>upper 16bit (at 1F801C0Ah+N*10h)</u>	
31	Sustain Mode (0=Linear, 1=Exponential)

```

30   Sustain Direction (0=Increase, 1=Decrease) (until Key OFF flag)
29   Not used?          (should be zero)
28-24 Sustain Shift   (0..1Fh = Fast..Slow)
23-22 Sustain Step    (0..3 = "+7,+6,+5,+4" or "-8,-7,-6,-5") (inc/dec)
21   Release Mode       (0=Linear, 1=Exponential)
-     Release Direction (Fixed, always Decrease) (until Level 0000h)
20-16 Release Shift   (0..1Fh = Fast..Slow)
-     Release Step      (Fixed, always "-8")

```

The Attack phase gets started when the software sets the voice ON flag (see below), the hardware does then automatically go through Attack/Decay/Sustain, and switches from Sustain to Release when the software sets the Key OFF flag.

1F801D80h - Mainvolume left

1F801D82h - Mainvolume right

1F801C00h+N*10h - Voice 0..23 Volume Left

1F801C02h+N*10h - Voice 0..23 Volume Right

Fixed Volume Mode (when Bit15=0):

```

15   Must be zero      (0=Volume Mode)
0-14  Voice volume/2   (-4000h..+3FFFh = Volume -8000h..+7FFEh)

```

Sweep Volume Mode (when Bit15=1):

```

15   Must be set        (1=Sweep Mode)
14   Sweep Mode         (0=Linear, 1=Exponential)
13   Sweep Direction    (0=Increase, 1=Decrease)
12   Sweep Phase        (0=Positive, 1=Negative)
7-11 Not used?          (should be zero)
6-2   Sweep Shift       (0..1Fh = Fast..Slow)
1-0   Sweep Step        (0..3 = "+7,+6,+5,+4" or "-8,-7,-6,-5") (inc/dec)

```

Sweep is another Volume envelope, additionally to the ADSR volume envelope (unlike ADSR, sweep can be used for stereo effects, such like blending from left to right). Sweep starts at the current volume (which can be set via Bit15=0, however, caution - the Bit15=0 setting isn't applied until the next 44.1kHz cycle; so setting the initial level with Bit15=0, followed by the sweep parameter with Bit15=1 works only if there's a suitable delay between the two operations). Once when sweep is started, the current volume level increases to +7FFFh, or decreases to 0000h.

Sweep Phase should be equal to the sign of the current volume (not yet tested, in the

negative mode it does probably "increase" to -7FFFh?). The Phase bit seems to have no effect in Exponential Decrease mode.

1F801DB0h - CD Audio Input Volume (for normal CD-DA, and compressed XA-ADPCM)

1F801DB4h - External Audio Input Volume

```
0-15  Volume Left   (-8000h..+7FFFh)
16-31 Volume Right (-8000h..+7FFFh)
```

Note: The CDROM controller supports additional CD volume control (including ability to convert stereo CD output to mono, or to swap left/right channels).

Envelope Operation depending on Shift/Step/Mode/Direction

```
AdsrCycles = 1 SHL Max(0,ShiftValue-11)
AdsrStep = StepValue SHL Max(0,11-ShiftValue)
IF exponential AND increase AND AdsrLevel>6000h THEN AdsrCycles=AdsrCycles*4
IF exponential AND decrease THEN AdsrStep=AdsrStep*AdsrLevel/8000h
Wait(AdsrCycles)           ;cycles counted at 44.1kHz clock
AdsrLevel=AdsrLevel+AdsrStep ;saturated to 0..+7FFFh
```

Exponential Increase is a fake (simply changes to a slower linear increase rate at higher volume levels).

1F801C0Ch+N*10h - Voice 0..23 Current ADSR volume (R/W)

```
15-0  Current ADSR Volume (0..+7FFFh) (or -8000h..+7FFFh on manual write)
```

Reportedly Release can go down to -1 (FFFFh), but that isn't true; and release ends at 0... or does THAT depend on an END flag found in the sample-data?
The register is read/writeable, writing allows to let the ADSR generator to "jump" to a specific volume level. But, ACTUALLY, the ADSR generator does overwrite the setting (from another internal register) whenever applying a new Step?!

1F801DB8h - Current Main Volume Left/Right

1F801E00h+voice*04h - Voice 0..23 Current Volume Left/Right

```
0-15  Current Volume Left  (-8000h..+7FFFh)
16-31 Current Volume Right (-8000h..+7FFFh)
```

These are internal registers, normally not used by software (the Volume settings are usually set via Ports 1F801D80h and 1F801C00h+N*10h).

Note

Negative volumes are phase inverted, otherwise same as positive.

7.5 SPU Voice Flags

1F801D88h - Voice 0..23 Key ON (Start Attack/Decay/Sustain) (KON) (W)

0-23 Voice 0..23 On (0=No change, 1=Start Attack/Decay/Sustain)
24-31 Not used

Starts the ADSR Envelope, and automatically initializes ADSR Volume to zero, and copies Voice Start Address to Voice Repeat Address.

1F801D8Ch - Voice 0..23 Key OFF (Start Release) (KOFF) (W)

0-23 Voice 0..23 Off (0=No change, 1=Start Release)
24-31 Not used

For a full ADSR pattern, OFF would be usually issued in the Sustain period, however, it can be issued at any time (eg. to abort Attack, skip the Decay and Sustain periods, and switch immediately to Release).

1F801D9Ch - Voice 0..23 ON/OFF (status) (ENDX) (R)

0-23 Voice 0..23 Status (0>Newly Keyed On, 1=Reached LOOP-END)
24-31 Not used

The bits get CLEARED when setting the corresponding KEY ON bits.

The bits get SET when reaching an LOOP-END flag in ADPCM header.bit0.

R/W

Key On and Key Off should be treated as write-only (although, reading returns the most recently 32bit value, this doesn't provide any status information about whether sound is on or off).

The on/off (status) (ENDX) register should be treated read-only (writing is possible in so

far that the written value can be read-back for a short moment, however, thereafter the hardware is overwriting that value).

7.6 SPU Noise Generator

1F801D94h - Voice 0..23 Noise mode enable (NON)

```
0-23  Voice 0..23 Noise (0=ADPCM, 1=Noise)
24-31 Not used
```

SPU Noise Generator

The signed 16bit output Level is calculated as so (repeated at 44.1kHz clock):

```
Wait(1 cycle)           ;at 44.1kHz clock
Timer=Timer-NoiseStep ;subtract Step (4..7)
ParityBit = NoiseLevel.Bit15 xor Bit12 xor Bit11 xor Bit10 xor 1
IF Timer<0 then NoiseLevel = NoiseLevel*2 + ParityBit
IF Timer<0 then Timer=Timer+(20000h SHR NoiseShift) ;reload timer once
IF Timer<0 then Timer=Timer+(20000h SHR NoiseShift) ;reload again if needed
```

Note that the Noise frequency is solely controlled by the Shift/Step values in SPUCNT register (the ADPCM Sample Rate has absolutely no effect on noise), so when using noise for multiple voices, all of them are forcefully having the same frequency; the only workaround is to store a random ADPCM pattern in SPU RAM, which can be then used with any desired sample rate(s).

7.7 SPU Control and Status Register

1F801DAAh - SPU Control Register (SPUCNT)

15	SPU Enable	(0=Off, 1=On)	(Don't care for CD Audio)
14	Mute SPU	(0=Mute, 1=Unmute)	(Don't care for CD Audio)
13-10	Noise Frequency Shift	(0..0Fh = Low .. High Frequency)	
9-8	Noise Frequency Step	(0..03h = Step "4,5,6,7")	
7	Reverb Master Enable	(0=Disabled, 1=Enabled)	
6	IRQ9 Enable	(0=Disabled/Acknowledge, 1=Enabled; only when Bit15=1)	
5-4	Sound RAM Transfer Mode	(0=Stop, 1=ManualWrite, 2=DMAwrite, 3=DMAread)	
3	External Audio Reverb	(0=Off, 1=On)	
2	CD Audio Reverb	(0=Off, 1=On) (for CD-DA and XA-ADPCM)	
1	External Audio Enable	(0=Off, 1=On)	
0	CD Audio Enable	(0=Off, 1=On) (for CD-DA and XA-ADPCM)	

Changes to bit0-5 aren't applied immediately; after writing to SPUCNT, it'd be usually recommended to wait until the LSBs of SPUSTAT are updated accordingly. Before setting a new Transfer Mode, it'd be recommended first to set the "Stop" mode (and, again, wait until Stop is applied in SPUSTAT).

1F801DAEh - SPU Status Register (SPUSTAT) (R)

15-12	Unknown/Unused	(seems to be usually zero)
11	Writing to First/Second half of Capture Buffers	(0=First, 1=Second)
10	Data Transfer Busy Flag	(0=Ready, 1=Busy)
9	Data Transfer DMA Read Request	(0=No, 1=Yes)
8	Data Transfer DMA Write Request	(0=No, 1=Yes)
7	Data Transfer DMA Read/Write Request	; seems to be same as SPUCNT.Bit5
6	IRQ9 Flag	(0=No, 1=Interrupt Request)
5-0	Current SPU Mode	(same as SPUCNT.Bit5-0, but, applied a bit delayed)

When switching SPUCNT to DMA-read mode, status bit9 and bit7 aren't set immediately (apparently the SPU is first internally collecting the data in the Fifo, before transferring it). Bit11 indicates if data is currently written to the first or second half of the four 1K-byte capture buffers (for CD Audio left/right, and voice 1/3). Note: Bit11 works only if Bit2 and/or Bit3 of Port 1F801DACH are set.

The SPUSTAT register should be treated read-only (writing is possible in so far that the written value can be read-back for a short moment, however, thereafter the hardware is overwriting that value).

7.8 SPU Memory Access

1F801DA6h - Sound RAM Data Transfer Address

15-0 Address in sound buffer divided by eight

Used for manual write and DMA read/write SPU memory. Writing to this register stores the written value in 1F801DA6h, and does additional store the value (multiplied by 8) in another internal "current address" register (that internal register does increment during transfers, whilst the 1F801DA6h value DOESN'T increment).

1F801DA8h - Sound RAM Data Transfer Fifo

15-0 Data (max 32 halfwords)

Used for manual-write. Not sure if it can be also used for manual read?

1F801DACH - Sound RAM Data Transfer Control (should be 0004h)

15-4	Unknown/no effect?	(should be zero)
3-1	Sound RAM Data Transfer Type (see below)	(should be 2)
0	Unknown/no effect?	(should be zero)

The Transfer Type selects how data is forwarded from Fifo to SPU RAM:

Transfer Type	Halfwords in Fifo	Halfwords written to SPU RAM
0,1,6,7 Fill	A,B,C,D,E,F,G,H,...,X	X,X,X,X,X,X,X,X,...
2 Normal	A,B,C,D,E,F,G,H,...,X	A,B,C,D,E,F,G,H,...
3 Rep2	A,B,C,D,E,F,G,H,...,X	A,A,C,C,E,E,G,G,...
4 Rep4	A,B,C,D,E,F,G,H,...,X	A,A,A,A,E,E,E,E,...
5 Rep8	A,B,C,D,E,F,G,H,...,X	H,H,H,H,H,H,H,H,...

Rep2 skips the 2nd halfword, Rep4 skips 2nd..4th, Rep8 skips 1st..7th.

Fill uses only the LAST halfword in Fifo, that might be useful for memfill purposes, although, the length is probably determined by the number of writes to the Fifo (?) so one must still issue writes for ALL halfwords...?

Note:

The above rather bizarre results apply to WRITE mode. In READ mode, the register causes the same halfword to be read 2/4/8 times (for rep2/4/8).

SPU RAM Manual Write

- Be sure that [1F801DACH] is set to 0004h
- Set SPUCNT to "Stop" (and wait until it is applied in SPUSTAT)
- Set the transfer address
- Write 1..32 halfword(s) to the Fifo
- Set SPUCNT to "Manual Write" (and wait until it is applied in SPUSTAT)
- Wait until Transfer Busy in SPUSTAT goes off (that, AFTER above apply-wait)

For multi-block transfers: Repeat the above last three steps (that is rarely done by any games, but it is done by the BIOS intro; observe that waiting for SPUCNT writes being applied in SPUSTAT won't work in that case (since SPUCNT was already in manual write mode from previous block), so one must instead use some hardcoded delay of at least 300h cycles; the BIOS is using a much longer bizarre delay though).

SPU RAM DMA-Write

- Be sure that [1F801DACH] is set to 0004h
- Set SPUCNT to "Stop" (and wait until it is applied in SPUSTAT)
- Set the transfer address
- Set SPUCNT to "DMA Write" (and wait until it is applied in SPUSTAT)
- Start DMA4 at CPU Side (blocksize=10h, control=01000201h)
- Wait until DMA4 finishes (at CPU side)

SPU RAM Manual-Read

As by now, there's no known method for reading SPU RAM without using DMA.

SPU RAM DMA-Read (stable reading, with [1F801014h].bit24-27 = nonzero)

- Be sure that [1F801014h] is set to 220931E1h (bit24-27 MUST be nonzero)
- Be sure that [1F801DACH] is set to 0004h
- Set SPUCNT to "Stop" (and wait until it is applied in SPUSTAT)
- Set the transfer address
- Set SPUCNT to "DMA Read" (and wait until it is applied in SPUSTAT)
- Start DMA4 at CPU Side (blocksize=10h, control=01000200h)

- Wait until DMA4 finishes (at CPU side)

SPU RAM DMA-Read (unstable reading, with [1F801014h].bit24-27 = zero)

Below describes some dirt effects and some trickery to get around those dirt effects.

Below problems (and workarounds) apply ONLY if [1F801014h].bit24-27 = zero.
Ie. below info describes what happens when [1F801014h] is mis-initialized.
Normally one should set [1F801014h]=220931E1h (and can ignore below info).

With [1F801014h].bit24-27=zero, reading SPU RAM via DMA works glitchy:
The first received halfword within each block is FFFFh. So with a DMA blocksize of 10h words (=20h halfwords), the following is received:

```
1st block:    FFFFh, halfwords[00h..1Eh]
2nd block:    FFFFh, halfwords[20h..3Eh]
etc.
```

that'd theoretically match the SPU Fifo Size, but, because of the inserted FFFFh value, the last Fifo entry isn't received, ie. halfword[1Fh,3Fh] are lost. As a workaround, one can increase the DMA blocksize to 11h words, and then the following is received:

```
1st block:    FFFFh, halfwords[00h..1Eh], twice halfword[1Fh]
2nd block:    FFFFh, halfwords[20h..3Eh], twice halfword[3Fh]
etc.
```

this time, all data is received, but after the transfer one must still remove the FFFFh values, and the duplicated halfwords by software. Aside from the \<inserted> FFFFh values there are occassionaly some unstable halfwords ORed by FFFFh (or ORed by other garbage values), this can be fixed by using "rep2" mode, which does then receive:

```
1st block:    FFFFh, halfwords[00h,00h,..0Eh,0Eh], triple halfword[0Fh]
2nd block:    FFFFh, halfwords[10h,10h,..1Eh,1Eh], triple halfword[1Fh]
etc.
```

again, remove the first halfword (FFFFh) and the last halfword, and, take the duplicated halfwords ANDed together. Unstable values occur only every 32 halfwords or so (probably when the SPU is simultaneously reading ADPCM data), but do never occur on two continous halfwords, so, even if one halfword was ORed by garbage, the other halfword is always correct, and the result of the ANDed halfwords is 100% stable.

Note: The unstable reading does NOT occur always, when resetting the PSX a couple of times it does occassionally boot-up with totally stable reading, since there is no known

way to activate the stable "mode" via I/O ports, the stable/unstable behaviour does eventually depend on internal clock dividers/multipliers, and whether they are starting in sync with the CPU or not.

Caution: The "rep2" trick cannot be used in combination with reverb (reverb seems to be using the Port 1F801DACH Sound RAM Data Transfer Control, too).

7.9 SPU Interrupt

1F801DA4h - Sound RAM IRQ Address (IRQ9)

15-0 Address in sound buffer divided by eight

See also: SPUCNT (IRQ enable/disable/acknowledge) and SPUSTAT (IRQ flag).

Voice Interrupt

Triggers an IRQ when a voice reads ADPCM data from the IRQ address.

Mind that ADPCM cannot be stopped (uh, except, probably they CAN be stopped, by setting the sample rate to zero?), all voices are permanently reading data from SPU RAM - even in Noise mode, even if the Voice Volume is zero, and even if the ADSR pattern has finished the Release period - so even inaudible voices can trigger IRQs. To prevent unwanted IRQs, best set all unused voices to an endless looped dummy ADPCM block. For stable IRQs, the IRQ address should be aligned to the 16-byte ADPCM blocks. If the IRQ address is in the middle of a 16-byte ADPCM block, then the IRQ doesn't seem to trigger always (unknown why, but it seems to occasionally miss IRQs, even if the block gets repeated several times).

Capture Interrupt

Setting the IRQ address to 0000h..01FFh (aka byte address 00000h..00FFFh) will trigger IRQs on writes to the four capture buffers. Each of the four buffers contains 400h bytes (=200h samples), so the IRQ rate will be around 86.13Hz (44100Hz/200h).

CD-Audio capture is always active (even CD-Audio output is disabled in SPUCNT, and even if the drive door is open). Voice capture is (probably) also always active (even if the corresponding voice is off).

Capture IRQs do NOT occur if 1F801DACH.bit3-2 are both zero.

Reverb Interrupt

Reverb is also triggering interrupts if the IRQ address is located in the reverb buffer area. Unknown \<which> of the various reverb read(s) and/or reverb write(s) are triggering interrupts.

Data Transfers

Data Transfers (usually via DMA4) to/from SPU-RAM do also trap SPU interrupts.

Note

The IRQ Address is used in the following games (not exhaustive): Metal Gear Solid: Dialogue and Konami intro. Legend of Mana Hercules: the memory card loading screen's lip sync. Tokimeki Memorial 2 Crash Team Racing: Lip sync, requires capture buffers. The Misadventures of Tron Bonne: Dialogues. Need For Speed 3: (somewhat?).

7.10 SPU Reverb Registers

Reverb Volume and Address Registers (R/W)

Port	Reg	Name	Type	Expl.
1F801D84h	spu	vLOUT	volume	Reverb Output Volume Left
1F801D86h	spu	vROUT	volume	Reverb Output Volume Right
1F801DA2h	spu	mBASE	base	Reverb Work Area Start Address in Sound RAM
1F801DC0h	rev00	dAPF1	disp	Reverb APF Offset 1
1F801DC2h	rev01	dAPF2	disp	Reverb APF Offset 2
1F801DC4h	rev02	vIIR	volume	Reverb Reflection Volume 1
1F801DC6h	rev03	vCOMB1	volume	Reverb Comb Volume 1
1F801DC8h	rev04	vCOMB2	volume	Reverb Comb Volume 2
1F801DCAh	rev05	vCOMB3	volume	Reverb Comb Volume 3
1F801DCCh	rev06	vCOMB4	volume	Reverb Comb Volume 4
1F801DCEh	rev07	vWALL	volume	Reverb Reflection Volume 2
1F801DD0h	rev08	vAPF1	volume	Reverb APF Volume 1
1F801DD2h	rev09	vAPF2	volume	Reverb APF Volume 2
1F801DD4h	rev0A	mLSAME	src/dst	Reverb Same Side Reflection Address 1 Left
1F801DD6h	rev0B	mRSAME	src/dst	Reverb Same Side Reflection Address 1 Right
1F801DD8h	rev0C	mLCOMB1	src	Reverb Comb Address 1 Left
1F801DDAh	rev0D	mRCOMB1	src	Reverb Comb Address 1 Right
1F801DDCh	rev0E	mLCOMB2	src	Reverb Comb Address 2 Left
1F801DDEh	rev0F	mRCOMB2	src	Reverb Comb Address 2 Right
1F801DE0h	rev10	dLSAME	src	Reverb Same Side Reflection Address 2 Left
1F801DE2h	rev11	dRSAME	src	Reverb Same Side Reflection Address 2 Right
1F801DE4h	rev12	mLDIFF	src/dst	Reverb Different Side Reflect Address 1 Left
1F801DE6h	rev13	mRDIFF	src/dst	Reverb Different Side Reflect Address 1 Right
1F801DE8h	rev14	mLCOMB3	src	Reverb Comb Address 3 Left

1F801DEAh	rev15	mRCOMB3	src	Reverb Comb Address 3 Right
1F801DECh	rev16	mLCOMB4	src	Reverb Comb Address 4 Left
1F801DEEh	rev17	mRCOMB4	src	Reverb Comb Address 4 Right
1F801DF0h	rev18	dLDIFF	src	Reverb Different Side Reflect Address 2 Left
1F801DF2h	rev19	dRDIFF	src	Reverb Different Side Reflect Address 2 Right
1F801DF4h	rev1A	mLAPF1	src/dst	Reverb APF Address 1 Left
1F801DF6h	rev1B	mRAPF1	src/dst	Reverb APF Address 1 Right
1F801DF8h	rev1C	mLAPF2	src/dst	Reverb APF Address 2 Left
1F801DFAh	rev1D	mRAPF2	src/dst	Reverb APF Address 2 Right
1F801DFCh	rev1E	vLIN	volume	Reverb Input Volume Left
1F801DFEh	rev1F	vRIN	volume	Reverb Input Volume Right

All volume registers are signed 16bit (range -8000h..+7FFFh).

All src/dst/disp/base registers are addresses in SPU memory (divided by 8), src/dst are relative to the current buffer address, the disp registers are relative to src registers, the base register defines the start address of the reverb buffer (the end address is fixed, at 7FFEh). Writing a value to mBASE does additionally set the current buffer address to that value.

1F801D98h - Voice 0..23 Reverb mode aka Echo On (EON) (R/W)

0-23	Voice 0..23 Destination (0=To Mixer, 1=To Mixer and to Reverb)
24-31	Not used

Sets reverb for the channel. As soon as the sample ends, the reverb for that channel is turned off... that's fine, but WHEN does it end?

In Reverb mode, the voice seems to output BOTH normal (immediately) AND via Reverb (delayed).

Reverb Bits in SPUCNT Register (R/W)

The SPUCNT register contains a Reverb Master Enable flag, and Reverb Enable flags for External Audio input and CD Audio input.

When the Reverb Master Enable flag is cleared, the SPU stops to write any data to the Reverb buffer (that is useful when zero-filling the reverb buffer; ensuring that already-zero values aren't overwritten by still-nonzero values).

However, the Reverb Master Enable flag does not disable output from Reverb buffer to the speakers (that might be useful to output uncompressed 22050Hz samples) (otherwise, to disable the buffer output, set the Reverb Output volume to zero and/or zerofill the reverb buffer).

7.11 SPU Reverb Formula

Reverb Formula

```

____Input from Mixer (Input volume multiplied with incoming data)_____
Lin = vLIN * LeftInput ;from any channels that have Reverb enabled
Rin = vRIN * RightInput ;from any channels that have Reverb enabled
____Same Side Reflection (left-to-left and right-to-right)_____
[mLSAME] = (Lin + [dLSAME]*vWALL - [mLSAME-2])*vIIR + [mLSAME-2] ;L-to-L
[mRSAME] = (Rin + [dRSAME]*vWALL - [mRSAME-2])*vIIR + [mRSAME-2] ;R-to-R
____Different Side Reflection (left-to-right and right-to-left)_____
[mLDIFF] = (Lin + [dRDIFF]*vWALL - [mLDIFF-2])*vIIR + [mLDIFF-2] ;R-to-L
[mRDIF] = (Rin + [dLDIFF]*vWALL - [mRDIF-2])*vIIR + [mRDIF-2] ;L-to-R
____Early Echo (Comb Filter, with input from buffer)_____
Lout=vCOMB1*[mLCOMB1]+vCOMB2*[mLCOMB2]+vCOMB3*[mLCOMB3]+vCOMB4*[mLCOMB4]
Rout=vCOMB1*[mRCOMB1]+vCOMB2*[mRCOMB2]+vCOMB3*[mRCOMB3]+vCOMB4*[mRCOMB4]
____Late Reverb APF1 (All Pass Filter 1, with input from COMB)_____
Lout=Lout-vAPF1*[mLAPF1-dAPF1], [mLAPF1]=Lout, Lout=Lout*vAPF1+[mLAPF1-dAPF1]
Rout=Rout-vAPF1*[mRAPF1-dAPF1], [mRAPF1]=Rout, Rout=Rout*vAPF1+[mRAPF1-dAPF1]
____Late Reverb APF2 (All Pass Filter 2, with input from APF1)_____
Lout=Lout-vAPF2*[mLAPF2-dAPF2], [mLAPF2]=Lout, Lout=Lout*vAPF2+[mLAPF2-dAPF2]
Rout=Rout-vAPF2*[mRAPF2-dAPF2], [mRAPF2]=Rout, Rout=Rout*vAPF2+[mRAPF2-dAPF2]
____Output to Mixer (Output volume multiplied with input from APF2)_____
LeftOutput = Lout*vLOUT
RightOutput = Rout*vROUT
____Finally, before repeating the above steps_____
BufferAddress = MAX(mBASE, (BufferAddress+2) AND 7FFEh)
Wait one 22050Hz cycle, then repeat the above stuff

```

Notes

The values written to memory are saturated to -8000h..+7FFFh.

The multiplication results are divided by +8000h, to fit them to 16bit range.

All memory addresses are relative to the current BufferAddress, and wrapped within mBASE..7FFEh when exceeding that region.

All data in the Reverb buffer consists of signed 16bit samples. The Left and Right Reverb Buffer addresses should be chosen so that one half of the buffer contains Left samples, and the other half Right samples (ie. the data is L,L,L,L,... R,R,R,R,...; it is NOT interlaced like L,R,L,R,...), during operation, when the buffer address increases, the Left half will overwrite the older samples of the Right half, and vice-versa.

The reverb hardware spends one 44100h cycle on left calculations, and the next 44100h cycle on right calculations (unlike as shown in the above formula, where left/right are shown simultaneously at 22050Hz).

Reverb Disable

SPUCNT.bit7 disables writes to reverb buffer, but reads from reverb buffer do still occur. If vAPF2 is zero then it does simply read "Lout=[mLAPF2-dAPF2]" and "Rout=[mRAPF2-dAPF2]". If vAPF2 is nonzero then it does additionally use data from APF1, if vAPF1 and vAPF2 are both nonzero then it's also using data from COMB. However, the SAME/DIFF stages aren't used when reverb is disabled.

Bug

vIIR works only in range -7FFFh..+7FFFh. When set to -8000h, the multiplication by -8000h is still done correctly, but, the final result (the value written to memory) gets negated (this is a pretty strange feature, it is NOT a simple overflow bug, it does affect the "+[mLSAME-2]" addition; although that part normally shouldn't be affected by the "*vIIR" multiplication). Similar effects might (?) occur on some other volume registers when they are set to -8000h.

Speed of Sound

The speed of sound is circa 340 meters per second (in dry air, at room temperature). For example, a voice that travels to a wall at 17 meters distance, and back to its origin, should have a delay of 0.1 seconds.

7.12 SPU Reverb Examples

Reverb Examples

Below are some Reverb examples, showing the required memory size (ie. set Port 1F801DA2h to "(80000h-size)/8"), and the Reverb register settings for Port 1F801DC0h..1F801DFFh, ie. arranged like so:

```
dAPF1  dAPF2  vIIR   vCOMB1  vCOMB2  vCOMB3  vCOMB4  vWALL    ;1F801DC0h..CEh
vAPF1  vAPF2  mLSAME mRSAME mLcomb1 mLcomb1 mLcomb2 mLcomb2 ;1F801DD0h..DEh
dLSAME dRSAME mLDIFF mRDIFf mLcomb3 mLcomb3 mLcomb4 mLcomb4 ;1F801DE0h..EEh
dLDIFF dRDIFf mLAPF1 mRAPF1 mLAPF2 mRAPF2 vLIN   vRIN    ;1F801DF0h..FEh
```

Also, don't forget to initialize Port 1F801D84h, 1F801D86h, 1F801D98h, and SPUCNT, and to zerofill the Reverb Buffer (so that no garbage values are output when activating reverb). For whatever reason, one MUST also initialize Port 1F801DACH (otherwise reverb stays off).

Room (size=26C0h bytes)

```
007Dh,005Bh,6D80h,54B8h,BED0h,0000h,0000h,BA80h
5800h,5300h,04D6h,0333h,03F0h,0227h,0374h,01EFh
0334h,01B5h,0000h,0000h,0000h,0000h,0000h,0000h
0000h,0000h,01B4h,0136h,00B8h,005Ch,8000h,8000h
```

Studio Small (size=1F40h bytes)

```
0033h,0025h,70F0h,4FA8h,BCE0h,4410h,C0F0h,9C00h
5280h,4EC0h,03E4h,031Bh,03A4h,02AFh,0372h,0266h
031Ch,025Dh,025Ch,018Eh,022Fh,0135h,01D2h,00B7h
018Fh,00B5h,00B4h,0080h,004Ch,0026h,8000h,8000h
```

Studio Medium (size=4840h bytes)

```
00B1h,007Fh,70F0h,4FA8h,BCE0h,4510h,BEF0h,B4C0h
5280h,4EC0h,0904h,076Bh,0824h,065Fh,07A2h,0616h
076Ch,05EDh,05ECh,042Eh,050Fh,0305h,0462h,02B7h
042Fh,0265h,0264h,01B2h,0100h,0080h,8000h,8000h
```

Studio Large (size=6FE0h bytes)

```
00E3h,00A9h,6F60h,4FA8h,BCE0h,4510h,BEF0h,A680h
5680h,52C0h,0DFBh,0B58h,0D09h,0A3Ch,0BD9h,0973h
0B59h,08DAh,08D9h,05E9h,07ECh,04B0h,06EFh,03D2h
05EAh,031Dh,031Ch,0238h,0154h,00AAh,8000h,8000h
```

Hall (size=ADE0h bytes)

```
01A5h,0139h,6000h,5000h,4C00h,B800h,BC00h,C000h
6000h,5C00h,15BAh,11BBh,14C2h,10BDh,11BCh,0DC1h
11C0h,0DC3h,0DC0h,09C1h,0BC4h,07C1h,0A00h,06CDh
09C2h,05C1h,05C0h,041Ah,0274h,013Ah,8000h,8000h
```

Half Echo (size=3C00h bytes)

```
0017h,0013h,70F0h,4FA8h,BCE0h,4510h,BEF0h,8500h
5F80h,54C0h,0371h,02AFh,02E5h,01DFh,02B0h,01D7h
0358h,026Ah,01D6h,011Eh,012Dh,00B1h,011Fh,0059h
01A0h,00E3h,0058h,0040h,0028h,0014h,8000h,8000h
```

Space Echo (size=F6C0h bytes)

```
033Dh,0231h,7E00h,5000h,B400h,B000h,4C00h,B000h  
6000h,5400h,1ED6h,1A31h,1D14h,183Bh,1BC2h,16B2h  
1A32h,15EFh,15EEh,1055h,1334h,0F2Dh,11F6h,0C5Dh  
1056h,0AE1h,0AE0h,07A2h,0464h,0232h,8000h,8000h
```

Chaos Echo (almost infinite) (size=18040h bytes)

```
0001h,0001h,7FFFh,7FFFh,0000h,0000h,0000h,8100h  
0000h,0000h,1FFFh,0FFFh,1005h,0005h,0000h,0000h  
1005h,0005h,0000h,0000h,0000h,0000h,0000h,0000h  
0000h,0000h,1004h,1002h,0004h,0002h,8000h,8000h
```

Delay (one-shot echo) (size=18040h bytes)

```
0001h,0001h,7FFFh,7FFFh,0000h,0000h,0000h,0000h  
0000h,0000h,1FFFh,0FFFh,1005h,0005h,0000h,0000h  
1005h,0005h,0000h,0000h,0000h,0000h,0000h,0000h  
0000h,0000h,1004h,1002h,0004h,0002h,8000h,8000h
```

Reverb off (size=10h dummy bytes)

```
0000h,0000h,0000h,0000h,0000h,0000h,0000h,0000h  
0000h,0000h,0001h,0001h,0001h,0001h,0001h,0001h  
0000h,0000h,0001h,0001h,0001h,0001h,0001h,0001h  
0000h,0000h,0001h,0001h,0001h,0001h,0000h,0000h
```

Note that the memory offsets should be 0001h here (not 0000h), otherwise zerofilling the reverb buffer seems to fail (maybe because zero memory offsets somehow cause the fill-value to mixed with the old value or so; that appears even when reverb master enable is zero). Also, when not using reverb, Port 1F801D84h, 1F801D86h, 1F801D98h, and the SPUCNT reverb bits should be set to zero.

7.13 SPU Unknown Registers

1F801DA0h - Some kind of a read-only status register.. or just garbage..?

```
0-15 Unknown?
```

Usually 9D78h, occassionaly changes to 17DAh or 108Eh for a short moment.
 Other day: Usually 9CF8h, or occassionaly 9CFAh.
 Another day: Usually 0000h, or occassionaly 4000h.

1F801DBCh - 4 bytes - Unknown? (R/W)

```
80 21 4B DF
```

Other day (dots = same as above):

```
.. 31 ...
```

1F801E60h - 32 bytes - Unknown? (R/W)

```
7E 61 A9 96 47 39 F9 1E E1 E1 80 DD E8 17 7F FB
FB BF 1D 6C 8F EC F3 04 06 23 89 45 C1 6D 31 82
```

Other day (dots = same as above):

```
... . . . . . . . . . . . . . . . . . . . . . . . . 7B ...
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 86
```

The bytes at 1F801DBCh and 1F801E60h usually have the above values on cold-boot. The registers are read/write-able, although writing any values to them doesn't seem to have any effect on sound output. Also, the SPU doesn't seem to modify the registers at any time during sound output, nor reverb calculations, nor activated external audio input... the registers seem to be just some kind of general-purpose RAM.

7.14 SPU Internal State Machine from SPU RAM Timing

7.14.1 Introduction

The 33.8 Mhz clock of the PSX is a well chosen value. It is exactly 768×44.1 Khz = For each audio sample in CD quality, there are 768 cycles of system clock. So, the state machine has to repeat its complete cycle every 768 system clock cycles.

Now the full job to do within those 768 cycles: - 24 channels to process. - Reverb to compute and write back. - Write back to voice 1 / 3, audio CD L/R. - Do transfer from/to CPU bus of SPU RAM data if asked.

7.14.2 First look at the data from logic analyzer.

By looking at the signal of the SPU RAM chip, it is possible to figure out what it is reading and writing.

- A read or a write to the SPU Ram is happening in 8 clock cycles. (Did not check in detail, but probably allow refresh and everything)
- Each channel is using 24 cycles. (3 operations of 8 cycles)
- Has TWO read for the current ADPCM block : one to the header of the currently played ADPCM block, one to the current 16 bit of the ADPCM.
- A unrelated READ (see later) - 8 Cycle for each operation : WRITE CD Left, WRITE CD Right, Voice 1 WRITE, Voice 3 WRITE.
- Reverb operations : 14 memory operations of 8 cycles.

7.14.3 Sequence of work

When doing the analysis from data, it is possible to figure out what are the operations, in what order they are done. But it is not possible to figure out what is the FIRST operation in the loop. So we arbitrarily decide to start the loop at 'Voice 1' (voice being from 1 to 24).

- Voice 1
- Write CD Left
- Write CD Right
- Write Voice 1
- Write Voice 3
- Reverb
- Voice 2
- Voice 3
- Voice 4
- ...
- ...
- Voice 23
- Voice 24

As written earlier, each Voice is 3x RAM access (one unrelated), reverb is 14x RAM access, then 4x RAM access for the all write.

7.14.4 What we can guess from those information.

- If system wants to keep reverb done in the end, and write in sync against Voice 1 and 3, then the loop would most likely start at Voice 2.
- ADPCM decoder has to keep ADPCM decoder internal state about the samples. As the algorithm depends on the previous value inside a block, it can't do a direct access to a given sample in the block.
- We also understand how reverb is using 22 KHz because of the lack of bandwidth to do everything in 768 cycles if done at 44.1 KHz.
- Even when voices are not active, they always read something. It is possible to guess that the sample is simply ignored at some point in the data path (volume set to zero internally or mux not selecting the value). Interestingly, it may be possible if garbage is introduced in those read, to know how it is cancelled (enabling suddenly the channel and reading the sample out of the channel 1 or 3) -> DSP keeps history of sample for Gaussian Interpolation.

7.14.5 Reverb Computation Order

	[Left Side]	[Right Side]	
READ REVERB	dLSame	dRSame	
READ REVERB	mLSame-1	mRSame-1	
READ REVERB	dRDifff	dLDiff	
XXXX REVERB	mLSame	mRSame	<-- WRITE becomes READ if REVERB DISABLED.
READ REVERB	mLDiff-1	mRDifff-1	
READ REVERB	mLComb1	mRComb1	
XXXX REVERB	mLDiff	mRDifff	<-- WRITE becomes READ if REVERB DISABLED.
READ REVERB	mLComb2	mRComb2	
READ REVERB	mLComb3	mRComb3	
READ REVERB	mLComb4	mRComb4	
READ REVERB	mLAPF1 - dAPF1	mRAPF1 - dAPF1	
READ REVERB	mLAPF2 - dAPF2	mRAPF2 - dAPF2	
XXXX REVERB	mLAPF1	mRAPF1	<-- WRITE becomes READ if REVERB DISABLED.
XXXX REVERB	mLAPF2	mRAPF2	<-- WRITE becomes READ if REVERB DISABLED.

We anticipate that the easiest way in hardware to disable/enable the REVERB function would be to switch those WRITE into READ.

7.14.6 Voices

```

Read Header word in current ADPCM block.
Read Current Sample 16 bit word in current ADPCM block.
Read [UNRELATED ADR ? Not related to current block...]

```

7.14.7 Notes

- Remaining cycles.
- With $24 \times 8 + 4 \times 8 + 14 \times 8 = 720$ cycles out of 768 cycles.
- That would mean 6 READ/WRITE should still be possible.
- UNRELATED READ in voices : probably used for transfer from [CPU->SPU RAM] or [SPU RAM->CPU]
- That would equate to a transfer performance of 24×2 byte $\times 44100$ KHz = 2,116,800 bytes/sec
- The fixed READ timing would explain also why CPU can't read directly SPU RAM. As the SPU need to be the master to push the data.
- It only works with DMA waiting for the data to be sent.

Everything is not fully clear yet, testing of SPU with proper tests to validate/invalidate various assumption. Our finding are based on a logic analyzer log using the PSX boot sounds, knowing the values of the registers thanks to emulators.

8. Interrupts

1F801070h I_STAT - Interrupt status register (R=Status, W=Acknowledge)

1F801074h I_MASK - Interrupt mask register (R/W)

Status: Read I_STAT (0=No IRQ, 1=IRQ)

Acknowledge: Write I_STAT (0=Clear Bit, 1=No change)

Mask: Read/Write I_MASK (0=Disabled, 1=Enabled)

0	IRQ0 VBLANK (PAL=50Hz, NTSC=60Hz)
1	IRQ1 GPU Can be requested via GP0(1Fh) command (rarely used)
2	IRQ2 CDROM
3	IRQ3 DMA
4	IRQ4 TMR0 Timer 0 aka Root Counter 0 (Sysclk or Dotclk)
5	IRQ5 TMR1 Timer 1 aka Root Counter 1 (Sysclk or H-blank)
6	IRQ6 TMR2 Timer 2 aka Root Counter 2 (Sysclk or Sysclk/8)
7	IRQ7 Controller and Memory Card - Byte Received Interrupt
8	IRQ8 SIO
9	IRQ9 SPU
10	IRQ10 Controller - Lightpen Interrupt. Also shared by PIO and DTL cards.
11-15	Not used (always zero)
16-31	Garbage

Secondary IRQ10 Controller (Port 1F802030h)

EXP2 DTL-H2000 I/O Ports

Interrupt Request / Execution

The interrupt request bits in I_STAT are edge-triggered, ie. the get set ONLY if the corresponding interrupt source changes from "false to true".

If one or more interrupts are requested and enabled, ie. if "(I_STAT AND I_MASK)=nonzero", then cop0r13.bit10 gets set, and when cop0r12.bit10 and cop0r12.bit0 are set, too, then the interrupt gets executed.

Interrupt Acknowledge

To acknowledge an interrupt, write a "0" to the corresponding bit in I_STAT. Most interrupts (except IRQ0,4,5,6) must be additionally acknowledged at the I/O port that has caused them (eg. JOY_CTRL.bit4).

Observe that the I_STAT bits are edge-triggered (they get set only on High-to-Low, or False-to-True edges). The correct acknowledge order is:

First, acknowledge I_STAT	(eg. I_STAT.bit7=0)
Then, acknowledge corresponding I/O port	(eg. JOY_CTRL.bit4=1)

When doing it vice-versa, the hardware may miss further IRQs (eg. when first setting JOY_CTRL.4=1, then a new IRQ may occur in JOY_STAT.4 within a single clock cycle, thereafter, setting I_STAT.7=0 would successfully reset I_STAT.7, but, since JOY_STAT.4 is already set, there'll be no further edge, so I_STAT.7 won't be ever set in future).

COP0 Interrupt Handling

Relevant COP0 registers are cop0r13 (CAUSE, reason flags), and cop0r12 (SR, control flags), and cop0r14 (EPC, return address), and, cop0cmd=10h (aka RFE opcode) is used to prepare the return from interrupts. For more info, see [COP0 - Exception Handling](#)

PSX specific COP0 Notes

COP0 has six hardware interrupt bits, of which, the PSX uses only cop0r13.bit10 (the other ones, cop0r13.bit11-15 are always zero). cop0r13.bit10 is NOT a latch, ie. it gets automatically cleared as soon as "(I_STAT AND I_MASK)=zero", so there's no need to do an acknowledge at the cop0 side. COP0 additionally has two software interrupt bits, cop0r13.bit8-9, which do exist in the PSX, too, these bits are read/write-able latches which can be set/cleared manually to request/acknowledge exceptions by software.

Halt Function (Wait for Interrupt)

The PSX doesn't have a HALT opcode, so, even if the program is merely waiting for an interrupt to occur, the CPU is always running at full speed, which is resulting in high power consumption, and, in case of emulators, high CPU emulation load. To save energy, and to make emulation smoother on slower computers, I've added a Halt function for use in emulators:

[EXP2 Nocash Emulation Expansion](#)

9. DMA Channels

DMA Register Summary

```

1F80108xh DMA0 channel 0 MDECin (RAM to MDEC)
1F80109xh DMA1 channel 1 MDECout (MDEC to RAM)
1F8010Axh DMA2 channel 2 GPU (lists + image data)
1F8010Bxh DMA3 channel 3 CDROM (CDROM to RAM)
1F8010Cxh DMA4 channel 4 SPU
1F8010Dxh DMA5 channel 5 PIO (Expansion Port)
1F8010Exh DMA6 channel 6 OTC (reverse clear OT) (GPU related)
1F8010F0h DPCR - DMA Control register
1F8010F4h DICR - DMA Interrupt register

```

These ports control DMA at the CPU-side. In most cases, you'll additionally need to initialize an address (and transfer direction, transfer enabled, etc.) at the remote-side (eg. at the GPU-side for DMA2).

1F801080h+N*10h - D#_MADR - DMA base address (Channel 0..6) (R/W)

0-23	Memory Address where the DMA will start reading from/writing to
24-31	Not used (always zero)

In SyncMode=0, the hardware doesn't update the MADR registers (it will contain the start address even during and after the transfer) (unless Chopping is enabled, in that case it does update MADR, same does probably also happen when getting interrupted by a higher priority DMA channel).

In SyncMode=1 and SyncMode=2, the hardware does update MADR (it will contain the start address of the currently transferred block; at transfer end, it'll hold the end-address in SyncMode=1, or the 00FFFFFFh end-code in SyncMode=2)

Note: Address bit0-1 are writeable, but any updated current/end addresses are word-aligned with bit0-1 forced to zero.

1F801084h+N*10h - D#_BCR - DMA Block Control (Channel 0..6) (R/W)

For SyncMode=0 (ie. for OTC and CDROM):

0-15 BC	Number of words (0001h..FFFFh) (or 0=10000h words)
16-31 0	Not used (usually 0 for OTC, or 1 ("one block") for CDROM)

For SyncMode=1 (ie. for MDEC, SPU, and GPU-vram-data):

0-15	BS	Blocksize (words) ;for GPU/SPU max 10h, for MDEC max 20h
16-31	BA	Amount of blocks ;ie. total length = BS*BA words

For SyncMode=2 (ie. for GPU-command-lists):

0-31	0	Not used (should be zero) (transfer ends at END-CODE in list)
------	---	---

BC/BS/BA can be in range 0001h..FFFFh (or 0=10000h). For BS, take care not to set the blocksize larger than the buffer of the corresponding unit can hold. (GPU and SPU both have a 16-word buffer). A larger blocksize means faster transfer.

SyncMode=1 decrements BA to zero, SyncMode=0 with chopping enabled decrements BC to zero (aside from that two cases, D#_BCR isn't changed during/after transfer).

1F801088h+N*10h - D#_CHCR - DMA Channel Control (Channel 0..6) (R/W)

0	Transfer Direction	(0=To Main RAM, 1=From Main RAM)
1	Memory Address Step	(0=Forward;+4, 1=Backward;-4)
2-7	Not used	(always zero)
8	Chopping Enable	(0=Normal, 1=Chopping; run CPU during DMA gaps)
9-10	SyncMode, Transfer Synchronisation/Mode (0-3):	
0	Start immediately and transfer all at once	(used for CDROM, OTC)
1	Sync blocks to DMA requests	(used for MDEC, SPU, and GPU-data)
2	Linked-List mode	(used for GPU-command-lists)
3	Reserved	(not used)
11-15	Not used	(always zero)
16-18	Chopping DMA Window Size (1 SHL N words)	
19	Not used	(always zero)
20-22	Chopping CPU Window Size (1 SHL N clks)	
23	Not used	(always zero)
24	Start/Busy	(0=Stopped/Completed, 1=Start/Enable/Busy)
25-27	Not used	(always zero)
28	Start/Trigger	(0=Normal, 1=Manual Start; use for SyncMode=0)
29	Unknown (R/W)	Pause? (0=No, 1=Pause?) (For SyncMode=0 only?)
30	Unknown (R/W)	
31	Not used	(always zero)

The Start/Trigger bit is automatically cleared upon BEGIN of the transfer, this bit needs to be set only in SyncMode=0 (setting it in other SyncModes would force the first block to be transferred instantly without DRQ, which isn't desired).

The Start/Busy bit is automatically cleared upon COMPLETION of the transfer, this bit must be always set for all SyncModes when starting a transfer.

For DMA6/OTC there are some restrictions, D6_CHCR has only three read/write-able bits:

Bit24,28,30. All other bits are read-only: Bit1 is always 1 (step=backward), and the other bits are always 0.

1F8010F0h - DPCR - DMA Control Register (R/W)

0-2	DMA0, MDECin	Priority	(0..7; 0=Highest, 7=Lowest)
3	DMA0, MDECin	Master Enable	(0=Disable, 1=Enable)
4-6	DMA1, MDECout	Priority	(0..7; 0=Highest, 7=Lowest)
7	DMA1, MDECout	Master Enable	(0=Disable, 1=Enable)
8-10	DMA2, GPU	Priority	(0..7; 0=Highest, 7=Lowest)
11	DMA2, GPU	Master Enable	(0=Disable, 1=Enable)
12-14	DMA3, CDROM	Priority	(0..7; 0=Highest, 7=Lowest)
15	DMA3, CDROM	Master Enable	(0=Disable, 1=Enable)
16-18	DMA4, SPU	Priority	(0..7; 0=Highest, 7=Lowest)
19	DMA4, SPU	Master Enable	(0=Disable, 1=Enable)
20-22	DMA5, PIO	Priority	(0..7; 0=Highest, 7=Lowest)
23	DMA5, PIO	Master Enable	(0=Disable, 1=Enable)
24-26	DMA6, OTC	Priority	(0..7; 0=Highest, 7=Lowest)
27	DMA6, OTC	Master Enable	(0=Disable, 1=Enable)
28-30	Unknown, Priority Offset or so?	(R/W)	
31	Unknown, no effect?	(R/W)	

Initial value on reset is 07654321h. If two or more channels have the same priority setting, then the priority is determined by the channel number (DMA0=Lowest, DMA6=Highest).

1F8010F4h - DICR - DMA Interrupt Register (R/W)

0-5	Unknown	(read/writeable)
6-14	Not used	(always zero)
15	Force IRQ (sets bit31)	(0=None, 1=Force Bit31=1)
16-22	IRQ Enable for DMA0..DMA6	(0=None, 1=Enable)
23	IRQ Master Enable for DMA0..DMA6	(0=None, 1=Enable)
24-30	IRQ Flags for DMA0..DMA6	(0=None, 1=IRQ) (Write 1 to reset)
31	IRQ Master Flag	(0=None, 1=IRQ) (Read only)

IRQ flags in Bit(24+n) are set upon DMA*n* completion - but caution - they are set ONLY if enabled in Bit(16+n).

Bit31 is a simple readonly flag that follows the following rules:

```
IF b15=1 OR (b23=1 AND (b16-22 AND b24-30)>0) THEN b31=1 ELSE b31=0
```

Upon 0-to-1 transition of Bit31, the IRQ3 flag (in Port 1F801070h) gets set.
 Bit24-30 are acknowledged (reset to zero) when writing a "1" to that bits (and, additionally, IRQ3 must be acknowledged via Port 1F801070h).

1F8010F8h (usually 7FFAC68Bh? or 0BFAC688h)

(changes to 7FE358D1h after DMA transfer)

1F8010FCCh (usually 00FFFFF7h) (...maybe OTC fill-value)

(stays so even after DMA transfer)

Contains strange read-only values (but not the usual "Garbage").
 Not yet tested during transfer, might be remaining length and address?

Commonly used DMA Control Register values for starting DMA transfers

DMA0	MDEC.IN	01000201h	(always)
DMA1	MDEC.OUT	01000200h	(always)
DMA2	GPU	01000200h (VramRead), 01000201h (VramWrite), 01000401h (List)	
DMA3	CDROM	11000000h (normal), 11400100h (chopped, rarely used)	
DMA4	SPU	01000201h (write), 01000200h (read, rarely used)	
DMA5	PIO	N/A (not used by any known games)	
DMA6	OTC	11000002h (always)	

XXX: DMA2 values 01000201h (VramWrite), 01000401h (List) aren't 100% confirmed to be used by ALL existing games. All other values are always used as listed above.

DMA Transfer Rates

DMA0	MDEC.IN	1 clk/word ;0110h clks per 100h words ;\plus whatever
DMA1	MDEC.OUT	1 clk/word ;0110h clks per 100h words ;/decompression time
DMA2	GPU	1 clk/word ;0110h clks per 100h words ;-plus ...
DMA3	CDROM/BIOS	24 clks/word ;1800h clks per 100h words ;\plus single/double
DMA3	CDROM/GAMES	40 clks/word ;2800h clks per 100h words ;/speed sector rate
DMA4	SPU	4 clks/word ;0420h clks per 100h words ;-plus ...
DMA5	PIO	20 clks/word ;1400h clks per 100h words ;-not actually used
DMA6	OTC	1 clk/word ;0110h clks per 100h words ;-plus nothing

MDEC decompression time is still unknown (may vary on RLE and color/mono).
 GPU polygon rendering time is unknown (may be quite slow for large polys).
 GPU vram read/write time is unknown (may vary on horizontal screen resolution).
 CDROM BIOS default is 24 clks, for some reason most games change it to 40 clks.
 SPU transfer is unknown (may have some extra delays).
 XXX is SPU really only 4 clks (theoretically SPU access should be slower)?
 PIO isn't used by any games (and if used: could be configured to other rates)

OTC is just writing to RAM without extra overload.

CDROM/SPU/PIO timings can be configured via Memory Control registers.

DRAM Hyper Page mode

DMA is using DRAM Hyper Page mode, allowing it to access DRAM rows at 1 clock cycle per word (effectively around 17 clks per 16 words, due to required row address loading, probably plus some further minimal overload due to refresh cycles). This is making DMA much faster than CPU memory accesses (CPU DRAM access takes 1 opcode cycle plus 6 waitstates, ie. 7 cycles in total)

CPU Operation during DMA

Basically, the CPU is stopped during DMA (theoretically, the CPU could be kept running when accessing only cache, scratchpad and on-chip I/O ports like DMA registers, and during the CDROM/SPU/PIO waitstates it could even access Main RAM, but these situations aren't supported).

However, the CPU operation resumes during periods when DMA gets interrupted (ie. after SyncMode 1 blocks, after SyncMode 2 list entries) (or in SyncMode 0 with Chopping enabled).

10. Timers

1F801100h+N*10h - Timer 0..2 Current Counter Value (R/W)

```
0-15 Current Counter value (incrementing)
16-31 Garbage
```

This register is automatically incrementing. It is write-able (allowing to set it to any value). It gets forcefully reset to 0000h on any write to the Counter Mode register, and on counter overflow (either when exceeding FFFFh, or when exceeding the selected target value).

1F801104h+N*10h - Timer 0..2 Counter Mode (R/W)

```
0      Synchronization Enable (0=Free Run, 1=Synchronize via Bit1-2)
1-2    Synchronization Mode (0-3, see lists below)
      Synchronization Modes for Counter 0:
      0 = Pause counter during Hblank(s)
      1 = Reset counter to 0000h at Hblank(s)
      2 = Reset counter to 0000h at Hblank(s) and pause outside of Hblank
      3 = Pause until Hblank occurs once, then switch to Free Run
      Synchronization Modes for Counter 1:
      Same as above, but using Vblank instead of Hblank
      Synchronization Modes for Counter 2:
      0 or 3 = Stop counter at current value (forever, no h/v-blank start)
      1 or 2 = Free Run (same as when Synchronization Disabled)
3      Reset counter to 0000h (0=After Counter=FFFFh, 1=After Counter=Target)
4      IRQ when Counter=Target (0=Disable, 1=Enable)
5      IRQ when Counter=FFFFh (0=Disable, 1=Enable)
6      IRQ Once/Repeat Mode (0=One-shot, 1=Repeatedly)
7      IRQ Pulse/Toggle Mode (0=Short Bit10=0 Pulse, 1=Toggle Bit10 on/off)
8-9    Clock Source (0-3, see list below)
      Counter 0: 0 or 2 = System Clock, 1 or 3 = Dotclock
      Counter 1: 0 or 2 = System Clock, 1 or 3 = Hblank
      Counter 2: 0 or 1 = System Clock, 2 or 3 = System Clock/8
10    Interrupt Request (0=Yes, 1=No) (Set after Writing) (W=1) (R)
11    Reached Target Value (0=No, 1=Yes) (Reset after Reading) (R)
12    Reached FFFFh Value (0=No, 1=Yes) (Reset after Reading) (R)
13-15 Unknown (seems to be always zero)
16-31 Garbage (next opcode)
```

In one-shot mode, the IRQ is pulsed/toggled only once (one-shot mode doesn't stop the counter, it just suppresses any further IRQs until a new write to the Mode register occurs; if both IRQ conditions are enabled in Bit4-5, then one-shot mode triggers only one of

those conditions; whichever occurs first).

Normally, Pulse mode should be used (Bit10 is permanently set, except for a few clock cycles when an IRQ occurs). In Toggle mode, Bit10 is set after writing to the Mode register, and becomes inverted on each IRQ (in one-shot mode, it remains zero after the IRQ) (in repeat mode it inverts Bit10 on each IRQ, so IRQ4/5/6 are triggered only each 2nd time, ie. when Bit10 changes from 1 to 0).

The "free run" mode is simply saying that the counter will not reset at a given threshold value.

1F801108h+N*10h - Timer 0..2 Counter Target Value (R/W)

0-15	Counter Target value
16-31	Garbage

When the Target flag is set (Bit3 of the Control register), the counter increments up to (including) the selected target value, and does then restart at 0000h.

Dotclock/Hblank

For more info on dotclock and hblank timings, see:

[GPU Timings](#)

Caution: Reading the Current Counter Value can be a little unstable (when using dotclk or hblank as clock source); the GPU clock isn't in sync with the CPU clock, so the timer may get changed during the CPU read cycle. As a workaround: repeat reading the timer until the received value is the same (or slightly bigger) than the previous value.

11. CDROM Drive

Playstation CDROM I/O Ports

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Playstation CDROM Commands

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Playstation CDROM Coprocessor

[CDROM Internal Info on PSX CDROM Controller](#)

11.1 CDROM Controller I/O Ports

1F801800h - Index/Status Register (Bit0-1 R/W) (Bit2-7 Read Only)

```

0-1 Index    Port 1F801801h-1F801803h index (0..3 = Index0..Index3)      (R/W)
2   ADPBUSY XA-ADPCM fifo empty  (0=Empty) ;set when playing XA-ADPCM sound
3   PRMEMPT Parameter fifo empty (1=Empty) ;triggered before writing 1st byte
4   PRMWRDY Parameter fifo full  (0=Full)  ;triggered after writing 16 bytes
5   RSLRRDY Response fifo empty (0=Empty) ;triggered after reading LAST byte
6   DRQSTS Data fifo empty     (0=Empty) ;triggered after reading LAST byte
7   BUSYSTS Command/parameter transmission busy (1=Busy)

```

Bit3,4,5 are bound to 5bit counters; ie. the bits become true at specified amount of reads/writes, and thereafter once on every further 32 reads/writes.

1F801801h.Index0 - Command Register (W)

```
0-7  Command Byte
```

Writing to this address sends the command byte to the CDROM controller, which will then read-out any Parameter byte(s) which have been previously stored in the Parameter Fifo. It takes a while until the command/parameters are transferred to the controller, and until the response bytes are received; once when completed, interrupt INT3 is generated (or INT5 in case of invalid command/parameter values), and the response (or error code) can be then read from the Response Fifo. Some commands additionally have a second response, which is sent with another interrupt.

1F801802h.Index0 - Parameter Fifo (W)

0-7	Parameter Byte(s) to be used for next Command
-----	---

Before sending a command, write any parameter byte(s) to this address.

1F801803h.Index0 - Request Register (W)

0-4	0	Not used (should be zero)
5	SMEN	Want Command Start Interrupt on Next Command (0=No change, 1=Yes)
6	BFWR	...
7	BFRD	Want Data (0=No/Reset Data Fifo, 1=Yes/Load Data Fifo)

1F801802h.Index0..3 - Data Fifo - 8bit/16bit (R)

After ReadS/ReadN commands have generated INT1, software must set the Want Data bit (1F801803h.Index0.Bit7), then wait until Data Fifo becomes not empty (1F801800h.Bit6), the datablock (disk sector) can be then read from this register.

0-7	Data 8bit	(one byte), or alternately,
0-15	Data 16bit	(LSB=First byte, MSB=Second byte)

The PSX hardware allows to read 800h-byte or 924h-byte sectors, indexed as [000h..7FFh] or [000h..923h], when trying to read further bytes, then the PSX will repeat the byte at index [800h-8] or [924h-4] as padding value.

Port 1F801802h can be accessed with 8bit or 16bit reads (ie. to read a 2048-byte sector, one can use 2048 load-byte opcodes, or 1024 load halfword opcodes, or, more conventionally, a 512 word DMA transfer; the actual CDROM databus is only 8bits wide, so CPU/DMA are apparently breaking 16bit/32bit reads into multiple 8bit reads from 1F801802h).

1F801801h.Index1 - Response Fifo (R)**1F801801h.Index0,2,3 - Response Fifo (R) (Mirrors)**

0-7 Response Byte(s) received after sending a Command

The response Fifo is a 16-byte buffer, most or all responses are less than 16 bytes, after reading the last used byte (or before reading anything when the response is 0-byte long), Bit5 of the Index/Status register becomes zero to indicate that the last byte was received. When reading further bytes: The buffer is padded with 00h's to the end of the 16-bytes, and does then restart at the first response byte (that, without receiving a new response, so it'll always return the same 16 bytes, until a new command/response has been sent/received).

1F801802h.Index1 - Interrupt Enable Register (W)**1F801803h.Index0 - Interrupt Enable Register (R)****1F801803h.Index2 - Interrupt Enable Register (R) (Mirror)**

0-4 Interrupt Enable Bits (usually all set, ie. 1Fh=Enable All IRQs)
5-7 Unknown/unused (write: should be zero) (read: usually all bits set)

XXX WRITE: bit5-7 unused should be 0 // READ: bit5-7 unused

1F801803h.Index1 - Interrupt Flag Register (R/W)**1F801803h.Index3 - Interrupt Flag Register (R) (Mirror)**

0-2 Read: Response Received Write: 7=Acknowledge ;INT1..INT7
3 Read: Unknown (usually 0) Write: 1=Acknowledge ;INT8 ;XXX CLRBFEEMPTY
4 Read: Command Start Write: 1=Acknowledge ;INT10h;XXX CLRBFWRDY
5 Read: Always 1 ;XXX "_" Write: 1=Unknown ;XXX SMADPCLR
6 Read: Always 1 ;XXX "_" Write: 1=Reset Parameter Fifo ;XXX CLRPRM
7 Read: Always 1 ;XXX "_" Write: 1=Unknown ;XXX CHPRST

Writing "1" bits to bit0-4 resets the corresponding IRQ flags; normally one should write 07h to reset the response bits, or 1Fh to reset all IRQ bits. Writing values like 01h is possible (eg. that would change INT3 to INT2, but doing that would be total nonsense). After acknowledge, the Response Fifo is made empty, and if there's been a pending

command, then that command gets send to the controller.

The lower 3bit indicate the type of response received,

INT0	No response received (no interrupt request)
INT1	Received SECOND (or further) response to ReadS/ReadN (and Play+Report)
INT2	Received SECOND response (to various commands)
INT3	Received FIRST response (to any command)
INT4	DataEnd (when Play/Forward reaches end of disk) (maybe also for Read?)
INT5	Received error-code (in FIRST or SECOND response) INT5 also occurs on SECOND GetID response, on unlicensed disks INT5 also occurs when opening the drive door (even if no command was sent, ie. even if no read-command or other command is active)
INT6	N/A
INT7	N/A

The other 2bit indicate something else,

INT8	Unknown (never seen that bit set yet)
INT10h	Command Start (when INT10h requested via 1F801803h.Index0.Bit5)

The response interrupts are queued, for example, if the 1st response is INT3, and the second INT5, then INT3 is delivered first, and INT5 is not delivered until INT3 is acknowledged (ie. the response interrupts are NOT ORed together to produce INT7 or so). The upper bits however can be ORed with the lower bits (ie. Command Start INT10h and 1st Response INT3 would give INT13h).

1F801802h.Index2 - Audio Volume for Left-CD-Out to Left-SPU-Input (W)

1F801803h.Index2 - Audio Volume for Left-CD-Out to Right-SPU-Input (W)

1F801801h.Index3 - Audio Volume for Right-CD-Out to Right-SPU-Input (W)

Allows to configure the CD for mono/stereo output (eg. values "80h,0,80h,0" produce normal stereo volume, values "40h,40h,40h,40h" produce mono output of equivalent volume).

When using bigger values, the hardware does have some incomplete saturation support; the saturation works up to double volume (eg. overflows that occur on "FFh,0,FFh,0" or "80h,80h,80h,80h" are clipped to min/max levels), however, the saturation does NOT

work properly when exceeding double volume (eg. mono with quad-volume "FFh,FFh,FFh,FFh").

```
0-7  Volume Level (00h..FFh) (00h=Off, FFh=Max/Double, 80h=Default/Normal)
```

After changing these registers, write 20h to 1F801803h.Index3.

Unknown if any existing games are actually supporting mono output. Resident Evil 2 uses these ports to produce fade-in/fade-out effects (although, for that purpose, it should be much easier to use Port 1F801DB0h).

1F801803h.Index3 - Audio Volume Apply Changes (by writing bit5=1)

0	ADPMUTE Mute ADPCM	(0=Normal, 1=Mute)
1-4	- Unused (should be zero)	
5	CHNGATV Apply Audio Volume changes (0=No change, 1=Apply)	
6-7	- Unused (should be zero)	

1F801801h.Index1 - Sound Map Data Out (W)

```
0-7  Data
```

This register seems to be restricted to 8bit bus, unknown if/how the PSX DMA controller can write to it (it might support only 16bit data for CDROM).

1F801801h.Index2 - Sound Map Coding Info (W)

0	Mono/Stereo	(0=Mono, 1=Stereo)
1	Reserved	(0)
2	Sample Rate	(0=37800Hz, 1=18900Hz)
3	Reserved	(0)
4	Bits per Sample	(0=4bit, 1=8bit)
5	Reserved	(0)
6	Emphasis	(0=Off, 1=Emphasis)
7	Reserved	(0)

Command Execution

Command/Parameter transmission is indicated by bit7 of 1F801800h.

When that bit gets zero, the response can be read immediately (immediately for MOST commands, but not ALL commands; so better wait for the IRQ).

Alternately, you can wait for an IRQ (which seems to take place MUCH later), and then read the response.

If there are any pending cdrom interrupts, these MUST be acknowledged before sending the command (otherwise bit7 of 1F801800h will stay set forever).

Command Busy Flag - 1F801800h.Bit7

Indicates ready-to-send-new-command,

```
0=Ready to send a new command
1=Busy sending a command/parameters
```

Trying to send a new command in the Busy-phase causes malfunction (the older command seems to get lost, the newer command executes and returns its results and triggers an interrupt, but, thereafter, the controller seems to hang). So, always wait until the Busy-bit goes off before sending a command.

When the Busy-flag goes off, a new command can be send immediately (even if the response from the previous command wasn't received yet), however, the new command stays in the Busy-phase until the IRQ from the previous command is acknowledged, at that point the actual transmission of the new command starts, and the Busy-flag goes off (once when the transmission completes).

Misc

Trying to do a 32bit read from 1F801800h returns the 8bit value at 1F801800h multiplied by 01010101h.

To init the CD

```
-Flush all IRQs
-1F801803h.Index0=0
-Com_Delay=4901 (=1325h) (Port 1F801020h) (means 16bit or 32bit write?)
  (the write seems to be 32bit, clearing the upper16bit of the register)
-Send two Getstat commands
-Send Command 0Ah (Init)
-Demute
```

Seek-Busy Phase

Warning: most or all of the info in the sentence below appear to incorrect (either that, or I didn't understand that rather confusing sentence).

REPORTEDLY:

"You should not send some commands while the CD is seeking (ie. Getstat returns with bit6 set). Thing is that stat only gets updated after a new command. I haven't tested this for other command, but for the play command (03h) you can just keep repeating the [which?] command and checking stat returned by that, for bit6 to go low (and bit7 to go high in this case). If you don't and try to do a getloc [GetlocP and/or GetlocL?] directly after the play command reports it's done [what done? meaning sending start-to-play was "done"? or meaning play reached end-of-disc?], the CD will stop. (I guess the CD can't get it's current location while it's seeking, so the logic stops the seek to get an exact fix, but never restarts..)"

Sound Map Flowchart

Sound Map mode allows to output XA-ADPCM from Main RAM (rather than from CDROM).

```

SPU: Init Master Volume Left/Right (Port 1F801D80h/1F801D82h)
SPU: Init CD Audio Volume Left/Right (Port 1F801DB0h/1F801DB2h)
SPU: Enable CD Audio (Port 1F801DAAh.Bit0=1)
CDROM/CMD: send Stop command (probably better to avoid conflicts)
CDROM/CMD: send Demute command (if muted) (but works only if disc inserted)
CDROM/HOST: init Codinginfo (Port 1F801801h.Index2)
CDROM/HOST: enable ADPCM (Port 1F801803h.Index3.Bit0=0) ;probably needed?
... set dummy addr/len with DISHXFRC=1 ? <-- NOT required !
... set SMEN ... and dummy BFWR? <-- BOTH bits required ?
transfer 900h bytes (same format as ADPCM sectors) (Port 1F801801h.Index1)
Note: Before sending a byte, one should wait for DRQs (1F801801h.Bit6=1)
Note: ADPCM output doesn't start until the last (900h'th) byte is transferred

```

Sound Map mode may be very useful for testing XA-ADPCM directly from within an exe file (without needing a cdrom with ADPCM sectors). And, Sound Map supports both 4bit and 8bit compression (the SPU supports only 4bit).

Caution: If ADPCM wasn't playing, and one sends one 900h-byte block, then it will get stored in one of three 900h-byte slots in SRAM, and one would expect that that slot to be played when the ADPCM output starts - however, actually, the hardware will more or less randomly play one of the three slots; not necessarily the slot that was updated most recently.

11.2 CDROM Controller Command Summary

Command Summary

Command	Parameters	Response(s)
00h -	-	INT5(11h,40h) ; reportedly "Sync" uh?

01h Getstat	-	INT3(stat)
02h Setloc	E amm,ass,asect	INT3(stat)
03h Play	E (track)	INT3(stat), optional INT1(report bytes)
04h Forward	E -	INT3(stat), optional INT1(report bytes)
05h Backward	E -	INT3(stat), optional INT1(report bytes)
06h ReadN	E -	INT3(stat), INT1(stat), datablock
07h MotorOn	E -	INT3(stat), INT2(stat)
08h Stop	E -	INT3(stat), INT2(stat)
09h Pause	E -	INT3(stat), INT2(stat)
0Ah Init	-	INT3(late-stat), INT2(stat)
0Bh Mute	E -	INT3(stat)
0Ch Demute	E -	INT3(stat)
0Dh Setfilter	E file,channel	INT3(stat)
0Eh Setmode	mode	INT3(stat)
0Fh Getparam	-	INT3(stat,mode,null,file,channel)
10h GetlocL	E -	INT3(amm,ass,asect,mode,file,channel,sm,ci)
11h GetlocP	E -	INT3(track,index,mm,ss,sect,amm,ass,asect)
12h SetSession	E session	INT3(stat), INT2(stat)
13h GetTN	E -	INT3(stat,first,last) ;BCD
14h GetTD	E track (BCD)	INT3(stat,mm,ss) ;BCD
15h SeekL	E -	INT3(stat), INT2(stat) ;\use prior Setloc
16h SeekP	E -	INT3(stat), INT2(stat) ;/to set target
17h -	-	INT5(11h,40h) ;reportedly "SetClock" uh?
18h -	-	INT5(11h,40h) ;reportedly "GetClock" uh?
19h Test	sub_function	depends on sub_function (see below)
1Ah GetID	E -	INT3(stat), INT2/5(stat,flg,typ,atip,"SCEx")
1Bh ReadS	E?-	INT3(stat), INT1(stat), datablock
1Ch Reset	-	INT3(stat), Delay
1Dh GetQ	E adr,point	INT3(stat), INT2(10bytesSubQ,peak_lo) ;\not
1Eh ReadTOC	-	INT3(late-stat), INT2(stat) ;/vC0
1Fh VideoCD	sub,a,b,c,d,e	INT3(stat,a,b,c,d,e) ;<-- SCPH-5903 only
1Fh..4Fh -	-	INT5(11h,40h) ;-Unused/invalid
50h Secret 1	-	INT5(11h,40h) ;\
51h Secret 2	"Licensed by"	INT5(11h,40h) ;
52h Secret 3	"Sony"	INT5(11h,40h) ; Secret Unlock Commands
53h Secret 4	"Computer"	INT5(11h,40h) ; (not in version vC0, and,
54h Secret 5	"Entertainment"	INT5(11h,40h) ; nonfunctional in japan)
55h Secret 6	"<region>"	INT5(11h,40h) ;
56h Secret 7	-	INT5(11h,40h) ;/
57h SecretLock	-	INT5(11h,40h) ;-Secret Lock Command
58h..5Fh Crash	-	Crashes the HC05 (jumps into a data area)
6Fh..FFh -	-	INT5(11h,40h) ;-Unused/invalid

E = Error 80h appears on some commands (02h..09h, 0Bh..0Dh, 10h..16h, 1Ah, 1Bh?, and 1Dh) when the disk is missing, or when the drive unit is disconnected from the mainboard.

sub_function numbers (for command 19h)

Test commands are invoked with command number 19h, followed by a sub_function number as first parameter byte. The Kernel seems to be using only sub_function 20h (to detect the CDROM Controller version).

sub	params	response	;Effect
00h	-	INT3(stat)	;Force motor on, clockwise, even if door open
01h	-	INT3(stat)	;Force motor on, anti-clockwise, super-fast
02h	-	INT3(stat)	;Force motor on, anti-clockwise, super-fast
03h	-	INT3(stat)	;Force motor off (ignored during spin-up)
04h	-	INT3(stat)	;Start SCEx reading and reset counters
05h	-	INT3(total,success)	;Stop SCEx reading and get counters
06h *	n	INT3(old) ;\early	;Adjust balance in RAM, send CX(30+n XOR 7)
07h *	n	INT3(old) ; PSX	;Adjust gain in RAM, send CX(38+n XOR 7)
08h *	n	INT3(old) ;/only	;Adjust balance in RAM only
06h..0Fh -		INT5(11h,10h)	;N/A (11h,20h when NONZERO number of params)
10h	-	INT3(stat) ;CX(..)	;Force motor on, anti-clockwise, super-fast
11h	-	INT3(stat) ;CX(03)	;Move Lens Up (leave parking position)
12h	-	INT3(stat) ;CX(02)	;Move Lens Down (enter parking position)
13h	-	INT3(stat) ;CX(28)	;Move Lens Outwards
14h	-	INT3(stat) ;CX(2C)	;Move Lens Inwards
15h	-	INT3(stat) ;CX(22)	;If motor on: Move outwards,inwards,motor off
16h	-	INT3(stat) ;CX(23)	;No effect?
17h	-	INT3(stat) ;CX(E8)	;Force motor on, clockwise, super-fast
18h	-	INT3(stat) ;CX(EA)	;Force motor on, anti-clockwise, super-fast
19h	-	INT3(stat) ;CX(25)	;No effect?
1Ah	-	INT3(stat) ;CX(21)	;No effect?
1Bh..1Fh -		INT5(11h,10h)	;N/A (11h,20h when NONZERO number of params)
20h	-	INT3(yy,mm,dd,ver)	;Get cdrom BIOS date/version (yy,mm,dd,ver)
21h	-	INT3(n)	;Get Drive Switches (bit0=POS0, bit1=DOOR)
22h *** -		INT3("for ...")	;Get Region ID String
23h *** -		INT3("CXD...")	;Get Chip ID String for Servo Amplifier
24h *** -		INT3("CXD...")	;Get Chip ID String for Signal Processor
25h *** -		INT3("CXD...")	;Get Chip ID String for Decoder/FIFO
26h..2Fh -		INT5(11h,10h)	;N/A (11h,20h when NONZERO number of params)
30h *	i,x,y	INT3(stat)	;Prototype/Debug stuff ;\supported on
31h *	x,y	INT3(stat)	;Prototype/Debug stuff ; early PSX only
4xh *	i	INT3(x,y)	;Prototype/Debug stuff ;/
30h..4Fh ..		INT5(11h,10h)	;N/A always 11h,10h (no matter of params)
50h	a[,b[,c]]	INT3(stat)	;Servo/Signal send CX(a:b:c)
51h **	39h,xx	INT3(stat,hi,lo)	;Servo/Signal send CX(39xx) with response
51h..5Fh -		INT5(11h,10h)	;N/A
60h	lo,hi	INT3(databyte)	;HC05 SUB-CPU read RAM and I/O ports
61h..70h -		INT5(11h,10h)	;N/A
71h ***	adr	INT3(databyte)	;Decoder Read one register
72h ***	adr,dat	INT3(stat)	;Decoder Write one register
73h ***	adr,len	INT3(databytes..)	;Decoder Read multiple registers, bugged
74h ***	adr,len,..	INT3(stat)	;Decoder Write multiple registers, bugged
75h *** -		INT3(lo,hi,lo,hi)	;Decoder Get Host Xfer Info Remain/Addr
76h ***	a,b,c,d	INT3(stat)	;Decoder Prepare Transfer to/from SRAM
77h..FFh -		INT5(11h,10h)	;N/A

- * sub_functions 06h..08h, 30h..31h, and 4xh are supported only in vC0 and vC1.
- ** sub_function 51h is supported only in BIOS version vC2 and up.
- *** sub_functions 22h..25h, 71h..76h supported only in BIOS version vC1 and up.

Unsupported GetQ,VCD,SecretUnlock (command 1Dh,1Fh,5xh)

INT5 will be returned if the command is unsupported. That, WITHOUT removing the Parameters from the FIFO, so the parameters will be accidentally passed to the NEXT command. To avoid that: clear the parameter FIFO via [1F801803h.Index1]=40h after receiving the INT5 error.

11.3 CDROM - Control Commands

Sync - Command 00h --> INTx(stat+1,40h) (?)

Reportedly "command does not succeed until all other commands complete. This can be used for synchronization - hence the name."

Uh, actually, returns error code 40h = Invalid Command...?

Setfilter - Command 0Dh,file,channel --> INT3(stat)

Automatic ADPCM (CD-ROM XA) filter ignores sectors except those which have the same channel and file numbers in their subheader. This is the mechanism used to select which of multiple songs in a single .XA file to play.

Setfilter does not affect actual reading (sector reads still occur for all sectors).

XXX err... that is... does not affect reading of non-ADPCM sectors (normal "data" sectors are kept received regardless of Setfilter).

Setmode - Command 0Eh,mode --> INT3(stat)

7	Speed	(0=Normal speed, 1=Double speed)
6	XA-ADPCM	(0=Off, 1=Send XA-ADPCM sectors to SPU Audio Input)
5	Sector Size	(0=800h=DataOnly, 1=924h=WholeSectorExceptSyncBytes)
4	Ignore Bit	(0=Normal, 1=Ignore Sector Size and Setloc position)
3	XA-Filter	(0=Off, 1=Process only XA-ADPCM sectors that match Setfilter)
2	Report	(0=Off, 1=Enable Report-Interrupts for Audio Play)
1	AutoPause	(0=Off, 1=Auto Pause upon End of Track) ;for Audio Play
0	CDDA	(0=Off, 1=Allow to Read CD-DA Sectors; ignore missing EDC)

The "Ignore Bit" does reportedly force a sector size of 2328 bytes (918h), however, that doesn't seem to be true. Instead, Bit4 seems to cause the controller to ignore the sector

size in Bit5 (instead, the size is kept from the most recent Setmode command which didn't have Bit4 set). Also, Bit4 seems to cause the controller to ignore the \<exact> Setloc position (instead, data is randomly returned from the "Setloc position minus 0..3 sectors"). And, Bit4 causes INT1 to return status.Bit3=set (IdError). Purpose of Bit4 is unknown?

Init - Command 0Ah --> INT3(stat) --> INT2(stat)

Multiple effects at once. Sets mode=00h (or not ALL bits cleared?), activates drive motor, Standby, abort all commands.

Reset - Command 1Ch,(...) --> INT3(stat) --> Delay(1/8 seconds)

Resets the drive controller, reportedly, same as opening and closing the drive door. The command executes no matter if/how many parameters are used (tested with 0..7 params). INT3 indicates that the command was started, but there's no INT that would indicate when the command is finished, so, before sending any further commands, a delay of 1/8 seconds (or 400000h clock cycles) must be issued by software.

Note: Executing the command produces a click sound in the drive mechanics, maybe it's just a rapid motor on/off, but it might something more serious, like ignoring the /POS0 signal...?

MotorOn - Command 07h --> INT3(stat) --> INT2(stat)

Activates the drive motor, works ONLY if the motor was off (otherwise fails with INT5(stat, 20h); that error code would normally indicate "wrong number of parameters", but means "motor already on" in this case).

Commands like Read, Seek, and Play are automatically starting the Motor when needed (which makes the MotorOn command rather useless, and it's rarely used by any games).

Myth: Older homebrew docs are referring to MotorOn as "Standby", claiming that it would work similar as "Pause", that is wrong: the command does NOT pause anything (if the motor is on, then it does simply trigger INT5, but without pausing reading or playing).

Note: The game "Nightmare Creatures 2" does actually attempt to use MotorOn to "pause" after reading files, but the hardware does simply ignore that attempt (aside from doing the INT5 thing).

Stop - Command 08h --> INT3(stat) --> INT2(stat)

Stops motor with magnetic brakes (stops within a second or so) (unlike power-off where it'd keep spinning for about 10 seconds), and moves the drive head to the begin of the

first track. Official way to restart is command 0Ah, but almost any command will restart it.

The first response returns the current status (this already with bit5 cleared), the second response returns the new status (with bit1 cleared).

Pause - Command 09h --> INT3(stat) --> INT2(stat)

Aborts Reading and Playing, the motor is kept spinning, and the drive head maintains the current location within reasonable error.

The first response returns the current status (still with bit5 set if a Read command was active), the second response returns the new status (with bit5 cleared).

Data/ADPCM Sector Filtering/Delivery

The PSX CDROM BIOS is first trying to send sectors to the ADPCM decoder, and, if that didn't work out, then it's trying to send them to the main CPU (and if that didn't work out either, then it's silently ignoring the sector).

```
try_deliver_as_adpcm_sector:
reject if CD-DA AUDIO format
reject if sector isn't MODE2 format
reject if adpcm_disabled(setmode.6)
reject if filter_enabled(setmode.3) AND selected file/channel doesn't match
reject if submode isn't audio+realtime (bit2 and bit6 must be both set)
deliver: send sector to xa-adpcm decoder when passing above cases
try_deliver_as_data_sector:
reject data-delivery if "try_deliver_as_adpcm_sector" did do adpcm-delivery
reject if filter_enabled(setmode.3) AND submode is audio+realtime (bit2+bit6)
1st delivery attempt: send INT1+data, unless there's another INT pending
delay, and retry at later time... but this time with file/channel checking!
reject if filter_enabled(setmode.3) AND selected file/channel doesn't match
2nd delivery attempt: send INT1+data, unless there's another INT pending
```

BUG: Note that the data delivery is done in two different attempts: The first one regardless of file/channel, and the second one only on matching file/channel (if filtering is enabled).

11.4 CDROM - Seek Commands

Setloc - Command 02h,amm,ass,asect --> INT3(stat)

Sets the seek target - but without yet starting the seek operation. The actual seek is invoked by certain commands: SeekL (Data) and SeekP (Audio) are doing plain seeks (and do Pause after completion). ReadN/ReadS are similar to SeekL (and do start reading data after the seek operation). Play is similar to SeekP (and does start playing audio after the seek operation).

The amm,ass,asect parameters refer to the entire disk (not to the current track). To seek to a specific location within a specific track, use GetTD to get the start address of the track, and add the desired time offset to it.

SeekL - Command 15h --> INT3(stat) --> INT2(stat)

Seek to Setloc's location in data mode (using data sector header position data, which works/exists only on Data tracks, not on CD-DA Audio tracks).

After the seek, the disk stays on the sought location forever (namely: when seeking sector N, it does stay at around N-8..N-0 in single speed mode, or at around N-5..N+2 in double speed mode).

Trying to use SeekL on Audio CDs passes okay on the first response, but (after two seconds or so) the second response will return an error (stat+4,04h), and stop the drive motor... that error doesn't appear ALWAYS though... works in some situations... such like when previously reading data sectors or so...?

SeekP - Command 16h --> INT3(stat) --> INT2(stat)

Seek to Setloc's location in audio mode (using the Subchannel Q position data, which works on both Audio on Data disks).

After the seek, the disk stays on the sought location forever (namely: when seeking sector N, it does stay at around N-9..N-1 in single speed mode, or at around N-2..N in double speed mode).

Note: Some older docs claim that SeekP would recurse only "MM:SS" of the "MM:SS:FF" position from Setloc - that is wrong, it does seek to MM:SS:FF (verified on a PSone). After the seek, status is stat.bit7=0 (ie. audio playback off), until sending a new Play command (without parameters) to start playback at the sought location.

SetSession - Command 12h,session --> INT3(stat) --> INT2(stat)

Seeks to session (ie. moves the drive head to the session, with stat bit6 set during the seek phase).

When issued during active-play, the command returns error code 80h.

When issued during play-spin-up, play is aborted.

```
__Errors__
session = 00h causes error code 10h.      ;INT5(03h,10h), no 2nd/3rd response
__On a non-multisession-disk__
session = 01h passes okay.                ;INT3(stat), and once INT2(stat)
session = 02h or higher cause seek error ;INT3(stat), and twice INT5(06h,40h)
__On a multisession-disk with N sessions__
session = 01h..N+1 passes okay    ;where N+1 moves to the END of LAST session
session = N+2 or higher cause seek error ;2nd response = INT5(06h,20h)
```

after seek error --> disk stops spinning at 2nd response, then restarts spinning for 1 second or so, then stops spinning forever... and following gettn/gettd/getid/getloci/getlocl fail with error 80h...

The command does automatically read the TOC of the new session.

There seems to be no way to determine the current sessions number (via Getparam or so), and more important, no way to determine if the disk is a multi-session disk or not... except by trial... which would stop the drive motor on seek errors on single-session disks...?

For setloc, one must probably specify minutes within the 1st track of the new session (the 1st track of 1st session usually/always starts at 00:02:00, but for other sessions one would need to use GetTD)...?

11.5 CDROM - Read Commands

ReadN - Command 06h --> INT3(stat) --> INT1(stat) --> datablock

Read with retry. The command responds once with "stat,INT3", and then it's repeatedly sending "stat,INT1 --> datablock", that is continued even after a successful read has occurred; use the Pause command to terminate the repeated INT1 responses.

Unknown which responses are sent in case of read errors?

====

ReadN and ReadS cause errors if you're trying to read an unlicensed CD or CD-R without a mod chip. Sectors on Audio CDs can be read only when CDDA is enabled via Setmode (otherwise error code 40h is returned).

=====

Actually, Read seems to work on unlicensed CD-R's, but the returned data is the whole sector or so (the 2048 data bytes preceded by a 12byte header, and probably/maybe followed by error-correction info; in fact the total received data in the Data Fifo is 4096 bytes; the last some bytes probably being garbage) (however error correction is NOT performed by hardware, so the 2048 data bytes may be trashy) (however, if the error correction info IS received, then error correction could be performed by software) (also Setloc doesn't seem to work accurately on unlicensed CD-R's).

=====

```
;Read occasionally returns 11h,40h ..? when TOC isn't loaded?
```

After receiving INT1, the Kernel does,

```
[1F801800h]=00h
00h=[1F801800h]
[1F801803h]=00h
00h=[1F801803h]
[1F801800h]=00h
[1F801803h]=80h
```

and then,

```
[1F801018h]=00020943h ;cdrom_delay
[1F801020h]=0000132Ch ;com_delay
```

then,

```
x=[1F8010F4h] AND 00FFFFFFh ;result is 00840000h
[1F8010F4h] = x OR 00880000h
[1F8010F0h] = [1F8010F0h] OR 00008000h
[1F8010B0h] = A0010000h ;addr
[1F8010B4h] = 00010200h ;LSBs=num words, MSBs=ignored/bullshit
[1F8010B4h] = 11000000h ;DMA control
```

thereafter,

```
[1F801800h]=01h
[1F801803h]=40h      ;reset parameter fifo
[0]=00000000h
[0]=00000001h
[0]=00000002h
[0]=00000003h
[1F801800h]=00h
[1F801801h]=09h      ;command9 (pause)
```

ReadS - Command 1Bh --> INT3(stat) --> INT1(stat) --> datablock

Read without automatic retry. Not sure what that means... does WHAT on errors? Maybe intended for continuous streaming video output (to skip bad frames, rather than to interrupt the stream by performing read-retrys).

ReadN/ReadS

Both ReadN/ReadS are reading data sequentially, starting at the sector specified with Setloc, and then automatically reading the following sectors.

CDROM Incoming Data / Buffer Overrun Timings

The Read commands are continuously receiving 75 sectors per second (or 150 sectors at double speed), and, basically, the software must be fast enough to process that amount of incoming data. However, the PSX hardware includes a buffer that can hold up to a handful (exact number is unknown?) of sectors, so, occasional delays of more than 1/75 seconds between processing two sectors aren't causing lost sectors, unless the delay(s) are summing up too much. The relevant steps for receiving data are:

```
Wait for Interrupt Request (INT1)           ;indicates that data is available
Send Data Request (1F801803h.Index0.Bit7=1);accept data
Acknowledge INT1                          ;
Copy Data to Main RAM (via I/O or DMA)    ;read data
```

The Data Request accepts the data for the currently pending interrupt, it should be usually issued between receiving/acknowledging INT1 (however, it can be also issued shortly after the acknowledge; even if there are further sectors in the buffer, there seems to be a small delay between the acknowledge and the next interrupt, and Data Requests during that period are still treated to belong to the old interrupt).

If a buffer overrun has occurred \<before> issuing the Data Request, then wrong data will

be received, ie. some sectors will be skipped (the hardware doesn't seem to support a buffer-overrun error flag? Anyways, see GetlocL description for a possible way to detect buffer-overruns).

If a buffer overrun occurs \<after> issuing the Data Request, then the requested data can be still read via I/O or DMA intactly, ie. the requested data is "locked", and the overrun will affect only the following sectors.

ReadTOC - Command 1Eh --> INT3(stat) --> INT2(stat)

Caution: Supported only in BIOS version vC1 and up. Not supported in vC0.

Reread the Table of Contents of current session without reset. The command is rather slow, the second response appears after about 1 second delay. The command itself returns only status information (to get the actual TOC info, use GetTD and GetTN commands).

Note: The TOC contains information about the tracks on the disk (not file names or so, that kind of information is obtained via Read commands). The TOC is read automatically on power-up, when opening/closing the drive door, and when changing sessions (so, normally, it isn't required to use this command).

Setloc, Read, Pause

A normal CDROM access (such like reading a file) consists of three commands:

Setloc, Read, Pause

Normally one shouldn't mess up the ordering of those commands, but if one does, following rules do apply:

Setloc is memorizing the wanted target, and marks it as unprocessed, and has no other effect (it doesn't start reading or seeking, and doesn't interrupt or redirect any active reads).

If Read is issued with an unprocessed Setloc, then the drive is automatically seeking the Setloc location (and marks Setloc as processed).

If Read is issued without an unprocessed Setloc, the following happens: If reading is already in progress then it just continues reading. If Reading was Paused, then reading resumes at the most recently received sector (ie. returning that sector once another time).

11.6 CDROM - Status Commands

Status code (stat)

The 8bit status code is returned by Getstat command (and many other commands), the meaning of the separate stat bits is:

7	Play	Playing CD-DA	\only ONE of these bits can be set
6	Seek	Seeking	; at a time (ie. Read/Play won't get
5	Read	Reading data sectors	; /set until after Seek completion)
4	ShellOpen	Once shell open (0=Closed, 1=Is/was Open)	
3	IdError	(0=Okay, 1=GetID denied) (also set when Setmode.Bit4=1)	
2	SeekError	(0=Okay, 1=Seek error)	(followed by Error Byte)
1	Spindle Motor	(0=Motor off, or in spin-up phase, 1=Motor on)	
0	Error	Invalid Command/parameters	(followed by Error Byte)

If the shell is closed, then bit4 is automatically reset to zero after reading stat with the Getstat command (most or all other commands do not reset that bit after reading). If stat bit0 or bit2 is set, then the normal respons(es) and interrupt(s) are not send, and, instead, INT5 occurs, and an error-byte is send as second response byte, with the following values:

___	These values appear in the FIRST response; with stat.bit0 set ___
10h	- Invalid Sub_function (for command 19h), or invalid parameter value
20h	- Wrong number of parameters
40h	- Invalid command
80h	- Cannot respond yet (eg. required info was not yet read from disk yet) (namely, TOC not-yet-read or so) (also appears if no disk inserted at all)
___	These values appear in the SECOND response; with stat.bit2 set ___
04h	- Seek failed (when trying to use SeekL on Audio CDs)
___	These values appear even if no command was sent; with stat.bit2 set ___
08h	- Drive door became opened

80h appears on some commands (02h..09h, 0Bh..0Dh, 10h..16h, 1Ah, 1Bh?, and 1Dh) when the disk is missing, or when the drive unit is disconnected from the mainboard.

When the shell is opened, INT5 is triggered regardless of whether a command was executing or not. When this happens, all bits except shell open and error are cleared in the status register. The error byte in the INT5 is set to 08h.

Some games send a Stop command before changing discs, but others just wait for the user to open the shell, causing the disc to stop. The game can then send GetStat commands, looping until bit 4 is cleared to detect when the new disc has been inserted.

Stat Seek/Play/Read bits

There's is only max ONE of the three Seek/Play/Read bits set at a time, ie. during Seek, ONLY the seek bit is set (and Read or Play doesn't get until seek completion), that is important for Gran Turismo 1, which checks for seek completion by waiting for READ getting set (rather than waiting for SEEK getting cleared).

Getstat - Command 01h --> INT3(stat)

Returns stat (like many other commands), and additionally does reset the shell open flag (for the following commands; unless the shell is still opened). This is different as for most or all other commands (which may return stat, but which do not reset the shell open flag).

In other docs, the command is eventually referred to as "Nop", believing that it does nothing than returning stat (ignoring the fact that it's having the special shell open reset feature).

Getparam - Command 0Fh --> INT3(stat,mode,null,file,channel)

Returns stat (see Getstat above), mode (see Setmode), a null byte (always 00h), and file/channel filter values (see Setfilter).

GetlocL - Command 10h --> INT3(amm,ass,asect,mode,file,channel,sm,ci)

Retrieves 4-byte sector header, plus 4-byte subheader of the current sector. GetlocL can be send during active Read commands (but, mind that the GetlocL-INT3-response can't be received until any pending Read-INT1's are acknowledged).

The PSX hardware can buffer a handful of sectors, the INT1 handler receives the \<oldest> buffered sector, the GetlocL command returns the header and subheader of the \<newest> buffered sector. Note: If the returned \<newest> sector number is much bigger than the expected \<oldest> sector number, then it's likely that a buffer overrun has occurred.

GetlocL fails (with error code 80h) when playing Audio CDs (or Audio Tracks on Data CDs). These errors occur because Audio sectors don't have any header/subheader (instead, equivalent data is stored in Subchannel Q, which can be read with GetlocP). GetlocL also fails (with error code 80h) when the drive is in Seek phase (such like shortly after a new ReadN/ReadS command). In that case one can retry issuing GetlocL (until it passes okay, ie. until the seek has completed). During Seek, the drive seems to decode only Subchannel position data (but no header/subheader data), accordingly GetlocL won't work during seek (however, GetlocP does work during Seek).

GetlocP - Command 11h - INT3(track,index,mm,ss,sect,amm,ass,asect)

Retrieves 8 bytes of position information from Subchannel Q with ADR=1. Mainly intended for displaying the current audio position during Play. All results are in BCD.

```

track: track number (AAh=Lead-out area) (FFh=unknown, toc, none?)
index: index number (Usually 01h)
mm: minute number within track (00h and up)
ss: second number within track (00h to 59h)
sect: sector number within track (00h to 74h)
amm: minute number on entire disk (00h and up)
ass: second number on entire disk (00h to 59h)
asect: sector number on entire disk (00h to 74h)

```

Note: GetlocP is also used for reading the LibCrypt protection data:

[CDROM Protection - LibCrypt](#)

GetTN - Command 13h --> INT3(stat,first,last) ;BCD

Get first track number, and last track number in the TOC of the current Session. The number of tracks in the current session can be calculated as (last-first+1). The first track number is usually 01h in the first (or only) session, and "last track of previous session plus 1" in further sessions.

GetTD - Command 14h,track --> INT3(stat,mm,ss) ;BCD

For a disk with NN tracks, parameter values 01h..NNh return the start of the specified track, parameter value 00h returns the end of the last track, and parameter values bigger than NNh return error code 10h.

The GetTD values are relative to Index=1 and are rounded down to second boundaries (eg. if track=N Index=0 starts at 12:34:56, and Track=N Index=1 starts at 12:36:56, then GetTD(N) will return 12:36, ie. the sector number is truncated, and the Index=0 region is skipped).

GetQ - Command 1Dh,adr,point --> INT3(stat) --> INT2(10bytesSubQ,peak_lo)

Caution: Supported only in BIOS version vC1 and up. Not supported in vC0.
 Caution: When unsupported, Parameter Fifo isn't cleared after the command.

Allows to read 10 bytes from Subchannel Q in Lead-In (see CDROM Subchannels chapter for details). Unlike GetTD, this command allows to receive the exact MM:SS:FF address of the point'ed Track (GetTD reads a memorized MM:SS value from RAM, whilst GetQ reads

the full MM:SS:FF from the disk, which is slower than GetTD, due to the disk-access). With ADR=1, point can be any point number for ADR=1 in Lead-in (eg. 01h..99h=Track N, A2h=Lead-Out). The returned 10 bytes are raw SubQ data (starting with the ADR/Control value; of which the lower 4bits are always ADR=1). The 11th returned byte is the Peak LSB (similar as in Play+Report, but in this case only the LSB is transferred, which is apparently a bug in CDROM BIOS, the programmer probably wanted to send 10 bytes without peak, or 12 bytes with full peak; although peak wouldn't be too useful, as it should always zero during Lead-In... but some discs do seem return non-zero values for whatever reason).

Aside from ADR=1, a value of ADR=5 can be used on multisession disks (eg. with point B0h, C0h). Not sure if any other ADR values can be used (ADR=3, ISRC is usually not in the Lead-In, ADR=2, EAN may be in the lead-in, but one may need to specify point equal to the first EAN byte).

If the ADR/Point combination isn't found, then a timeout occurs after circa 6 seconds (to avoid this, use GetTN to see which tracks/points exist). After the timeout, the command starts playing track 1. If the controller wasn't already in audio mode before sending the command, then it does switch off the drive motor for a moment (that, after the timeout, and before starting playback).

In case of timeout, the normal INT3/INT2 responses are replaced by INT3/INT5/INT5 (INT3 at command start, 1st INT5 at timeout/stop, and 2nd INT5 at restart/play).

Note: GetQ sends scratch noise to the SPU while seeking to the Lead-In area.

GetID - Command 1Ah --> INT3(stat) --> INT2/5 (stat,flags,type,atip,"SCEx")

Drive Status	1st Response	2nd Response
Door Open	INT5 (11h, 80h)	N/A
Spin-up	INT5 (01h, 80h)	N/A
Detect busy	INT5 (03h, 80h)	N/A
No Disk	INT3 (stat)	INT5 (08h, 40h, 00h, 00h, 00h, 00h, 00h, 00h)
Audio Disk	INT3 (stat)	INT5 (0Ah, 90h, 00h, 00h, 00h, 00h, 00h, 00h)
Unlicensed:Mode1	INT3 (stat)	INT5 (0Ah, 80h, 00h, 00h, 00h, 00h, 00h, 00h)
Unlicensed:Mode2	INT3 (stat)	INT5 (0Ah, 80h, 20h, 00h, 00h, 00h, 00h, 00h)
Unlicensed:Mode2+Audio	INT3 (stat)	INT5 (0Ah, 90h, 20h, 00h, 00h, 00h, 00h, 00h)
Debug/Yaroze:Mode2	INT3 (stat)	INT2 (02h, 00h, 20h, 00h, 20h, 20h, 20h, 20h)
Licensed:Mode2	INT3 (stat)	INT2 (02h, 00h, 20h, 00h, 53h, 43h, 45h, 4xh)
Modchip:Audio/Mode1	INT3 (stat)	INT2 (02h, 00h, 00h, 00h, 53h, 43h, 45h, 4xh)

The status byte (ie. the first byte in the responses), may differ in some cases; values shown above are typically received when issuing GetID shortly after power-up; however, shortly after the detect-busy phase, seek-busy flag (bit6) bit may be set, and, after

issuing commands like Play/Read/Stop, bit7,6,5,1 may differ. The meaning of the separate 2nd response bytes is:

```

1st byte: stat (as usually, but with bit3 same as bit7 in 2nd byte)
2nd byte: flags (bit7=denied, bit4=audio... or reportedly import, uh?)
    bit7: Licensed (0=Licensed Data CD, 1=Denied Data CD or Audio CD)
    bit6: Missing (0=Disk Present, 1=Disk Missing)
    bit4: Audio CD (0=Data CD, 1=Audio CD) (always 0 when Modchip installed)
3rd byte: Disk type (from TOC Point=A0h) (eg. 00h=Audio or Mode1, 20h=Mode2)
4th byte: Usually 00h (or 8bit ATIP from Point=C0h, if session info exists)
    that 8bit ATIP value is taken form the middle 8bit of the 24bit ATIP value
5th-8th byte: SCEx region (eg. ASCII "SCEE" = Europe) (0,0,0,0 = Unlicensed)

```

The fourth letter of the "SCEx" string contains region information: "SCEI" (Japan/NTSC), "SCEA" (America/NTSC), "SCEE" (Europe/PAL). The "SCEx" string is displayed in the intro, and the PSX refuses to boot if it doesn't match up for the local region.

With a modchip installed, the same response is sent for Mode1 and Audio disks (except for Audio disks with very short TOCs (eg. singles) because SCEx reading is aborted immediately after reading all TOC entries on Audio disks); whether it is Audio or Mode1 can be checked by examining Subchannel Q ADR/Control.Bit6 (eg. via command 19h, 60h, 50h, 00h).

Yaroze does return "SCEA" for SCEA discs, but, for SCEI, SCEE, SCEW discs it does return four ASCII spaces (20h).

11.7 CDROM - CD Audio Commands

To play CD-DA Audio CDs, init the following SPU Registers: CD Audio Volume, Main Volume, and SPU Control Bit0. Then send Demute command, and Play command.

Mute - Command 0Bh --> INT3(stat)

Turn off audio streaming to SPU (affects both CD-DA and XA-ADPCM).

Even when muted, the CDROM controller is internally processing audio sectors (as seen in 1F801800h.Bit2, which works as usually for XA-ADPCM), muting is just forcing the CD output volume to zero.

Mute is used by Dino Crisis 1 to mute noise during modchip detection.

Demute - Command 0Ch --> INT3(stat)

Turn on audio streaming to SPU (affects both CD-DA and XA-ADPCM). The Demute command is needed only if one has formerly used the Mute command (by default, the

PSX is demuted after power-up (...and/or after Init command?), and is demuted after cdrom-booting).

Play - Command 03h (,track) --> INT3(stat) --> optional INT1(report bytes)

Starts CD Audio Playback. The parameter is optional, if there's no parameter given (or if it is 00h), then play either starts at Setloc position (if there was a pending unprocessed Setloc), or otherwise starts at the current location (eg. the last point seeked, or the current location of the current song; if it was already playing). For a disk with N songs, Parameters 1..N are starting the selected track. Parameters N+1..99h are restarting the begin of current track. The motor is switched off automatically when Play reaches the end of the disk, and INT4(stat) is generated (with stat.bit7 cleared).

The track parameter seems to be ignored when sending Play shortly after power-up (ie. when the drive hasn't yet read the TOC).

====

"Play is almost identical to CdlReadS, believe it or not. The main difference is that this does not trigger a completed read IRQ. CdlPlay may be used on data sectors. However, all sectors from data tracks are treated as 00, so no sound is played. As CdlPlay is reading, the audio data appears in the sector buffer, but is not reliable. Game Shark "enhancement CDs" for the 2.x and 3.x versions used this to get around the PSX copy protection." Hmmm, what/where is the sector buffer... in the SPU?

And, what/who are the 2.x and 3.x versions?

Forward - Command 04h --> INT3(stat) --> optional INT1(report bytes)

Backward - Command 05h --> INT3(stat) --> optional INT1(report bytes)

After sending the command, the drive is in fast forward/backward mode, skipping every some sectors. The skipping rate is fixed (it doesn't increase after some seconds) (however, it increases when (as long as) sending the command again and again). The sound becomes (obviously) non-continous, and also rather very silent, muffled, and almost inaudible (that's making it rather useless; unless it's combined with a track/minute/second display). To terminate forward/backward, send a new Play command (with no parameters, so play starts at the "searched" location). Backward automatically switches to Play when reaching the begin of Track 1. Forward automatically Stops the drive motor with INT4(stat) when reaching the end of the last track.

Forward/Backwards work only if the drive was in Play state, and only if Play had already started (ie. not shortly/immediately after a Play command); if the drive was not in Play state, then INT5(stat+1,80h) occurs.

Setmode bits used for Play command

During Play, only bit 7,2,1 of Setmode are used, all other Setmode bits are ignored (that, including bit0, ie. during Play the drive is always in CD-DA mode, regardless of that bit). Bit7 (double speed) should be usually off, although it can be used for a fast forward effect (with audible output). Bit2 (report) activates an optional interrupt for Play, Forward, and Backward commands (see below). Bit1 (autopause) pauses play at the end of the track.

Report --> INT1(stat,track,index,mm/amm,ss+80h/ass,sect/asect,peaklo,peakhi)

With report enabled via Setmode, the Play, Forward, and Backward commands do repeatedly generate INT1 interrupts, with eight bytes response length. The interrupt isn't generated on ALL sectors, and the response changes between absolute time, and time within current track (the latter one indicated by bit7 of ss):

```
amm/ass/asect are returned on asect=00h,20h,40h,60h ;-absolute time
mm/ss+80h/sect are returned on asect=10h,30h,50h,70h ;-within current track
(or, in case of read errors, report may be returned on other asect's)
```

The last two response bytes (peaklo,peakhi) contain the Peak value, as received from the CXD2510Q Signal Processor. That is: An unsigned absolute peak level in lower 15bit, and an L/R flag in upper bit. The L/R bit is toggled after each SUBQ read, however the PSX Report mode does usually forward SUBQ only every 10 frames (but does read SUBQ in <every> frame), so L/R will stay stuck in one setting (but may toggle after one second; ie. after 75 frames). And, peak is reset after each read, so 9 of the 10 frames are lost.
Note: Report mode affects only CD Audio (not Data, nor XA-ADPCM sectors).

AutoPause --> INT4(stat)

Autopause can be enabled/disabled via Setmode.bit1:

```
Setmode.bit1=1: AutoPause=On --> Issue INT4(stat) and PAUSE at end of TRACK
Setmode.bit1=0: AutoPause=Off --> Issue INT4(stat) and STOP at end of DISC
```

End of Track is determined by sensing a track number transition in SubQ position info. After autopause, the disc stays at the <end> of the old track, NOT at the <begin> of the next track (so trying to resume playing by sending a new Play command without new Seek/Setloc command will instantly pause again).

Caution: SubQ track transitions may pause instantly when accidentally starting to play at the end of the previous track rather than at begin of desired track (this <might> happen due to seek inaccuracies, for example, GetTD does round down TOC entries from

MM:SS:FF to MM:SS:00, which may be off by 0.99 seconds, although this error should be usually compensated by the leading 2-second pregap/index0 region at the begin of each track, unfortunately there are a few .CUE sheet files that do lack both PREGAP and INDEX 00 entries on audio tracks, which might cause problems with autopause). AutoPause is used by Rayman and Tactics Ogre.

Playing XA-ADPCM Sectors (compressed audio data)

Aside from normal uncompressed CD Audio disks, the PSX can also play XA-ADPCM compressed sectors. XA-ADPCM sectors are organized in Files (not in tracks), and are "played" with Read command (not Play command).

To play XA-ADPCM, initialize the SPU for CD Audio input (as described above), enable ADPCM via Setmode, then select the sector via Setloc, and issue a Read command (typically ReadS).

XA-ADPCM sectors are interleaved, ie. only each Nth sector should be played (where "N" depends on the Motor Speed, mono/stereo format, and sample rate). If the "other" sectors do contain XA-ADPCM data too, then the Setfilter command (and XA-Filter enable flag in Setmode) must be used to select the desired sectors. If the "other" sectors do contain code or data (eg. MDEC video data) which is wanted to be send to the CPU, then SetFilter isn't required to be enabled (although it shouldn't disturb reading even if it is enabled).

If XA-ADPCM (and/or XA-Filter) is enabled via Setmode, then INT1 is generated only for non-ADPCM sectors.

The Setmode sector-size selection is don't care for forwarding XA-ADPCM sectors to the SPU (the hardware does always decompress all 900h bytes).

11.8 CDROM - Test Commands

[CDROM - Test Commands - Version, Switches, Region, Chipset, SCEx](#)

[CDROM - Test Commands - Test Drive Mechanics](#)

[CDROM - Test Commands - Prototype Debug Transmission](#)

[CDROM - Test Commands - Read/Write Decoder RAM and I/O Ports](#)

[CDROM - Test Commands - Read HC05 SUB-CPU RAM and I/O Ports](#)

11.9 CDROM - Test Commands - Version, Switches, Region, Chipset, SCEEx

19h,20h --> INT3(yy,mm,dd,ver)

Indicates the date (Year-month-day, in BCD format) and version of the HC05 CDROM controller BIOS. Known/existing values are:

(unknown)	;DTL-H2000 (with SPC700 instead HC05)
94h,09h,19h,C0h	;PSX (PU-7) 19 Sep 1994, version vC0 (a)
94h,11h,18h,C0h	;PSX (PU-7) 18 Nov 1994, version vC0 (b)
95h,05h,16h,C1h	;PSX (LATE-PU-8) 16 May 1995, version vC1 (a)
95h,07h,24h,C1h	;PSX (LATE-PU-8) 24 Jul 1995, version vC1 (b)
95h,07h,24h,D1h	;PSX (LATE-PU-8, debug ver) 24 Jul 1995, version vD1 (debug)
96h,08h,15h,C2h	;PSX (PU-16, Video CD) 15 Aug 1996, version vC2 (VCD)
96h,08h,18h,C1h	;PSX (LATE-PU-8,yaroze) 18 Aug 1996, version vC1 (yaroze)
96h,09h,12h,C2h	;PSX (PU-18) (japan) 12 Sep 1996, version vC2 (a.jap)
97h,01h,10h,C2h	;PSX (PU-18) (us/eur) 10 Jan 1997, version vC2 (a)
97h,08h,14h,C2h	;PSX (PU-20) 14 Aug 1997, version vC2 (b)
98h,06h,10h,C3h	;PSX (PU-22) 10 Jul 1998, version vC3 (a)
99h,02h,01h,C3h	;PSX/PSone (PU-23, PM-41) 01 Feb 1999, version vC3 (b)
A1h,03h,06h,C3h	;PSone/late (PM-41(2)) 06 Jun 2001, version vC3 (c)
(unknown)	;PS2, xx xxx xxxx, late PS2 models...?

19h,21h --> INT3(flags)

Returns the current status of the POS0 and DOOR switches. Bit0=HeadIsAtPos0, Bit1=DoorIsOpen, Bit2-7=AlwaysZero.

19h,22h --> INT3("for Europe")

Caution: Supported only in BIOS version vC1 and up. Not supported in vC0.

Indicates the region that console is to be used in:

INT5(11h,10h)	--> NTSC, Japan (vC0)	--> requires "SCEI" discs
INT3("for Europe")	--> PAL, Europe	--> requires "SCEE" discs
INT3("for U/C")	--> NTSC, North America	--> requires "SCEA" discs
INT3("for Japan")	--> NTSC, Japan / NTSC, Asia	--> requires "SCEI" discs
INT3("for NETNA")	--> Region-free yaroze version	--> requires "SCEEx" discs
INT3("for US/AEP")	--> Region-free debug version	--> accepts unlicensed CDRs

The CDROMs must contain a matching SCEx string accordingly.

The string "for Europe" does also suggest 50Hz PAL/SECAM video hardware.

The Yaroze accepts any normal SCEE,SCEA,SCEI discs, plus special SCEW discs.

19h,23h --> INT3("CXD2940Q/CXD1817Q/CXD2545Q/CXD1782BR") ;Servo Amplifier

19h,24h --> INT3("CXD2940Q/CXD1817Q/CXD2545Q/CXD2510Q") ;Signal Processor

19h,25h --> INT3("CXD2940Q/CXD1817Q/CXD1815Q/CXD1199BQ") ;Decoder/FIFO

Caution: Supported only in BIOS version vC1 and up. Not supported in vC0.

Indicates the chipset that the CDROM controller is intended to be used with. The strings aren't always precisely correct (CXD1782BR is actually CXA1782BR, ie. CXA, not CXD) (and CXD1199BQ chips exist on PU-7 boards, but later PU-8 boards do actually use CXD1815Q) (and CXD1817Q is actually CXD1817R) (and newer PSones are using CXD2938Q or possibly CXD2941R chips, but nothing called CXD2940Q).

Note: Yaroze responds by CXD1815BQ instead of CXD1199BQ (but not by CXD1815Q).

19h,04h --> INT3(stat) ;Read SCEx string (and force motor on)

Resets the total/success counters to zero, and does then try to read the SCEx string from the current location (the SCEx is stored only in the Lead-In area, so, if the drive head is elsewhere, it will usually not find any strings, unless a modchip is permanently simulating SCEx strings).

This is a raw test command (the successful or unsuccessful results do not lock/unlock the disk). The results can be read with command 19h,05h (which will terminate the SCEx reading), or they can be read from RAM with command 19h,60h,lo,hi (which doesn't stop reading). Wait 1-2 seconds before expecting any results.

Note: Like 19h,00h, this command forces the drive motor to spin at standard speed (synchronized with the data on the disk), works even if the shell is open (but stops spinning after a while if the drive is empty).

19h,05h --> INT3(total,success) ;Get SCEx Counters

Returns the total number of "Sxxx" strings received (where at least the first byte did match), and the number of full "SCEx" strings (where all bytes did match). Typically, the values are "01h,01h" for Licensed PSX Data CDs, or "00h,00h" for disk missing, unlicensed data CDs, Audio CDs.

The counters are reset to zero, and SCEx receive mode is active for a few seconds after booting a new disk (on power up, on closing the drive door, on sending a Reset command, and on sub_function 04h). The disk is unlocked if the "success" counter is nonzero, the only exception is sub_function 04h which does update the counters, but does not lock/unlock the disk.

11.10 CDROM - Test Commands - Test Drive Mechanics

Signal Processor and Servo Amplifier

19h,50h,msb[,mid,[lsb[,xlo]]] --> INT3(stat)

Sends an 8bit/16bit/24bit command to the hardware, depending on number of parameters:

```

1 byte  --> send CX(Xx)           ;short 8bit command
2 bytes --> send CX(Xxxx)         ;longer 16bit command
3 bytes --> send CX(Xxxxxx)       ;full 24bit command
4 bytes --> send CX(Xxxxxxx)      ;extended 32bit command (BIOS vC3 only)
4..15 bytes: acts same as max (3 or 4 bytes) (extra bytes are ignored)
0 bytes or more than 15 bytes: generates an error

```

19h,51h,msb[,mid,[lsb]] --> INT3(stat,hi,lo) ;BIOS vC2/vC3 only

Supported by newer CDROM BIOSes only (such that use CXD2545Q or newer chips). Works same as 19h,50h, but does additionally receive a response. The command is always sending a 24bit CX(Xxxxxx) command, but it doesn't verify the number of parameter bytes (when using more than 3 bytes: extra bytes are ignored, when using less than 3 bytes: garbage is appended, which is somewhat valid because 8bit/16bit commands can be padded to 24bit size by appending "don't care" bits). The command can be used to send any CX(..) command, but actually it does make sense only for the get-status commands, see below "19h,51h,39h,xxh" description.

19h,51h,39h,xxh --> INT3(stat,hi,lo) ;BIOS vC2/vC3 only

Supported by newer CDROM BIOSes only (such that use CXD2545Q or newer chips). Sends CX(39xx) to the hardware, and receives a response (the response.hi byte is usually 00h for 8bit responses, or 00h..01h for 9bit responses). For example, this can be used to dump the Coefficient RAM.

19h,03h --> INT3(stat) ;force motor off

Forces the motor to stop spinning (ignored during spin-up phase).

19h,17h --> INT3(stat) ;force motor on, clockwise, super-fast**19h,01h --> INT3(stat) ;force motor on, anti-clockwise, super-fast****19h,02h --> INT3(stat) ;force motor on, anti-clockwise, super-fast****19h,10h --> INT3(stat) ;force motor on, anti-clockwise, super-fast****19h,18h --> INT3(stat) ;force motor on, anti-clockwise, super-fast**

Forces the drive motor to spin at maximum speed (which is much faster than normal or double speed), in normal (clockwise), or reversed (anti-clockwise) direction. The commands work even if the shell is open. The commands do not try to synchronize the motor with the data on the disk (and do thus work even if no disk is inserted).

19h,00h --> INT3(stat) ;force motor on, clockwise (even if shell open)

This command seems to have effect only if the drive motor was off. If it was off, it does FFh-fills the TOC entries in RAM, and seek to the begin of the TOC at 98:30:00 or so (where minute=98 means minus two). From that location, it follows the spiral on the disk, although it does occasionally jump back some seconds. After clearing the TOC, the command does not write new data to the TOC buffer in RAM.

Note: Like 19h,04h, this command forces the drive motor to spin at standard speed (synchronized with the data on the disk), works even if the shell is open (but stops spinning after a while if the drive is empty).

19h,11h --> INT3(stat) ;Move Lens Up (leave parking position)

19h,12h --> INT3(stat) ;Move Lens Down (enter parking position)

19h,13h --> INT3(stat) ;Move Lens Outwards (away from center of disk)

Moves the laser lens. The inwards/outwards commands do move ONLY the lens (ie. unlike as for Seek commands, the overall-laser-unit remains in place, only the lens is moved).

19h,15h - if motor on: move head outwards + inwards + motor off

Moves the drive head to outer-most and inner-most position. Note that the drive doesn't have a switch that'd tell the controller when it has reached the outer-most position (so it'll forcefully hit against the outer edge) (ie. using this command too often may destroy the drive mechanics).

Note: The same destructive hit-outer-edge effect happens when using Setloc/Seek with too large values (like minute=99h).

19h,16h --> INT3(stat) ;Unknown / makes some noise if motor is on

19h,19h --> INT3(stat) ;Unknown / no effect

19h,1Ah --> INT3(stat) ;Unknown / makes some noise if motor is on

Seem to have no effect?

19h,16h seems to Move Lens Inwards, too.

19h,06h,new --> INT3(old) ;Adjust balance in RAM, and apply it via CX(30+n)

19h,07h,new --> INT3(old) ;Adjust gain in RAM, and apply it via CX(38+n)

19h,08h,new --> INT3(old) ;Adjust balance in RAM only

These commands are supported only by older CDROM BIOS versions (those with CXA1782BR Servo Amplifier).

Later BIOSes will respond with INT5(11h,20h) when trying to use these commands

(because CXD2545Q and later Servo Amplifiers don't support the CX(30/38+n) commands).

11.11 CDROM - Test Commands - Prototype Debug Transmission

Serial Debug Messages

Older CDROM BIOSes are supporting debug message transmission via serial bus, using lower 3bit of the HC05 "databus" combined with the so-called "ROMSEL" pin (which apparently doesn't refer to Read-Only-Memory, but rather something like Runtime-Output-Message, or whatever).

Data is transferred in 24bit units (8bit command/index from HC05, followed by 16bit data to/from HC05), bigger messages are divided into multiple such 24bit snippets.

There are no connectors for external debug hardware on any PSX mainboards, so the whole stuff seems to be dating back to prototypes. And it seems to be removed from later BIOSes (which appear to use "ROMSEL" as "SCLK"; for receiving status info from the new CXD2545Q chips).

19h,30h,index,dat1,dat2 --> INT3(stat) ;Prototype/Debug stuff

19h,31h,dat1,dat2 --> INT3(stat) ;Prototype/Debug stuff

19h,4xh,index --> INT3(dat1,dat2) ;Prototype/Debug stuff

These functions are supported on older CDROM BIOS only; later BIOSes respond by INT5(11h,10h).

The functions do not affect the CDROM operation (they do simple allow to transfer data between Main CPU and external debug hardware).

Sub functions 30h and 31h may fail with INT5(11h,80h) when receiving wrong signals on the serial input line.

Sub function "4xh" value can be 40h..4Fh (don't care).

INT5 Debug Messages

Alongsides to INT5 errors, the BIOS is usually also sending information via the above serial bus (the error info is divided into multiple 8bit+16bit snippets, and contains stat, error code, mode, current SubQ position, and most recently issued command).

11.12 CDROM - Test Commands - Read/Write Decoder RAM and I/O Ports

Caution: Below commands 19h,71h..76h are supported only in BIOS version vC1 and up.
Not supported in vC0.

19h,71h,index --> INT3(databyte) ;Read single register

index can be 00h..1Fh, bigger values seem to be mirrored to "index AND 1Fh", with one exception: index 13h is NOT mirrored, instead, index 33h, 53h, 93h, B3h, D3h, F3h return INT5(stat+1,10h), and index 73h returns INT5(stat+1,20h).

Aside from returning a value, the commands seem to DO something (like moving the drive head when a disk is inserted). Return values are usually:

index	value	
00h	04h	; 04h=empty, 8Eh=licensed, 24h=audio
01h	[0B1h]	; DCh=empty/licensed, DDh=audio
02h	00h	
03h	00h	; or variable when disk inserted
04h	00h	
05h	80h	; or 86h or 89h when disk inserted
06h	C0h	
07h	02h	
08h	8Ah	
09h	C0h	
0Ah	00h	
0Bh	C0h	
0Ch	[1F2h]	
0Dh	[1F3h]	
0Eh	00h	; or 8Eh or E6h when disk inserted ;D4h/audio
0Fh	00h	; or sometimes 01h when disk inserted ;50h/audio
10h	C0h	
11h	E0h	
12h	71h	
13h	stat	
14h	FFh	
15h..1Fh	C0h-filled	; or 17h --> DEh

19h,72h,index,databyte --> INT3(stat) ;Write single register

;other response on param xx16h,xx18h with xx>00h

19h,73h,index,len --> INT3(databytes...) ;Read multiple registers (bugged)

19h,74h,index,len,databytes --> INT3(stat) ;Write multiple registers (bugged)

Same as read/write single register, but trying to transfer multiple registers at once. BUG: The transfer should range from 00h to len-1, but the loop counter is left uninitialized (set to X=48h aka "command number 19h-minus-1-mul-2" instead of X=00h). Causing to the function to read/write garbage at index 48h..FFh, it does then wrap to 00h and do the correct intended transfer, but the preceding bugged part may have smashed RAM or I/O ports.

19h,75h --> INT3(remain.lo,remain.hi,addr.lo,addr.hi) ;Get Host Xfer Info

Returns a 4-byte value. In my early tests, on the first day it returned B1h,CEh,4Ch,01h, on the next day 2Ch,E4h,95h,D5h, and on all following days 00h,C0h,00h,00h (no idea why/where the earlier values came from).

The first byte seems to be always 00h; no matter of [1F0h].

The second byte seems to be always C0h; no matter of [1F1h].

The third,fourth bytes are [1F2h,1F3h].

That two bytes are 0Ch,08h after Read commands.

```
The first bytes are NOT affected by:  
destroying [1F0h] via too-many-parameters in command-buffer,  
changes to [1F1h] which may occur after read command (eg. may be 20h)
```

19h,76h,len_lo,len_hi,addr_lo,addr_hi --> INT3(stat) ;Prepare SRAM Transfer

Prepare Transfer to/from 32K SRAM.

After INT3, data can be read (same way as sector data after INT1).

11.13 CDROM - Test Commands - Read HC05 SUB-CPU RAM and I/O Ports

19h,60h,addr_lo,addr_hi --> INT3(data) ;Read one byte from Drive RAM or I/O

Reads one byte from the controller's RAM or I/O area, see the memory map below for more info. Among others, the command allows to read Subchannel Q data, eg. at [200h..209h], including ADR=2/UPC/EAN and ADR=3/ISRC values (which are suppressed by GetlocP). Eg. wait for ADR\<>2, then for ADR=2, then read the remaining 9 bytes

(because of the delayed IRQs, this works only at single speed) (at double speed one can read only 5 bytes before the values get overwritten by new data). Unknown if older boards (with 4.00MHz oscillators) are fast enough to read all 10 SubQ bytes.

CDROM Controller I/O Area and RAM Memory Map

First 40h bytes are I/O ports (as in MC68HC05 datasheet):

000h 4	FF 7B 00 FF (other when disk inserted)
004h 5	11 00 20 20 0C
009h 1	00 (when disk inserted: changes between 00 or 80)
00Ah 2	71 00
00Ch 1	00 (when disk inserted: changes between 00 or 80)
00Dh 3	20 20 20
010h 8	02 80 00 60 00 00 99(orBB) 98
018h 4	changes randomly (even when no disk inserted)
01Ch 3	40 00 41
01Fh 1	changes randomly (even when no disk inserted)
020h 30	20h-filled
03Eh 2	82h 20h

Next 200h bytes are RAM:

040h 4	08 00 00 00 ;or 98 07 xx 0B when disk inserted ;[40].Bit1=MUTE
044h 4	00h-filled
048h 3	40 20 00 ;or 58 71 0F when disk inserted
04Bh 1	changes randomly (nodisk: 00 or 80 / disk: BFh)
04Ch 1	Zero (or C0h)
04Dh 3	MM:SS:FF (begin of current track MM:SS:00h) (or increasing addr)
050h 10	Subchannel Q (adjusted position values)
05Ah 2	...
05Ch 1	00h (or 64h)
05Dh 3	MM:SS:FF (current read address) (sticky address during pause)
060h 1	increments at circa 16Hz or so (or other rate when spinning)
061h 12	00h-filled ;or else when disk inserted
06Dh 1	01 ;or 0C when disk inserted
06Eh 2	SetFilter setting (file,channel)
070h 16	00h-filled ;or else when disk inserted
080h 8	00h-filled
088h 3	03:SS:FF (three, second, fraction)
08Bh 3	03:SS:FF (three, second, fraction)
08Eh 2	01 FF (or other values)
090h 1	00h (or 91h when disk inserted + spinning)
091h 13	Zero
09Eh 1	00h (or 01h when disk inserted + spinning)
09Fh 1	Zero
0A0h 1	Always 23h
0A1h 1	09h (5Dh when disk inserted)
0A2h 7	00h-filled
0A9h 1	40

```

0AAh 4 00h-filled
0AEh 1 00 (no disk) or 01 (disk) or so
0AFh 1 00 ;or 06 when disk inserted
0B0h 7 00 DC 00 02 00 E0 08 ;\or else when disk inserted
0B7h 1 20 ;Bit6+7=MUTE ;
0B8h 3 DE 00 00 ;
0BBh 1 SetMode setting (mode)
0BCh 1 GetStat setting (stat)
0BDh 3 00h-filled
0C0h 6 FFh-filled ;stack... ;\
0C6h 1 Usually DFh ;sometimes [0EBh and up] are non-FFh, too
0C7h 15 FFh-filled ;(depending on disk or commands or so)
0D6h 1 Usually FDh (or FFh) ;
0D7h 24 FFh-filled ; stack
0EFh 4 on power-up FFh-filled, other once when disk read ;
0F3h 7 changes randomly (even when no disk inserted) ;
0FAh 6 2E 3C 2A D6 10 95 ;
100h 2x99 TOC Entries for Start of Track 1..99 (MM:SS)
1C6h 1 TOC First Track number (usually 01h)
1C7h 1 TOC Last Track number (usually 01h or higher)
1C8h 3 TOC Entry for Start of Lead-Out (MM:SS:FF)
1CBh 2 Zero
1CDh 1 Depends on disk (01 or 02 or 06) (or 00 when no disk)
1CEh 1 Zero
1CFh 1 Depends on disk (NULL minus N*6) (or 00 when no disk)
        (maybe reflection level / laser intensity or so)
        [1CDh..1CFh]
        01 00 E8 --> licensed/metalgear/kain
        01 00 EE --> licensed/alone2
        06 00 E2 or 00 00 02 00 E8 --> licensed/wipeout
        02 00 DC --> unlicensed/elo
        02 00 D6 --> unlicensed/driver
        00 00 EE --> audio/lola
        00 00 FA --> audio/marilyn
        00 00 F4 --> audio/westen
        00 00 00 --> disk missing
        last byte is always in steps of 6
1D0h 4 SCEEx String
1D4h 4 Zero
1D8h 2 SCEEx Counters (total,success) ;for command 19h,05h
1DAh 6 00h-filled (or ... SS:FF)
1EOh 6 Command Buffer (usually 19h,60h,E2h,01h = Read RAM Command)
1E6h 7 00h-filled (unless destroyed by more-than-6-byte-commands)
1EDh 3 Setloc setting (MM:SS:FF)
1F0h 1 00h (unless destroyed by more-than-6-byte-commands)
1F1h 3 C0h 00h 00h ;or 20h,0Ch,50h or C0h,0Ch,08h ;for command(19h,75h)
        ;or 00h,00h,00h for audio
        ;or 80h,00h,00h for disk missing
1F4h 4 00h-filled ... or SCEEx string
1F8h 1 00h
1F9h 1 Selected Target (parameter from Play and SetSession commands)
1FAh 5 00h-filled ;01 01 00 8B 00 00 ;or 01 02 8B 00 00
        01 00 8B 00 00 -- audio/unlicensed
        01 01 00 00 00 -- licensed

```

```

1FFh 1      00h-on power up, changes when disk inserted ;or 01 = Playing
1FDh 3      MM:SS:FF (only during command 19h,00h) (MM=98..99=TOC)
200h 10     Subchannel Q (real values)
20Ah 2      whatever
20Ch 1      Zero
20Dh 1      Desired Session (from SetSession command)
20Eh 1      Current Session (actual location of drive head)
20Fh 1      Zero
210h 10     Subchannel Q (adjusted position values)
21Ah 6      00h-filled
220h 4      Data Sector Header (MM:SS:FF:Mode)
224h 4      Data Sector CD-XA Subheader (file,channel,sm,ci)
228h 1      00h
229h 1      Usually 00h (shortly other value on power-up, and maybe on seek)
22Ah 1      10h (or 00h when no disk)
22Bh 3      00h-filled
22Eh 2      01,03 or 0A,00 or 03,01 (or else for other disk)
230h 3      00h-filled (or other during spin-up / read-toc or so)
233h 0Dh    00h-filled (unused RAM)

```

Other/invalid addresses are:

```

240h..2FFh - Invalid (00h-filled) (no ROM, RAM, or I/O mapped here)
300h..3FFh - Mirror of 200h..2FFh ;\the BIOS is doing that
400h..FFFFh - Mirrors of 000h..3FFh ;/mirroring by software

```

Writing to RAM

There is no command for writing to RAM. Except that, one can write to the command/parameter buffer at 1E0h and up. Normally, the longest known command should have 6 bytes (19h,76h,a,b,c,d), and longer commands results in "bad number of parameters" response - however, despite of that error message, the controller does still store ALL parameter bytes in RAM (at address 1E1h..2E0h, then wrapping back to 1E1h). Whereas, writing more than 16 bytes (FIFO storage size) will mirror the FIFO content twice, and more than 32 bytes (FIFO counter size) will work only when feeding extra data into the FIFO during transmission. Anyways, writing to 1E1h and up doesn't allow to do interesting things (such like manipulating the stack and executing custom code on the CPU).

Subchannel Q Notes

The "adjusted position values" at 050h, 210h, 310h contain only position information (with ADR=1) (the PSX seems to check only the lower 2bit of the 4bit ADR value, so it also treats ADR=5 as ADR=1, too). Additionally, during Lead-In, bytes 7..9 are

overwritten by the position value from bytes 3..5. The "real values" contain unadjusted data, including ADR=2 and ADR=3 etc.

11.14 CDROM - Secret Unlock Commands

SecretUnlockPart1 - Command 50h --> INT5(11h,40h)

SecretUnlockPart2 - Command 51h,"Licensed by" --> INT5(11h,40h)

SecretUnlockPart3 - Command 52h,"Sony" --> INT5(11h,40h)

SecretUnlockPart4 - Command 53h,"Computer" --> INT5(11h,40h)

SecretUnlockPart5 - Command 54h,"Entertainment" --> INT5(11h,40h)

SecretUnlockPart6 - Command 55h,\<region> --> INT5(11h,40h)

SecretUnlockPart7 - Command 56h --> INT5(11h,40h)

Caution: Supported only in BIOS version vC1 and up. Not supported in vC0.

Caution: Supported only in Europe/USA. Nonfunctional in Japan/Asia.

Caution: When unsupported, Parameter Fifo isn't cleared after the command.

Sending these commands with the correct strings (in order 50h through 56h) does disable the "SCEx" protection. The region can be detected via test command 19h,22h, and must be translated to the following \<region> string:

"of America"	;for NTSC/US	;\
"(Europe)"	;for PAL/Europe	; handled, and actually working
"World wide"	;for Yaroze	;/
"Inc."	;for NTSC/JP	;-non-functional

In the unlocked state, ReadN/ReadS are working for unlicensed CD-Rs, and for imported CDROMs from other regions (both without needing modchips). However there are some cases which may still cause problems: The GetID command (1Ah) does still identify the disc as being unlicensed, same for the Get SCEx Counters test command (19h,05h). And, if a game should happen to send the Reset command (1Ch) for some weird reason, then the BIOS would forget the unlocking, same for games that set the "HCRISD" I/O port bit. On the contrary, opening/closing the drive door does not affect the unlocking

state.

The commands have been discovered in September 2013, and appear to be supported by all CDROM BIOS versions (from old PSXes up to later PSones).

Note that the commands do always respond with INT5 errors (even on successful unlocking).

Japanese consoles are internally containing code for processing the Secret Unlock commands, but they are not actually executing that code, and even if they would do so: they are ignoring the resulting unlocking flag, making the commands nonfunctional in Japan/Asia regions.

SecretLock - Command 57h --> INT5(11h,40h)

Undoes the unlocking and restores the normal locked state (same happens when sending the Unlocking commands in wrong order or with wrong parameters).

SecretCrash - Command 58h..5Fh --> Crash

Jumps to a data area and executes random code. Results are more or less unpredictable (as they involve executing undefined opcodes). Eventually the CPU might hit a RET opcode and recover from the crash.

11.15 CDROM - Video CD Commands

Caution: Supported only on SCPH-5903, not supported on any other consoles.

Caution: When unsupported, Parameter Fifo isn't cleared after the command.

1Fh VideoCD	sub,a,b,c,d,e	INT3(stat,a,b,c,d,e) ;<- SCPH-5903 only
1Fh..4Fh -	-	INT5(11h,40h) ;-Unused/invalid

VideoCdSio - Cmd 1Fh,01h,JoyL,JoyH,State,Task,0 --> INT3(stat,req,mm,ss,ff,x)

The JoyL/JoyH bytes contain 16bit button (and drive door) bits:

0	Drive Door	(0=Open)	(from CDROM stat bit4)	;Open
1	Button /\	(0=Pressed)	(from PSX pad bit12)	;N/A ;PBC: Back/LevelUp
2	Button []	(0=Pressed)	(from PSX pad bit15)	;Enter Menu
3	Button ()	(0=Pressed)	(from PSX pad bit13)	;Leave Menu ;PBC: Confirm
4	Button ><	(0=Pressed)	(from PSX pad bit14)	;N/A
5	Start	(0=Pressed)	(from PSX pad bit3)	;Play/Pause
6	Select	(0=Pressed)	(from PSX pad bit0)	;Stop (prompt restart/resume)
7	Always 0	(0)	(fixed)	;N/A

```

8 DPAD Up      (0=Pressed) (from PSX pad bit4) ;Menu Up           ;PBC: +1
9 DPAD Right   (0=Pressed) (from PSX pad bit5) ;Menu Right/change ;PBC: +10
10 DPAD Down    (0=Pressed) (from PSX pad bit6) ;Menu Down          ;PBC: -1
11 DPAD Left    (0=Pressed) (from PSX pad bit7) ;Menu Left/change   ;PBC: -10
12 Button R1    (0=Pressed) (from PSX pad bit11) ;Prev Track/Restart Track
13 Button R2    (0=Pressed) (from PSX pad bit9)  ;Fast Forward (slowly)
14 Button L1    (0=Pressed) (from PSX pad bit10) ;Next Track (if any)
15 Button L2    (0=Pressed) (from PSX pad bit8)  ;Fast Backward (slowly)

```

The State byte can be:

```

00h Motor Off (or spin-up) (when stat.bit1=0)
01h Playing       (when stat.bit7=1)
02h Paused (and not seeking) (when stat.bit6=0)
(note: State remains unchanged when seeking)

```

The Task byte can be:

```

00h = Confirms that "Tocread" (aka setsession 1) request was processed
01h = Detect VCD Disc (used on power-up, and after door open) (after spin-up)
02h = Handshake (request ack response)
0Ah = Door opened during play (int5/door error)
80h = No disc
FFh = No change (nop)

```

The req byte in the INT3 response can be:

```

00h Normal (no special event occurred and no action requested)
01h Request CD to Seek_and_Play (using mm:ss:ff response parameter bytes)
02h Request CD to Pause           ;cmd(09h) -->int3(stat),int2(stat)
03h Request CD to Stop            ;cmd(08h) -->int3(stat),int2(stat)
04h Request CD to Tocread (setsession1);cmd(12h,01h)-->int3(stat),int2(stat)
05h Handshake Command was processed, and this is the "ack" response
06h Request CD to Fast Forward   ;cmd(04h) -->int3(stat)
07h Request CD to Fast Backward  ;cmd(05h) -->int3(stat)
80h Detect Command was processed, and disc was detected as VCD
81h Detect Command was processed, and disc was detected as Non-VCD

```

VideoCdSwitch - Cmd 1Fh,02h,flag,x,x,x,x --> INT3(stat,0,0,x,x,x)

```

00h      = Normal PSX Mode (PortF.3=LOW) (Audio/Video from GPU/SPU chips)
01h..FFh = Special VCD Mode (PortF.3=HIGH) (Audio/Video from MDEC/OSD chips)

```

Some findings on the SC430924 firmware...

The version/date is "15 Aug 1996, version C2h", although the "C2h" is misleading: The firmware is nearly identical to version "C1h" from PU-8 boards (the stuff added in normal "C2h" versions would be for PU-18 boards with different cdrom chipset).

Compared to the original C1h version, there are only a few changes: A initialization function for initializing port F on power-up. And new command (command 1Fh, inserted in the various command tables), with two subfunctions (01h and 02h):

- Command 1Fh,01h,a,b,c,d,e --> INT3(stat,a,b,c,d,e) Serial 5-byte read-write
- Command 1Fh,02h,v,x,x,x,x --> INT3(stat,0,0,x,x,x) Toggle 1bit (port F.bit3)

Whereas,

```
x = don't care/garbage
v = toggle state (00h=normal=PortF.3=LOW, 01h..FFh=special=PortF.3=HIGH)
      (toggle gpu vs mpeg maybe?)
a,b,c,d,e = five bytes sent serially, and five bytes response received
            serially (send/receive done simultaneously)
```

The Port F bits are:

```
Port F.Bit0 = Serial Data In
Port F.Bit1 = Serial Data Out
Port F.Bit2 = Serial Clock Out
Port F.Bit3 = Toggle (0=Normal, 1=Special)
```

And that's about all. Ie. essentially, the only change is that the new command controls Port F. There is no interaction with the remaining firmware (ie. reading, seeking, and everything is working as usually, without any video-cd related changes).

The SCEEx stuff is also not affected (ie. Video CDs would be seen as unlicensed discs, so the PSX couldn't read anything from those discs, aside from Sub-Q position data, of course). The SCEEx region is SCEI aka "Japan" (or actually for Asia in this case).

Note

The SPU MUTE Flag (SPUCNT.14) does also affect VCD Audio (mute is applied to the final analog audio amplifier). All other SPUCNT bits can be zero for VCD.

11.16 CDROM - Mainloop/Responses

SUB-CPU Mainloop

The SUB-CPU is running a mainloop that is handling hardware events (by simple polling, not by IRQs):

```
check for incoming sectors (from CDROM decoder)
check for incoming commands (from Main CPU)
do maintenance stuff on the drive mechanics
```

There is no fixed priority: if both incoming sector and incoming command are present, then the SUB-CPU may handle either one, depending on which portion of the mainloop it is currently executing.

There is no fixed timing: if the mainloop is just checking for a specific event, then a new event may be processed immediately, otherwise it may take whole mainloop cycle until the SUB-CPU sees the event.

Whereas, the mainloop cycle execution time isn't constant: It may vary depending on various details. Especially, some maintenance stuff is only handled approximately around 15 times per second (so there are 15 slow mainloop cycles per second).

Responses

The PSX can deliver one INT after another. Instead of using a real queue, it's merely using some flags that do indicate which INT(s) need to be delivered. Basically, there seem to be two flags: One for Second Response (INT2), and one for Data/Report Response (INT1).

There is no flag for First Response (INT3); because that INT is generated immediately after executing a command.

The flag mechanism means that the SUB-CPU cannot hold more than one undelivered INT1. That, although the CDROM Decoder does notify the SUB-CPU about all newly received sectors, and it can hold up to eight sectors in the 32K SRAM. However, the SUB-CPU BIOS merely sets a sector-delivery-needed flag (instead of memorizing which/how many sectors need to be delivered, and, accordingly, the PSX can use only three of the available eight SRAM slots: One for currently pending INT1, one for undelivered INT1, and one for currently/incompletely received sector).

First Response (INT3) (or INT5 if failed)

The first response is sent immediately after processing a command. In detail:
The mainloop checks for incoming commands once every some clock cycles, and
executes commands under following condition:

Main CPU has sent a command, AND, there is no INT pending
(if an INT is pending, then the command won't be executed yet, but will be
executed in following mainloop cycles; once when INT got acknowledged)
(even if no INT is pending, the mainloop may generate INT1/INT2 before
executing the command, if so, as said above, the command won't execute yet)

Once when the command gets executed it will send the first response immediately after
the command execution (which may only take a few clock cycles, or some more cycles,
for example Init/ReadTOC do include some time consuming initializations). Anyways,
there will be no other INTs generated during command execution, so once when the
command execution has started, it's guaranteed that the next INT will contain the first
response.

Second Responses (INT2) (or INT5 if failed)

Some commands do send a second response after actual command execution:

07h MotorOn	E -	INT3(stat), INT2(stat)
08h Stop	E -	INT3(stat), INT2(stat)
09h Pause	E -	INT3(stat), INT2(stat)
0Ah Init	-	INT3(late-stat), INT2(stat)
12h SetSession	E session	INT3(stat), INT2(stat)
15h SeekL	E -	INT3(stat), INT2(stat) ;use prior Setloc
16h SeekP	E -	INT3(stat), INT2(stat) ;to set target
1Ah GetID	E -	INT3(stat), INT2/5(stat,flg,typ,atip,"SCEx")
1Dh GetQ	E adr,point	INT3(stat), INT2(10bytesSubQ,peak_lo)
1Eh ReadTOC	-	INT3(late-stat), INT2(stat)

In some cases (like seek or spin-up), it may take more than a second until the 2nd
response is sent.

It should be highly recommended to WAIT until the second response is generated
BEFORE sending a new command (it wouldn't make too much sense to send a new
command between first and second response, and results would be unknown, and
probably totally unpredictable).

Error Notes: If the command has been rejected (INT5 sent as 1st response) then the 2nd
response isn't sent (eg. on wrong number of parameters, or if disc missing). If the

command fails at a later stage (INT5 as 2nd response), then there are cases where another INT5 occurs as 3rd response (eg. on SetSession=02h on non-multisession-disk).

Data/Report Responses (INT1)

03h Play	E (track)	INT3(stat), optional INT1(report bytes)
04h Forward	E -	INT3(stat), optional INT1(report bytes)
05h Backward	E -	INT3(stat), optional INT1(report bytes)
06h ReadN	E -	INT3(stat), INT1(stat), datablock
1Bh ReadS	E?-	INT3(stat), INT1(stat), datablock

11.17 CDROM - Response Timings

Here are some response timings, measured in 33MHz units on a PAL PSone. The CDROM BIOSes mainloop is doing some maintenance stuff once and when, meaning that the response time will be higher in such mainloop cycles (max values), and less in normal cycles (min values). The maintenance timings do also depend on whether the motor is on or off (and probably on various other factors like seeking).

First Response

The First Response interrupt is sent almost immediately after processing the command (that is, when the mainloop sees a new command without any old interrupt pending). For GetStat, timings are as so:

Command	Average	Min	Max
GetStat (normal)	000c4e1h	0004a73h..003115bh	
GetStat (when stopped)	0005cf4h	000483bh..00093f2h	

Timings for most other commands should be similar as above. One exception is the Init command, which is doing some initialization before sending the 1st response:

Init	0013cceh	000f820h..00xxxxxxh
------	----------	---------------------

The ReadTOC command is doing similar initialization, and should have similar timing as Init command. Some (rarely used) Test commands include things like serial data transfers, which may be also quite slow.

Second Response

Command	Average	Min	Max
GetID	0004a00h	0004922h..0004c2bh	
Pause (single speed)	021181ch	020eaefh..0216e3ch	; \time equal to
Pause (double speed)	010bd93h	010477Ah..011B302h	; /about 5 sectors
Pause (when paused)	0001df2h	0001d25h..0001f22h	
Stop (single speed)	0d38acah	0c3bc41h..0da554dh	
Stop (double speed)	18a6076h	184476bh..192b306h	
Stop (when stopped)	0001d7bh	0001ce8h..0001eefh	

Moreover, Seek/Play/Read/SetSession/MotorOn/Init/ReadTOC are sending second responses which depend on seek time (and spin-up time if the motor was off). The seek timings are still unknown, and they are probably quite complicated:

The CDROM BIOS seems to split seek distance somehow into coarse steps (eg. minutes) and fine steps (eg. seconds/sectors), so 1-minute seek distance may have completely different timings than 59-seconds distance.

The amount of data per spiral winding increases towards ends of the disc (so the drive head will need to be moved by shorter distance when moving from minute 59 to 60 as than moving from 00 to 01).

The CDROM BIOS contains some seek distance table, which is probably optimized for 72-minute discs (or whatever capacity is used on original PSX discs). 80-minute CDRs may have tighter spiral windings (the above seek table is probably causing the drive head to be moved too far on such discs, which will raise the seek time as the head needs to be moved backwards to compensate that error).

INT1 Rate

Command	Average	Min	Max
Read (single speed)	006e1cdh	00686dah..0072732h	
Read (double speed)	0036cd2h	00322dfh..003ab2bh	

The INT1 rate needs to be precise for CD-DA and CD-XA Audio streaming, exact clock cycle values should be: $\text{SystemClock} * 930h / 4 / 44100\text{Hz}$ for Single Speed (and half as much for Double Speed) (the "Average" values are AVERAGE values, not exact values).

11.18 CDROM - Response/Data Queueing

[Below are some older/outdated test cases]

Sector Buffer

The CDROM sector buffer is 32Kx8 SRAM (IC303). The buffer is apparently divided into 8 slots, theoretically allowing to buffer up to 8 sectors.

BUG: The drive controller seems to allow only 2 of those 8 sectors (the oldest sector, and the current/newest sector).

Ie. after processing the INT1 for the oldest sector, one would expect the controller to generate another INT1 for next newer sector - but instead it appears to jump directly to INT1 for the newest sector (skipping all other unprocessed sectors). There is no known way to get around that effect.

So far, the big 32Kbyte buffer is entirely useless (the two accessible sectors could have been as well stored in a 8Kbyte chip) (unless, maybe the 32Kbytes have been intended for some error-correction "read-ahead" purposes, rather than as "look-back" buffer for old sectors; one of the unused slots might be also used for XA-ADPCM sectors).

The bottom line is that one should process INT1's as soon as possible (ie. before the cdrom controller receives and skips further sectors). Otherwise sectors would be lost without notice (there appear to be absolutely no overrun status flags, nor overrun error interrupts).

Update:

This is confirmed, as found in the SCEA_BBS.pdf bulletin board archive:

```
12/29/95 10:24 AM
Re(4): CD buffer
Thomas Boyd
CD
Dan Burnash
OK. This is the story of the CD ROM subsystem sector buffer:
The CD-ROM subsystem sector buffer is currently 32K. It is located in the CD-ROM subsystem.
It uses a sort-of tripple buffering system to read sectors in and make one (and ONLY one)
sector
available to the user.
Common questions that spring to mind and their answers:
Q: 32K - (2352 bytes/sector)*(3 buffered sectors) = lots of leftover RAM! Can I use it? A: No.
It is
not accessible by anything but the CD-ROM subsystem.
Q: How disappointing. As consolation, can I be told what the extra memory is used for? A: The
memory was going to be used for sound mapping, but (1) the system would be too slow, and
(2) sound mapping is already done by the SPU. The current implementation of this memory is ...
nothing. It is vestigal and will be cut out in future manufacturing cost reduction designs.
Tom
```

Sector Buffer Test Cases

```
Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Process INT1 --> receives sector header for 0:2:1
Process INT1 --> receives sector header for 0:2:2
Process INT1 --> receives sector header for 0:2:3
```

Above shows the normal flow when processing INT1's as they arise. Now, inserting delays (and not processing INT1's during that delays):

```
Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
delay(1)
Process INT1 --> receives sector header for 0:2:1 (oldest sector)
Process INT1 --> receives sector header for 0:2:6 (newest sector)
Process INT1 --> receives sector header for 0:2:7 (next sector)
```

Above suggests that the CDROM buffer can hold max 2 sectors (the oldest and current one). However, using a longer delay:

```
Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
delay(2)
Process INT1 --> receives sector header for 0:2:9 (oldest/overwritten)
Process INT1 --> receives sector header for 0:2:11 (newest sector)
Process INT1 --> receives sector header for 0:2:12 (next sector)
```

Above indicates that sector buffer can hold 8 sectors (as the sector 1 slot is overwritten by sector 9). And, another test with even longer delay:

```
Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
delay(3)
Process INT1 --> receives sector header for 0:2:17 (currently received)
Process INT1 --> receives sector header for 0:2:16 (newest full sector)
Process INT1 --> receives sector header for 0:2:17 (next sector)
Process INT1 --> receives sector header for 0:2:18 (next sector)
```

Above is a special case where sector 17 appears twice; the first one is the sector 1 slot (which was overwritten by sector 9, and apparently then half overwritten by sector 17).

Sector Buffer VS GetlocL Response Tests

```
Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
```

```

GetlocL
Process INT3 --> receives getloc info for 0:2:0
Process INT1 --> receives sector header for 0:2:1
Process INT1 --> receives sector header for 0:2:2
Process INT1 --> receives sector header for 0:2:3

```

Another test, with Delay BEFORE Getloc:

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Delay(1)
GetlocL
Process INT1 --> receives sector header for 0:2:1
Process INT3 --> receives getloc info for 0:2:6
Process INT1 --> receives sector header for 0:2:6
Process INT1 --> receives sector header for 0:2:7

```

Another test, with Delay AFTER Getloc:

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
GetlocL
Delay(1)
Process INT3 --> receives getloc info for 0:2:0
Process INT1 --> receives sector header for 0:2:5
Process INT1 --> receives sector header for 0:2:6
Process INT1 --> receives sector header for 0:2:7

```

Another test, with Delay BEFORE and AFTER Getloc:

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Delay(1)
GetlocL
Delay(1)
Process INT1 --> receives sector header for 0:2:9
Process INT1 --> receives sector header for 0:2:11
Process INT3 --> receives getloc info for 0:2:12
Process INT1 --> receives sector header for 0:2:12
Process INT1 --> receives sector header for 0:2:13

```

Sector Buffer VS Pause Response Tests

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Pause
Process INT3 --> receives stat=22h (first pause response)
Process INT2 --> receives stat=02h (second pause response)

```

Another test, with Delay BEFORE Pause:

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Delay(1)
Pause
Process INT1 --> receives sector header for 0:2:1 (oldest)
Process INT3 --> receives stat=22h (first pause response)
Process INT2 --> receives stat=02h (second pause response)

```

Another test, with Delay AFTER Pause:

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Pause
Delay(1)
Process INT3 --> receives stat=22h (first pause response)
Process INT2 --> receives stat=02h (second pause response)

```

Another test, with Delay BEFORE and AFTER Pause:

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Delay(1)
Pause
Delay(1)
Process INT1 --> receives sector header for 0:2:9 (oldest/overwritten)
Process INT3 --> receives stat=22h (first pause response)
Process INT2 --> receives stat=02h (second pause response)

```

For above: Note that, despite of Pause, the CDROM is still writing to the internal buffer (and overwrites slot 1 by sector 9) (this might be because the Pause command isn't processed at all until INT1 is processed).

Double Commands (Getloc then Pause)

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
GetlocL
Pause
Process INT3 --> receives stat=22h (first pause response)
Process INT2 --> receives stat=02h (second pause response)

```

Another test,

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0

```

```

Delay(1)
GetlocL
Pause
Process INT1 --> receives sector header for 0:2:1
Process INT1 --> receives sector header for 0:2:6
Process INT3 --> receives stat=22h (first pause response)
Process INT2 --> receives stat=02h (second pause response)

```

Another test,

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
GetlocL
Delay(1)
Pause
Process INT3 --> receives getloc info for 0:2:0 (first getloc response)
Process INT3 --> receives stat=22h (first pause response)
Process INT2 --> receives stat=02h (second pause response)

```

Another test,

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Delay(1)
GetlocL
Delay(1)
Pause
Process INT1 --> receives sector header for 0:2:9 (oldest/overwritten)
Process INT3 --> receives stat=22h (first pause response)
Process INT2 --> receives stat=02h (second pause response)

```

Double Commands (Pause then Getloc)

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Pause
GetlocL
Process INT3 --> receives getloc info for 0:2:0 (first getloc response)
Process INT1 --> receives sector header for 0:2:1
Process INT1 --> receives sector header for 0:2:2
Process INT1 --> receives sector header for 0:2:3

```

Another test,

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Delay(1)
Pause
GetlocL

```

```

Process INT1 --> receives sector header for 0:2:1
Process INT3 --> receives getloc info for 0:2:6 (first getloc response)
Process INT1 --> receives sector header for 0:2:6
Process INT1 --> receives sector header for 0:2:7

```

Another test,

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Pause
Delay(1)
GetlocL
Process INT3 --> receives stat=22h (first pause response)
Process INT3 --> receives getloc info for 0:2:6 (first getloc response)
(No further INT's, ie. read is paused, but second-pause-response is lost).

```

Another test,

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Pause
Delay(1)
GetlocL
Delay(1)
Process INT3 --> receives stat=22h (first pause response)
Process INT3 --> receives getloc info for 0:2:6 (first getloc response)
Process INT2 --> receives stat=02h (second pause response)

```

Another test,

```

Setloc(0:2:0)+Read
Process INT1 --> receives sector header for 0:2:0
Delay(1)
Pause
Delay(1)
GetlocL
Process INT1 --> receives sector header for 0:2:9
Process INT1 --> receives sector header for 0:2:11
Process INT3 --> receives getloc info for 0:2:12 (first getloc response)
Process INT1 --> receives sector header for 0:2:12
Process INT1 --> receives sector header for 0:2:13

```

11.19 CDROM Disk Format

Overview

The PSX uses a ISO 9660 filesystem, with data stored on CD-XA (Mode2) Sectors. ISO 9660 is standard for CDROM disks, although newer CDROMs may use extended filesystems, allowing to use long filenames and lowercase filenames, the PSX Kernel doesn't support such stuff, and, in fact, it's putting some restrictions on the ISO standard: it's limiting file names to MSDOS-style 8.3 format, and it's allowing only a limited number of files and directories per disk.

CDROM Filesystem (ISO 9660 aka ECMA-119)

Originally intended for Model Sectors (but is also used for CD-XA Mode2)
 Supports "FILENAME.EXT;VERSION" filenames (version is usually "1")
 Supports all-uppercase filenames and directory names (0-9, A-Z, underscore)
 For PSX: Max 8-character filenames with max 3-character extensions
 For PSX: Max 8-character directory names, without extension
 For PSX: Max one sector per directory (?)
 For PSX: Max one sector (or less?) per path table (?)

CDROM Extended Architecture (CD-ROM XA aka CD-XA)

Uses Mode2 Sectors (see Sector Encoding chapter)
 Allows 800h or 914h byte data per sector (with/without error correction)
 Allows to break interleaved data into separate files/channels
 Supports XA-ADPCM compressed audio data
 Stores "CD-XA001" at 400h Primary Volume Descriptor (?)
 Stores 14 extra bytes in System Use area (LEN_SU) of Directory Entries

Physical Audio/CDROM Disk Format (ISO/IEC 10149 aka ECMA-130)

Defines physical metrics of the CDROM and Audio disks
 Defines Sub-channels and Track.Index and Minute.Second.Fraction numbering
 Defines 14bit-per-byte encoding, and splits sectors into frames
 Defines ECC and EDC (error correction and error detection codes)

Available Documentation

ISO documents are commercial standards (not available for download), however, they are based on ECMA standards (which are free for download, however, the ECMA stuff is in PDF format, so one may treat it as commercial bullshit, too). CD-ROM XA is commercial only

(not available for download), and, CD-XA doesn't seem to have become very popular outside of the PSX-world, so there's very little information available, portions of CD-XA are also used in the CD-i standard (which may be a little better or worse documented).

Stuff

```

sessions one or more sessions per disk
tracks    99 tracks per disk      (01h..99h) (usually only 01h on Data Disks)
index     99 indices per track   (01h..99h) (rarely used, usually always 01h)
minutes   74 minutes per disk    (00h..73h) (or more, with some restrictions)
seconds   60 seconds per minute (00h..59h)
sectors   75 sectors per second (00h..74h)
frames    98 frames per sector
bytes     33 bytes per frame   (24+1+8 = data + subchannel + error correction)
bits      14 bits per byte    (256 valid combinations, and many invalid ones)

```

Track.Index (stored in subchannel, in BCD format)

Multiple Tracks are usually used only on Audio Disks (one track for each song, numbered 01h and up), a few Audio Disks may also split Tracks into separate fragments with different Index values (numbered 01h and up, but most tracks have only Index 01h). A simple Data Disk would usually contain only one Track (all sectors marked Track=01h and Index=01h), although some more complex Data Disks may have multiple Data tracks and/or Audio tracks.

Minute.Second.Sector (stored in subchannel, and in Data sectors, BCD format)

The sectors on CDROMs and CD Audio disks are numbered in Minutes, Seconds, and 1/75 fragments of a second (where a "second" is referring to single-speed drives, ie. the normal CD Audio playback speed).

Minute.Second.Sector is stored twice in the subchannel (once the "absolute" time, and once the "local" time).

The "absolute" sector number (counted from the begin of the disk) is mainly relevant for Seek purposes (telling the controller if the drive head is on the desired location, or if it needs to move the head backwards or forwards).

The "local" sector number (counted from the begin of the track) is mainly relevant for Audio Players, allowing to pass the data directly to the Minute:Second display, without needing to subtract the start address of the track.

Data disks are additionally storing the "absolute" values in their Data Areas, basically that's just the subchannel data duplicated, but more precisely assigned - the problem with the subchannel data is that the CD Audio standard seems to lack a clear definition

that would assign the begin of the sub-channel block to the exact begin of a sector; so, when using only the subchannel data, some Drive Controllers may assign the begin of a new sector to another location as than other Controllers do, for Audio Disks that isn't too much of a problem, but for Data Disks it'd be fatal.

Subchannels

Each frame contains 8 subchannel bits (named P,Q,R,S,T,U,V,W). So, a sector (with 98 frames) contains 98 bits (12.25 bytes) for each subchannel.

[CDROM Subchannels](#)

Error Correction

Each Frame contains 8 bytes Error Correction information, which is mainly used for Audio Disks, but it isn't 100% fail-proof, for that reason, Data Disks are containing additional Error Correction in the 930h-byte data area (the audio correction is probably focusing on repairing the MSBs of the 16bit samples, and gives less priority on the LSBs). Error Correction is some kind of a huge complex checksum, which allows to detect the location of faulty bytes, and to fix them.

930h-Byte Sectors

The "user" area for each sector is 930h bytes (2352 bytes). That region is combined of the 24-byte data per frame (and excludes the 8-byte audio error correction info, and the 1-byte subchannel data).

Most CDROM Controllers are only giving access to this 930h-byte region (ie. there's no way to read the audio error correction info by software, and only limited access to the subchannel data, such like allowing to read only the Q-channel for showing track/minute/second in audio playback mode).

On Audio disks, the 930h bytes are plain data, on Data disks that bytes are containing headers, error correction, and usually only 800h bytes user data (for more info see Sector Encoding chapter).

Sessions

Multi-Sessions are mainly used on CDR's, allowing to append newer data at the end of the disk at a later time. First of, the old session must contain a flag indicating that there may be a newer session, telling the CDROM Controller to search if one such exists (and if that is equally flagged, to search for an even newer session, and so on until reaching the last and newest session).

Each session contains a complete new ISO Volume Descriptor, and may additionally contain new Path Tables, new Directories, and new Files. The Driver Controller is usually recursing only the Volume Descriptor of the newest session. However, the various Directory Records of the new session may refer to old files or old directories from previous sessions, allowing to "import" the older files, or to "rename" or "delete" them by assigning new names to that files, or by removing them from the directory.

The PSX is reportedly not supporting multi-session disks, but that doesn't seem to be correct, namely, the Setsession command is apparently intended for that purpose... though not sure if the PSX Kernel is automatically searching the newest session... otherwise the boot executable in the first session would need to do that manually by software, and redirect control to the boot executable in the last session.

11.20 CDROM Subchannels

Subchannel P

Subchannel P contains some kind of a Pause flag (to indicate muted areas between Audio Tracks). This subchannel doesn't have any checksum, so the data cannot be trusted to be intact (unless when sensing a longer stream of all-one's, or all zero's). Theoretically, the 98 pause bits are somehow associated to the 98 audio frames (with 24 audio bytes each) of the sector. However, reportedly, Subchannel P does contain two sync bits, if that is true, then there'd be only 96 pause flags for 98 audio frames. Strange.

Note: Another way to indicate "paused" regions is to set Subchannel Q to ADR=1 and Index=00h.

Subchannel Q

contains the following information:

Bits Expl.
2 Sub-channel synchronization field
8 ADR/Control (see below)
72 Data (content depends on ADR)
16 CRC-16-CCITT error detection code (big-endian: bytes ordered MSB, LSB)

Possible values for the ADR/Control field are:

Bit0-3 ADR (0=No data, 1..3=see below, 4..0Fh=Reserved)
Bit4 Audio Preemphasis (0=No, 1=Yes) (Audio only, must be 0 for Data)
Bit5 Digital Copy (0=Prohibited, 1=Allowed)

Bit6	Data	(0=Audio, 1=Data)
Bit7	Four-Channel Audio (0=Stereo, 1=Quad)	(Audio only, must be 0 for Data)

The 72bit data regions are, depending on the ADR value...

Subchannel Q with ADR=1 during Lead-In -- Table of Contents (TOC)

8	Track number (fixed, must be 00h=Lead-in)
8	Point (01h..99h or A0h..A2h, see last three bytes for more info)
24	MSF address (incrementing address within the Lead-in area) Note: On some disks, these values are chosen so that the lead-in <starts> at 00:00:00, on other disks so that it <ends> at 99:59:74.
8	Reserved (00h)

When Point=01h..99h (Track 1..99) or Point=A2h (Lead-Out):

24	MSF address (absolute address, start address of the "Point" track)
----	--

When Point=A0h (First Track Number):

8	First Track number (BCD)
8	Disk Type Byte (00h=CD-DA or CD-ROM, 10h=CD-I, 20h=CD-ROM-XA)
8	Reserved (00h)

When Point=A1h (Last Track Number):

8	Last Track number (BCD)
16	Reserved (0000h)

ADR=1 should exist in 3 consecutive lead-in sectors.

Subchannel Q with ADR=1 in Data region -- Position

8	Track number (01h..99h=Track 1..99)
8	Index number (00h=Pause, 01h..99h=Index within Track)
24	Track relative MSF address (decreasing during Pause)
8	Reserved (00h)
24	Absolute MSF address

ADR=1 is required to exist in at least 9 out of 10 consecutive data sectors.

Subchannel Q with ADR=1 during Lead-Out -- Position

8	Track number (fixed, must be AAh=Lead-Out)
8	Index number (fixed, must be 01h) (there's no Index=00h in Lead-Out)
24	Track relative MSF address (increasing, 00:00:00 and up)
8	Reserved (00h)
24	Absolute MSF address

ADR=1 should exist in 3 consecutive lead-out sectors (and may be then followed by ADR=5 on multisession disks).

Subchannel Q with ADR=2 -- Catalogue number of the disc (UPC/EAN barcode)

52	EAN-13 barcode number (13-digit BCD)
12	Reserved (000h)
8	Absolute Sector number (BCD, 00h..74h) (always 00h during Lead-in)

If the first digit of the EAN-13 number is "0", then the remaining digits are a UPC-A barcode number. Either the 13-digit EAN-13 number, or the 12-digit UPC-A number should be printed as barcode on the rear-side of the CD package.

The first some digits contain a country code (EAN only, not UPC), followed by a manufacturer code, followed by a serial number. The last digit contains a checksum, which can be calculated as 250 minus the sum of the first 12 digits, minus twice the sum of each second digit, modulated by 10.

ADR=2 isn't included on all CDs, and, many CDs do have ADR=2, but the 13 digits are all zero. Most CDROM drives do not allow to read EAN/UPC numbers.

If present, ADR=2 should exist in at least 1 out of 100 consecutive sectors. ADR=2 may occur also in Lead-in.

Subchannel Q with ADR=3 -- ISRC number of the current track

(ISO 3901 and DIN-31-621):

12	Country Code	(two 6bit characters)	(ASCII minus 30h) ;eg. "US"
18	Owner Code	(three 6bit characters)	(ASCII minus 30h)
2	Reserved	(zero)	
8	Year of recording	(2-digit BCD) ;eg. 82h for 1982	
20	Serial number	(5-digit BCD)	;usually increments by 1 or 10 per track
4	Reserved	(zero)	
8	Absolute Sector number	(BCD, 00h..74h)	(always 00h during Lead-in)

Most CDROM drives for PC's do not allow to read ISRC numbers (or even worse, they may accidentally return the same ISRC number on every two tracks).

If present, ADR=3 should exist in at least 1 out of 100 consecutive sectors. However, reportedly, ADR=3 should not occur in Lead-in.

Subchannel Q with ADR=5 in Lead-in -- Multisession Lead-In Info

When Point=B0h:

- 8 Track number (fixed, must be 00h=Lead-in)
- 8 POINT = B0h (multi-session disc)
- 24 MM:SS:FF = the start time for the next possible session's program area, a final session is indicated by FFh:FFh:FFh, or when the ADR=5 / Point=B0h is absent.
- 8 Number of different Mode-5 pointers present.
- 24 MM:SS:FF = the maximum possible start time of the outermost Lead-out

When Point=C0h:

- 8 Track number (fixed, must be 00h=Lead-in)
- 8 POINT = C0h (Identifies a Multisession disc, together with POINT=B0h)
- 24 ATIP values from Special Information 1, ID=101
- 8 Reserved (must be 00h)
- 24 MM:SS:FF = Start time of the first Lead-in area of the disc

And, optionally, when Point=C1h:

- 8 Track number (fixed, must be 00h=Lead-in)
- 8 POINT=C1h
- 8x7 Copy of information from A1 point in ATIP

Subchannel Q with ADR=5 in Lead-Out -- Multisession Lead-Out Info

- 8 Track number (fixed, must be AAh=Lead-out)
- 8 POINT = D1h (Identifies a Multisession lead-out)
- 24 Usually zero (or maybe ATIP as in Lead-In with Point=C0h...?)
- 8 Seems to be the session number?
- 24 MM:SS:FF = Absolute address of the First data sector of the session

Present in 3 consecutive sectors (3x ADR=1, 3x ADR=5, 3x ADR=1, 3x ADR=5, etc).

Subchannel Q with ADR=5 in Lead-in -- CDR/CDRW Skip Info (Audio Only)

When Point=01h..40h:

- 8 Track number (fixed, must be 00h=Lead-in)
- 8 POINT=01h..40h (This identifies a specific playback skip interval)

```

24 MM:SS:FF Skip interval stop time in 6 BCD digits
 8 Reserved (must be 00h)
24 MM:SS:FF Skip interval start time in 6 BCD digits

```

When Point=B1h:

```

8 Track number (fixed, must be 00h=Lead-in)
8 POINT=B1h (Audio only: This identifies the presence of skip intervals)
8x4 Reserved (must be 00h,00h,00h,00h)
8 the number of skip interval pointers in POINT=01h..40h
8 the number of skip track assignments in POINT=B2h..B4h
8 Reserved (must be 00h)

```

When Point=B2h,B3h,B4h:

```

8 Track number (fixed, must be 00h=Lead-in)
8 POINT=B2h,B3h,B4h (This identifies tracks that should be skipped)
8 1st Track number to skip upon playback (01h..99h, must be nonzero)
8 2nd Track number to skip upon playback (01h..99h, or 00h=None)
8 3rd Track number to skip upon playback (01h..99h, or 00h=None)
8 Reserved (must be 00h)... unclear... OR.... 4th (of 7) skip info's...?
8 4th Track number to skip upon playback (01h..99h, or 00h=None)
8 5th Track number to skip upon playback (01h..99h, or 00h=None)
8 6th Track number to skip upon playback (01h..99h, or 00h=None)

```

Note: Skip intervals are seldom written by recorders and typically ignored by readers.

Subchannel R..W

Subchannels R..W are usually unused, except for some extended formats:

```

CD-TEXT in the Lead-In area (see below)
CD-TEXT in the Data area      (rarely used)
CD plus Graphics (CD+G)      (rarely used)

```

Most CDROM drives do not allow to read these subchannels. CD-TEXT was designed by Sony and Philips in 1997, so it should be found only on (some) newer discs. Most CD/DVD players don't support it (the only exception is that CD-TEXT seems to be popular for car hifi equipment). Most record labels don't support CD-TEXT, even Sony seems to have discontinued it on their own records after some years (so CD-TEXT is very rare on original disks, however, CDR software does often allow to write CD-TEXT on CDRs).

Subchannel R..W, when used for CD-TEXT in the Lead-In area

CD-TEXT is stored in the six Subchannels R..W. Of the 12.25 bytes (98 bits) per subchannel, only 12 bytes are used. Together, all 6 subchannels have a capacity of 72 bytes (6x12 bytes) per sector. These 72 bytes are divided into four CD-TEXT fragments (of 18 bytes each). The format of these 18 bytes is:

```

00h 1 Header Field ID1: Pack Type Indicator
01h 1 Header Field ID2: Track Number
02h 1 Header Field ID3: Sequence Number
03h 1 Header Field ID4: Block Number and Character Position Indicator
04h 12 Text/Data Field
10h 2 CRC-16-CCITT (big-endian) (across bytes 00h..0Fh)

```

ID1 - Pack Type Indicator:

80h	Titel	(TEXT)
81h	Performer	(TEXT)
82h	Songwriter	(TEXT)
83h	Composer	(TEXT)
84h	Arranger	(TEXT)
85h	Message	(TEXT)
86h	Disc ID	(TEXT?) (content/format/purpose unknown?)
87h	Genre	(BINARY) (ID codes unknown?)
88h	TOC	(BINARY) (content/format/purpose unknown?)
89h	TOC2	(BINARY) (content/format/purpose unknown?)
8Ah	Reserved for future	
8Bh	Reserved for future	
8Ch	Reserved for future	
8Dh	Reserved for "content provider" aka "closed information"	
8Eh	UPC/EAN and ISRC Codes	(TEXT) (content/format/purpose unknown?)
8Fh	Blocksize	(BINARY) (see below)

ID2 - Track Number:

00h	Title/Performer/etc. for the Disc
01h..63h	Title/Performer/etc. for Track 1..99 (Non-BCD) (Bit7=Extension)

ID3 - Sequence Number:

00h..FFh	Incrementing Number (00h=First 18-byte fragment, 01h=Second, etc.)
----------	--

ID4 - Block Number and Character Position Indicator:

Bit7	Character Set	(0=8bit, 1=16bit)
Bit6-4	Block Number	(0..7 = Language number, as set by "Blocksize")
Bit3-0	Character Position	(0..0Eh=Position, 0Fh=Append to prev fragment)

Example Data (generated with CDRWIN):

```

ID TR SQ CH <-----Text/Data-----> -CRC- <---Text--->
80 00 00 00 54 65 73 74 44 69 73 6B 54 69 74 6C E2 22 TestDiskTitl
80 00 01 0C 65 00 54 65 73 74 54 72 61 63 6B 54 C9 1B e.TestTrackT
80 01 02 0A 69 74 6C 65 31 00 54 65 73 74 54 72 40 3A itle1.TestTr
80 02 03 06 61 63 6B 54 69 74 6C 65 32 00 00 00 80 E3 ackTitle2...
81 00 04 00 54 65 73 74 44 69 73 6B 50 65 72 66 03 DF TestDiskPerf
81 00 05 0C 6F 72 6D 65 72 00 54 65 73 74 54 72 12 A5 ormer.TestTr
81 01 06 06 61 63 6B 50 65 72 66 6F 72 6D 65 72 BC 5B ackPerformer
81 01 07 0F 31 00 54 65 73 74 54 72 61 63 6B 50 AC 41 1.TestTrackP
81 02 08 0A 65 72 66 6F 72 6D 65 72 32 00 00 00 64 1A erformer2...
8F 00 09 00 01 01 02 00 04 05 00 00 00 00 00 00 6D E2 .....
8F 01 0A 00 00 00 00 00 00 00 03 0B 00 00 00 00 CD 0C .....
8F 02 0B 00 00 00 00 00 09 00 00 00 00 00 00 00 FC 8C .....
00 ;<-- for some reason, CDRWIN stores an ending 00h byte in .CDT files

```

Each Text string is terminated by a 00h byte (or 0000h for 16bit character set). If there's still room in the 12-byte data region, then first characters for the next Text string (for the next track) are appended after the 00h byte (if there's no further track, then the remaining bytes should be padded with 00h).

The "Blocksize" (ID1=8Fh) consists three packs with 24h bytes of data (first 0Ch bytes stored with ID2=00h, next 0Ch bytes with ID2=01h, and last 0Ch bytes with ID2=02h):

00h	1	Character set (00h,01h,80h,81h,82h = see below)
01h	1	First track number (usually/always 01h)
02h	1	Last track number (01h..63h)
03h	1	1bit-cd-text-in-data-area-flag, 7bit-copy-protection-flags
04h	16	Number of 18-byte packs for ID1=80h..8Fh
14h	8	Last sequence number of block 0..7 (or 00h=none)
1Ch	8	Language codes for block 0..7 (definitions are unknown)

Character Set values (for ID1=8Fh, ID2=00h, DATA[0]=charset):

00h	ISO 8859-1
01h	ISO 646, ASCII
80h	MS-JIS
81h	Korean character code
82h	Mandarin (standard) Chinese character code
Other	= reserved

"In case the same character strings is used for consecutive tracks, character 09h (or 0909h for 16bit charset) may be used to indicate the same as previous track. It shall not be used for the first track."

adjust_crc_16_ccitt(addr_len) ;for CD-TEXT and Subchannel Q

```
lsb=00h, msb=00h      ;initial value (zero for both CD-TEXT and Sub-Q)
for i=0 to len-1      ;-len (10h for CD-TEXT, 0Ah for Sub-Q)
    x = [addr+i] xor msb
    x = x xor (x shr 4)
    msb = lsb xor (x shr 3) xor (x shl 4)
    lsb = x xor (x shl 5)
next i
[addr+len+0]=msb xor FFh, [addr+len+1]=lsb xor FFh ;inverted / big-endian
```

11.21 CDROM Sector Encoding

Audio

```
000h 930h Audio Data (2352 bytes) (LeftLsb,LeftMsb,RightLsb,RightMsb)
```

Mode0 (Empty)

```
000h 0Ch Sync
00Ch 4 Header (Minute,Second,Sector,Mode=00h)
010h 920h Zerofilled
```

Mode1 (Original CDROM)

```
000h 0Ch Sync
00Ch 4 Header (Minute,Second,Sector,Mode=01h)
010h 800h Data (2048 bytes)
810h 4 EDC (checksum accross [000h..80Fh])
814h 8 Zerofilled
81Ch 114h ECC (error correction codes)
```

Mode2/Form1 (CD-XA)

```
000h 0Ch Sync
00Ch 4 Header (Minute,Second,Sector,Mode=02h)
010h 4 Sub-Header (File, Channel, Submode AND DFh, Codinginfo)
014h 4 Copy of Sub-Header
018h 800h Data (2048 bytes)
```

```
818h 4      EDC (checksum accross [010h..817h])
81Ch 114h ECC (error correction codes)
```

Mode2/Form2 (CD-XA)

```
000h 0Ch  Sync
00Ch 4      Header (Minute,Second,Sector,Mode=02h)
010h 4      Sub-Header (File, Channel, Submode OR 20h, Codinginfo)
014h 4      Copy of Sub-Header
018h 914h Data (2324 bytes)
92Ch 4      EDC (checksum accross [010h..92Bh]) (or 00000000h if no EDC)
```

encode_sector

```
sector[000h]=00h,FFh,FFh,FFh,FFh,FFh,FFh,FFh,FFh,FFh,FFh,00h
sector[00ch]=bcd(adr/75/60)           ;0..7x
sector[00dh]=bcd(adr/75 MOD 60)     ;0..59
sector[00eh]=bcd(adr MOD 75)        ;0..74
sector[00fh]=mode
if mode=00h then
    sector[010h..92Fh]=zerofilled
if mode=01h then
    adjust_edc(sector+0, 800h+10h)
    sector[814h..817h]=00h,00h,00h,00h,00h,00h,00h,00h
    calc_p_parity(sector)
    calc_q_parity(sector)
if mode=02h and form=1
    sector[012h]=sector[012h] AND (NOT 20h) ;indicate not form2
    sector[014h..017h]=sector[010h..013h]   ;copy of sub-header
    adjust_edc(sector+10h,800h+8)
    push sector[00ch]                      ;\temporarily clear header
    sector[00ch]=00000000h                  ;/
    calc_p_parity(sector)
    calc_q_parity(sector)
    pop sector[00ch]                       ;-restore header
if mode=02h and form=2
    sector[012h]=sector[012h] OR 20h       ;indicate form2
    sector[014h..017h]=sector[010h..013h]   ;copy of sub-header
    adjust_edc(sector+10h,914h+8)          ;edc is optional for form2
```

calc_parity(sector,offs,len,j0,step1,step2)

```
src=00ch, dst=81ch+offs, srcmax=dst
for i=0 to len-1
    base=src, x=0000h, y=0000h
    for j=j0 to 42
        x=x xor GF8_PRODUCT[j,sector[src+0]]
        y=y xor GF8_PRODUCT[j,sector[src+1]]
    src=src+step1, if (step1=2*44) and (src>=srcmax) then src=src-2*1118
```

```

sector[dst+2*len+0]=x AND 0FFh, [dst+0]=x SHR 8
sector[dst+2*len+1]=y AND 0FFh, [dst+1]=y SHR 8
dst=dst+2, src=base+step2

```

calc_p_parity(sector) = calc_parity(sector,0,43,19,2*43,2)
calc_q_parity(sector) = calc_parity(sector,43*4,26,0,2*44,2*43)

adjust_edc(addr,len)

```

x=00000000h
for i=0 to len-1
    x=x xor byte[addr+i], x=(x shr 8) xor edc_table[x and FFh]
word[addr+len]=x ;append EDC value (little endian)

```

init_tables

```

for i=0 to FFh
    x=i, for j=0 to 7, x=x shr 1, if carry then x=x xor D8018001h
    edc_table[i]=x
GF8_LOG[00h]=00h, GF8_ILOG[FFh]=00h, x=01h
for i=00h to FEh
    GF8_LOG[x]=i, GF8_ILOG[i]=x
    x=x SHL 1, if carry8bit then x=x xor 1dh
for j=0 to 42
    xx=GF8_ILOG[44-j], yy=subfunc(xx xor 1,19h)
    xx=subfunc(xx,01h), xx=subfunc(xx xor 1,18h)
    xx=GF8_LOG[xx], yy = GF8_LOG[yy]
    GF8_PRODUCT[j,0]=0000h
    for i=01h to FFh
        x=xx+GF8_LOG[i], if x>=255 then x=x-255
        y=yy+GF8_LOG[i], if y>=255 then y=y-255
        GF8_PRODUCT[j,i]=GF8_ILOG[x]+(GF8_ILOG[y] shl 8)

```

subfunc(a,b)

```

if a>0 then
    a=GF8_LOG[a]-b, if a<0 then a=a+255
    a=GF8_ILOG[a]
return (a)

```

11.22 CDROM XA Subheader, File, Channel, Interleave

The Sub-Header for normal data sectors is usually 00h,00h,08h,00h (some PSX sectors have 09h instead 08h, indicating the end of "something" or so?)

1st Subheader byte - File Number (FN)

0-7 File Number (00h..FFh) (for Audio/Video Interleave, see below)

2nd Subheader byte - Channel Number (CN)

0-4 Channel Number (00h..1Fh) (for Audio/Video Interleave, see below)
5-7 Should be always zero

3rd Subheader byte - Submode (SM)

```

0 End of Record (EOR) (all Volume Descriptors, and all sectors with EOF)
1 Video      ;\Sector Type (usually ONE of these bits should be set)
2 Audio      ; Note: PSX .STR files are declared as Data (not as Video)
3 Data       ;/
4 Trigger     (for application use)
5 Form2       (0=Form1/800h-byte data, 1=Form2, 914h-byte data)
6 Real Time (RT)
7 End of File (EOF) (or end of Directory/PathTable/VolumeTerminator)

```

The EOR bit is set in all Volume Descriptor sectors, the last sector (ie. the Volume Descriptor Terminator) additionally has the EOF bit set. Moreover, EOR and EOF are set in the last sector of each Path Table, and last sector of each Directory, and last sector of each File.

4th Subheader byte - Codinginfo (CI)

When used for Data sectors:

0-7 Reserved (00h)

When used for XA-ADPCM audio sectors:

```

0-1 Mono/Stereo      (0=Mono, 1=Stereo, 2-3=Reserved)
2-2 Sample Rate       (0=37800Hz, 1=18900Hz, 2-3=Reserved)
4-5 Bits per Sample   (0=Normal/4bit, 1=8bit, 2-3=Reserved)
6   Emphasis          (0=Normal/Off, 1=Emphasis)
7   Reserved           (0)

```

Audio/Video Interleave (Multiple Files/Channels)

The CDROM drive mechanics are working best when continuously following the data spiral on the disk, that works fine for uncompressed Audio Data at normal speed, but

compressed Audio Data the disk is spinning much too fast. To avoid the drive to need to pause reading or to do permanent backwards seeking, CD-XA allows to store data interleaved in separate files/channels. With common interleave values like so:

```

Interleave  Data Format
1/1 (none) 44100Hz Stereo CD Audio at normal speed
1/8          37800Hz Stereo ADPCM compressed Audio at double speed
1/16         18900Hz Stereo ADPCM compressed Audio at double speed
1/16         37800Hz Mono   ADPCM compressed Audio at double speed
1/32         18900Hz Mono   ADPCM compressed Audio at double speed
7/8          15fps 320x224 pixel MDEC compressed Videos at double speed
Unknown if 1/16 and 1/32 interleaves are actually possible (the PSX cdrom
controller seems to overwrite the IC303 sector buffer entries once every
eight sectors, so ADPCM data may get destroyed on interleaves above 1/8).
(Crash Team Racing uses 37800Hz Mono at Double speed, so 1/16 must work).

```

For example, 1/8 means that the controller processes only each 8th sector (each having the same File Number and Channel Number), and ignores the next 7 sectors (which must have other File Number and/or other Channel Number). There are various ways to arrange multiple files or channels, for example,

```

one file with eight 1/8 audio channels
one file with one 1/8 audio channels, plus one 7/8 video channel (*)
one file with one 1/8 audio channels, plus 7 unused channels
eight different files with one 1/8 audio channel each
etc.

```

(*) If the Audio and Video data belongs together then both should use the SAME channel.
Note: Above interleave values are assuming that PSX Game Disks are always running at double speed (that's fastest for normal data files, and ADPCM files are usually using the same speed; otherwise it'd be necessary to change the drive speed everytime when switching between Data to ADPCM modes).

Note: The file/channel numbers can be somehow selected with the Setfilter command. No idea if the controller is automatically switching to the next channel or so when reaching the end of the file?

Real Time Streaming

With the above Interleave, files can be played continuously at real time - that, unless read-errors do occur. In that case the drive controller would usually perform time-consuming error-correction and/or read-retries. For video/audio streaming the resulting delay would be tendentially more annoying as than processing or skipping the incorrect data.

In such cases the drive controller is allowed to ignore read errors; that probably on sectors that have the Real Time (RT) flag set in their subheaders. The controller is probably doing some read-ahead buffering (so, if it has buffered enough data, then it may still perform read retries and/or error correction, as long as it doesn't affect real time playback).

11.23 CDROM XA Audio ADPCM Compression

CD-ROM XA ADPCM is used for Audio data compression. Each 16bit sample is encoded in 4bit nibbles; so the compression rate is almost 1:4 (only almost 1:4 because there are 16 header bytes within each 128-byte portion). The data is usually/always stored on 914h-byte sectors (without error correction).

Subheader

The Subheader (see previous chapter) contains important info for ADPCM: The file/channel numbers for Interleaved data, and the codinginfo flags: mono/stereo flag, 37800Hz/18900Hz sampling rate, 4bit/8bit format, and emphasis.

ADPCM Sectors

Each sector consists of 12h 128-byte portions (=900h bytes) (the remaining 14h bytes of the sectors 914h-byte data region are 00h filled).

The separate 128-byte portions consist of a 16-byte header,

00h..03h	Copy of below 4 bytes (at 04h..07h)
04h	Header for 1st Block/Mono, or 1st Block/Left
05h	Header for 2nd Block/Mono, or 1st Block/Right
06h	Header for 3rd Block/Mono, or 2nd Block/Left
07h	Header for 4th Block/Mono, or 2nd Block/Right
08h	Header for 5th Block/Mono, or 3rd Block/Left ; \unknown/unused
09h	Header for 6th Block/Mono, or 3rd Block/Right ; for 8bit ADPCM
0Ah	Header for 7th Block/Mono, or 4th Block/Left ; (maybe 0, or maybe
0Bh	Header for 8th Block/Mono, or 4th Block/Right ;/copy of above)
0Ch..0Fh	Copy of above 4 bytes (at 08h..0Bh)

followed by twentyeight data words (4x28-bytes),

```

10h..13h 1st Data Word (packed 1st samples for 2-8 blocks)
14h..17h 2nd Data Word (packed 2nd samples for 2-8 blocks)
18h..1Bh 3rd Data Word (packed 3rd samples for 2-8 blocks)
...
Nth Data Word (packed Nth samples for 2-8 blocks)
7Ch..7Fh 28th Data Word (packed 28th samples for 2-8 blocks)

```

and then followed by the next 128-byte portion.

The "Copy" bytes are allowing to repair faulty headers (ie. if the CDROM controller has sensed a read-error in the header then it can eventually replace it by the copy of the header).

XA-ADPCM Header Bytes

```

0-3   Shift  (0..12) (0=Loudest) (13..15=Reserved/Same as 9)
4-5   Filter (0..3) (only four filters, unlike SPU-ADPCM which has five)
6-7   Unused (should be 0)

```

Note: The 4bit (or 8bit) samples are expanded to 16bit by left-shifting them by 12 (or 8), that 16bit value is then right-shifted by the selected 'shift' amount. For 8bit ADPCM shift should be 0..8 (values 9..12 will cut-off the LSB(s) of the 8bit value, this works, but isn't useful). For both 4bit and 8bit ADPCM, reserved shift values 13..15 will act same as shift=9).

XA-ADPCM Data Words (32bit, little endian)

```

0-3   Nibble for 1st Block/Mono, or 1st Block/Left  (-8h..+7h)
4-7   Nibble for 2nd Block/Mono, or 1st Block/Right (-8h..+7h)
8-11  Nibble for 3rd Block/Mono, or 2nd Block/Left  (-8h..+7h)
12-15 Nibble for 4th Block/Mono, or 2nd Block/Right (-8h..+7h)
16-19 Nibble for 5th Block/Mono, or 3rd Block/Left  (-8h..+7h)
20-23 Nibble for 6th Block/Mono, or 3rd Block/Right (-8h..+7h)
24-27 Nibble for 7th Block/Mono, or 4th Block/Left  (-8h..+7h)
28-31 Nibble for 8th Block/Mono, or 4th Block/Right (-8h..+7h)

```

or, for 8bit ADPCM format:

```

0-7   Byte for 1st Block/Mono, or 1st Block/Left    (-80h..+7Fh)
8-15  Byte for 2nd Block/Mono, or 1st Block/Right  (-80h..+7Fh)
16-23 Byte for 3rd Block/Mono, or 2nd Block/Left   (-80h..+7Fh)
24-31 Byte for 4th Block/Mono, or 2nd Block/Right (-80h..+7Fh)

```

decode_sector(src)

```

src=src+12+4+8 ;skip sync,header,subheader
for i=0 to 11h
  for blk=0 to 3
    IF stereo ;left-samples (LO-nibbles), plus right-samples (HI-nibbles)
      decode_28_nibbles(src,blk,0,dst_left,old_left,older_left)
      decode_28_nibbles(src,blk,1,dst_right,old_right,older_right)
    ELSE ;first 28 samples (LO-nibbles), plus next 28 samples (HI-nibbles)
      decode_28_nibbles(src,blk,0,dst_mono,old_mono,older_mono)
      decode_28_nibbles(src,blk,1,dst_mono,old_mono,older_mono)
    ENDIF
  next blk
  src=src+128
next i
src=src+14h+4 ;skip padding,edc

```

decode_28_nibbles(src,blk,nibble,dst,old,older)

```

shift = 12 - (src[4+blk*2+nibble] AND 0Fh)
filter = (src[4+blk*2+nibble] AND 30h) SHR 4
f0 = pos_xa_adpcm_table[filter]
f1 = neg_xa_adpcm_table[filter]
for j=0 to 27
  t = signed4bit((src[16+blk+j*4] SHR (nibble*4)) AND 0Fh)
  s = (t SHL shift) + ((old*f0 + older*f1+32)/64);
  s = MinMax(s,-8000h,+7FFFh)
  halfword[dst]=s, dst=dst+2, older=old, old=s
next j

```

Pos/neg Tables

```

pos_xa_adpcm_table[0..4] = (0, +60, +115, +98, +122)
neg_xa_adpcm_table[0..4] = (0, 0, -52, -55, -60)

```

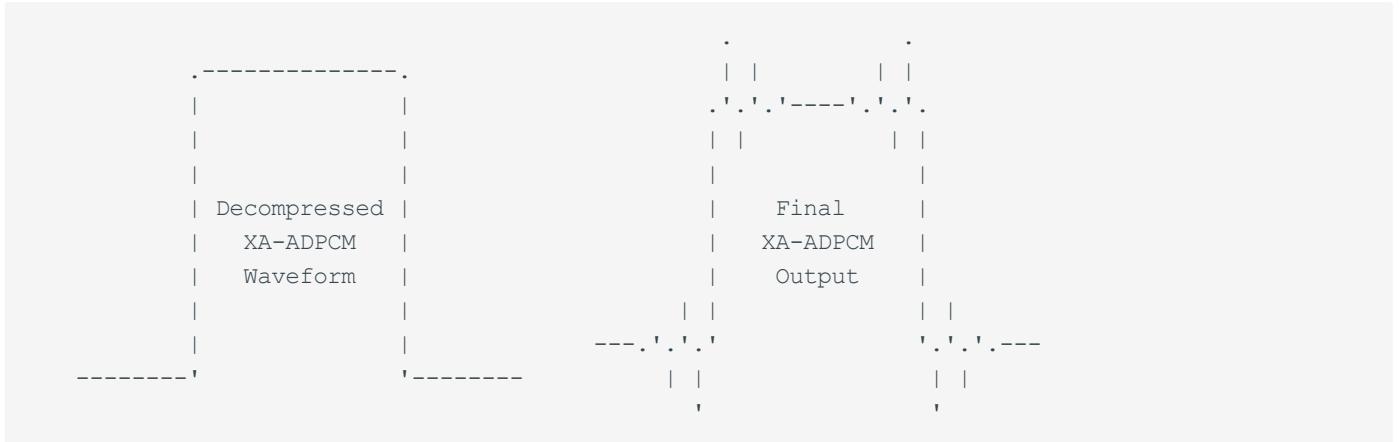
Note: XA-ADPCM supports only four filters (0..3), unlike SPU-ADPCM which supports five filters (0..4).

Old/Older Values

The incoming old/older values are usually that from the previous part, or garbage (in case of decoding errors in the previous part), or whatever (in case there was no previous part) (ie. maybe zero on power-up?) (and maybe there's also a way to reset the values to zero at the begin of a new file, or *maybe* it's silently done automatically when issuing seek commands?).

25-point Zigzag Interpolation

The CDROM decoder is applying some weird 25-point zigzag interpolation when resampling the 37800Hz XA-ADPCM output to 44100Hz. This part is different from SPU-ADPCM (which uses 4-point gaussian pitch interpolations). For example, XA-ADPCM interpolation applied to a square wave looks like this:



The zigzagging does produce some (inaudible) 22050Hz noise, and does produce some low-pass (?) filtering ("sinc filter"). The effect can be reproduced somewhat like so:

```

<B> Output37800Hz(sample):</B>
ringbuf[p AND 1Fh]=sample, p=p+1, sixstep=sixstep-1
if sixstep=0
  sixstep=6
  Ouput44100Hz(ZigZagInterpolate(p,Table1))
  Ouput44100Hz(ZigZagInterpolate(p,Table2))
  Ouput44100Hz(ZigZagInterpolate(p,Table3))
  Ouput44100Hz(ZigZagInterpolate(p,Table4))
  Ouput44100Hz(ZigZagInterpolate(p,Table5))
  Ouput44100Hz(ZigZagInterpolate(p,Table6))
  Ouput44100Hz(ZigZagInterpolate(p,Table7))
endif
<B> ZigZagInterpolate(p,TableX):</B>
sum=0
for i=1 to 29, sum=sum+(ringbuf[(p-i) AND 1Fh]*TableX[i])/8000h, next i
return MinMax(sum,-8000h,+7FFFh)
<B> Table1, Table2, Table3, Table4, Table5, Table6, Table7 ;Index</B>
0      , 0      , 0      , 0      , -0001h, +0002h, -0005h ;1
0      , 0      , 0      , -0001h, +0003h, -0008h, +0011h ;2
0      , 0      , -0001h, +0003h, -0008h, +0010h, -0023h ;3
0      , -0002h, +0003h, -0008h, +0011h, -0023h, +0046h ;4
0      , 0      , -0002h, +0006h, -0010h, +002Bh, -0017h ;5
-0002h, +0003h, -0005h, +0005h, +000Ah, +001Ah, -0044h ;6
+000Ah, -0013h, +001Fh, -001Bh, +006Bh, -00EBh, +015Bh ;7
-0022h, +003Ch, -004Ah, +00A6h, -016Dh, +027Bh, -0347h ;8
+0041h, -004Bh, +00B3h, -01A8h, +0350h, -0548h, +080Eh ;9
-0054h, +00A2h, -0192h, +0372h, -0623h, +0AFAh, -1249h ;10

```

```
+0034h, -00E3h, +02B1h, -05BFh, +0BCDh, -16FAh, +3C07h ;11
+0009h, +0132h, -039Eh, +09B8h, -1780h, +53E0h, +53E0h ;12
-010Ah, -0043h, +04F8h, -11B4h, +6794h, +3C07h, -16FAh ;13
+0400h, -0267h, -05A6h, +74BBh, +234Ch, -1249h, +0AFAh ;14
-0A78h, +0C9Dh, +7939h, +0C9Dh, -0A78h, +080Eh, -0548h ;15
+234Ch, +74BBh, -05A6h, -0267h, +0400h, -0347h, +027Bh ;16
+6794h, -11B4h, +04F8h, -0043h, -010Ah, +015Bh, -00EBh ;17
-1780h, +09B8h, -039Eh, +0132h, +0009h, -0044h, +001Ah ;18
+0BCDh, -05BFh, +02B1h, -00E3h, +0034h, -0017h, +002Bh ;19
-0623h, +0372h, -0192h, +00A2h, -0054h, +0046h, -0023h ;20
+0350h, -01A8h, +00B3h, -004Bh, +0041h, -0023h, +0010h ;21
-016Dh, +00A6h, -004Ah, +003Ch, -0022h, +0011h, -0008h ;22
+006Bh, -001Bh, +001Fh, -0013h, +000Ah, -0005h, +0002h ;23
+000Ah, +0005h, -0005h, +0003h, -0001h, 0 , 0 ;24
-0010h, +0006h, -0002h, 0 , 0 , 0 , 0 ;25
+0011h, -0008h, +0003h, -0002h, +0001h, 0 , 0 ;26
-0008h, +0003h, -0001h, 0 , 0 , 0 , 0 ;27
+0003h, -0001h, 0 , 0 , 0 , 0 , 0 ;28
-0001h, 0 , 0 , 0 , 0 , 0 , 0 ;29
```

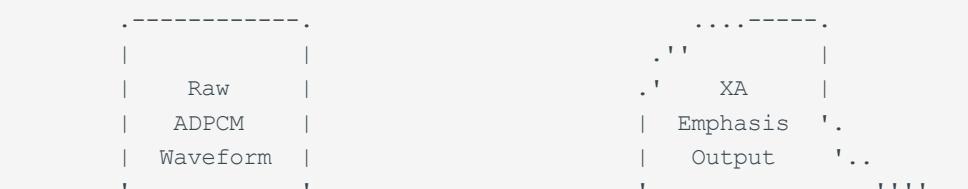
The above formula/table gives nearly correct results, but with small rounding errors in some cases - possibly due to actual rounding issues, or due to factors with bigger fractional portions, or due to a completely different formula...

Probably, the hardware does actually do the above stuff in two steps: first, applying a zig-zag filter (with only around 21-points) to the 37800Hz output, and then doing 44100Hz interpolation (2-point linear or 4-point gaussian or whatever) in a second step.

That two-step theory would also match well for 18900Hz resampling (which has lower-pitch zigzag, and gets spread accross about fifty 44100Hz samples).

XA-ADPCM Emphasis

With XA-Emphasis enabled in Sub-header, output will appear as so:



The exact XA-Emphasis formula is unknown (maybe it's just same as for CD-DA's SUBQ emphasis). Additionally, zig-zag interpolation is applied (somewhere before or after applying the emphasis stuff).

Note: The Emphasis feature isn't used by any known PSX games.

Uninitialized Six-step Counter

The hardware does contain some six-step counter (for interpolating 37800Hz to 44100Hz, ie. to insert one extra sample after each six samples). The 900h-byte sectors contain a multiple of six samples, so the counter will be always same before & after playing a sector. However, the initial counter value on power-up is uninitialized random (and the counter will fallback to that initial random setting after each 900h-byte sector).

RIFF Headers (on PCs)

When reading files that consist of 914h-byte sectors on a PC, the PC seems to automatically insert a 2Ch-byte RIFF fileheader. Like so, for ADPCM audio files:

```

00h 4    "RIFF"
04h 4    Total Filesize (minus 8)
08h 8    "CDXAfmt "
10h 4    Size of below stuff (10h)
14h 14   Stuff (looks like the "LEN_SU" region from XA-Directory Record)
22h 2    Zero (probably just dummy padding for 32bit alignment)
24h 4    "data"
28h 4    Size of following data (usually N*930h)

```

That RIFF stuff isn't stored on the CDROM (at least not in the file area) (however, some of that info, like the "=UXA" stuff, is stored in the directory area of the CDROM).

After the RIFF header, the normal sector data is appended, that, with the full 930h bytes per sector (ie. the 914h data bytes preceeded by sync bytes, header, subheader, and followed by the EDC value).

The Channel Interleave doesn't seem to be resolved, ie. the Channels are kept arranged as how they are stored on the CDROM. However, File Interleave \<should> be resolved, ie. other Files that "overlap" the file shouldn't be included in the file.

11.24 CDROM ISO Volume Descriptors

System Area (prior to Volume Descriptors)

The first 16 sectors on the first track are the system area, for a Playstation disk, it contains the following:

```

Sector 0..3 - Zero-filled (Mode2/Form1, 4x800h bytes, plus ECC/EDC)
Sector 4     - Licence String
Sector 5..11 - Playstation Logo (3278h bytes) (remaining bytes FFh-filled)
Sector 12..15 - Zero-filled (Mode2/Form2, 4x914h bytes, plus EDC)

```

Of which, the Licence String in sector 4 is,

```

000h 32   Line 1      ("          Licensed by          ")
020h 32+6 Line 2 (EU) ("Sony Computer Entertainment Euro", "pe   ") ;\either
020h 32+1 Line 2 (JP) ("Sony Computer Entertainment Inc.", 0Ah) ; one of
020h 32+6 Line 2 (US) ("Sony Computer Entertainment Amer", " ica ") ;/these
041h 1983 Empty (JP)    (filled by repeating pattern 62x30h,1x0Ah, 1x30h)
046h 1978 Empty (EU/US) (filled by 00h-bytes)

```

The Playstation Logo in sectors 5..11 contains data like so,

```

0000h .. 41h,00h,00h,00h,00h,00h,00h,01h,00h,00h,00h,1Ch,23h,00h,00h
0010h .. 51h,01h,00h,00h,A4h,2Dh,00h,00h,99h,00h,00h,00h,1Ch,00h,00h,00h
0020h .. ...
3278h 588h FF-filled (remaining bytes on sector 11)

```

the Logo contains a header, polygons, vertices and normals for the "PS" logo (which is displayed when booting from CDROM). Some BIOS versions are comparing these 3278h bytes against an identical copy in ROM, and refuse to boot if the data isn't 1:1 the same:

- US/ASIA BIOS always accepts changed logos.
- PAL BIOS accepts changed logos up to v3.0E (and refuses in v4.0E and up).
- JP BIOS never accepts changed logos (and/or changed license strings?).

Note: PAL BIOS with "region-patch-modchip" does behave same as US/ASIA BIOS.

Volume Descriptors (Sector 16 and up)

Playstation disks usually have only two Volume Descriptors,

```

Sector 16 - Primary Volume Descriptor
Sector 17 - Volume Descriptor Set Terminator

```

Primary Volume Descriptor (sector 16 on PSX disks)

000h 1	Volume Descriptor Type	(01h=Primary Volume Descriptor)
001h 5	Standard Identifier	("CD001")
006h 1	Volume Descriptor Version	(01h=Standard)
007h 1	Reserved	(00h)
008h 32	System Identifier	(a-characters) ("PLAYSTATION")
028h 32	Volume Identifier	(d-characters) (max 8 chars for PSX?)
048h 8	Reserved	(00h)
050h 8	Volume Space Size	(2x32bit, number of logical blocks)
058h 32	Reserved	(00h)
078h 4	Volume Set Size	(2x16bit) (usually 0001h)
07Ch 4	Volume Sequence Number	(2x16bit) (usually 0001h)
080h 4	Logical Block Size in Bytes	(2x16bit) (usually 0800h) (1 sector)
084h 8	Path Table Size in Bytes	(2x32bit) (max 800h for PSX)
08Ch 4	Path Table 1 Block Number	(32bit little-endian)
090h 4	Path Table 2 Block Number	(32bit little-endian) (or 0=None)
094h 4	Path Table 3 Block Number	(32bit big-endian)
098h 4	Path Table 4 Block Number	(32bit big-endian) (or 0=None)
09Ch 34	Root Directory Record	(see next chapter)
0BEh 128	Volume Set Identifier	(d-characters) (usually empty)
13Eh 128	Publisher Identifier	(a-characters) (company name)
1BEh 128	Data Preparer Identifier	(a-characters) (empty or other)
23Eh 128	Application Identifier	(a-characters) ("PLAYSTATION")
2BEh 37	Copyright Filename	("FILENAME.EXT;VER") (empty or text)
2E3h 37	Abstract Filename	("FILENAME.EXT;VER") (empty)
308h 37	Bibliographic Filename	("FILENAME.EXT;VER") (empty)
32Dh 17	Volume Creation Timestamp	("YYYYMMDDHHMMSSFF",timezone)
33Eh 17	Volume Modification Timestamp	("0000000000000000",00h)
34Fh 17	Volume Expiration Timestamp	("0000000000000000",00h)
360h 17	Volume Effective Timestamp	("0000000000000000",00h)
371h 1	File Structure Version	(01h=Standard)
372h 1	Reserved for future	(00h-filled)
373h 141	Application Use Area	(00h-filled for PSX and VCD)
400h 8	CD-XA Identifying Signature	("CD-XA001" for PSX and VCD)
408h 2	CD-XA Flags (unknown purpose)	(00h-filled for PSX and VCD)
40Ah 8	CD-XA Startup Directory	(00h-filled for PSX and VCD)
412h 8	CD-XA Reserved	(00h-filled for PSX and VCD)
41Ah 345	Application Use Area	(00h-filled for PSX and VCD)
573h 653	Reserved for future	(00h-filled)

Volume Descriptor Set Terminator (sector 17 on PSX disks)

000h 1	Volume Descriptor Type	(FFh=Terminator)
001h 5	Standard Identifier	("CD001")
006h 1	Terminator Version	(01h=Standard)
007h 2041	Reserved	(00h-filled)

Boot Record (none such on PSX disks)

000h 1	Volume Descriptor Type	(00h=Boot Record)
001h 5	Standard Identifier	("CD001")
006h 1	Boot Record Version	(01h=Standard)
007h 32	Boot System Identifier	(a-characters)
027h 32	Boot Identifier	(a-characters)
047h 1977	Boot System Use	(not specified content)

Supplementary Volume Descriptor (none such on PSX disks)

000h 1	Volume Descriptor Type	(02h=Supplementary Volume Descriptor)
001h ..	Same as for Primary Volume Descriptor	(see there)
007h 1	Volume Flags	(8bit)
008h ..	Same as for Primary Volume Descriptor	(see there)
058h 32	Escape Sequences	(32 bytes)
078h ..	Same as for Primary Volume Descriptor	(see there)

Volume Partition Descriptor (none such on PSX disks)

000h 1	Volume Descriptor Type	(03h=Volume Partition Descriptor)
001h 5	Standard Identifier	("CD001")
006h 1	Volume Partition Version	(01h=Standard)
007h 1	Reserved	(00h)
008h 32	System Identifier	(a-characters) (32 bytes)
028h 32	Volume Partition Identifier	(d-characters) (32 bytes)
048h 8	Volume Partition Location	(2x32bit) Logical Block Number
050h 8	Volume Partition Size	(2x32bit) Number of Logical Blocks
058h 1960	System Use	(not specified content)

Reserved Volume Descriptors (none such on PSX disks)

000h 1	Volume Descriptor Type	(04h..FEh=Reserved, don't use)
001h 2047	Reserved	(don't use)

11.25 CDROM ISO File and Directory Descriptors

The location of the Root Directory is described by a 34-byte Directory Record being located in Primary Volume Descriptor entries 09Ch..0BDh. The data therein is: Block Number (usually 22 on PSX disks), LEN_FI=01h, Name=00h, and, LEN_SU=00h (due to the 34-byte limit).

Format of a Directory Record

00h 1	Length of Directory Record (LEN_DR) (33+LEN_FI+pad+LEN_SU)
01h 1	Extended Attribute Record Length (usually 00h)
02h 8	Data Logical Block Number (2x32bit)
0Ah 8	Data Size in Bytes (2x32bit)
12h 7	Recording Timestamp (yy-1900, mm, dd, hh, mm, ss, timezone)
19h 1	File Flags 8 bits (usually 00h=File, or 02h=Directory)
1Ah 1	File Unit Size (usually 00h)
1Bh 1	Interleave Gap Size (usually 00h)
1Ch 4	Volume Sequence Number (2x16bit, usually 0001h)
20h 1	Length of Name (LEN_FI)
21h LEN_FI	File/Directory Name ("FILENAME.EXT;1" or "DIR_NAME" or 00h or 01h)
xxh 0..1	Padding Field (00h) (only if LEN_FI is even)
xxh LEN_SU	System Use (LEN_SU bytes) (see below for CD-XA disks)

LEN_SU can be calculated as "LEN_DR-(33+LEN_FI+Padding)". For CD-XA disks (as used in the PSX), LEN_SU is 14 bytes:

00h 2	Owner ID Group (whatever, usually 0000h, big endian)
02h 2	Owner ID User (whatever, usually 0000h, big endian)
04h 2	File Attributes (big endian):
0	Owner Read (usually 1)
1	Reserved (0)
2	Owner Execute (usually 1)
3	Reserved (0)
4	Group Read (usually 1)
5	Reserved (0)
6	Group Execute (usually 1)
7	Reserved (0)
8	World Read (usually 1)
9	Reserved (0)
10	World Execute (usually 1)
11	IS_MODE2 (0=MODE1 or CD-DA, 1=MODE2)
12	IS_MODE2_FORM2 (0=FORMAT1, 1=FORMAT2)
13	IS_INTERLEAVED (0=No, 1=Yes...?) (by file and/or channel?)
14	IS_CDDA (0=Data or ADPCM, 1=CD-DA Audio Track)
15	IS_DIRECTORY (0=File or CD-DA, 1=Directory Record)
Commonly used Attributes are:	
0D55h=Normal Binary File (with 800h-byte sectors)	
2555h=Unknown (wipeout .AV files) (MODE1 ??)	
4555h=CD-DA Audio Track (wipeout .SWP files, alone .WAV file)	
3D55h=Streaming File (ADPCM and/or MDEC or so)	
8D55h=Directory Record (parent-, current-, or sub-directory)	
06h 2	Signature ("XA")
08h 1	File Number (Must match Subheader's File Number)
09h 5	Reserved (00h-filled)

The names are alphabetically sorted, no matter if the names refer to files or directories (ie. SUBDIR would be inserted between STRFILE.EXT and SYSFILE.EXT). The first two entries (with non-ascii names 00h and 01h) are referring to current and parent directory.

Path Tables

The Path Table contain a summary of the directory names (the same information is also stored in the directory records, so programs may either use path tables or directory records; the path tables are allowing to read the whole directory tree quickly at once, without needing to seek from directory to directory).

Path Table 1 is in Little-Endian format, Path Table 3 contains the same data in Big-Endian format. Path Table 2 and 4 are optional copies of Table 1 and 3. The size and location of the tables is stored in Volume Descriptor entries 084h..09Bh. The format of the separate entries within a Path Table is,

00h 1	Length of Directory Name (LEN_DI) (01h..08h for PSX)
01h 1	Extended Attribute Record Length (usually 00h)
02h 4	Directory Logical Block Number
06h 2	Parent Directory Number (0001h and up)
08h LEN_DI	Directory Name (d-characters, d1-characters) (or 00h for Root)
xxh 0..1	Padding Field (00h) (only if LEN_DI is odd)

The first entry (directory number 0001h) is the root directory, the root doesn't have a name, nor a parent (the name field contains a 00h byte, rather than ASCII text, LEN_DI is 01h, and parent is 0001h, making the root it's own parent; ignoring the fact that incest is forbidden in many countries).

The next entries (directory number 0002h and up) (if any) are sub-directories within the root (sorted in alphabetical order, and all having parent=0001h). The next entries are sub-directories (if any) of the first sub-directory (also sorted in alphabetical order, and all having parent=0002h). And so on.

PSX disks usually contain all four tables (usually on sectors 18,19,20,21).

Format of an Extended Attribute Record (none such on PSX disks)

If present, an Extended Attribute Record shall be recorded over at least one Logical Block. It shall have the following contents.

00h 4	Owner Identification (numerical value) ;\used only if
04h 4	Group Identification (numerical value) ; File Flags Bit4=1
08h 2	Permission Flags (16bit, little-endian) ;/
0Ah 17	File Creation Timestamp ("YYYYMMDDHHMMSSFF",timezone)
1Bh 17	File Modification Timestamp ("0000000000000000",00h)

2Ch 17	File Expiration Timestamp	("00000000000000000000",00h)
3Dh 17	File Effective Timestamp	("00000000000000000000",00h)
4Eh 1	Record Format	(numerical value)
4Fh 1	Record Attributes	(numerical value)
50h 4	Record Length	(numerical value)
54h 32	System Identifier	(a-characters, a1-characters)
74h 64	System Use	(not specified content)
B4h 1	Extended Attribute Record Version	(numerical value)
B5h 1	Length of Escape Sequences	(LEN_ESC)
B6h 64	Reserved for future standardization	(00h-filled)
F6h 4	Length of Application Use	(LEN_AU)
FAh LEN_AU	Application Use	
xxh LEN_ESC	Escape Sequences	

Unknown WHERE that data is located... the Directory Records can specify the Extended Attribute Length, but not the location... maybe it's meant to be located in the first some bytes or blocks of the File or Directory...?

11.26 CDROM ISO Misc

Both Byte Order

All 16bit and 32bit numbers in the ISO region are stored twice, once in Little-Endian order, and then in Big-Endian Order. For example,

```
2x16bit value 1234h    ---> stored as 34h,12h,12h,34h
2x32bit value 12345678h ---> stored as 78h,56h,34h,12h,12h,34h,56h,78h
```

Exceptions are the 16bit Permission Flags which are stored only in Little-Endian format (although the flags are four 4bit groups, so that isn't a real 16bit number), and, the Path Tables are stored in both formats, but separately, ie. one table contains only Little-Endian numbers, and the other only Big-Endian numbers.

d-characters (Filenames)

```
"0..9", "A..Z", and "_"
```

a-characters

```
"0..9", "A..Z", SPACE, !"%"&'()*+,-./:;<=>?_"
```

Ie. all ASCII characters from 20h..5Fh except "#\$@[]^"

SEPARATOR 1 = 2Eh (aka ".") (extension; eg. "EXT")
 SEPARATOR 2 = 3Bh (aka ";") (file version; "1".."32767")

Fixed Length Strings/Filenames

The Volume Descriptors contain a number fixed-length string/filename fields (unlike the Directory Records and Path Tables which have variable lengths). These fields should be padded with SPACE characters if they are empty, or if the string is shorter than the maximum length.

Filename fields in Volume Descriptors are referring to files in the Root Directory. On PSX disks, the filename fields are usually empty, but some disks are mis-using the Copyright Filename to store the Company Name (although no such file exists on the disk).

Volume Descriptor Timestamps

The various timestamps occupy 17 bytes each, in form of

```
"YYYYMMDDHHMMSSFF",timezone  
"0000000000000000",00h ;empty timestamp
```

The first 16 bytes are ASCII Date and Time digits (Year, Month, Day, Hour, Minute, Second, and 1/100 Seconds. The last byte is Offset from Greenwich Mean Time in number of 15-minute steps from -48 (West) to +52 (East); or actually: to +56 when recursing Kiribati's new timezone.

Note: PSX games manufactured in year 2000 were accidentally marked to be created in year 0000.

Recording Timestamps

Occupy only 7 bytes, in non-ascii format

```
year-1900,month,day,hour,minute,second,timezone  
00h,00h,00h,00h,00h,00h ;empty timestamp
```

The year ranges from 1900+0 to 1900+255.

File Flags

If this Directory Record identifies a directory then bit 2,3,7 shall be set to ZERO.

If no Extended Attribute Record is associated with the File Section identified by this Directory Record then bit positions 3 and 4 shall be set to ZERO.

0	Existence	(0=Normal, 1=Hidden)
1	Directory	(0=File, 1=Directory)
2	Associated File	(0=Not an Associated File, 1=Associated File)
3	Record	<p>If set to ZERO, shall mean that the structure of the information in the file is not specified by the Record Format field of any associated Extended Attribute Record (see 9.5.8).</p> <p>If set to ONE, shall mean that the structure of the information in the file has a record format specified by a number other than zero in the Record Format Field of the Extended Attribute Record (see 9.5.8).</p>
4	Restrictions	(0=None, 1=Restricted via Permission Flags)
5	Reserved	(0)
6	Reserved	(0)
7	Multi-Extent	(0=Final Directory Record for the file, 1=Not final)

Permission Flags (in Extended Attribute Records)

0-3	Permissions for upper-class owners
4-7	Permissions for normal owners
8-11	Permissions for upper-class users
12-15	Permissions for normal users

This is a bit bizarre, an upper-class owner is "an owner who is a member of a group of the System class of user". An upper-class user is "any user who is a member of the group specified by the Group Identification field". The separate 4bit permission codes are:

Bit0	Permission to read the file	(0=Yes, 1=No)
Bit1	Must be set (1)	
Bit2	Permission to execute the file	(0=Yes, 1=No)
Bit3	Must be set (1)	

11.27 CDROM File Formats

FILENAME.EXT

The BIOS seems to support only (max) 8-letter filenames with 3-letter extension, typically all uppercase, eg. "FILENAME.EXT". Eventually, once when the executable has started, some programs might install drivers for long filenames(?)

SYSTEM.CNF

Contains boot info in ASCII/TXT format, similar to the CONFIG.SYS or AUTOEXEC.BAT files for MSDOS. A typical SYSTEM.CNF would look like so:

```
BOOT = cdrom:\abcd_123.45;1 arg ;boot exe (drive:\path\name.ext;version)
TCB = 4 ;HEX (=4 decimal) ;max number of threads
EVENT = 10 ;HEX (=16 decimal) ;max number of events
STACK = 801FFF00 ;HEX (=memtop-256)
```

The first line specifies the executable to load, from the "cdrom:" drive, "\" root directory, filename "abcd_123.45" (case-insensitive, the real name in the disk directory would be uppercase, ie. "ABCD_123.45"), and, finally ";1" is the file's version number (a rather strange ISO-filesystem specific feature) (the version number should be usually/always 1). Additionally, "arg" may contain an optional 128-byte command line argument string, which is copied to address 00000180h, where it may be interpreted by the executable (most or all games don't use that feature).

Each line in the file should be terminated by 0Dh,0Ah characters... not sure if it's also working with only 0Dh, or only 0Ah...?

A note on the "ABCD_123.45" file:

This is a normal executable (exactly as for the .EXE files, described below), however, the filename/extension is taken from the game code (the "ABCD-12345" text that is printed on the CD cover), but, with the minus replaced by an underscore, and due to the 8-letter filename limit, the last two characters are stored in the extension region.

That "XXXX_NNN.NN" naming convention seems to apply for all official licensed PSX games, not sure if it's possible to specify something like "FILENAME.EXE" as boot-file.

XXXX_NNN.NN (Boot-Executable) (filename specified in SYSTEM.CNF)

FILENAME.EXE (General-Purpose Executable)

PSX executables are having an 800h-byte header, followed by the code/data.

000h-007h	ASCII ID "PS-X EXE"	
008h-00Fh	Zerofilled	
010h	Initial PC	(usually 80010000h, or higher)
014h	Initial GP/R28	(usually 0)
018h	Destination Address in RAM	(usually 80010000h, or higher)
01Ch	Filesize (must be N*800h)	(excluding 800h-byte header)
020h	Unknown/Unused	(usually 0)
024h	Unknown/Unused	(usually 0)
028h	Memfill Start Address	(usually 0) (when below Size=None)

02Ch	Memfill Size in bytes	(usually 0) (0=None)
030h	Initial SP/R29 & FP/R30 Base	(usually 801FFFF0h) (or 0=None)
034h	Initial SP/R29 & FP/R30 Offs	(usually 0, added to above Base)
038h-04Bh	Reserved for A(43h) Function	(should be zerofilled in exefile)
04Ch-xxxxh	ASCII marker	
	"Sony Computer Entertainment Inc. for Japan area"	
	"Sony Computer Entertainment Inc. for Europe area"	
	"Sony Computer Entertainment Inc. for North America area"	
	(or often zerofilled in some homebrew files)	
	(the BIOS doesn't verify this string, and boots fine without it)	
xxxxh-7FFh	Zerofilled	
800h...	Code/Data	(loaded to entry[018h] and up)

The code/data is simply loaded to the specified destination address, ie. unlike as in MSDOS .EXE files, there is no relocation info in the header.

Note: In bootfiles, SP is usually 801FFFF0h (ie. not 801FFF00h as in system.cnf). When SP is 0, the unmodified caller's stack is used. In most cases (except when manually calling DoExecute), the stack values in the exeheader seem to be ignored though (eg. replaced by the SYSTEM.CNF value).

The memfill region is zerofilled by a "relative" fast word-by-word fill (so address and size must be multiples of 4) (despite of the word-by-word filling, still it's SLOW because the memfill executes in uncached slow ROM).

The reserved region at [038h-04Bh] is internally used by the BIOS to memorize the caller's RA,SP,R30,R28,R16 registers (for some bizarre reason, this information is saved in the exe header, rather than on the caller's stack).

Additionally to the initial PC,R28,SP,R30 values that are contained in the header, two parameter values are passed to the executable (in R4 and R5 registers) (however, usually that values are simply R4=1 and R5=0).

Like normal functions, the executable can return control to the caller by jumping to the incoming RA address (provided that it hasn't destroyed the stack or other important memory locations, and that it has pushed/popped all registers) (returning works only for non-boot executables; if the boot executable returns to the BIOS, then the BIOS will simply lockup itself by calling the "SystemErrorBootOrDiskFailure" function).

The PSX uses the standard CDROM ISO9660 filesystem without any encryption (ie. you can put an original PSX CDROM into a DOS/Windows computer, and view the content of the files in text or hex editors without problems).

PSX.EXE

Aside from SYSTEM.CNF, the Kernel seems to be also checking for a file named PSX.EXE, purpose is unknown, maybe this is the default executable name when SYSTEM.CNF is not found?

11.28 CDROM Protection - SCEx Strings

SCEx String

The heart of the PSX copy-protection is the four-letter "SCEx" string, encoded in the wobble signal of original PSX disks, which cannot be reproduced by normal CD writers. The last letter varies depending on the region, "SCEI" for Japan, "SCEA" for America (and all other NTSC countries except Japan), "SCEE" for Europe (and all other PAL countries like Australia). If the string is missing (or if it doesn't match up for the local region) then the PSX refuses to boot. The verification is done by the Firmware inside of the CDROM Controller (not by the PSX BIOS, so there's no way to bypass it by patching the BIOS ROM chip).

Wobble Groove and Absolute Time in Pregroove (ATIP) on CD-R's

A "blank" CDR contains a pre-formatted spiral on it. The number of windings in the spiral varies depending on the number of minutes that can be recorded on the disk. The spiral isn't made of a straight line (-----), but rather a wobbled line (/VV), which is used to adjust the rotation speed during recording; at normal drive speed, wobble should produce a 22050Hz sine wave.

Additionally, the CDR wobble is modulated to provide ATIP information, ATIP is used for locating and positioning during recording, and contains information about the approximate laser power necessary for recording, the last possible time location that lead out can start, and the disc application code.

Wobble is commonly used only on (recordable) CDRs, ie. usually NOT on (readonly) CDROMs and Audio Disks. The copyprotected PSX CDROMs are having a short CDR-style wobble period in the first some seconds, which seems to contain the "SCEx" string instead of ATIP information.

Other Protections

Aside from the SCEx string, PSX disks are required to contain region and licence strings (in the ISO System Area, and in the .EXE file headers), and the "PS" logo (in the System

Area, too). This data can be reproduced with normal CD writers, although it may be illegal to distribute unlicensed disks with licence strings.

11.29 CDROM Protection - Bypassing it

Modchips

A modchip is a small microcontroller which injects the "SCEx" signal to the mainboard, so the PSX can be booted even from CDRs which don't contain the "SCEx" string. Some modchips are additionally patching region checks contained in the BIOS ROM.

Note: Although regular PSX disks are black, the hardware doesn't verify the color of the disks, and works also with normal silver disks.

Disk-Swap-Trick

Once when the PSX has recognized a disk with the "SCEx" signal, it'll be satisfied until a new disk is inserted, which is sensed by the SHELL_OPEN switch. When having that switch blocked, it is possible to insert a CDR without the PSX noticing that the disk was changed.

Additionally, the trick requires some boot software that stops the drive motor (so the new disk can be inserted, despite of the PSX thinking that the drive door is still closed), and that does then start the boot executable on the new disk.

The boot software can be stored on a special boot-disk (that do have the "SCEx" string on it). Alternately, a regular PSX game disk could be used, with the boot software stored somewhere else (eg. on Expansion ROM, or BIOS ROM replacement, or Memory Card).

Booting via BIOS ROM or Expansion ROM

The PSX can be quite easily booted via Expansion ROM, or BIOS ROM replacements, allowing to execute code that is stored in the ROM, or that is received via whatever serial or parallel cable connection from a PC.

However, even with a BIOS replacement, the protection in the CDROM controller is still active, so the ROM can't read "clean" data from the CDROM Drive (unless the Disk-Swap trick is used).

Whereas, no "clean" data doesn't mean no data at all. The CDROM controller does still seem to output "raw" data (without removing the sector header, and without handling error correction, and with only limited accuracy on the sector position). So, eventually, a customized BIOS could convert the "raw" data to "clean" data.

Secret Unlock Commands

There is an "official" backdoor that allows to disable the SCEEx protection by software via secret commands (for example, sending those commands can be done via BIOS patches, nocash BIOS clone, or Expansion ROMs).

CDROM - Secret Unlock Commands

Booting via Memory Card

Some games that load data from memory cards may get confused if the save data isn't formatted as how they expect it - with some fine tuning you can get them to "crash" in a manner that they do accidentally execute bootcode stored on the memory card.

Requires a tools to write to the memory card (eg. parallel port cable), and the memory card data customized for a specific game, and an original CDROM with that specific game. Once when the memory card code is booted, the Disk-Swap trick can be used.

11.30 CDROM Protection - Modchips

Modchip Source Code

The Old Crow mod chip source code works like so:

```

entrypoint:           ;at power_up
    gate=input/highz
    data=input/highz
    wait 50 ms
    data=output/low
    wait 850 ms
    gate=output/low
    wait 314 ms
loop:
    wait 72 ms          ;pause (eighteen "1=low" bits)
    sendbyte("S")        ;1st letter
    sendbyte("C")        ;2nd letter
    sendbyte("E")        ;3rd letter
    sendbyte(...)         ;4th letter (A, E, or I, depending on region)
    goto loop
sendbyte(char):
    sendbit(0)           ;one start bit (0=highz)
    for i=0 to 7
        sendbit(char AND 1) ;output data (LSB first)
        char=char/2
    next i
    sendbit(1)           ;1st stop bit (1=low)
    sendbit(1)           ;2nd stop bit (1=low)

```

```

    return
sendbit(bit):
    if bit=1 then data=output/low elseif bit=0 then data=input/highz
    wait 4 ms           ;4ms per bit = 250 bits per second
    return

```

Connection for the data/gate/sync signals:

For older PSX boards (data/gate):

Board	data	gate	
PU-xx	unknown?	unknown?	;older PSX boards

For newer PSX and PSone boards (data/sync):

Board	data	sync	
PU-23, PM-41	CXD2938Q.Pin42	CXD2938Q.Pin5	;newer PSX and older PSone
PM-41 (2)	CXD2941R.Pin36	CXD2941R.Pin76	;newer PSone boards

On the mainboard should be a big SMD capacitor (connected to the "data" pin), and a big testpoint (connected to the "sync" pin); it's easier to connect the signals to that locations than to the tiny CXD-chip pins.

gate and data must be tristate outputs, or open-collector outputs (or normal high/low outputs passed through a diode).

Note on "data" pin (all boards)

Transfers the "SCEx" data. Note that the signal produced by the modchip is looking entirely different than the signal produced by original disks, the real signal would be modulated 22050Hz wobble, while the modchip is simply dragging the signal permanently LOW throughout "1" bits, and leaves it floating for "0" bits. Anyways the "faked" signal seems to be accurate enough to work.

Note on "gate" pin (older PSX boards only)

The "gate" pin needs to be LOW only for use with original licensed disks (reportedly otherwise the SCEx string on that disks would conflict with the SCEx string from the modchip).

At the mainboard side, the "gate" signal is an input, and "data" is an inverted output of the gate signal (so dragging gate to low, would cause data to go high).

Note on "sync" pin (newer PSX and PSone boards only)

The "sync" pin is a testpoint on the mainboard, which does (at single speed) output a frequency of circa 44.1kHz/6 (of which some clock pulses seem to be longer or shorter, probably to indicate adjustments to the rotation speed).

Some modchips are connected directly to "sync" (so they are apparently synchronizing the data output with that signal; which is not implemented in the above source code). Anyways, other modchips are using a more simplified connection: The modchip itself connects only to the "data" pin, and "sync" is required to be wired to IC723.Pin17.

Note on Multi-Region chips

Modchips that are designed to work in different regions are sending a different string (SCEA, SCEE, SCEI) in each loop cycle. Due to the slow 250bps transfer rate, it may take a while until the PSX has received the correct string, so this multi-region technique may cause a noticeable boot-delay.

Stealth (hidden modchip)

The Stealth connection is required for some newer games with anti-modchip protection, ie. games that refuse to run if they detect a modchip. The detection relies on the fact that the SCEEx signal is normally received only when booting the disk, whilst older modchips were sending that signal permanently. Stealth modchips are sending the signal only on power-up (and when inserting a new disk, which can be sensed via SHELL_OPEN signal). Modchip detection reportedly works like so (not too sure if all commands are required, some seem to be rather offtopic):

1. Com 19h,20h ;Retrieve CDROM Controller timestamp
2. Com 01h ;CdlNop: Get CD status
3. Com 07h ;CdlMotorOn: Make CD-ROM drive ready (blah?)
4. Com 02h,1,1,1 ;CdlSetloc(01:01:01) (sector that does NOT have SCEEx data)
5. Com 0Eh,1 ;CdlSetmode: Turn on CD-DA read mode
6. Short Delay
7. Com 16h ;CdlSeekP: Seek to Setloc's parameters (4426)
8. Com 0Bh ;CdlMute: Turn off sound so CdlPlay is inaudible
9. Com 03h ;CdlPlay: Start playing CD-DA.
10. Com 19h,04h ;ResetSCEExInfo (reset GetSCEExInfo response to 0,0)
11. Long Delay ;wait until the modchip (if any) has output SCEEx data
12. Com 19h,05h ;GetSCEExInfo (returns total,success counters)
13. Com 09h ;CdlPause: Stop command 19h.

If GetSCExInfo returns nonzero values, then the console is equipped with a modchip, and if so, anti-modchip games would refuse to work (no matter if the disk is an illegal copy, or not).

NTSC-Boot BIOS Patch

Typically connects to two or three BIOS address/data lines, apparently watching that signals, and dragging a data line LOW at certain time, to skip software based region checks (eg. allowing to play NTSC games on PAL consoles).

Aside from the modchip connection, that additionally requires to adjust the video signal (in 60Hz NTSC mode, the PSX defaults to generate a NTSC video signal) (whilst most PAL screens can handle 60Hz refresh, they can't handle NTSC colors) (on PSone boards, this can be fixed simply by grounding the /PAL pin; IC502.Pin13) (on older PSX boards it seems to be required to install an external color clock generator).

MODCHIP Connection Example

Connection for 8pin "12C508" mod chip from fatcat.co.nz for a PAL PSone with PM-41 board (ie. with 208pin SPU CXD2938Q, and 52pin IC304 "C 3060, SC430943PB"):

```

1 3.5V      (supply)
2 IC304.Pin44 (unknown?) (XLAT)
3 BIOS.Pin15 (D2)
4 BIOS.Pin31 (A18)
5 SPU.Pin5   ("sync")
6 SPU.Pin42  ("data")
7 IC304.Pin19 (SHELL_OPEN)
8 GND        (supply)

```

The chip can be used in a Basic connection (with only pin1,5,6,8 connected), or Stealth and NTSC-Boot connection (additionally pin2,3,4,7 connected). Some other modchips (such without internal oscillator) are additionally connected to a 4MHz or 4.3MHz signal on the mainboard. Some early modchips also connected to a bunch of additional pins that were reportedly for power-on timings (whilst newer chips use hardcoded power-on delays).

Nocash BIOS "Modchip" Feature

The nocash PSX bios outputs the "data" signal on the A20 address line, so (aside from the BIOS chip) one only needs to install a 1N4148 diode and two wires to unlock the CDROM:

```
SPU.Pin42 "data" -----|>|----- CPU.Pin149 (A20)
SPU.Pin5  "sync"  -----|----- IC723.Pin17
```

With the "sync" connection, the SCEX signal from the disk is disabled (ie. even original licensed disks are no longer recognized, unless SCEX is output via A20 by software). For more variants, see:

[CDROM Protection - Chipless Modchips](#)

11.31 CDROM Protection - Chipless Modchips

The nocash kernel clone outputs a SCEX signal via A20 and A21 address lines, (so one won't need a separate modchip/microprocessor):

```
A20 = the normal SCEX signal (inverted ASCII, eg. "A" = BEh) ;all boards
A21 = uninverted SCEX signal (uninverted ASCII, eg. "A" = 41h) ;PU-7..PU-20
A21 = always 1 during SCEX output ;PU-22 and up
```

When using the clone bios as internal ROM replacement, A20 can be used with simple wires/diodes. Doing that with external expansion ROMs would cause the console to stop working when unplugging the ROM, hence needing a slightly more complex circuit with transistors/logic chips.

External Expansion ROM version, for older boards (PU-7 through PU-20):

```
.-----. .-----.  
GATE-----|C NPN | . DATA-----|C NPN | .  
A20--[10K]--|B BC | | A21--[10K]--|B BC | |  
GND-----|E 547 | ' GND-----|E 547 | '  
-----|-----'
```

External Expansion ROM version, for newer boards (PU-22):

```

-----.
A21----|OE1,OE2           |
A20----|IN1    74HC126 OUT1|--- DATA
WFCK---|IN2           OUT2|--- SYNC
'-----'

```

Internal Kernel ROM version, for older boards (PU-7 through PU-20):

```

GATE-----GND
DATA-----A20

```

Internal Kernel ROM version, for newer boards (PU-22 through PM-41(2)):

```

SYNC-----WFCK
DATA---|>|---A20

```

What pin is where...

GATE is IC703.Pin2 (?) (8pin chip with marking "082B")	; PU-7? .. PU-16
GATE is IC706.Pin7/10 (16pin "118" (uPC5023GR-118)	; PU-18 .. PU-20
SYNC is IC723.Pin17(TEO) (20pin "SONY CXA2575N")	; PU-22 .. PM-41(2)
DATA is IC???.Pin7 (CG) (8pin chip with marking "2903")	; PU-7? .. PU-16
DATA is IC706.Pin1 (CG) (16pin "118" (uPC5023GR-118)	; PU-18 .. PU-20
DATA is HC05.Pin17 (CG) (52pin "SONY SC4309xxPB")	; PU-7 .. EARLY-PU-8
DATA is HC05.Pin32 (CG) (80pin "SONY E35D, 4246xx 185")	; LATE-PU-8 .. PU-20
DATA is SPU.Pin42 (CEI) (208pin "SONY CXD2938Q")	; PU-22 .. PM-41
DATA is SPU.Pin36? (CEI) (176pin "SONY CXD2941R")	; PM-41(2)
WFCK is SPU.Pin5 (WFCK) (208pin "SONY CXD2938Q")	; PU-22 .. PM-41
WFCK is SPU.Pin84(WFCK) (176pin "SONY CXD2941R")	; PM-41(2)
A20 is CPU.Pin149(A20) (208-pin CPU CXD8530 or CXD8606)	; PU-7 .. PM-41(2)
A20 is EXP.Pin28 (A20) (68-pin Expansion Port)	; PU-7 .. PU-22
A21 is CPU.Pin150(A21) (208-pin CPU CXD8530 or CXD8606)	; PU-7 .. PM-41(2)
A21 is EXP.Pin62 (A21) (68-pin Expansion Port)	; PU-7 .. PU-22

GATE on PU-18 is usually IC706.Pin7 (but IC706.Pin10 reportedly works, too).

GATE on PU-20 is usually IC706.Pin10 (but IC706.Pin7 might work, too).

11.32 CDROM Protection - LibCrypt

LibCrypt is an additional copy-protection, used by about 100 PSX games. The protection uses a 16bit decryption key, which is stored as bad position data in Subchannel Q. The 16bit key is then used for a simple XOR-decryption on certain 800h-byte sectors.

Protected sectors generation schemas

There are some variants on how the Subchannel Q data is modified:

1. 2 bits from both MSFs are modified,
CRC-16 is recalculated and XORed with 0x0080.
Games: MediEvil (E) .
2. 2 bits from both MSFs are modified,
original CRC-16 is XORed with 0x8001.
Games: CTR: Crash Team Racing (E) (No EDC) , CTR: Crash Team Racing (E)
(EDC) , Dino Crisis (E) , Eagle One: Harrier Attack (E) et al.
3. Either 2 bits or none from both MSFs are modified,
CRC-16 is recalculated and XORed with 0x0080.
Games: Ape Escape (S) et al.

Anyways, the relevant part is that the modified sectors have wrong CRCs (which means that the PSX cdrom controller will ignore them, and the GetlocP command will keep returning position data from the previous sector).

LibCrypt sectors

The modified sectors could be theoretically located anywhere on the disc, however, all known protected games are having them located on the same sectors:

No.	<----- Minute=03/Normal ----->		<----- Minute=09/Backup ----->	
Bit15	14105 (03:08:05)	14110 (03:08:10)	42045 (09:20:45)	42050 (09:20:50)
Bit14	14231 (03:09:56)	14236 (03:09:61)	42166 (09:22:16)	42171 (09:22:21)
Bit13	14485 (03:13:10)	14490 (03:13:15)	42432 (09:25:57)	42437 (09:25:62)
Bit12	14579 (03:14:29)	14584 (03:14:34)	42580 (09:27:55)	42585 (09:27:60)
Bit11	14649 (03:15:24)	14654 (03:15:29)	42671 (09:28:71)	42676 (09:29:01)
Bit10	14899 (03:18:49)	14904 (03:18:54)	42813 (09:30:63)	42818 (09:30:68)
Bit9	15056 (03:20:56)	15061 (03:20:61)	43012 (09:33:37)	43017 (09:33:42)
Bit8	15130 (03:21:55)	15135 (03:21:60)	43177 (09:35:52)	43182 (09:35:57)
Bit7	15242 (03:23:17)	15247 (03:23:22)	43289 (09:37:14)	43294 (09:37:19)
Bit6	15312 (03:24:12)	15317 (03:24:17)	43354 (09:38:04)	43359 (09:38:09)
Bit5	15378 (03:25:03)	15383 (03:25:08)	43408 (09:38:58)	43413 (09:38:63)
Bit4	15628 (03:28:28)	15633 (03:28:33)	43634 (09:41:59)	43639 (09:41:64)
Bit3	15919 (03:32:19)	15924 (03:32:24)	43963 (09:46:13)	43968 (09:46:18)
Bit2	16031 (03:33:56)	16036 (03:33:61)	44054 (09:47:29)	44059 (09:47:34)
Bit1	16101 (03:34:51)	16106 (03:34:56)	44159 (09:48:59)	44164 (09:48:64)
Bit0	16167 (03:35:42)	16172 (03:35:47)	44312 (09:50:62)	44317 (09:50:67)

Each bit is stored twice on Minute=03 (five sectors apart). For some reason, there is also a "backup copy" on Minute=09 (however, the libcrypt software doesn't actually support using that backup stuff, and, some discs don't have the backup at all (namely, discs with less than 10 minutes on track 1?)).

A modified sector means a "1" bit, an unmodified means a "0" bit. The 16bit keys of the existing games are always having eight "0" bits, and eight "1" bits (meaning that there are 16 modified sectors on Minute=03, and, if present, another 16 ones one Minute=09).

Example (Legacy of Kain)

Legacy of Kain (PAL) is reading the LibCrypt data during the title screen, and does then display GOT KEY!!! on TTY terminal (this, no matter if the correct 16bit key was received).

The actual protection jumps in a bit later (shortly after learning to glide, the game will hang when the first enemies appear if the key isn't okay). Thereafter, the 16bit key is kept used once and when to decrypt 800h-byte sector data via simple XORing.

The 16bit key (and some other related counters/variables) aren't stored in RAM, but rather in COP0 debug registers (which are mis-used as general-purpose storage in this case), for example, the 16bit key is stored in LSBs of the "cop0r3" register.

11.33 CDROM Disk Images CCD/IMG/SUB (CloneCD)

File.IMG - 2352 (930h) bytes per sector

Contains the sector data, recorded at 930h bytes per sector. Unknown if other sizes are also used/supported (like 800h bytes/sector, or even images with mixed sizes of 800h and 930h for different tracks).

File.SUB - 96 (60h) bytes per sector (subchannel P.W with 96 bits each)

Contains subchannel data, recorded at 60h bytes per sector.

```
00h..0Bh 12 Subchannel P (Pause-bits, usually all set, or all cleared)
0Ch..17h 12 Subchannel Q (ADR/Control, custom info, CRC-16-CCITT)
18h..5Fh .. Subchannel R..W (usually zero) (can be used for CD-TEXT)
```

Optionally, the .SUB file can be omitted (it's needed only for discs with non-standard subchannel data, such like copy-protected games).

File.CCD - Lead-in info in text format

Contains Lead-in info in ASCII text format. Lines should be terminated by 0Dh,0Ah. The overall CCD filestructure is:

```
[CloneCD]      ;File ID and version
[Disc]         ;Overall Disc info
[CDText]       ;CD-TEXT (included only if present)
[Session N]    ;Session(s) (numbered 1 and up)
[Entry N]      ;Lead-in entries (numbered 0...TocEntries-1")
[TRACK N]     ;Track info (numbered 1 and up)
```

Read on below for details on the separate sections.

[CloneCD]

```
Version=3          ;-version (usually 3) (rarely 2)
```

[Disc]

```
TocEntries=4      ;-number of [Entry N] fields (lead-in info blocks)
Sessions=1        ;-number of sessions (usually 1)
DataTracksScrambled=0 ;-unknown purpose (usually 0)
```

CDTextLength=0 ;-total size of 18-byte CD-TEXT chunks (usually 0)
CATALOG=NNNNNNNNNNNNNN ;-13-digit EAN-13 barcode (included only if present)

[CDText]

```
Entries=N      ;number of following entries (CDTextLength/18) (not /16)
Entry 0=80 00 NN ;entry 0
Entry 1=80 NN ;entry 1
...
Entry XX=8f NN ;entry N-1
Note: Each entry contains 16 bytes (ie. "18-byte CD-TEXT" with CRC excluded)
"NN NN NN.." consists of 2-digit lowercase HEX numbers (without leading "0x")
```

[Session 1]

PreGapMode=2 ;-unknown purpose (usually 1 or 2)
PreGapSubC=1 ;-unknown purpose (usually 0 or 1)

[Entry 0]

[Entry 0..2] are usually containing Point A0h..A2h info. [Entry 3..N] are usually TOC info for Track 1 and up.

Session=1	<i>; -session number that this entry belongs to (usually 1)</i>
Point=0xa0	<i>; -point (0..63h=Track, non-BCD!) (A0h..XXh=specials) Q2</i>
ADR=0x01	<i>; -lower 4bit of ADR/Control (usually 1) Q0.lo</i>
Control=0x04	<i>; -upper 4bit of ADR/Control (eg. 0=audio, 4=data) Q0.hi</i>
TrackNo=0	<i>; -usually/always 0 (as [Entry N]'s are in Lead-in) Q1</i>
AMin=0	<i>; \current MSF address Q3</i>
ASec=0	<i>; (dummy zero values) (actual content) Q4</i>
AFrame=0	<i>; would be current lead-in position) Q5</i>
ALBA=-150	<i>; /ALBA=((AMin*60+ASec)*75+AFrame)-PreGapSize</i>
Zero=0	<i>; -probably reserved byte from Q channel Q6</i>
PMin=1	<i>; \referenced MSF address (non-BCD!), for certain Q7</i>
PSec=32	<i>; Point's, PMin may contain a Track number, and PSec Q8</i>
PFframe=0	<i>; the disc type value (that without non-BCD-glitch) Q9</i>
PLBA=6750	<i>; /PLBA=((PMin*60+PSec)*75+PFframe)-PreGapSize</i>

[TRACK 1] :-track number (non-BCD) (1..99)

```
MODE=2           ;-mode (0=Audio, 1=Model, 2=Mode2)
ISRC=XXXXXXXXNNNNNNN ;-12-letter/digit ISRC code (included only if present)
INDEX 0=N       ;-1st sector with index 0, missing EVEN if any?
INDEX 1=N       ;-1st sector with index 1, usually same as track's PLBA
INDEX 2=N       ;-1st sector with index 2, if any
etc.
```

Missing Sectors & Sector Size

The .CCD file doesn't define the "PreGapSize" (the number of missing sectors at begin of first track). It seems to be simply constant " PreGapSize=150". Unless one is supposed to calculate it as "PreGapSize=((PMin*60+PSec)*75+PFrame)-PLBA".

The SectorSize seems to be also constant, "SectorSize=930h".

Non-BCD Caution

All Min/Sec/Frame/Track/Index values are expressed in non-BCD, ie. they must be converted to BCD to get the correct values (as how they are stored on real CDs).

Exceptions are cases where those bytes have other meanings: For example, "PSec=32" does normally mean BcdSecond=32h, but for Point A0h it would mean DiscType=20h=CD-ROM-XA).

The Point value is also special, it is expressed in hex (0xNN), but nonetheless it is non-BCD, ie. Point 1..99 are specified as 0x01..0x63, whilst, Point A0h..FFh are specified as such (ie. as 0xA0..0xFF).

Versions

Version=1 doesn't seem to exist (or it is very rare). Version=2 is quite rare, and it seems to lack the [TRACK N] entries (meaning that there is no MODE and INDEX information, except that the INDEX 1 location can be assumed to be same as PLBA). Version=3 is most common, this version includes [TRACK N] entries, but often only with INDEX=1 (and up, if more indices), but without INDEX 0 (on Track 1 it's probably missing due to pregap, on further Tracks it's missing without reason) (so, only ways to reproduce INDEX=0 would be to guess it being located 2 seconds before INDEX=1, or, to use the information from the separate .SUB file, if that file is present; note: presence of index 0 is absolutely required for some games like PSX Tomb Raider 2).

Entry & Points & Sessions

The [Entry N] fields are usually containing Point A0h,A1h,A2h, followed by Point 1..N (for N tracks). For multiple sessions: The session is terminated by Point B0h,C0h. The next session does then contain Point A0h,A1h,A2h, and Point N+1..X (for further tracks). The INDEX values in the [TRACK N] entries are originated at the begin of the corresponding session, whilst PLBA values in [Entry N] entries are always originated at the begin of the disk.

11.34 CDROM Disk Images CDI (DiscJuggler)

Overall Format

```

Sector Data (sector 00:00:00 and up)           ;-body
Number of Sessions (1 byte)      <--- located at "Filesize-Footersize"
Session Block for 1st session (15 bytes)       ;\
nnn-byte info for 1st track                  ; 1st session
nnn-byte info for 2nd track (if any)          ;
etc.                                         ;/
Session Block for 2nd session (15 bytes)       ;\
nnn-byte info for 1st track                  ; 2nd session (if any)
nnn-byte info for 2nd track (if any)          ;
etc.                                         ;/
etc.                                         ;-further sessions (if any)
Session Block for no-more-sessions (15 bytes); -end marker
nnn-byte Disc Info Block                   ;-general disc info
Entrypoint (4 bytes)           <--- located at "Filesize-4"

```

Sector Data

Contains Sector Data for sector 00:00:00 and up (ie. all sectors are stored in the file, there are no missing "pregap" sectors).

Sector Size can be 800h..990h bytes/sector (sector size may vary per track).

Number of Sessions (1 byte)

00h	1	Number of Sessions (usually 1)
-----	---	--------------------------------

Session Block (15-bytes)

00h	1	Unknown (00h)
01h	1	Number of Tracks in session (01h..63h) (or 00h=No More Sessions)
02h	7	Unknown (00h-filled)
09h	1	Unknown (01h)
0Ah	3	Unknown (00h-filled)
0Dh	2	Unknown (FFh, FFh)

Track/Disc Header (30h+F bytes) (used in Track Blocks and Disc Info Block)

00h	12	Unknown (FFh, FFh, 00h, 00h, 01h, 00h, 00h, FFh, FFh, FFh, FFh)
0Ch	3	Unknown (DAh, 0Ah, D5h or 64h, 05h, 2Ah) (random/id/chksum?)
0Fh	1	Total Number of Tracks on Disc (00h..63h) (non-BCD)
10h	1	Length of below Path/Filename (F)
11h	(F)	Full Path/Filename (eg. "C:\folder\file.cdi")

```

11h+F 11 Unknown (00h-filled)
1Ch+F 1 Unknown (02h)
1Dh+F 10 Unknown (00h-filled)
27h+F 1 Unknown (80h)
28h+F 4 Unknown (000057E40h) (=360000 decimal) (disc capacity 80 minutes?)
2Ch+F 2 Unknown (00h,00h)
2Eh+F 2 Medium Type (0098h=CD-ROM, 0038h=DVD-ROM)

```

Track Block (E4h+F+I+T bytes)

00h	30h+F	Track/Disc Header (see above)
30h+F	02h	Number of Indices (usually 0002h) (I=Num*4)
32h+F	(I)	32bit Lengths (per index) (eg. 00000096h, 00007044h)
32h+FI	04h	Number of CD-Text blocks (usually 0) (T=Num*18+VariableLen's)
36h+FI	(T)	CD-Text (if any) (see "mirage_parser_cdi_parse_cdtext")
36h+FIT	02h	Unknown (00h,00h)
38h+FIT	01h	Track Mode (0=Audio, 1=Mode1, 2=Mode2/Mixed)
39h+FIT	07h	Unknown (00h,00h,00h,00h,00h,00h)
40h+FIT	04h	Session Number (starting at 0) (usually 00h)
44h+FIT	04h	Track Number (non-BCD, starting at 0) (00h..62h)
48h+FIT	04h	Track Start Address (eg. 00000000h)
4Ch+FIT	04h	Track Length (eg. 000070DAh)
50h+FIT	0Ch	Unknown (00h-filled)
5Ch+FIT	04h	Unknown (00000000h or 00000001h)
60h+FIT	04h	read_mode (0..4) <ul style="list-style-type: none"> 0: Mode1, 800h, 2048 1: Mode2, 920h, 2336 2: Audio, 930h, 2352 3: Raw+PQ, 940h, 2352+16 non-interleaved (P=only 1bit) 4: Raw+PQRSTUVW, 990h, 2352+96 interleaved
64h+FIT	4	Control (Upper 4bit of ADR/Control, eg. 00000004h=Data)
68h+FIT	1	Unknown (00h)
69h+FIT	4	Track Length (eg. 000070DAh) (same as above)
6Dh+FIT	4	Unknown (00h,00h,00h,00h)
71h+FIT	12	ISRC Code 12-letter/digit (ASCII?) string (00h-filled if none)
7Dh+FIT	4	ISRC Valid Flag (0=None, Other?=Yes?)
81h+FIT	1	Unknown (00h)
82h+FIT	8	Unknown (FFh,FFh,FFh,FFh,FFh,FFh,FFh)
8Ah+FIT	4	Unknown (00000001h)
8Eh+FIT	4	Unknown (00000080h)
92h+FIT	4	Unknown (00000002h) (guess: maybe audio num channels??)
96h+FIT	4	Unknown (00000010h) (guess: maybe audio bits/sample??)
9Ah+FIT	4	Unknown (0000AC44h) (44100 decimal, ie. audio sample rate?)
9Eh+FIT	2Ah	Unknown (00h-filled)
C8h+FIT	4	Unknown (FFh,FFh,FFh,FFh)
CCh+FIT	12	Unknown (00h-filled)
D8h+FIT	1	session_type ONLY if last track of a session (else 0) <ul style="list-style-type: none"> (0=Audio/CD-DA, 1=Mode1/CD-ROM, 2=Mode2/CD-XA)
D9h+FIT	5	Unknown (00h-filled)
DEh+FIT	1	Not Last Track of Session Flag (0=Last Track, 1=Not Last)
DFh+FIT	1	Unknown (00h)
E0h+FIT	4	address for last track of a session? (otherwise 00,00,FF,FF)

Disc Info Block (5Fh+F+V+T bytes)

00h	30h+F	Track/Disc Header (see above)
30h+F	4	Disc Size (total number of sectors)
34h+F	1	Volume ID Length (V) ;\from Primary Volume Descriptor[28h..47h]
35h+F	(V)	Volume ID String ;/(ISO Data discs) (unknown for Audio)
35h+FV	1	Unknown (00h)
36h+FV	4	Unknown (01h,00h,00h,00h)
3Ah+FV	4	Unknown (01h,00h,00h,00h)
3Eh+FV	13	EAN-13 Code 13-digit (ASCII?) string (00h-filled if none)
4Bh+FV	4	EAN-13 Valid Flag (0=None, Other?=Yes?)
4Fh+FV	4	CD-Text Length in bytes (T=Num*1)
53h+FV	(T)	CD-Text (for Lead-in) (probably 18-byte units?)
53h+FVT	8	Unknown (00h-filled)
5Bh+FVT	4	Unknown (06h,00h,00h,80h)

Entrypoint (4 bytes) (located at "Filesize-4")

00h	4	Footer Size in bytes
-----	---	----------------------

11.35 CDROM Disk Images CUE/BIN/CDT (Cdrwin)

.CUE/.BIN (CDRWIN)

CDRWIN stores disk images in two separate files. The .BIN file contains the raw disk image, starting at sector 00:02:00, with 930h bytes per sector, but without any TOC or subchannel information. The .CUE file contains additional information about the separate track(s) on the disk, in ASCII format, for example:

```
FILE "PATH\FILENAME.BIN" BINARY
TRACK 01 MODE2/2352
    INDEX 01 00:00:00      ;real address = 00:02:00  (+2 seconds)
TRACK 02 AUDIO
    PREGAP 00:02:00       ;two missing seconds      (NOT stored in .BIN)
    INDEX 01 08:09:29      ;real address = 08:13:29  (+2 seconds +pregap)
TRACK 03 AUDIO
    INDEX 00 14:00:29      ;real address = 14:04:29  (+2 seconds +pregap)
    INDEX 01 14:02:29      ;real address = 14:06:29  (+2 seconds +pregap)
TRACK 04 AUDIO
    INDEX 00 18:30:20      ;real address = 18:34:20  (+2 seconds +pregap)
    INDEX 01 18:32:20      ;real address = 18:36:20  (+2 seconds +pregap)
```

The .BIN file does not contain ALL sectors, as said above, the first 2 seconds are not stored in the .BIN file. Moreover, there may be missing sectors somewhere in the middle

of the file (indicated as PREGAP in the .CUE file; PREGAPs are usually found between Data and Audio Tracks).

The MM:SS:FF values in the .CUE file are logical addresses in the .BIN file, rather than physical addresses on real CDROMs. To convert the .CUE values back to real addresses, add 2 seconds to all MM:SS:FF addresses (to compensate the missing first 2 seconds), and, if the .CUE contains a PREGAP, then the pregap value must be additionally added to all following MM:SS:FF addresses.

The end address of the last track is not stored in the .CUE, instead, it can be only calculated by converting the .BIN filesize to MM:SS:FF format and adding 2 seconds (plus any PREGAP values) to it.

FILE \<filename> BINARY|MOTOTOLA..or..MOTOROLA?|AIFF|WAVE|MP3

(must appear before any other commands, except CATALOG)
(uh, may also appear before further tracks)

FLAGS DCP 4CH PRE SCMS

INDEX NN MM:SS:FF

TRACK NN datatype

AUDIO	;930h	;bytes 000h..92Fh
CDG	;?	;?
MODE1/2048	;800h	;bytes 010h..80Fh
MODE1/2352	;930h	;bytes 000h..92Fh
MODE2/2336	;920h	;bytes 010h..92Fh
MODE2/2352	;930h	;bytes 000h..92Fh
CDI/2336	;920h	;?
CDI/2352	;930h	;bytes 000h..92Fh

PREGAP MM:SS:FF

POSTGAP MM:SS:FF

Duration of silence at the begin (PREGAP) or end (POSTGAP) of a track. Even if it isn't specified, the first track will always have a 2-second pregap.

The gaps are NOT stored in the BIN file.

REM comment

Allows to insert comments/remarks (which are usually ignored). Some third-party tools are mis-using REM to define additional information.

CATALOG 1234567890123

ISRC ABCDE1234567

(ISRC must be after TRACK, and before INDEX)

PERFORMER "The Band"

SONGWRITER "The Writer"

TITLE "The Title"

These entries allow to define basic CD-Text info directly in the .CUE file.

Some third-party utilites allow to define additional CD-Text info via REM lines, eg. "REM GENRE Rock".

Alternately, more complex CD-Text data can be stored in a separate .CDT file.

CDTEXTFILE "C:\LONG FILENAME.CDT"

Specifies an optional file which may contain CD-TEXT. The .CDT file consists of raw 18-byte CD-TEXT fragments (which may include any type of information, including exotic one's like a "Message" from the producer). For whatever reason, there's a 00h-byte appended at the end of the file. Alternately to the .CDT file, the less exotic types of CD-TEXT can be defined by PERFORMER, TITLE, and SONGWRITER commands in the .CUE file.

Missing

Unknown if newer CUE/BIN versions do also support subchannel data.

11.36 CDROM Disk Images MDS/MDF (Alcohol 120%)

File.MDF - Contains sector data (optionally with sub-channel data)

Contains the sector data, recorded at 800h..930h bytes per sector, optionally followed by 60h bytes subchannel data (appended at the end of each sector). The stuff seems to be start on 00:02:00 (ie. the first 150 sectors are missing; at least it is like so when "Session Start Sector" is -150).

The subchannel data (if present) consists of 8 subchannels, stored in 96 bytes (each byte containing one bit per subchannel).

```
Bit7..0 = Subchannel P..W (in that order, eg. Bit6=Subchannel Q)
```

The 96 bits (per subchannel) can be translated to bytes, as so:

```
1st..8th bit = Bit7..Bit0 of 1st byte (in that order, ie. MSB/Bit7 first)
9st..16th bit = Bit7..Bit0 of 2nd byte ("")
17th...       = etc.
```

File.MDS - Contains disc/lead-in info (in binary format)

An MDS file's structure consists of the following stuff ...

Header	(58h bytes)
Session block(s)	(usually one 18h byte entry)
Data blocks	(N*50h bytes)
Index blocks	(usually N*8 bytes)
Filename blocks(s)	(usually one 10h byte entry)
Filename string(s)	(usually one 6 byte string)

Header (58h bytes)

```
00h 16 File ID ("MEDIA DESCRIPTOR")
10h 2 Unknown (01h,03h or 01h,04h or 01h,05h) (Fileformat version?)
12h 2 Media Type (0=CD-ROM, 1=CD-R, 2=CD-RW, 10h=DVD-ROM, 12h=DCD-R)
14h 2 Number of sessions (usually 1)
16h 4 Unknown (02h,00h,00h,00h)
1Ah 2 Zero (for DVD: Length of BCA data)
1Ch 8 Zero
24h 4 Zero (for DVD: Offset to BCA data)
28h 18h Zero
40h 4 Zero (for DVD: Offset to Disc Structures) (from begin of .MDS file)
44h 0Ch Zero
```

50h 4	Offset to First Session-Block (usually 58h) (from begin of .MDS file)
54h 4	Zero (for DVD?: Offset to DPM data blocks) (from begin of .MDS file)

Session-Blocks (18h bytes)

00h 4	Session Start Sector (starting at FFFFFFF6Ah=-150 in first session)
04h 4	Session End Sector (XXX plus 150 ?)
08h 2	Session number (starting at 1) (non-BCD)
0Ah 1	Number of Data Blocks with any Point value (Total Data Blocks)
0Bh 1	Number of Data Blocks with Point>=A0h (Special Lead-In info)
0Ch 2	First Track Number in Session (01h..63h, non-BCD!)
0Eh 2	Last Track Number in Session (01h..63h, non-BCD!)
10h 4	Zero
14h 4	Offset to First Data-Block (usually 70h) (from begin of .MDS file)

Data-Blocks (50h bytes)

Block 0..2 are usually containing Point A0h..A2h info. Block 3..N are usually TOC info for Track 1 and up.

00h 1	Track mode (see below for details)
01h 1	Number of subchannels in .MDF file (0=None, 8=Sector has +60h bytes)
02h 1	ADR/Control (but with upper/lower 4bit swapped, ie. MSBs=ADR!) Q0
03h 1	TrackNo (usually/always 00h; as this info is in Lead-in area) Q1
04h 1	Point (Track 01h..63h, non-BCD!) (or A0h and up=Lead-in info) Q2
05h 4	Zero (probably dummy MSF and reserved byte from Q channel) Q3..Q6?
09h 1	Minute (Non-BCD!) (if track >= 0xA0 -> info about track ##) Q7 (if track = 0xA2 -> min. @ lead-out)
0Ah 1	Second (Non-BCD!) (if track = 0xA2 -> sec. @ lead-out) Q8
0Bh 1	Frame (Non-BCD!) (if track = 0xA2 -> frame @ lead-out) Q9

For Point>=A0h, below 44h bytes at [0Ch..4Fh] are zero-filled

0Ch 4	Offset to Index-block for this track (from begin of .MDS file)
10h 2	Sector size (800h..930h) (or 860h..990h if with subchannels)
12h 1	Unknown (02h) (maybe number of indices?)
13h 1h	Zero
24h 4	Track start sector, PLBA (00000000h=00:02:00)
28h 8	Track start offset (from begin of .MDF file)
30h 4	Number of Filenames for this track (usually 1)
34h 4	Offset to Filename Block for this track (from begin of .MDS file)
38h 18h	Zero

Trackmode:

(upper 4bit seem to be meaningless?)
00h=None (used for entries with Point=A0h..FF)

```

A9h=AUDIO      ;sector size = 2352    930h ;bytes 000h..92Fh
AAh=MODE1      ;sector size = 2048    800h ;bytes 010h..80Fh
ABh=MODE2      ;sector size = 2336    920h ;bytes 010h..92Fh
ACh=MODE2_FORM1 ;sector size = 2048    800h ;bytes 018h..817h (incomplete!)
ADh=MODE2_FORM2 ;sector size = 2324+0? 914h ;bytes 018h..91Bh (incomplete!)
ADh=MODE2_FORM2 ;sector size = 2324+4? 918h ;bytes ???...? (contains what?)
ECh=MODE2      ;sector size = 2448     990h ;(930h+60h) (with subchannels)

```

Index Blocks (usually 8 bytes per track)

```

00h 4 Number of sectors with Index 0 (usually 96h or zero)
04h 4 Number of sectors with Index 1 (usually size of main-track area)

```

Index blocks are usually 8 bytes in size (two indices per track). Maybe this block is/was intended to allow to contain more indices (although the Alcohol 120% does always store only 2 indices, even when recording a CD with more than 2 indices per track). The MDS file does usually contain Index blocks for \<all> Data Blocks (ie. including unused dummy Index Blocks for Data Blocks with Point>=A0h).

Filename Blocks (10h bytes)

```

00h 4 Offset to Filename (from begin of .MDS file)
04h 1 Filename format (0=8bit, 1=16bit characters)
05h 11 Zero

```

Normally all tracks are sharing the same filename block (although theoretically the tracks could use separate filename blocks; with different filenames).

Filename Strings (usually 6 bytes)

```

00h 6 Filename, terminated by zero (usually "*.mdf", 00h)

```

Contains the filename of the sector data (usually "*.mdf", indicating to use the same name as for the .mds file, but with .mdf extension).

Missing

Unknown if/how this format supports EAN-13, ISRC, CD-TEXT.

Unknown if Track/Point/Index are BCD or non-BCD.

11.37 CDROM Disk Images NRG (Nero)

.NRG (NERO)

Nero is probably the most bloated and most popular CD recording software. The first part of the file contains the disk image, starting at sector 00:00:00, with 800h..930h bytes per sector. Additional chunk-based information is appended at the end of the file, usually consisting of only four chunks: CUES, DAOI, END!, NERO (in that order).

Chunk Entrypoint (in last 8/12 bytes of file)

```
4 File ID "NERO"/"NER5"
4/8 Fileoffset of first chunk
```

Cue Sheet (summary of the Table of Contents, TOC)

```
4 Chunk ID "CUES"/"CUEX"
4 Chunk size (bytes)
```

below EIGHT bytes repeated for each track/index,
of which, first FOUR bytes are same for both CUES and CUEX,

```
1 ADR/Control from TOC (usually LSBS=ADR=1=fixed, MSBs=Control=Variable)
1 Track (BCD) (00h=Lead-in, 01h..99h=Track N, AAh=Lead-out)
1 Index (BCD) (usually 00h=prep, 01h=actual track)
1 Zero
```

next FOUR bytes for CUES,

```
1 Zero
1 Minute (BCD) ;starting at 00:00:00 = 2 seconds before ISO vol. descr.
1 Second (BCD)
1 Sector (BCD)
```

or, next FOUR four bytes for CUEX,

```
4 Logical Sector Number (HEX) ;starting at FFFFFFF6Ah (=00:00:00)
```

Caution: Above may contain two position 00:00:00 entries: one nonsense entry for Track 00 (lead-in), followed by a reasonable entry for Track 01, Index 00.

Disc at Once Information

```

4  Chunk ID "DAOI"/"DAOX"
4  Chunk size (bytes)
4  Garbage (usually same as above Chunk size)
13 EAN-13 Catalog Number (13-digit ASCII) (or 00h-filled if none/unknown)
1  Zero
1  Disk type (00h=Model or Audio, 20h=XA/Mode2) (and probably 10h=CD-I?)
1  Unknown (01h)
1  First track (Non-BCD) (01h..63h)
1  Last track (Non-BCD) (01h..63h)

```

below repeated for each track,

```

12 ISRC in ASCII (eg. "USXYZ9912345") (or 00h-filled if none/unknown)
2 Sector size (usually 800h, 920h, or 930h) (see Mode entry for more info)
1 Mode:
    0=Mode1/800h ;raw model data (excluding sync+header+edc+errorinfo)
    3=Mode2/920h ;almost full sector (excluding first 16 bytes; sync+header)
    6=Mode2/930h ;full sector (including first 16 bytes; sync+header)
    7=Audio/930h ;full sector (plain audio data)

Mode values from wikipedia:
    00h for data           Mode1/800h
    02h
    03h for Mode 2 Form 1 data   eh? FORM1???
    05h for raw data          Mode1?/930h
    06h for raw Mode 2/form 1 data Mode2/930h
    07h for audio             Audio/930h
    0Fh for raw data with sub-channel Mode1?/930h+WHAT?
    10h for audio with sub-channel Audio/930h+WHAT?
    11h for raw Mode 2/form 1 data with sub-channel Mode2/WHAT?+WHAT?

Note: Some newer files do actually use different sector sizes for each
track (eg. 920h for the data track, and 930h for any following audio
tracks), older files were using the same sector size for all tracks
(eg. if the disk contained 930-byte Audio tracks, then Data tracks
were stored at the same size, rather than at 800h or 920h bytes).

3 Unknown (always 00h,00h,01h)
4/8 Fileoffset 1 (Start of Track's Pregap) (with Index=00h)
4/8 Fileoffset 2 (Start of actual Track) (with Index=01h and up)
4/8 Fileoffset 3 (End of Track+1) (aka begin of next track's pregap)

```

End of chain

```

4  Chunk ID "END!"
4  Chunk size (always zero)

```

Track Information (contained only in Track at Once images)

```
4     Chunk ID "TINF"/"ETNF"/"ETN2"
4     Chunk size (bytes)
```

below repeated for each track,

```
4/4/8 Track fileoffset      ;\32bit in TINF/ETNF chunks,
4/4/8 Track length (bytes)   ;/64bit in ETN2 chunks
4     Mode (should be same as in DAO chunks, see there) (implies sector size)
0/4/4 Start lba on disc      ;\only in ETNF/ETN2 chunks,
0/4/4 Unknown?              ;/not in TINF chunks
```

Unknown 1 (contained only in Track at Once images)

```
4     Chunk ID "RELO"
4     Chunk size (bytes)
4     Zero
```

Unknown 2 (contained only in Track at Once images)

```
4     Chunk ID "TOCT"
4     Chunk size (bytes)
1     Disk type (00h=Model or Audio, 20h=XA/Mode2) (and probably 10h=CD-I?)
1     Zero (00h)
```

Session Info (begin of a session) (contained only in multi-session images)

```
4     Chunk ID "SINF"
4     Chunk size (bytes)
4     Number of tracks in session
```

CD-Text (contained only in whatever images)

```
4     Chunk ID None/"CDTX"
4     Chunk size (bytes) (must be a multiple of 18 bytes)
```

below repeated for each fragment,

```
18    Raw 18-byte CD-text data fragments
```

Media Type? (contained only in whatever images)

```
4  Chunk ID "MTYP"
4  Chunk size (bytes)
4  Unknown? (00000001h for CDROM) (maybe other value for DVD)
```

Notes

Newer/older .NRG files may contain 32bit/64bit values (and use "OLD"/"NEW" chunk names) (as indicated by the "/" slashes).

CAUTION: All 16bit/32bit/64bit values are in big endian byte-order.

Missing

Unknown if newer NRG versions do also support subchannel data.

11.38 CDROM Disk Image/Containers CDZ

.CDZ is a compressed disk image container format (developed by pSX Author, and used only by the pSX emulator). The disk is split into 64kbyte blocks, which allows fast random access (without needing to decompress all preceding sectors).

However, the compression ratio is surprisingly bad (despite of being specifically designed for cdrom compression, the format doesn't remove redundant sector headers, error correction information, and EDC checksums).

.CDZ File Structure

```
FileID ("CDZ", 00h for cdztool v0/v1, or "CDZ", 01h for cdztool v2 and up)
One or two Chunk(s)
```

.CDZ Chunk Format

Chunk Header in v0 (unreleased prototype):

```
4  32bit Decompressed Size (of all blocks) (must be other than "ZLIB")
```

Chunk Header in v1 (first released version):

```
4  ZLIB ID ("ZLIB")
8  64bit Decompressed Size (of all blocks)
```

Chunk Header in v2 and up (later versions):

```

4  Chunk ID (eg. "CUE",00h)
8  Chunk Size in bytes (starting at "ZLIB" up to including Footer, if any)
4  ZLIB ID ("ZLIB")
8  64bit Decompressed Size (of all blocks)

```

Chunk Body (same in all versions):

```

4  Number of Blocks (N)
4  Block 1 Compressed Size (CS.1)
4  Block 1 Decompressed Size (always 00010000h, except last block)
CS.1 Block 1 Compressed ZLIB Data (starting with 78h,9Ch)
...  ...
4  Block N Compressed Size (CS.N)      ; further block(s)
4  Block N Decompressed Size        ; (if any)
CS.N Block N Compressed ZLIB Data   ;/

```

Chunk Footer in v0 (when above header didn't have the "ZLIB" ID):

```
4*N      Directory Entries for N blocks      ;-this ONLY for BIN chunk
```

Chunk Footer in v1 and up:

```
BPD*(N-1) Directory Entries for N-1 blocks  ;\this ONLY for BIN chunk
1          Bytes per Directory Entry (BPD)    ;/(not for CUE/CCD/MDS)
```

The "Compressed ZLIB Data" parts contain Deflate'd data (starting with 2-byte ZLIB header, and ending with 4-byte ZLIB/ADLER checksum), for details see:

[Inflate - Core Functions](#)

[Inflate - Initialization & Tree Creation](#)

[Inflate - Headers and Checksums](#)

.CDZ Chunks / Content

The chunk(s) have following content:

noname+noname	--> .CUE+.BIN (cdztool v1 and below)
"BIN",0	--> .ISO (cdztool v2? and up)
"CUE",0+"BIN",0	--> .CUE+.BIN (cdztool v2 and up)
"CCD",0+"BIN",0	--> .CCD+.IMG (cdztool v2 and up)
"CCD",0+"BIN",01h	--> .CCD+.IMG+.SUB (930h sectors, plus 60h subchannels)
"MDS",0+"BIN",0	--> .MDS+.MDF (cdztool v5 only)

Note: cdztool doesn't actually recognize files with .ISO extension (however, one can rename them to .BIN, and then compress them as CUE-less .BIN file).

Cdztool.exe Versions

```
cdztool.exe v0, unreleased prototype
cdztool.exe v1, 22 May 2005, CRC32=620dbb08, 102400 bytes, pSX v1.0-5
cdztool.exe v2, 02 Jul 2006, CRC32=bcb29c1e, 110592 bytes, pSX v1.6
cdztool.exe v3, 22 Jul 2006, CRC32=4062ba82, 110592 bytes, pSX v1.7
cdztool.exe v4, 13 Aug 2006, CRC32=7388dd3d, 118784 bytes, pSX v1.8-11
cdztool.exe v5, 22 Jul 2007, CRC32=f25c1659, 155648 bytes, pSX v1.12-13
```

Note: v0 wasn't ever released (it's only noteworthy because later versions do have backwards compatibility for decompressing old v0 files). v1 didn't work with all operating systems (on Win98 it just says "Error: Couldn't create \<output>" no matter what one is doing, however, v1 does work on later windows versions like WinXP or so?).

11.39 CDROM Disk Image/Containers ECM

ECM (Error Code Modeler by Neill Corlett) is a utility that removes unnecessary ECC error correction and EDC error detection values from CDROM-images. This is making the images a bit smaller, but the real size reduction isn't gained until subsequently compressing the images via tools like ZIP. Accordingly, these files are extremely uncomfortable to use: One must first UNZIP them, and then UNECM them.

.EXT.ECM - Double extension

ECM can be applied to various CDROM-image formats (like .BIN, .CDI, .IMG, .ISO, .MDF, .NRG), as indicated by the double-extension. Most commonly it's applied to .BIN files (hence using extension .BIN.ECM).

Example / File Structure

```
45 43 4D 00 ;FileID "ECM",00h
3C ;Type 0, Len=10h (aka 0Fh+1)
00 FF FF FF FF FF FF FF FF 00 00 02 00 02 ;16 data bytes
02 ;Type 2, Len=1 (aka 00h+1)
00 00 08 00 00 00 00 00 00 00 00 ..... 00 00 00 ;804h data bytes
3C ;Type 0, Len=10h (aka 0Fh+1)
00 FF FF FF FF FF FF FF FF 00 00 02 01 02 ;16 data bytes
02 ;Type 2, Len=1 (aka 00h+1)
00 00 08 00 00 00 00 00 00 00 00 ..... 00 00 00 ;804h data bytes
...
...
```

FC FF FF FF 3F NN NN NN NN	;End Code (Len=FFFFFFFh+1) ;EDC (on decompressed data)
-------------------------------	---

Type/Length Byte(s)

Type/Length is encoded in 1..5 byte(s), with "More=1" indicating that further length byte(s) follow:

```
1st Byte: Bit7=More, Bit6-2=LengthBit4-0, Bit1-0=Type(0..3)
2nd Byte: Bit7=More, Bit6-0=LengthBit5-11
3rd Byte: Bit7=More, Bit6-0=LengthBit12-18
4th Byte: Bit7=More, Bit6-0=LengthBit19-25
5th Byte: Bit7-6=Reserved/Zero, Bit5-0=LengthBit26-31
```

Length=FFFFFFFh=End Indicator

The actual decompression LEN is: "LEN=Length+1"

ECM Decompression

Below is repeated LEN times (with LEN being the Length value plus 1):

```
Type 0: load 1 byte, save 1 byte
Type 1: load 803h bytes [0Ch..0Eh,10h..80Fh], save 930h bytes [0..92Fh]
Type 2: load 804h bytes [14h..817h], save 920h bytes [10h..92Fh]
Type 3: load 918h bytes [14h..91Bh], save 920h bytes [10h..92Fh]
```

Type 1-3 are reconstructing the missing bytes before saving. Type 2-3 are saving only 920h bytes, so (if the original image contained full 930h byte sectors) the missing 10h bytes must be inserted via Type 0. Type 0 can be also used for copying whole sectors as-is (eg. Audio sectors, or Data sectors with invalid Sync/Header/ECC/EDC values). And, Type 0 can be used to store non-sector data (such like the chunks at the end of .NRG or .CDI files).

Central Mistakes

There's a lot of wrong with the ECM format. The two central problems are that it doesn't support data-compression (and needs external compression tools like zip/rar), and, that it doesn't contain a sector look-up table (meaning that random access isn't possible unless when scanning the whole file until reaching the desired sector).

Worst-case Scenario

As if ECM as such wouldn't be uncomfortable enough, you may expect typical ECM users to get more things messed up. For example:

```
A RAR file containing a 7Z file containing a ECM file containing a BIN file.  
The BIN containing only Track 1, other tracks stored in APE files.  
And, of course, the whole mess without including the required CUE file.
```

11.40 CDROM Subchannel Images

SBI (redump.org)

SBI Files start with a 4-byte FileID:

```
4 bytes FileID ("SBI",00h)
```

The followed by entries as so:

```
3 bytes real absolute MM:SS:FF address where the sub q data was bad  
1 byte Format: the format can be 1, 2 or 3:  
Format 1: complete 10 bytes sub q data (Q0..Q9)  
Format 2: 3 bytes wrong relative MM:SS:FF address (Q3..Q5)  
Format 3: 3 bytes wrong absolute MM:SS:FF address (Q7..Q9)
```

Note: The PSX libcrypt protection relies on bad checksums (Q10..Q11), which will cause the PSX cdrom controller to ignore Q0..Q9 (and to keep returning position data from most recent sector with intact checksum).

Ironically, the SBI format cannot store the required Q10..Q11 checksum. The trick for using SBI files with libcrypted PSX discs is to ignore the useless Q0..Q9 data, and to assume that all sectors in the SBI file have wrong Q10..Q11 checksums.

M3S (Subchannel Q Data for Minute 3) (ePSXe)

M3S files are containing Subchannel Q data for all sectors on Minute=03 (the region where PSX libcrypt data is located) (there is no support for storing the (unused) libcrypt

backup copy on Minute=09). The .M3S filesize is 72000 bytes (60 seconds * 75 sectors * 16 bytes). The 16 bytes per sector are:

```
Q0..Q9  Subchannel Q data (normally position data)
Q10..Q11 Subchannel Q checksum
Q12..Q15 Dummy/garbage/padding (usually 0000000h or FFFFFFFFh)
```

Unfortunately, there are at least 3 variants of the format:

1. With CRC (Q0..Q11 intact) (and Q12..Q15 randomly 0000000h or FFFFFFFFh)
2. Without CRC (only Q0..Q9 intact, but Q10..Q15 zero-filled)
3. Without anything (only Q0 intact, but Q1..Q15 zero-filled)

The third variant is definitely corrupt (and one should ignore such zero-filled entries). The second variant is corrupt, too (but one might attempt to repair them by guessing the missing checksum: if it contains normal position values assume correct crc, if it contains uncommon values assume a libcrypted sector with bad crc).

The M3S format is intended for libcrypted PSX games, but, people seem to have also recorded (corrupted) M3S files for unprotected PSX games (in so far, more than often, the M3S files might cause problems, instead of solving them).

Note: The odd 16-byte format with 4-byte padding does somehow resemble the "P and Q Sub-Channel" format 'defined' in MMC-drafts; if the .M3S format was based on the MMC stuff: then the 16th byte might contain a Subchannel P "pause" flag in bit7.

CDROM Images with Subchannel Data

Most CDROM-Image formats can (optionally) contain subchannel recordings. The downsides are: Storing all 8 subchannels for a full CDROM takes up about 20MBytes. And, some entries may contain 'wrong' data (read errors caused by scratches cannot be automatically repaired since subchannels do not contain error correction info). If present, the subchannel data is usually appended at the end of each sector in the main binary file (one exception is CloneCD, which stores it in a separate .SUB file instead of in the .IMG file).

CCD/IMG/SUB (CloneCD)	P-W	60h-bytes Non-interleaved (in separate .SUB file)
CDI (DiscJuggler)	P-Q	10h-bytes Non-interleaved (in .CDI file)
""	P-W	60h-bytes Interleaved (in .CDI file)
CUE/BIN/CDT (Cdrwin)		N/A
ISO (single-track)		N/A
MDS/MDF (Alcohol 120%)	P-W	60h-bytes Interleaved (in .MDF file)
NRG (Nero)	P-W	60h-bytes Interleaved (in .NRG file)

Interleaved Subchannel format (eg. Alcohol .MDF files):

```

00h-07h  80 C0 80 80 80 80 80 C0      ;P=FFh, Q=41h=ADR/Control, R..W=00h
08h-0Fh  80 80 80 80 80 80 80 C0      ;P=FFh, Q=01h=Track,      R..W=00h
10h-17h  80 80 80 80 80 80 80 C0      ;P=FFh, Q=01h=Index,     R..W=00h
18h-1Fh  80 80 80 80 80 80 80 80      ;P=FFh, Q=00h=RelMinute, R..W=00h
20h-27h  80 80 80 80 80 80 80 80      ;P=FFh, Q=00h=RelSecond, R..W=00h
28h-2Fh  80 80 80 80 80 80 80 80      ;P=FFh, Q=00h=RelSector, R..W=00h
30h-37h  80 80 80 80 80 80 80 80      ;P=FFh, Q=00h=Reserved,  R..W=00h
38h-3Fh  80 80 80 80 80 80 80 80      ;P=FFh, Q=00h=AbsMinute, R..W=00h
40h-47h  80 80 80 80 80 80 C0 80      ;P=FFh, Q=02h=AbsSecond, R..W=00h
48h-4Fh  80 80 80 80 80 80 80 80      ;P=FFh, Q=00h=AbsSector, R..W=00h
50h-57h  80 80 C0 80 C0 80 80 80      ;P=FFh, Q=28h=ChecksumMsb, R..W=00h
58h-5Fh  80 80 C0 C0 80 80 C0 80      ;P=FFh, Q=32h=ChecksumLsb, R..W=00h

```

Non-Interleaved Subchannel format (eg. CloneCD .SUB files):

```

00h-0Bh  FF ;Subchannel P (Pause)
0Ch-17h  41 01 01 00 00 00 00 00 02 00 28 32 ;Subchannel Q (Position)
18h-23h  00 00 00 00 00 00 00 00 00 00 00 00 ;Subchannel R
24h-2Fh  00 00 00 00 00 00 00 00 00 00 00 00 ;Subchannel S
30h-3Bh  00 00 00 00 00 00 00 00 00 00 00 00 ;Subchannel T
3Ch-47h  00 00 00 00 00 00 00 00 00 00 00 00 ;Subchannel U
48h-53h  00 00 00 00 00 00 00 00 00 00 00 00 ;Subchannel V
54h-5Fh  00 00 00 00 00 00 00 00 00 00 00 00 ;Subchannel W

```

Non-Interleaved P-Q 10h-byte Subchannel format:

```

This is probably based on MMC protocol, which would be as crude as this:
The 96 pause bits are summarized in 1 bit. Pause/Checksum are optional.
00h-09h  41 01 01 00 00 00 00 00 02 00      ;Subchannel Q (Position)
0Ah-0Bh  28 32      ;<-- OPTIONAL, can be zero! ;Subchannel Q (Checksum)
0Ch-0Eh  00 00 00          ;Unused padding (zero)
OF       80          ;<-- OPTIONAL, can be zero! ;Subchannel P (Bit7=Pause)

```

11.41 CDROM Disk Images Other Formats

.ISO - A raw ISO9660 image (can contain a single data track only)

Contains raw sectors without any sub-channel information (and thus it's restricted to the ISO filesystem region only, and cannot contain extras like additional audio tracks or additional sessions). The image should start at 00:02:00 (although I wouldn't be surprised if some <might> start at 00:00:00 or so). Obviously, all sectors must have the same size, either 800h or 930h bytes (if the image contains only Mode1 or Mode2/Form1 sectors then 800h bytes would usually enough; if it contains one or more Mode2/Form2

sectors then all sectors should be 930h bytes).

Handling .ISO files does thus require to detect the image's sector size, and to search the sector that contains the first ISO Volume Descriptor. In case of 800h byte sectors it may be additionally required to detect if it is a Mode1 or Mode2/Form1 image; for PSX images (and any CD-XA images) it'd be Mode2.

.CHD

Something used by MAME/MESS. Originally intended for compressed ROM-images, but does also support compressed CDROM-images. Fileformat and compression ratio are unknown. Also unknown if it allows random-access.

Some info can be found in MAME source code (looking at the source code for the CHDMAN tool might be a good starting point... although the actual file structure might be hidden in other source files).

.C2D

Something. Can contain compressed or uncompressed CDROM-images. Fileformat and compression ratio are unknown. Also unknown if it allows random-access.

Some info on (uncompressed) .C2D files can be found in libmirage source code.

.ISZ

This is reportedly a "zipped" .ISO file, using some unknown compression format (unrelated to pkzip .zip file format).

.MDX

Reportedly a compressed MDS/MDF file, supported by Daemon Tools. Fileformat and compression ratio are unknown. Also unknown if it allows random-access.

.CU2/.BIN

Custom format used by PSIO (an SD-card based CDROM-drive emulator connected to PSX expansion port). The .CU2 file is somewhat intended to be smaller and easier to parse than normal .CUE files, the drawback is that it's kinda non-standard, and doesn't support INDEX and ADSR information. A sample .CUE file looks as so:

```
ntracks 3
size      39:33:17
data1    00:02:00
```

```

track02 31:36:46
track03 36:03:17
;(insert 2 blanks lines here, and insert 1 leading space in next line)
trk end 39:37:17

```

All track numbers and MM:SS:FF values are decimal. The ASCII strings should be as shown above, but they are simple ignored by the PSIO firmware (eg. using "popcorn666" instead of "size" or "track02" should also work). The first track should be marked "data1", but PSIO ignores that string, too (it does always treat track 1 as data, and track 2-99 as audio; thus not supporting PSX games with multiple data tracks). The "trk end" value should be equal to the "size" value plus 4 seconds (purpose is unknown, PSIO does just ignore the "trk end" value).

CU2 creation seems to require CDROM images in "CUE/BIN redump.org format" (with separate BIN files for each track), the CUE is then converted to a CU3 file (which is used only temporarily), until the whole stuff is finally converted to a CU2 file (and with all tracks in a single BIN file). Tools like RD2PSIO (aka redump2psio) or PSIO's own SYSCON.ZIP might help on doing some of those steps automatically.

Alongsides, PSIO uses a "multidisc.lst" file... for games that require more than one CDROM disc?

CD Image File Format (Xe - Multi System Emulator)

This is a rather crude file format, used only by the Xe Emulator. The files are meant to be generated by a utility called CDR (CD Image Ripper), which, in practice merely displays an "Unable to read TOC." error message.

The overall file structure is, according to "Xe User's Manual":

```

header: 200h bytes header (see below)
data: 990h bytes per sector (2352 Main, 96 Sub), 00:00:00->Lead Out

```

The header "definition" from the "Xe User's Manual" is as unclear as this:

```

000h 00
001h 00
002h First Track
003h Last Track
004h Track 1 (ADR << 4) | CTRL ;\
005h Track 1 Start Minutes ; Track 1
006h Track 1 Start Seconds ;
007h Track 1 Start Frames ;/
...
n+0 Last Track Start Minutes ;\ -Probably Further Tracks (?)
n+1 Last Track Start Seconds ; Last Track
n+2 Last Track Start Frames ;

```

n+3	Last Track (ADR << 4) CTRL	;/
n+4	Lead-Out Track Start Minutes	;\
n+5	Lead-Out Track Start Seconds	; Lead-Out
n+6	Lead-Out Track Start Frames	;
n+7	Lead-Out Track (ADR << 4) CTRL	;/
...	00	
1FFh	00	

Unknown if MM:SS:FF values and/or First+Last Track numbers are BCD or non-BCD.

Unknown if Last track is separately defined even if there is only ONE track.

Unknown if Track 2 and up include ADR/Control (and if yes: where?).

Unknown if ADR/Control is really meant to be \<before> MM:SS:FF on Track 1.

Unknown if ADR/Control is really meant to be \<after> MM:SS:FF on Last+Lead-Out.

Unknown if this format does have a file extension (if yes: which?).

Unknown if subchannel data is meant to be interleaved or not.

The format supports only around max 62 tracks (in case each track is 4 bytes).

There is no support for "special" features like multi-sessions, cd-text.

12. Controllers and Memory Cards

Controllers/Memory Cards

[Controller and Memory Card I/O Ports](#)
[Controller and Memory Card Misc](#)
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Controllers

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Memory Cards

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Pocketstation (Memory Card with built-in LCD screen and buttons)

[Pocketstation](#)

Pinouts

[Pinouts - Controller Ports and Memory-Card Ports](#)

12.1 Controller and Memory Card I/O Ports

1F801040h JOY_TX_DATA (W)

0-7	Data to be sent
8-31	Not used

Writing to this register starts the transfer (if, or as soon as TXEN=1 and JOY_STAT.2=Ready), the written value is sent to the controller or memory card, and, simultaneously, a byte is received (and stored in RX FIFO if JOY_CTRL.1 or JOY_CTRL.2 is set).

The "TXEN=1" condition is a bit more complex: Writing to SIO_TX_DATA latches the current TXEN value, and the transfer DOES start if the current TXEN value OR the latched TXEN value is set (ie. if TXEN gets cleared after writing to SIO_TX_DATA, then the transfer may STILL start if the old latched TXEN value was set).

1F801040h JOY_RX_DATA (R)

0-7	Received Data	(1st RX FIFO entry) (oldest entry)
8-15	Preview	(2nd RX FIFO entry)
16-23	Preview	(3rd RX FIFO entry)
24-31	Preview	(4th RX FIFO entry) (5th..8th cannot be previewed)

A data byte can be read when JOY_STAT.1=1. Data should be read only via 8bit memory access (the 16bit/32bit "preview" feature is rather unusable, and usually there shouldn't be more than 1 byte in the FIFO anyways).

1F801044h JOY_STAT (R)

0	TX Ready Flag 1	(1=Ready/Started)
1	RX FIFO Not Empty	(0=Empty, 1=Not Empty)
2	TX Ready Flag 2	(1=Ready/Finished)
3	RX Parity Error	(0>No, 1>Error; Wrong Parity, when enabled) (sticky)
4	Unknown (zero)	(unlike SIO, this isn't RX FIFO Overrun flag)
5	Unknown (zero)	(for SIO this would be RX Bad Stop Bit)
6	Unknown (zero)	(for SIO this would be RX Input Level AFTER Stop bit)
7	/ACK Input Level	(0=High, 1=Low)
8	Unknown (zero)	(for SIO this would be CTS Input Level)
9	Interrupt Request	(0=None, 1=IRQ7) (See JOY_CTRL.Bit4,10-12) (sticky)
10	Unknown (always zero)	
11-31	Baudrate Timer	(21bit timer, decrementing at 33MHz)

1F801048h JOY_MODE (R/W) (usually 000Dh, ie. 8bit, no parity, MUL1)

0-1	Baudrate Reload Factor (1=MUL1, 2=MUL16, 3=MUL64) (or 0=MUL1, too)
2-3	Character Length (0=5bits, 1=6bits, 2=7bits, 3=8bits)
4	Parity Enable (0=No, 1=Enable)
5	Parity Type (0=Even, 1=Odd) (seems to be vice-versa...?)
6-7	Unknown (always zero)
8	CLK Output Polarity (0=Normal:High=Idle, 1=Inverse:Low=Idle)
9-15	Unknown (always zero)

1F80104Ah JOY_CTRL (R/W) (usually 1003h,3003h,0000h)

0	TX Enable (TXEN) (0=Disable, 1=Enable)
1	/JOYn Output (0=High, 1=Low/Select) (/JOYn as defined in Bit13)
2	RX Enable (RXEN) (0=Normal, when /JOYn=Low, 1=Force Enable Once)
3	Unknown? (read/write-able) (for SIO, this would be TX Output Level)
4	Acknowledge (0=No change, 1=Reset JOY_STAT.Bits 3,9) (W)
5	Unknown? (read/write-able) (for SIO, this would be RTS Output Level)
6	Reset (0=No change, 1=Reset most JOY_registers to zero) (W)
7	Not used (always zero) (unlike SIO, no matter of FACTOR)
8-9	RX Interrupt Mode (0..3 = IRQ when RX FIFO contains 1,2,4,8 bytes)
10	TX Interrupt Enable (0=Disable, 1=Enable) ;when JOY_STAT.0-or-2 ;Ready
11	RX Interrupt Enable (0=Disable, 1=Enable) ;when N bytes in RX FIFO
12	ACK Interrupt Enable (0=Disable, 1=Enable) ;when JOY_STAT.7 ;/ACK=LOW
13	Desired Slot Number (0=/JOY1, 1=/JOY2) (set to LOW when Bit1=1)
14-15	Not used (always zero)

Caution: After slot selection (via Bits 1,13), one should issue a delay before sending the first data byte: Digital Joypads may work without delay, Dualshock and Mouse require at least some small delay, and older Analog Joypads require a huge delay (around 500 clock cycles for SCPH-1150), official kernel waits more than 2000 cycles (which is much more than needed).

1F80104Eh JOY_BAUD (R/W) (usually 0088h, ie. circa 250kHz, when Factor=MUL1)

0-15	Baudrate Reload value for decrementing Baudrate Timer
------	---

Timer reload occurs when writing to this register, and, automatically when the Baudrate Timer reaches zero. Upon reload, the 16bit Reload value is multiplied by the Baudrate Factor (see 1F801048h.Bit0-1), divided by 2, and then copied to the 21bit Baudrate Timer (1F801044h.Bit11-31). The 21bit timer decreases at 33MHz, and, it ellapses twice per bit (once for CLK=LOW and once for CLK=HIGH).

$$\text{BitsPerSecond} = (44100\text{Hz} * 300\text{h}) / \text{MIN}((\text{Reload} * \text{Factor}) \text{ AND NOT } 1), 1)$$

The default BAUD value is 0088h (equivalent to 44h cpu cycles), and default factor is MUL1, so CLK pulses are 44h cpu cycles LOW, and 44h cpu cycles HIGH, giving it a transfer rate of circa 250kHz per bit (33MHz divided by 88h cycles).

Note: The Baudrate Timer is always running; even if there's no transfer in progress.

/IRQ7 (/ACK) Controller and Memory Card - Byte Received Interrupt

Gets set after receiving a data byte - that only if an /ACK has been received from the peripheral (ie. there will be no IRQ if the peripheral fails to send an /ACK, or if there's no peripheral connected at all).

Actually, /IRQ7 means "more-data-request", accordingly, it does NOT get triggered after receiving the LAST byte.

I_STAT.7 is edge triggered (that means it can be acknowledge before or after acknowledging JOY_STAT.9). However, JOY_STAT.9 is NOT edge triggered (that means it CANNOT be acknowledged while the external /IRQ input is still low; ie. one must first wait until JOY_STAT.7=0, and then set JOY_CTRL.4=1) (this is apparently a hardware glitch; note: the LOW duration is circa 100 clock cycles).

/IRQ10 (/IRQ) Controller - Lightpen Interrupt

Pin8 on Controller Port. Routed directly to the Interrupt Controller (at 1F80107xh). There are no status/enable bits in the JOY_registers (at 1F80104xh).

RX FIFO / TX FIFO Notes

The JOY registers can hold up to 8 bytes in RX direction, and almost 2 bytes in TX direction (just like the SIO registers, see there for details), however, normally only 1 byte should be in the RX/TX registers (one shouldn't send a 2nd byte until /ACK is sensed, and, since the transfer CLK is dictated by the CPU, the amount of incoming data cannot exceed 1 byte; provided that one reads received response byte after each transfer). Unlike SIO, the JOY status register doesn't have a RX FIFO Overrun flag.

General Notes

RXEN should be usually zero (the hardware automatically enables receive when /JOYn is low). When RXEN is set, the next transfer causes data to be stored in RX FIFO even when /JOYn is high; the hardware automatically clears RXEN after the transfer.

For existing joypads and memory cards, data should be always transferred as 8bit no parity (although the JOY registers do support parity just like SIO registers).

Plugging and Unplugging Cautions

During plugging and unplugging, the Serial Data line may be dragged LOW for a moment; this may also affect other connected devices because the same Data line is shared for all controllers and memory cards (for example, connecting a joypad in slot 1 may corrupt memory card accesses in slot 2).

Moreover, the Sony Mouse does power-up with /ACK=LOW, and stays stuck in that state until it is accessed at least once (by at least sending one 01h byte to its controller port); this will also affect other devices (as a workaround one should always access BOTH controller ports; even if a game uses only one controller, and, code that waits for /ACK=HIGH should use timeouts).

Emulation Note

After sending a byte, the Kernel waits 100 cycles or so, and does THEN acknowledge any old IRQ7, and does then wait for the new IRQ7. Due to that bizarre coding, emulators can't trigger IRQ7 immediately within 0 cycles after sending the byte.

12.2 Controller and Memory Card Misc

BIOS Functions

Controllers can be probably accessed via InitPad and StartPad functions,

[BIOS Joypad Functions](#)

Memory cards can be accessed by the filesystem (with device names "bu00:" (slot1) and "bu10:" (slot2) or so). Before using that device names, it seems to be required to call InitCard, StartCard, and _bu_init (?).

Connectors

The PlayStation has four connectors (two controllers, two memory cards),

Memory Card 1	Memory Card 2
Controller 1	Controller 2

The controller ports have 9 pins, the memory cards only 8 pins. However, there are only 10 different pins in total.

JOYDAT, JOYCMD, JOYCLK	Data in/out/clock
+7.5V,+3.5V,GND	Supply
/JOY1,/JOY2	Selects controller/memorycard 1, or controller/memorycard 2
/ACK	Indicates that the device is ready to send more data (IRQ7)
/IRQ10	Lightgun (controllers only, not memory card) (IRQ10)

Most of these pins are shared for all 4 connectors (eg. a CLK signal meant to be sent to one device will also arrive at the other 3 devices).

The /JOYn signals are selecting BOTH the corresponding controller, and the corresponding memory card (whether it is a controller access or memory card access depends on the first byte transferred via the CMD line; this byte should be 01h=Controller, or 81h=Memory Card; or, a special case would be 21h=Yaroze Access Card).

Data In/Out

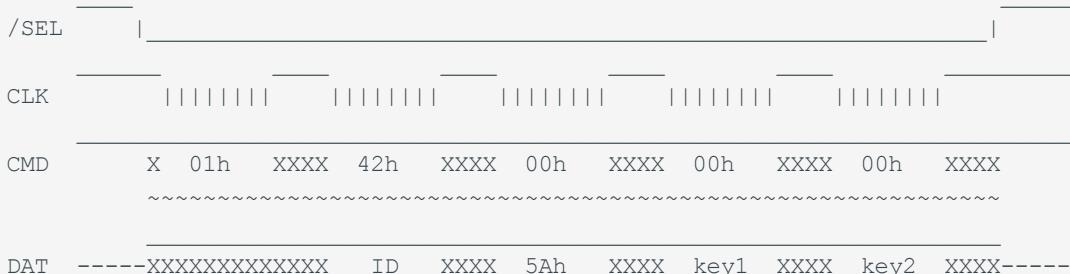
The data is transferred in units of bytes, via separate input and output lines. So, when sending byte, the hardware does simultaneously receive a response byte.

One exception is the first command byte (which selects either the controller, or the memory card) until that byte has been sent, neither the controller nor memory card are selected (and so the first "response" byte should be ignored; probably containing more or less stable high-z levels).

The other exception is, when you have send all command bytes, and still want to receive further data, then you'll need to send dummy command bytes (should be usually 00h) to receive the response bytes.

12.3 Controller and Memory Card Signals

Overview



Top command. First communication(device check)

X = none, - = Hi-Z

- * 0x81 is memory-card, 0x01 is standard-pad at top command.
- * serial data transfer is LSB-First format.
- * data is down edged output, PSX is read at up edge in shift clock.
- * PSX expects No-connection if not returned Acknowledge less than 100 usec.
- * clock pulse is 250KHz.
- * no need Acknowledge at last data.
- * Acknowledge signal width is more than 2 usec.
- * time is 16msec between SEL from previous SEL.
- * SEL- for memory card in PAD access.

12.4 Controller and Memory Card Multitap Adaptor

SCPH-1070 (Multitap)

The Multitap is an external adaptor that allows to connect 4 controllers, and 4 memory cards to one controller port. When using two adaptors (one on each slot), up to 8 controllers and 8 memory cards can be used.

Multitap Controller Access

Normally joypad reading is done by sending this bytes to the pad:

```
01 42 00 00 .. ;normal read
```

And with the multitap, there are even two different ways how to access extra pads:

```
01 42 01 00 .. ;method 1: receive special ID and data from ALL four pads
On 42 00 00 .. ;method 2: receive data from pad number "n" (1..4)
```

The first method seems to be the more commonly used one (and its special ID is also good for detecting the multitap); see below for details.

The second method works more like "normal" reads, among other it's allowing to transfer more than 4 halfwords per slot (unknown if any existing games are using that feature).

The IRQ10 signal (for Konami Lightguns) is simply wired to all four slots via small resistors (without special logic for activating/deactivating the IRQ on certain slots).

Multitap Controller Access, Method 1 Details

Below LONG response is activated by sending "01h" as third command byte; observe that sending that byte does NOT affect the current response. Instead, it does request that the NEXT command shall return special data, as so:

```
Halfword 0      --> Controller ID for MultiTap (5A80h=Multitap)
Halfword 1..4    --> Player A (Controller ID, Buttons, Analog Inputs, if any)
Halfword 5..8    --> Player B (Controller ID, Buttons, Analog Inputs, if any)
Halfword 9..12   --> Player C (Controller ID, Buttons, Analog Inputs, if any)
Halfword 13..16  --> Player D (Controller ID, Buttons, Analog Inputs, if any)
```

With this method, the Multitap is always sending 4 halfwords per slot (padded with FFFFh values for devices like Digital Joypads and Mice; which do use less than 4 halfwords); for empty slots it's padding all 4 halfwords with FFFFh.

Sending the request is possible ONLY if there is a controller in Slot A (if controller Slot A is empty then the Slot A access aborts after the FIRST byte, and it's thus impossible to send the request in the THIRD byte).

Sending the request works on access to Slot A, trying to send another request during the LONG response is glitchy (for whatever strange reason); one must thus REPEATEDLY do TWO accesses: one dummy Slot A access (with the request), followed by the long Slot A+B+C+D access.

```
Previous access had REQ=0 and returned Slot A data ---> returns Slot A data
Previous access had REQ=0 and returned Slot A-D data -> returns Slot A data
Previous access had REQ=1 and returned Slot A data ---> returns Slot A-D data
Previous access had REQ=1 and returned Slot A-D data -> returns garbage
Previous access had REQ=1 and returned garbage -----> returns Slot A-D data
```

In practice:

Toggling REQ on/off after each command: Returns responses toggling between normal Slot A data and long Slot A+B+C+D data.

Sending REQ=1 in ALL commands: Returns responses toggling between Garbage and long Slot A+B+C+D data.

Both of the above is working (one needs only the Slot A+B+C+D part, and it doesn't matter if the other part is Slot A, or Garbage; as long as the software is able/aware of ignoring the Garbage). Garbage response means that the multitap returns ONLY four bytes, like so: Hiz,80h,5Ah,LSB (ie. the leading HighZ byte, the 5A80h Multitap ID, and the LSB of the Slot A controller ID), and aborts transfer after that four bytes.

Multitap Memory Card Access

Normally memory card access is done by sending this bytes to the card:

```
80 xx . . . ;normal access
```

And with the multitap, memory cards can be accessed as so:

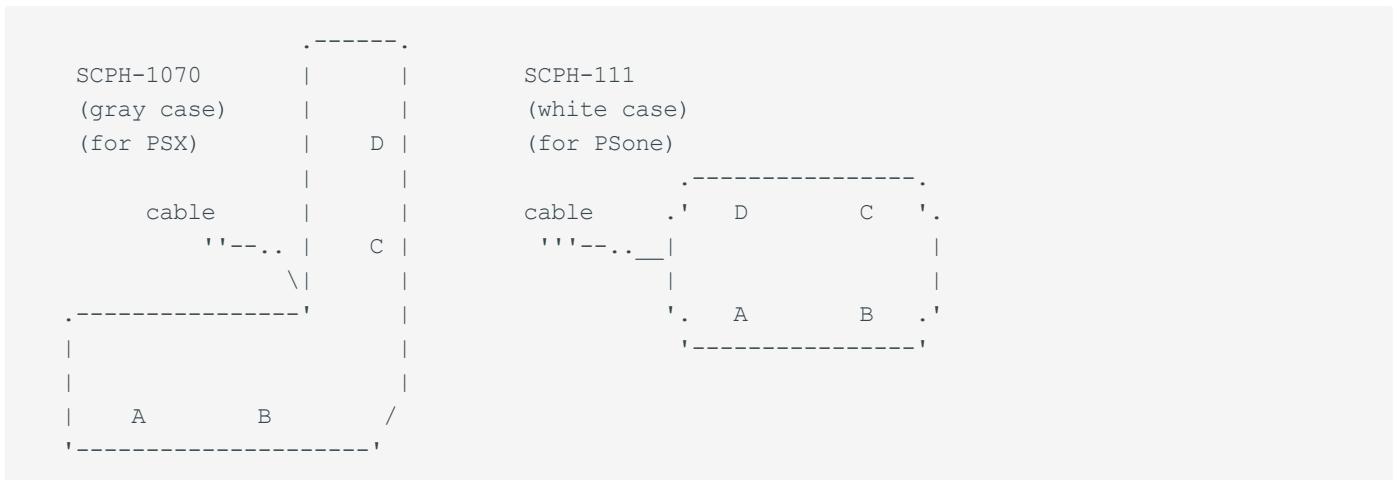
```
8n xx . . . ;access memory card in slot "n" (1..4)
```

That's the way how its done in Silent Hill. Although for the best of confusion, it doesn't actually work in that game (probably the developer has just linked in the multitap library, without actually supporting the multitap at higher program levels).

Multitap Games

```
Bomberman World
Breakout: Off the Wall Fun
Circuit Breakers
Crash Team Racing
FIFA series soccer games
Frogger
Gauntlet: Dark Legacy
Hot Shots Golf 2 & 3
NBA Live (any year) (up to 8 players with two multitaps)
Need For Speed 3
Need For Speed 5
Poy Poy (4 players hitting each other with rocks and trees)
Running Wild
```

Multitap Versions



The cable connects to one of the PSX controller ports (which also carries the memory card signals). The PSX memory card port is left unused (and is blocked by a small edge on the Multitap's plug).

MultiTap Parsed Controller IDs

Halfword 0 is parsed (by the BIOS) as usually, ie. the LSB is moved to MSB, and LSB is replaced by status byte (so ID 5A80h becomes 8000h=Multitap/okay, or xxFFh=bad). Halfwords 1,5,9,13 are NOT parsed (neither by the BIOS nor by the Multitap hardware), however, some info in the internet is hinting that Sony's libraries might be parsing these IDs too (so for example 5A41h would become 4100h=DigitalPad/okay, or xxFFh=bad).

Power Supply

The Multitap is powered by the PSX controller port. Unknown if there are any power supply restrictions (up to eight controllers and eight cards may scratch some limits, especially when doing things like activating rumble on all joypads). However, the Multitap hardware itself doesn't do much on supply restrictions (+3.5V is passed through something; maybe some fuse, loop, or 1 ohm resistor or so) (and +7.5V is passed without any restrictions).

See also

[Pinouts - Component List and Chipset Pin-Outs for Multitap, SCPH-1070](#)

12.5 Controllers - Communication Sequence

Controller Communication Sequence

```

Send Reply Comment
01h Hi-Z Controller Access (unlike 81h=Memory Card access), dummy response
42h idlo Receive ID bit0..7 (variable) and Send Read Command (ASCII "B")
TAP idhi Receive ID bit8..15 (usually/always 5Ah)
MOT swlo Receive Digital Switches bit0..7
MOT swhi Receive Digital Switches bit8..15
--- transfer stops here for digital pad (or analog pad in digital mode) ---
00h adc0 Receive Analog Input 0 (if any) (eg. analog joypad or mouse)
00h adc1 Receive Analog Input 1 (if any) (eg. analog joypad or mouse)
--- transfer stops here for analog mouse -----
00h adc2 Receive Analog Input 2 (if any) (eg. analog joypad)
00h adc3 Receive Analog Input 3 (if any) (eg. analog joypad)
--- transfer stops here for analog pad (in analog mode) -----
--- transfer stops here for nonstandard devices (steering/twist/paddle) ---

```

The TAP byte should be usually zero, unless one wants to activate Multitap (multi-player mode), for details, see

[Controller and Memory Card Multitap Adaptor](#)

The two MOT bytes are meant to control the rumble motors (for normal non-rumble controllers, that bytes should be 00h), however, the MOT bytes have no effect unless rumble is enabled via config commands, for details, see

[Controllers - Rumble Configuration](#)

Controller ID (Halfword Number 0)

```

0-3 Number of following halfwords (01h..0Fh=1..15, or 00h=16 halfwords)
4-7 Controller Type (or currently selected Controller Mode)
8-15 Fixed (5Ah)

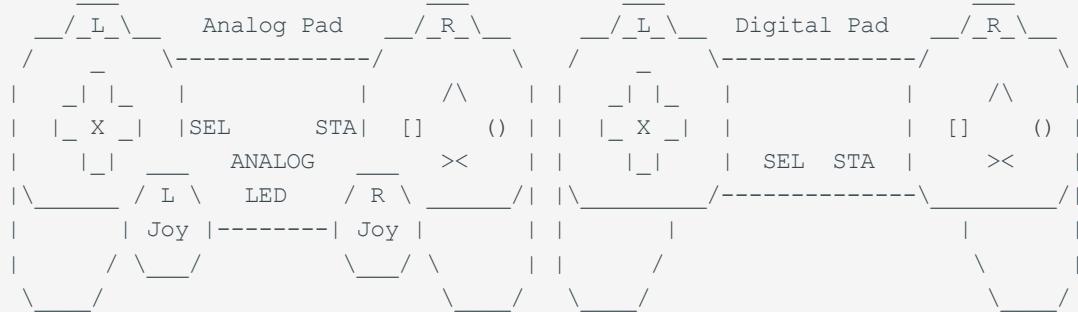
```

Known 16bit ID values are:

xx00h=N/A	(initial buffer value from InitPad BIOS function)
5A12h=Mouse	(two button mouse)
5A23h=NegCon	(steering twist/wheel/paddle)
5A31h=Konami Lightgun	(IRQ10-type)
5A41h=Digital Pad	(or analog pad/stick in digital mode; LED=Off)
5A53h=Analog Stick	(or analog pad in "flight mode"; LED=Green)
5A63h=Namco Lightgun	(Cinch-type)
5A73h=Analog Pad	(in normal analog mode; LED=Red)
5A80h=Multitap	(multiplayer adaptor) (when activated)
5AE3h=Jogcon	(steering dial)

5AF3h=Config Mode	(when in config mode; see rumble command 43h)
FFFFh=High-Z	(no controller connected, pins floating High-Z)

12.6 Controllers - Standard Digital/Analog Controllers



Standard Controllers

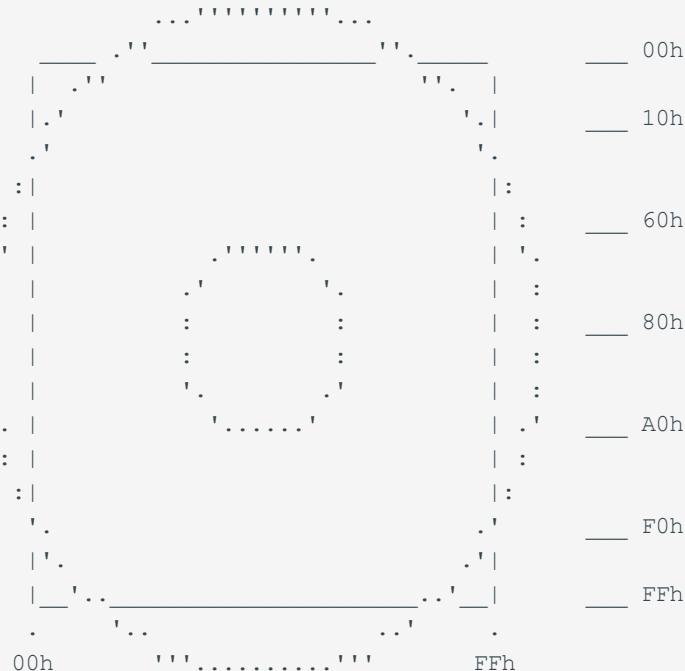
<u>Halfword 0 (Controller Info)</u>	
0-15	Controller Info (5A41h=digital, 5A73h=analog/pad, 5A53h=analog/stick)
<u>Halfword 1 (Digital Switches)</u>	
0	Select Button (0=Pressed, 1=Released)
1	L3/Joy-button (0=Pressed, 1=Released/None/Disabled) ;analog mode only
2	R3/Joy-button (0=Pressed, 1=Released/None/Disabled) ;analog mode only
3	Start Button (0=Pressed, 1=Released)
4	Joypad Up (0=Pressed, 1=Released)
5	Joypad Right (0=Pressed, 1=Released)
6	Joypad Down (0=Pressed, 1=Released)
7	Joypad Left (0=Pressed, 1=Released)
8	L2 Button (0=Pressed, 1=Released) (Lower-left shoulder)
9	R2 Button (0=Pressed, 1=Released) (Lower-right shoulder)
10	L1 Button (0=Pressed, 1=Released) (Upper-left shoulder)
11	R1 Button (0=Pressed, 1=Released) (Upper-right shoulder)
12	/\ Button (0=Pressed, 1=Released) (Triangle, upper button)
13	() Button (0=Pressed, 1=Released) (Circle, right button)
14	>< Button (0=Pressed, 1=Released) (Cross, lower button)
15	[] Button (0=Pressed, 1=Released) (Square, left button)
<u>Halfword 2 (Right joystick) (analog pad/stick in analog mode only)</u>	
0-7	adc0 RightJoyX (00h=Left, 80h=Center, FFh=Right)
8-15	adc1 RightJoyY (00h=Up, 80h=Center, FFh=Down)
<u>Halfword 3 (Left joystick) (analog pad/stick in analog mode only)</u>	
0-7	adc2 LeftJoyX (00h=Left, 80h=Center, FFh=Right)
8-15	adc3 LeftJoyY (00h=Up, 80h=Center, FFh=Down)

Analog Mode Note

On power-up, the controllers are in digital mode (with analog inputs disabled). Analog mode can be (de-)activated manually by pushing the Analog button. Alternately, analog mode can be (de-)activated by software via rumble configuration commands (though that's supported only on newer pads; those with two rumble motors).

The analog sticks are mechanically restricted to a "circular field of motion" (most joypads can reach "min/max" values only in "straight" horizontal or vertical directions, but not in "diagonal" directions).

Analog Joypad Range



Big Circle --> Mechanically possible field of motion
 Square Area --> Digitally visible 8bit field of motion
 Small Circle --> Resting position when releasing the joystick

Example min/center/max values for three different pads:

SCPH-1150	Min=(00,00), Mid: (72..90,79..AC), Max=(FF,FF) at 25'C
SCPH-1200	Min=(0E,0E), Mid: (6C..8A,75..79), Max=(ED,ED) at 16'C
SCPH-110	Min=(11,11), Mid: (8A..9F,70..96), Max=(FD,FD) at 16'C

Values may vary for other pads and/or different temperatures.

Dual Analog Pad in LED=Green Mode

Basically same as normal analog LED=Red mode, with following differences:

ID is 5A53h (identifying itself as analog stick) (rather than analog pad)
 Left/right joy-buttons disabled (as for real analog stick, bits are always 1)
 Some buttons are re-arranged: bit9=L1 bit10=[] bit11=/\ bit12=R1 bit15=R2

Concerning the button names, the real analog-stick does NOT have re-arranged buttons (eg. it's L1 button is in bit10), however, concerning the button locations, the analog stick's buttons are arranged completely differently as on analog pads (so it might be rather uncomfortable to play analog stick games on analog pads in LED=Red mode; the LED=Green mode is intended to solve that problem).

Might be useful for a few analog-stick games like MechWarrior 2, Ace Combat 2, Descent Maximum, and Colony Wars. In most other cases the feature is rather confusing (that's probably why the LED=Green mode wasn't implemented on the Dual Shock).

See also

[Pinouts - Component List and Chipset Pin-Outs for Digital Joypad, SCPH-1080](#)

[Pinouts - Component List and Chipset Pin-Outs for Analog Joypad, SCPH-1150](#)

[Pinouts - Component List and Chipset Pin-Outs for Analog Joypad, SCPH-1200](#)

[Pinouts - Component List and Chipset Pin-Outs for Analog Joypad, SCPH-110](#)

12.7 Controllers - Mouse

Sony Mouse Controller

<u>Halfword 0 (Controller Info)</u>		
0-15 Controller Info (5A12h=Mouse)		
<u>Halfword 1 (Mouse Buttons)</u>		
0-7	Not used	(All bits always 1)
8-9	Unknown	(Seems to be always 0) (maybe SNES-style sensitivity?)
10	Right Button	(0=Pressed, 1=Released)
11	Left Button	(0=Pressed, 1=Released)
12-15	Not used	(All bits always 1)
<u>Halfword 2 (Mouse Motion Sensors)</u>		
0-7	Horizontal Motion (-80h..+7Fh = Left..Right)	(00h>No motion)
8-15	Vertical Motion (-80h..+7Fh = Up..Down)	(00h>No motion)

Sony Mouse Hardware Bug on Power-On

On Power-on (or when newly connecting it), the Sony mouse does draw /ACK to LOW on power-on, and does then hold /ACK stuck in the LOW position.

For reference: Normal controllers and memory cards set /ACK=LOW only for around 100 clk cycles, and only after having received a byte from the console.

The /ACK pin is shared for both controllers and both memory cards, so the stuck /ACK is also "blocking" all other connected controllers/cards. To release the stuck /ACK signal:
Send a command (at least one 01h byte) to both controller slots.

Sony Mouse Compatible Games

```

3D Lemmings
Alien Resurrection
Area 51
Ark of Time
Atari Anniversary Edition
Atlantis: The Lost Tales
Breakout: Off the Wall Fun
Broken Sword: The Shadow of the Templars
Broken Sword II: The Smoking Mirror
Clock Tower: The First Fear
Clock Tower II: The Struggle Within
Command & Conquer: Red Alert
Command & Conquer: Red Alert - Retaliation
Constructor (Europe)
Die Hard Trilogy
Die Hard Trilogy 2: Viva Las Vegas
Discworld
Discworld II: Missing Presumed...!?
Discworld Noir
Dune 2000
Final Doom
Galaxian 3
Ghoul Panic
Klaymen Klaymen: Neverhood no Nazon (Japan)
Lemmings and Oh No! More Lemmings
Monopoly
Music 2000
Myst
Neorude (Japan)
Perfect Assassin
Policenauts (Japan)
Puchi Carat
Quake II
Railroad Tycoon II
Rescue Shot
Risk
Riven: The Sequel to Myst
RPG Maker

```

```

Sentinel Returns
SimCity 2000
Syndicate Wars
Tempest 2000 (Tempest X3)
Theme Aquarium (Japan)
Transport Tycoon
Warhammer: Dark Omen
Warzone 2100
X-COM: Enemy Unknown
X-COM: Terror from the Deep
Z

```

Note: There are probably many more mouse compatible games.

Plus: Dracula - The Resurrection

Sony Mouse Component List

PCB "TD-T41V/\, MITSUMI"

Component Side:

```

1x 3pin  4.00MHz "[M] 4000A, 85 2"
2x 2pin  button (left/right)
1x 8pin  connector (to cable with shield and 7 wires)
1x 3pin  "811, T994I"
2x 3pin  photo transistor (black) ;\or so, no idea which one is
2x 2pin  photo diode (transparent) ;/sender and which is sensor
1x 2pin  electrolyt capacitor 16V, 10uF

```

Solder/SMD Side:

```

1x 32pin "(M), SC442116, FB G22K, JSAA815B"
1x 14pin "BA10339F, 817 L67" (Quad Comparator)
2x 3pin "LC" (amplifier for photo diodes)
1x 3pin "24-" (looks like a dual-diode or so)
plus many SMD resistors/capacitors

```

Cable:

```

PSX.Controller.Pin1 JOYDAT ----- brown -- Mouse.Pin4
PSX.Controller.Pin2 JOYCMD ----- red   -- Mouse.Pin3
PSX.Controller.Pin3 +7.5V ----- N/A
PSX.Controller.Pin4 GND ----- orange -- Mouse.Pin7 GND (G)
PSX.Controller.Pin5 +3.5V ----- yellow -- Mouse.Pin1
PSX.Controller.Pin6 /JOYn ----- green -- Mouse.Pin5
PSX.Controller.Pin7 JOYCLK ----- blue  -- Mouse.Pin2
PSX.Controller.Pin8 /IRQ10 ----- N/A
PSX.Controller.Pin9 /ACK ----- purple -- Mouse.Pin6
PSX.Controller.Shield ----- shield -- Mouse.Pin8 GND (SHIELD)

```

RS232 Mice

Below is some info on RS232 serial mice. That info isn't directly PSX related as the PSX normally doesn't support those mice.

With some efforts, one can upgrade the PSX SIO port to support RS232 voltages, and with such a modded console one could use RS232 mice (in case one wants to do that). The nocash PSX bios can map a RS232 mouse to a spare controller slot (thereby simulating a Sony mouse), that trick may work with various PSX games.

Standard Serial Mouse

A serial mouse should be read at 1200 bauds, 7 data bits, no parity, 1 stop bit (7N1) with DTR and RTS on. For best compatibility, the mouse should output 2 stop bits (so it could be alternately also read as 7N2 or 8N1). When the mouse gets moved, or when a button gets pressed/released, the mouse sends 3 or 4 characters:

```

First Character _____
6   First Character Flag (1)
5   Left Button (1=Pressed)
4   Right Button (1=Pressed)
2-3 Upper 2bit of Vertical Motion
0-1 Upper 2bit of Horizontal Motion
Second Character _____
6   Non-first Character Flag (0)
5-0 Lower 6bit of Horizontal Motion
Third Character _____
6   Non-first Character Flag (0)
5-0 Lower 6bit of Vertical Motion
Fourth Character (if any) _____
6   Non-first Character Flag (0)
5   Middle Button (1=Pressed)
4   Unused ???
3-0 Wheel ???
```

Additionally, the mouse outputs a detection character (when switching RTS (or DTR?) off and on):

```

"M" = Two-Button Mouse (aka "Microsoft" mouse)
"3" = Three-Button Mouse (aka "Logitech" mouse)
"Z" = Mouse-Wheel
```

Normally, the detection response consist of a single character (usually "M"), though some mice have the "M" followed by 11 additional characters of garbage or version information (these extra characters have bit6=0, so after detection, one should ignore all characters until receiving the first data character with bit6=1).

Mouse Systems Serial Mouse (rarely used)

Accessed at 1200 bauds, just like standard serial mouse, but with 8N1 instead 7N1, and with different data bytes.

```

__First Byte_____
7-3 First Byte Code (10000b)
2 Left? Button (0=Pressed)
1 Middle? Button (0=Pressed)
0 Right? Button (0=Pressed)

__Second Byte_____
7-0 Horizontal Motion (X1)

__Third Byte_____
7-0 Vertical Motion (Y1)

__Fourth Byte_____
7-0 Horizontal Motion (X2)

__Fifth Byte_____
7-0 Vertical Motion (Y2)

```

The strange duplicated 8bit motion values are usually simply added together, ie.
 $X=X1+X2$ and $Y=Y1+Y2$, producing 9bit motion values.

Notes

The Sony Mouse connects directly to the PSX controller port. Alternately serial RS232 mice can be connected to the SIO port (with voltage conversion adaptor) (most or all commercial games don't support SIO mice, nor does the original BIOS do so, however, the nocash BIOS maps SIO mice to unused controller slots, so they can be used even with commercial games; if the game uses BIOS functions to read controller data).

Serial Mice (and maybe also the Sony mouse) do return raw mickeys, so effects like double speed threshold must (should) be implemented by software. Mice are rather rarely used by PSX games. The game "Perfect Assassin" includes ultra-crude mouse support, apparently without threshold, and without properly matching the cursor range to the screen resolution.

12.8 Controllers - Racing Controllers

neGcon Racing Controller (Twist) (NPC-101/SLPH-00001/SLEH-0003)

```

__Halfword 0 (Controller Info)_____
0-15 Controller Info (5A23h=neGcon)

__Halfword 1 (Digital Switches)_____
0-2 Not used (always 1) (would be Select, L3, R3 on other pads)

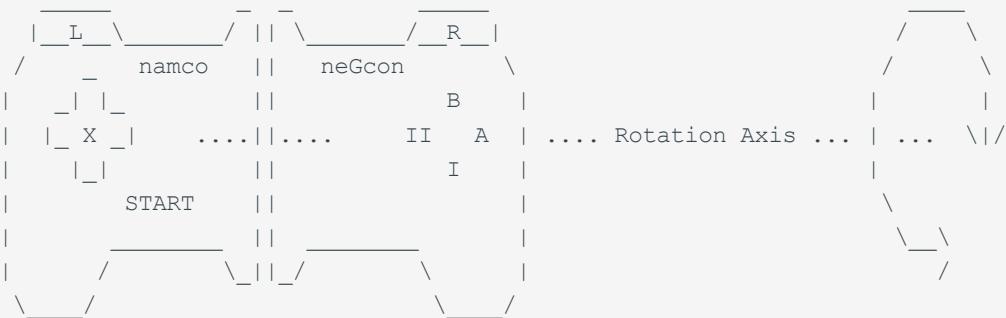
```

```

3      Start Button    (0=Pressed, 1=Released)
4      Joypad Up       (0=Pressed, 1=Released)
5      Joypad Right    (0=Pressed, 1=Released)
6      Joypad Down     (0=Pressed, 1=Released)
7      Joypad Left     (0=Pressed, 1=Released)
8-10   Not used       (always 1)          (would be L2, R2, L1 on other pads)
11     R Button        (0=Pressed, 1=Released) (would be R1 on other pads)
12     B Button        (0=Pressed, 1=Released) (would be /\ on other pads)
13     A Button        (0=Pressed, 1=Released) (would be () on other pads)
14-15  Not used       (always 1)          (would be ><, [] on other pads)
_____
0-7    Steering Axis   (00h=Left, 80h=Center, FFh=Right) (or vice-versa?)
8-15   Analog I button (00h=Out ... FFh=In)  (Out=released, in=pressed?)
_____
0-7    Analog II button (00h=Out ... FFh=In)  (Out=released, in=pressed?)
8-15   Analog L button (00h=Out ... FFh=In)  (Out=released, in=pressed?)

```

The Twist controller works like a paddle or steering wheel, but doesn't have a wheel or knob, instead, it can be twisted: To move into one direction (=maybe right?), turn its right end away from you (or its left end towards you). For the opposite direction (=maybe left?), do it vice-versa.



Namco Volume Controller (a paddle with two buttons) (SLPH-00015)

This is a cut-down variant of the neGcon, just a featureless small box. It does have the same ID value as neGcon (ID=5A23h), but, it excludes most digital, and all analog buttons.

namco	Halfword 1 (digital buttons):
	Bit3 Button A (0=Pressed) (aka neGcon Start button)
A B	Bit13 Button B (0=Pressed) (aka neGcon A button aka () button)
	Other bits (not used, always 1)
-	Halfword 2 and 3 (analog inputs):
()	Steering Axis (00h..FFh) (as for neGcon)
_____	Analog I,II,L button values (not used, always 00h)

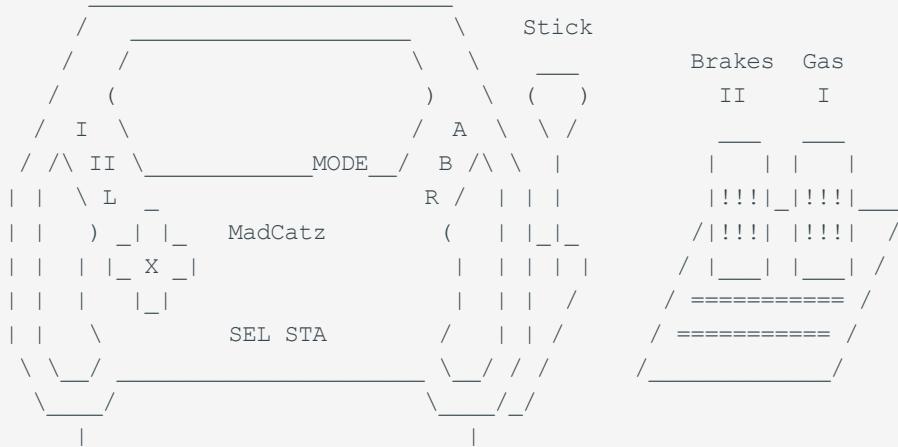
SANKYO N.ASUKA aka Nasca Pachinco Handle (SLPH-00007)

Another cut-down variant of the neGcon (with ID=5A23h, too). But, this one seems to have only one button. Unlike Namco's volume controller it doesn't look featureless. It looks pretty much as shown in the ascii-arts image below. Seems to be supported by several irem titles. No idea what exactly it is used for, it's probably not a sewing machine controller, nor an electronic amboss.

	Halfword 1 (digital buttons): Bit12 Button (0=Pressed) (aka neGcon B button aka /\ button) Other bits (not used, always 1) Halfword 2 and 3 (analog inputs): Steering Axis (00h..FFh) (as for neGcon) Analog I,II,L button values (not used, always 00h)
--	---

Mad Catz Steering Wheel (SLEH-0006)

A neGcon compatible controller. The Twist-feature has been replaced by a steering wheel (can be turned by 270 degrees), and the analog I and II buttons by foot pedals. The analog L button has been replaced by a digital button (ie. in neGcon mode, the last byte of the controller data can be only either 00h or FFh). When not using the pedals, the I/II buttons on the wheel can be used (like L button, they aren't analog though).



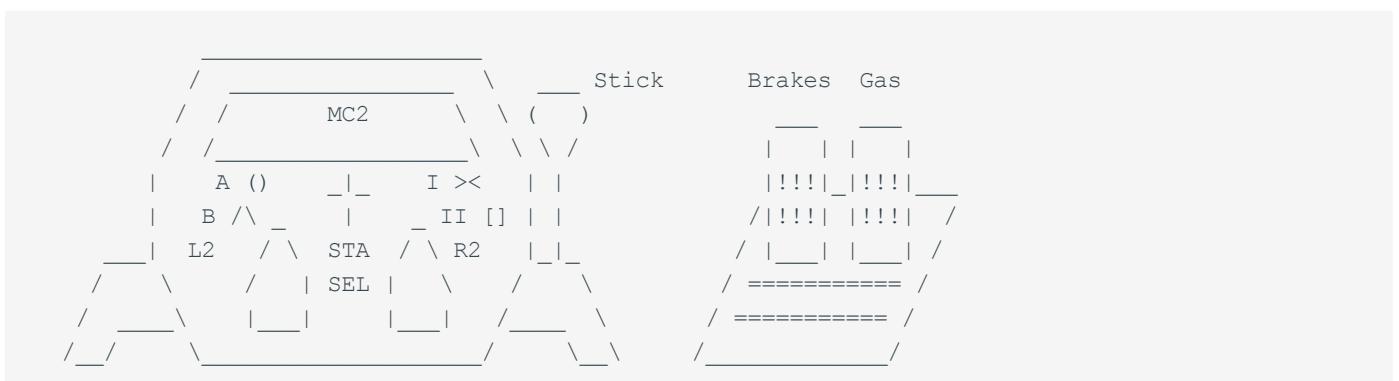
Unlike the neGon, the controller has Select, >\< and [] buttons, and a second set of L/R buttons (at the rear-side of the wheel) (no idea if L1/R1 or L2/R2 are at front?). Aside from the neGcon mode, the controller can be also switched to Digital mode (see below for button chart).

MadCatz Dual Force Racing Wheel

Same as above, but with a new Analog mode (additionally to Digital and neGcon modes). The new mode is for racing games that support only Analog Joypads (instead of neGcon). Additionally it supports vibration feedback.

MadCatz MC2 Vibration compatible Racing Wheel and Pedals

Same as above, but with a redesigned wheel with rearranged buttons, the digital pad moved to the center of the wheel, the L/R buttons at the rear-side of the wheel have been replaced by 2-way butterfly buttons ("pull towards user" acts as normal, the new "push away from user" function acts as L3/R3).



MadCatz Button Chart

Mode	Buttons.....	Gas	Brake	Stick	Wheel
Digital	>< [] () /\ L1 R1 L2 R2 L1 R1 >< ()		L1/R1	lt/rt	
Analog	>< [] () /\ L1 R1 L2 R2 L3 R3 UP DN		L1/R1	LT/RT	
Negcon	I II A B L R L R I II		up/dn	Twist	

Whereas, lt/rt/up/dn=Digital Pad, UP/DN=Left Analog Pad Up/Down, LT/RT=Right Analog Pad Left/Right. Analog mode is supported only by the Dual Force and MC2 versions, L3/R3 only by the MC2 version.

Namco Jogcon (NPC-105/SLEH-0020/SLPH-00126/SLUH-00059)

```
Halfword 0 (Controller Info)
0-15 Controller Info (5AE3h=Jogcon in Jogcon mode) (ie. not Digital mode)
halfword1: buttons: same as digital pad
halfword2:
  0 unknown (uh, this isn't LSB of rotation?)
  1-15 dial rotation (signed offset since last read?) (or absolute position?)
halfword3:
  0 flag: dial was turned left (0=no, 1=yes)
```

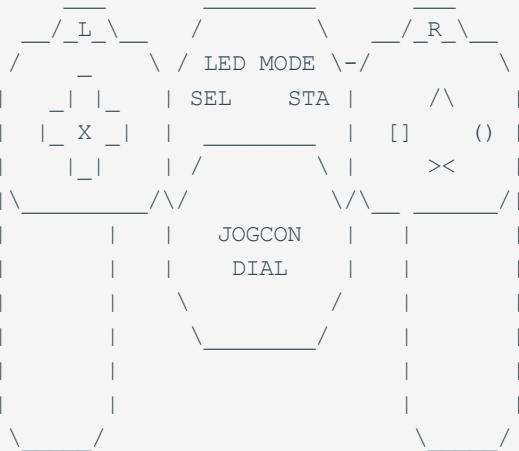
```

1      flag: dial was turned right (0=no, 1=yes)
2-15 unknown

```

Rotations of the dial are recognized by an optical sensor (so, unlike potentiometers, the dial can be freely rotated; by more than 360 degrees). The dial is also connected to a small motor, giving it a real force-feedback effect (unlike all other PSX controllers which merely have vibration feedback). Although that's great, the mechanics are reportedly rather cheap and using the controller doesn't feel too comfortable. The Jogcon is used only by Ridge Racer 4 for PS1 (and Ridge Racer 5 for PS2), and Breakout - Off the Wall Fun.

The Mode button probably allows to switch between Jogcon mode and Digital Pad mode (similar to the Analog button on other pads), not sure if the mode can be also changed by software via configuration commands...? Unknown how the motor is controlled; probably somewhat similar to vibration motors, ie. by the M1 and/or M2 bytes, but there must be also a way to select clockwise and anticlockwise direction)...? The controller does reportedly support config command 4Dh (same as analog rumble).



12.9 Controllers - Lightguns

There are two different types of PSX lightguns (which are incompatible with each other).

Namco Lightgun (GunCon)

Namco's Cinch-based lightguns are extracting Vsync/Hsync timings from the video signal (via a cinch adaptor) (so they are working completely independent of software timings).

[Controllers - Lightguns - Namco \(GunCon\)](#)

Konami Lightgun (IRQ10)

Konami's IRQ10-based lightguns are using the lightgun input on the controller slot (which requires IRQ10/timings being properly handled at software side).

[Controllers - Lightguns - Konami Justifier/Hyperblaster \(IRQ10\)](#)

The IRQ10-method is reportedly less accurate (although that may be just due to bugs at software side).

Third-Party Lightguns

There are also a lot of unlicensed lightguns which are either IRQ10-based, or Cinch-based, or do support both.

For example, the Blaze Scorpion supports both IRQ10 and Cinch, and it does additionally have a rumble/vibration function; though unknown how that rumble feature is accessed, and which games are supporting it).

Lightgun Games

[Controllers - Lightguns - PSX Lightgun Games](#)

Compatibility Notes (IRQ10 vs Cinch, PAL vs NTSC, Calibration)

Some lightguns are reportedly working only with PAL or only with NTSC games (unknown which guns, and unknown what is causing problems; the IRQ10 method should be quite hardware independent, the GunCon variant, too, although theoretically, some GunCon guns might have problems to extract Vsync/Hsync from either PAL or NTSC composite signals).

Lightguns from different manufacturers are reportedly returning slightly different values, so it would be recommended to include a calibration function in the game, using at least one calibration point (that would also resolve different X/Y offsets caused by modifying GP1 display control registers).

Lightguns are needing to sense light from the cathode ray beam; as such they won't work on regions of the screen that contain too dark/black graphics.

12.10 Controllers - Lightguns - Namco (GunCon)

GunCon Cinch-based Lightguns (Namco)

```

__Halfword 0 (Controller Info) _____
0-15 Controller Info (5A63h=Namco Lightgun; GunCon/Cinch Type)
__Halfword 1 (Buttons) _____
0-2 Not used (All bits always 1)
3 Button A (Left Side) (0=Pressed, 1=Released) ;aka Joypad Start
4-12 Not used (All bits always 1)
13 Trigger Button (0=Pressed, 1=Released) ;aka Joypad O-Button
14 Button B (Right Side) (0=Pressed, 1=Released) ;aka Joypad X-Button
15 Not used (All bits always 1)
__Halfword 2 (X) _____
0-15 8MHz clks since HSYNC (01h=Error, or 04Dh..1CDh)
__Halfword 3 (Y) _____
0-15 Scanlines since VSYNC (05h/0Ah=Error, PAL=20h..127h, NTSC=19h..F8h)

```

Caution: The gun should be read only shortly after begin of VBLANK.

Error/Busy Codes

Coordinates X=0001h, Y=0005h indicates "unexpected light":

ERROR: Sensed light during VSYNC (eg. from a Bulb or Sunlight).

Coordinates X=0001h, Y=000Ah indicates "no light", this can mean either:

ERROR: no light sensed at all (not aimed at screen, or screen too dark).

BUSY: no light sensed yet (when trying to read gun during rendering).

To avoid the BUSY error, one should read the gun shortly after begin of VBLANK (ie. AFTER rendering, but still BEFORE vsync). Doing that isn't as simple as one might think:

On a NTSC console, time between VBLANK and VSYNC is around 30000 cpu clks, reading the lightgun (or analog joypads) takes around 15000 cpu clks. So, reading two controllers within that timeframe may be problematic (and reading up to eight controllers via multitaps would be absolutely impossible). As a workaround, one may arrange the read-order to read lightguns at VBLANK (and joypads at later time). If more than one lightgun is connected, then one may need to restrict reading to only one (or maybe: max two) guns per frame.

Minimum Brightness

Below are some average minimum brightness values, the gun may be unable to return position data near/below that limits (especially coordinates close to left screen border are most fragile). The exact limits may vary from gun to gun, and will also depend on the TV Set's brightness setting.

```
666666h Minimum Gray
770000h Minimum Blue
007700h Minimum Green
000099h Minimum Red
```

The gun does also work with mixed colors (eg. white bold text on black background works without errors, but the returned coordinates are a bit "jumpy" in that case; returning the position of the closest white pixels).

BUG: On a plain RED screen, aiming at Y>=00F0h, the gun is randomly returning either Y, or Y-80h (that error occurs in about every 2nd frame, ie. at 50% chance). It's strange... no idea what is causing that effect.

Coordinates

The coordinates are updated in all frames (as opposed to some lightguns which do update them only when pulling the trigger).

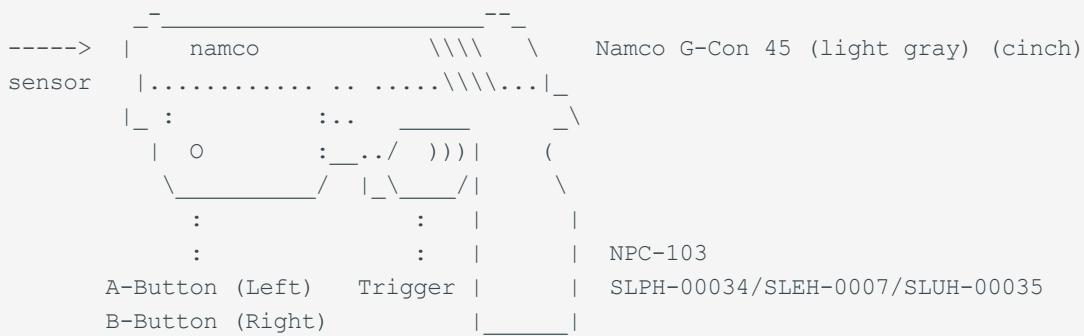
The absolute min/max coordinates may vary from TV set to TV set (some may show a few more pixels than others). The relation of the gun's Screen Coordinates to VRAM Coordinates does (obviously) depend on where the VRAM is located on the screen; ie. on the game's GP1(06h) and GP1(07h) settings.

Vertical coordinates are counted in scanlines (ie. equal to pixels). Horizontal coordinates are counted in 8MHz units (which would equal a resolution of 385 pixels; which can be, for example, converted to 320 pixel resolution as X=X*320/385).

Misinformation (from bugged homebrew source code)

```
_____  
_Halfword 2 (X)  
0-7   X-Coordinate    (actual: see X-Offset)           ;\with unspecified  
8-15  X-Offset        (00h: X=X-80, Nonzero: X=X-80+220) ;/dotclock?  
_____  
_Halfword 3 (Y)  
0-7   Y-Coordinate    (actual: Y=Y-25) (but then, max is only 230, not 263 ?)  
8-15  Pad ID          (uh, what id?) (reportedly too dark/bright error flag?)
```

Namco Lightgun Drawing



See also

[Pinouts - Component List and Chipset Pin-Outs for Namco Lightgun, NPC-103](#)

12.11 Controllers - Lightguns - Konami Justifier/Hyperblaster (IRQ10)

Overall IRQ10-Based Lightgun Access

```
Send 01h 42h 00h x0h 00h
Reply HiZ 31h 5Ah buttons
```

The purpose of the "x0h" byte is probably to enable IRQ10 (00h=off, 10h=on), this would allow to access more than one lightgun (with only one per frame having the IRQ enabled).

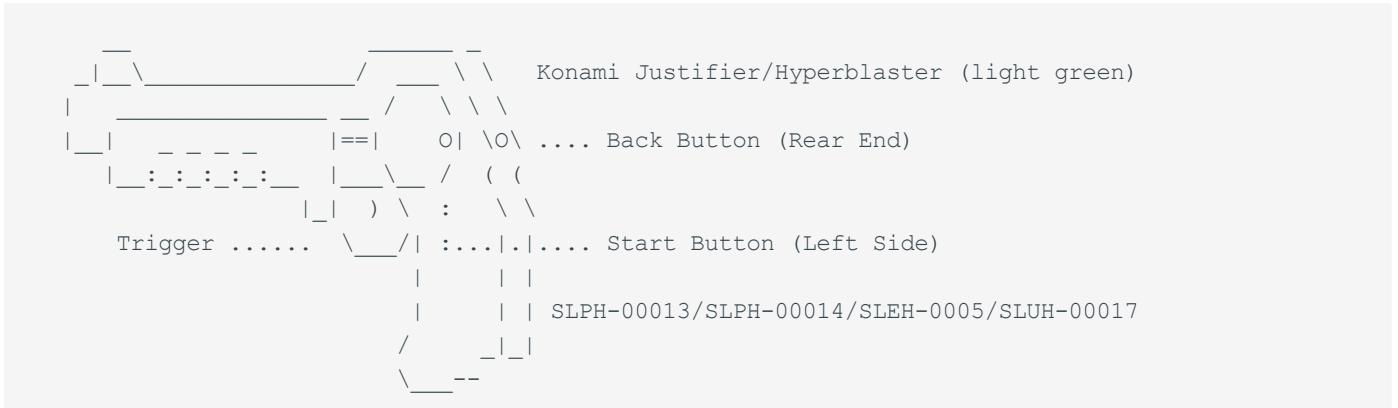
Standard IRQ10-based Lightguns (Konami)

The Controller Data simply consists of the ID and buttons states:

```
____Halfword 0 (Controller Info)_____
0-15 Controller Info (5A31h=Konami Lightgun; Timer/IRQ10 type)
____Halfword 1 (Buttons)_____
0-2 Not used (All bits always 1)
3 Start Button (Left Side) (0=Pressed, 1=Released) ;aka Joypad Start
4-13 Not used (All bits always 1)
14 Back Button (Rear End) (0=Pressed, 1=Released) ;aka Joypad X-Button
15 Trigger Button (0=Pressed, 1=Released) ;aka Joypad []-Button
```

The coordinates aren't part of the controller data, instead they must be read from Timer 0 and 1 upon receiving IRQ10 (see IRQ10 Notes below).

Konami Lightgun Drawing



Konami IRQ10 Notes

The PSX does have a lightgun input (Pin 8 of the controller), but, Sony did apparently "forget" to latch the current cathode ray beam coordinates by hardware when sensing the lightgun signal (quite strange, since that'd be a simple, inexpensive, and very obvious feature for a gaming console).

Instead, the lightgun signal triggers IRQ10, and the interrupt handler is intended to "latch" the coordinates by software (by reading Timer 0 and 1 values, which must be configured to be synchronized with the GPU).

That method requires IRQ handling to be properly implemented in software (basically, IRQs should not be disabled for longer periods, and DMA transfers should not block the bus for longer periods). In practice, most programmers probably don't realize how to do that, to the worst, Sony seems to have delivered a slightly bugged library (libgun) to developers.

For details on Timers, see:

[Timers](#)

In some consoles, IRQ10 seems to be routed through a Secondary IRQ Controller, see:
[EXP2 DTL-H2000 I/O Ports](#)

IRQ10 Priority

For processing IRQ10 as soon as possible, it should be assigned higher priority than all other IRQs (ie. when using the SysEnqIntRP BIOS function, it should be the first/newest element in priority chain 0). The libgun stuff assigns an even higher priority by patching the BIOS exception handler, causing IRQ10 to be processed shortly before processing the

priority chains (the resulting IRQ priority isn't actually higher as when using 1st element of chain 0; the main difference is that it skips some time consuming code which pushes registers R4..R30). For details on that patch, see:

BIOS Patches

Even if IRQ10 has highest priority, execution of (older) other IRQs may cause a new IRQ10 to be executed delayed (because IRQs are disabled during IRQ handling), to avoid that problem: Best don't enable any other IRQs except IRQ0 and IRQ10, or, if you need other IRQs, best have them enabled only during Vblank (there are no scanlines drawn during vblank, so IRQ10 should never trigger during that period). DMAs might also slow down IRQ execution, so best use them only during Vblank, too.

IRQ10 Timer Reading

To read the current timer values the IRQ10 handler would be required to be called `\<immediately>` after receiving the IRQ10 signal, which is more or less impossible; if the main program is trying to read a mul/div/gte result while the mul/div/gte operation is still busy may stop the CPU for some dozens of clock cycles, and active DMA transfers or cache hits and misses in the IRQ handler may cause different timings, moreover, timings may become completely different if IRQs are disabled (eg. while another IRQ is processed).

However, IRQ10 does also get triggered in the next some scanlines, so the first IRQ10 is used only as a notification that the CPU should watch out for further IRQ10's. Ie. the IRQ10 handler should disable all DMAs, acknowledge IRQ10, and then enter a waitloop that waits for the IRQ10 bit in I_STAT to become set again (or abort if a timeout occurs) and then read the timers, reportedly like so:

```
IF NTSC then X=(Timer0-140)*0.198166, Y=Timer1
IF PAL   then X=(Timer0-140)*0.196358, Y=Timer1
```

No idea why PAL/NTSC should use different factors, that factors are looking quite silly/bugged, theoretically, the pixel-to-clock ratio should be the exactly same for PAL and NTSC...?

Mind that reading Timer values in Dotclock/Hblank mode is unstable, for Timer1 this can be fixed by the read-retry method, for Timer0 this could be done too, but one would need to subtract the retry-time to get a correct coordinate; alternately Timer0 can run at system clock (which doesn't require read-retry), but it must be then converted to video clock (mul 11, div 7), and then from video clock to dot clock (eg. div 8 for 320-pixel mode).

Above can be repeated for the next some scanlines (allowing to take the medium values

as result, and/or to eliminate faulty values which are much bigger or smaller than the other values). Once when you have collected enough values, disable IRQ10, so it won't trigger on further scanlines within the current frame.

IRQ10 Bugs

BUG: The "libgun" library doesn't acknowledge the old IRQ10 \<immediately> before waiting for a new IRQ10, so the timer values after sensing the new IRQ10 are somewhat random (especially for the first processed scanline) (the library allows to read further IRQ10's in further scanlines, which return more stable results).

No idea how many times IRQ10 gets typically repeated? Sporting Clays allocates a buffer for up to 20 scanlines (which would cause pretty much of a slowdown since the CPU is just waiting during that period) (nethertheless, the game uses only the first timer values, ie. the bugged libgun-random values).

Unknown if/how two-player games (with 2 lightguns) are working with the IRQ10 method... if IRQ10 is generated ONLY after pressing the trigger button, then it may work, unless both players have Trigger pressed at the same time... and, maybe one can enable/disable the lightguns by whatever command being sent to the controller (presumably that "x0h" byte, see above), so that gun 1 generates IRQ10 only in each second frame, and gun 2 only in each other frame...?

12.12 Controllers - Lightguns - PSX Lightgun Games

PSX Lightgun Games

Some games are working only with IRQ10 or only with Cinch, some games support both methods:

```

Area 51 (Mesa Logic/Midway) (IRQ10)
Crypt Killer (Konami) (IRQ10)
Die Hard Trilogy 1: (Probe Entertainment) (IRQ10)
Die Hard Trilogy 2: Viva Las Vegas (n-Space) (IRQ10/Cinch)
Elemental Gearbolt (Working Designs) (IRQ10/Cinch)
Extreme Ghostbusters: Ultimate Invasion (LSP) (Cinch)
Galaxian 3 (Cinch)
Ghoul Panic (Namco) (Cinch)
Gunfighter: The Legend of Jesse James (Rebellion) (Cinch)
Judge Dredd (Gremlin) (Cinch)
Lethal Enforcers 1-2 (Konami) (IRQ10)
Maximum Force (Midway) (IRQ10/Cinch)
Mighty Hits Special (Altron) (EU/JPN) (Cinch)

```

```

Moorhuhn series (Phenomedia) (Cinch)
Point Blank 1-3 (Namco) (Cinch)
Project Horned Owl (Sony) (IRQ10)
Rescue Shot (Namco) (Cinch)
Resident Evil: Gun Survivor (Capcom) (JPN/PAL versions) (Cinch)
Silent Hill (IRQ10) ("used for an easter egg")
Simple 1500 Series Vol.024 - The Gun Shooting (unknown type)
Simple 1500 Series Vol.063 - The Gun Shooting 2 (unknown type)
Snatcher (IRQ10)
Sporting Clays (Charles Doty) (homebrew with buggy source code) (IRQ10/Cinch)
Star Wars: Rebel Assault II (IRQ10)
Time Crisis, and Time Crisis 2: Project Titan (Namco) (Cinch)

```

Note: The RPG game Dragon Quest Monsters does also contain IRQ10 lightgun code (though unknown if/when/where the game does use that code).

12.13 Controllers - Rumble Configuration

Rumble (aka "Vibration Function") is basically controlled by two previously unused bytes of the standard controller Read command.

There are two methods to control the rumble motors, the old method is very simple (but supports only one motor), the new method involves a bunch of new configuration commands (and supports two motors).

```

SCPH-1150 DualAnalog Pad with 1 motor ;-old rumble method
SCPH-1200 DualAnalog Pad with 2 motors, PSX-design ;\new rumble method
SCPH-110 DualAnalog Pad with 2 motors, PSone-design ;/
Blaze Scorpion Lightgun with rumble ;\unknow how to control rumble
Fishing controllers with rumble ;/
SCPH-1180 Analog Pad without rumble ;\unknow if there're config commands
SCPH-1110 Analog Stick without rumble ;/for analog mode (probably not)

```

Old Method, one motor, no config commands (SCPH-1150, SCPH-1200, SCPH-110)

The SCPH-1150 doesn't support any special config commands, instead, rumble is solely done via the normal joypad read command:

```

Send 01h 42h 00h xx yy (00h 00h 00h 00h)
Reply HiZ id 5Ah buttons (analog-inputs)

```

The rumble motor is simply controlled by three bits in the xx/yy bytes:

```

xx --> must be 40h..7Fh (ie. bit7=0, bit6=1) ;\switches motor on
yy --> must be 01h,03h,...,FDh,FFh (ie. bit0=1) ;/

```

The motor control is digital on/off (no analog slow/fast), recommended values would be yyxx=0140h=on, and yyxx=0000h=off.

LED state is don't care (rumble works with led OFF, RED, and GREEN). In absence of config commands, the LED can be controlled only manually (via Analog button), the current LED state is implied in the controller "id" byte.

For backwards compatibility, the above old method does also work on SCPH-1200 and SCPH-110 (for controlling the right/small motor), alternately those newer pads can use the config commands (for gaining access to both motors).

When the controller enters configuration mode, the old rumble method is disabled until a hard reset. Unknown if it's possible to re-enable the old rumble method programmatically.

New Method, two motors, with config commands (SCPH-1200, SCPH-110)

For using the new rumble method, one must unlock the new rumble mode, for that purpose Sony has invented a "slightly" overcomplicated protocol with not less than 16 new commands (the rumble relevant commands are 43h and 4Dh, also, command 44h may be useful for activating analog inputs by software, and, once when rumble is unlocked, command 42h is used to control the rumble motors). Anyways, here's the full command set...

Normal Mode

```
42h "B" Read Buttons (and analog inputs when in analog mode)
43h "C" Enter/Exit Configuration Mode (stay normal, or enter)
```

Configuration Mode

```

40h "@" Unknown (response HiZ F3h 5Ah 6x00h)
41h "A" Unknown (response HiZ F3h 5Ah 6x00h)
42h "B" Read Buttons AND analog inputs (even when in digital mode)
43h "C" Enter/Exit Configuration Mode (stay config, or exit)
44h "D" Set LED State (analog mode on/off)
45h "E" Get LED State (and whatever other status/version values)
46h "F" Get Variable Response A (depending on incoming bit)
47h "G" Get whatever values (response HiZ F3h 5Ah 00h 00h 02h 00h 01h 00h)
48h "H" Unknown (response HiZ F3h 5Ah 00h 00h 00h 00h 01h 00h)
49h "I" Unknown (response HiZ F3h 5Ah 6x00h)
4Ah "J" Unknown (response HiZ F3h 5Ah 6x00h)
4Bh "K" Unknown (response HiZ F3h 5Ah 6x00h)
4Ch "L" Get Variable Response B (depending on incoming bit)
4Dh "M" Unlock Rumble (and select response length)
4Eh "N" Unknown (response HiZ F3h 5Ah 6x00h)
4Fh "O" Unknown (response HiZ F3h 5Ah 6x00h)

```

Normal Mode - Command 42h "B" - Read Buttons (and analog inputs when enabled)

```

Send 01h 42h 00h xx yy (00h 00h 00h 00h)
Reply HiZ id 5Ah buttons (analog-inputs )

```

The normal read command, see Standard Controller chapter for details on buttons and analog inputs. The xx/yy bytes have effect only if rumble is unlocked; use Command 43h to enter config mode, and Command 4Dh to unlock rumble. Command 4Dh has billions of combinations, among others allowing to unlock only one of the two motors, and to exchange the xx/yy bytes, however, with the default values, xx/yy are assigned like so:

```

yy.bit0-7 ----> Left/Large Motor M1 (analog slow/fast) (00h=stop, FFh=fastest)
xx.bit0     ----> Right/small Motor M2 (digital on/off) (0=off, 1=on)

```

The Left/Large motor starts spinning at circa min=50h..60h, and, once when started keeps spinning down to circa min=38h. The exact motor start boundary depends on the current position of the weight (if it's at the "falling" side, then gravity helps starting), and also depends on external movements (eg. it helps if the user or the other rumble motor is shaking the controller), and may also vary from controller to controller, and may also depend on the room temperature, dirty or worn-out mechanics, etc.

Normal Mode - Command 43h "C" - Enter/Exit Configuration Mode

```

Send 01h 43h 00h xx 00h (zero padded...)
Reply HiZ id 5Ah buttons (analog inputs...)

```

When issuing command 43h from inside normal mode, the response is same as for command 42h (button data) (and analog inputs when in analog mode) (but without M1 and M2 parameters). While in config mode, the ID bytes are always "F3h 5Ah" (instead of the normal analog/digital ID bytes).

Entering configuration mode enables the DualShock rumble method and disables the legacy rumble method. Unknown if it's possible to re-enable the old rumble method programmatically.

```
xx=00h Stay in Normal mode
xx=01h Enter Configuration mode
```

Caution: Additionally to activating configuration commands, entering config mode does also activate a Watchdog Timer which does reset the controller if there's been no communication for about 1 second or so. The watchdog timer remains active even when returning to normal mode via Exit Config command. The reset does disable and lock rumble motors, and switches the controller to Digital Mode (with LED=off, and analog inputs disabled). To prevent this, be sure to keep issuing joypad reads even when not needing user input (eg. while loading data from CDROM).

Caution 2: A similar reset occurs when the user pushes the Analog button; this is causing rumble motors to be stopped and locked, and of course, the analog/digital state gets changed.

Caution 3: If config commands were used, and the user does then push the analog button, then the 5Ah-byte gets replaced by 00h (ie. responses change from "HiZ id 5Ah ..." to "HiZ id 00h ...").

Config Mode - Command 42h "B" - Read Buttons AND analog inputs

```
Send 01h 42h 00h M2 M1 00h 00h 00h 00h
Reply HiZ F3h 5Ah buttons analog-inputs
```

Same as command 42h in normal mode, but with forced analog response (ie. analog inputs and L3/R3 buttons are returned even in Digital Mode with LED=Off).

Config Mode - Command 43h "C" - Enter/Exit Configuration Mode

```
Send 01h 43h 00h xx 00h 00h 00h 00h 00h
Reply HiZ F3h 5Ah 00h 00h 00h 00h 00h
```

Equivalent to command 43h in normal mode, but returning 00h bytes rather than button data, can be used to return to normal mode.

```
xx=00h Enter Normal mode (Exit Configuration mode)
xx=01h Stay in Configuration mode
```

Back in normal mode, the rumble motors (if they were enabled) can be controlled with normal command 42h. Some controller revisions will only change config mode state upon receiving the entire command sequence while others will set it immediately on receiving the xx byte. So while aborting the command sequence early (i.e. setting JOY_CTRL to 0 after sending xx, which some homebrew software does) may work for setting config mode state on some controllers, in practice this technique is undefined behavior and use should be avoided.

Config Mode - Command 44h "D" - Set LED State (analog mode on/off)

```
Send 01h 44h 00h val sel 00h 00h 00h 00h
Reply HiZ F3h 5Ah 00h 00h 00h 00h 00h
```

If "sel=02h", then "val" is applied as new LED state (val=00h for LED off aka Digital mode, and val=01h for LED on/red aka analog mode).

Using this command has a side effect of resetting the DualShock rumble configuration to FFh FFh FFh FFh FFh FFh.

Config Mode - Command 45h "E" - Get LED State (and whatever values)

```
Send 01h 45h 00h 00h 00h 00h 00h 00h 00h
Reply HiZ F3h 5Ah 01h 02h val 02h 01h 00h
```

Returns val=00h for LED off, and val=01h for LED on/red. The other values might indicate the number of rumble motors, analog inputs, or version information, or so.

Config Mode - Command 46h "F" - Get Variable Response A

```
Send 01h 46h 00h xx 00h 00h 00h 00h 00h
Reply HiZ F3h 5Ah 00h 00h yy yy yy yy
```

Purpose unknown, but seems to be used by some games to identify the controller as a DualShock Analog Controller since Jogcon returns different values. Response varies: If xx=00h then yy=01h,02h,00h,0ah, else if xx=01h then yy=01h,01h,01h,14h. Other

values of xx will cause yy = 00h 00h 00h 00h to be returned. Unknown what happens if the other values after xx are modified, but it is likely that the controller will default to yy = 00h 00h 00h 00h.

Config Mode - Command 47h "G" - Get whatever values

```
Send 01h 47h 00h 00h 00h 00h 00h 00h 00h
Reply Hiz F3h 5Ah 00h 00h 02h 00h 01h 00h
```

Purpose unknown, but seems to be used by some games to identify the controller as a DualShock Analog Controller since Jogcon returns different values. Modifications to the sequence being sent to the controller seem to cause the controller to respond with 00h 00h 00h 00h 00h.

Config Mode - Command 4Ch "L" - Get Variable Response B

```
Send 01h 4Ch 00h xx 00h 00h 00h 00h 00h
Reply Hiz F3h 5Ah 00h 00h 00h yy 00h 00h
```

Purpose unknown, but as with 46h and 47h, may be used by some games to identify the controller as a DualShock Analog Controller. Response varies: If xx=00h then yy=04h, else if xx=01h then yy=07h. All other xx values and sequences seem to have a 00h 00h 00h 00h 00h response.

Config Mode - Command 4Dh "M" - Set Rumble Configuration (and select response length)

```
Send 01h 4Dh 00h aa bb cc dd ee ff
Reply Hiz F3h 5Ah <-----old values----->
```

Nocash's original notes state that this command unlocks the rumble motors -- however, based on hardware testing, the DualShock rumble mode is unlocked as soon as a controller enters configuration mode. This command just sets the DualShock rumble configuration.

The rumble configuration works as follows: The last 00h byte in the rumble configuration sequence determines which byte in the 42h pad read command will be used for setting the small motor strength. The last 01h byte in the sequence similarly determines which byte will be used for the large motor strength. If either 00h or 01h or both are not present in the configuration sequence, the corresponding motor will not be able to receive any rumble, as expected.

Most games will use 00h 01h FFh FFh FFh FFh, however a number of games will use uncommon sequences. For example, Final Fantasy VIII uses FFh 00h 01h FFh FFh FFh while Armored Core Project Phantasma uses 00h 00h 01h 01h FFh FFh.

Untested Nocash notes: The extra halfword(s) increase the transfer length by 1 or 2 halfwords (and accordingly, the digital mode ID changes from 41h to 42h or 43h), the controller returns 00h bytes for the extra halfwords, in analog mode, the ID and transfer length remains unchanged (since it always has extra halfwords for analog responses). So, the extra halfwords seem to be output to the controller (rather than response data), possibly intended to control additional rumble motors or to output data to other hardware features.

Config Mode - Command 48h "H" - Unknown (response HiZ F3h 5Ah 4x00h 01h 00h)

```
Send 01h 48h 00h 00h 00h 00h 00h 00h 00h
Reply HiZ F3h 5Ah 00h 00h 00h 00h 01h 00h
```

This command does return a bunch of 00h bytes, and one 01h byte. Purpose unknown. The command does not seem to be used by any games.

Config Mode - Command 40h "@" - Unknown (response HiZ F3h 5Ah 6x00h)

Config Mode - Command 41h "A" - Unknown (response HiZ F3h 5Ah 6x00h)

Config Mode - Command 49h "I" - Unknown (response HiZ F3h 5Ah 6x00h)

Config Mode - Command 4Ah "J" - Unknown (response HiZ F3h 5Ah 6x00h)

Config Mode - Command 4Bh "K" - Unknown (response HiZ F3h 5Ah 6x00h)

Config Mode - Command 4Eh "N" - Unknown (response HiZ F3h 5Ah 6x00h)

Config Mode - Command 4Fh "O" - Unknown (response HiZ F3h 5Ah 6x00h)

```
Send 01h 4xh 00h 00h 00h 00h 00h 00h 00h
Reply HiZ F3h 5Ah 00h 00h 00h 00h 00h 00h
```

These commands do return a bunch of 00h bytes. Purpose unknown. These commands do not seem to be used by any games.

Note

Rumble is a potentially annoying feature, so games that do support rumble should also include an option to disable it.

12.14 Controllers - Dance Mats

PSX Dance Mats are essentially normal joypads with uncommonly arranged buttons, the huge mats are meant to be put on the floor, so the user could step on them.

Dance Mat vs Joypad Compatibility

There are some differences to normal joypads: First of, the L1/L2/R1/R2 shoulder buttons are missing in most variants. And, the mats are allowing to push Left+Right and Up+Down at once, combinations that aren't mechanically possible on normal joypads (some dancing games do actually require those combinations, whilst some joypad games may get confused on them).

Dance Mat Unknown Things

Unknown if the mat was sold in japan, and if so, with which SLPH/SCPH number.
 Unknown if the mat's middle field is also having a button assigned.
 Unknown if the mat is having a special controller ID, or if there are other ways to detect mats (the mats are said to be compatible with skateboard games, so the mats are probably identifying themselves as normal digital joypad; assuming that those skateboard games haven't been specifically designed for mats).

Dance Mat Games

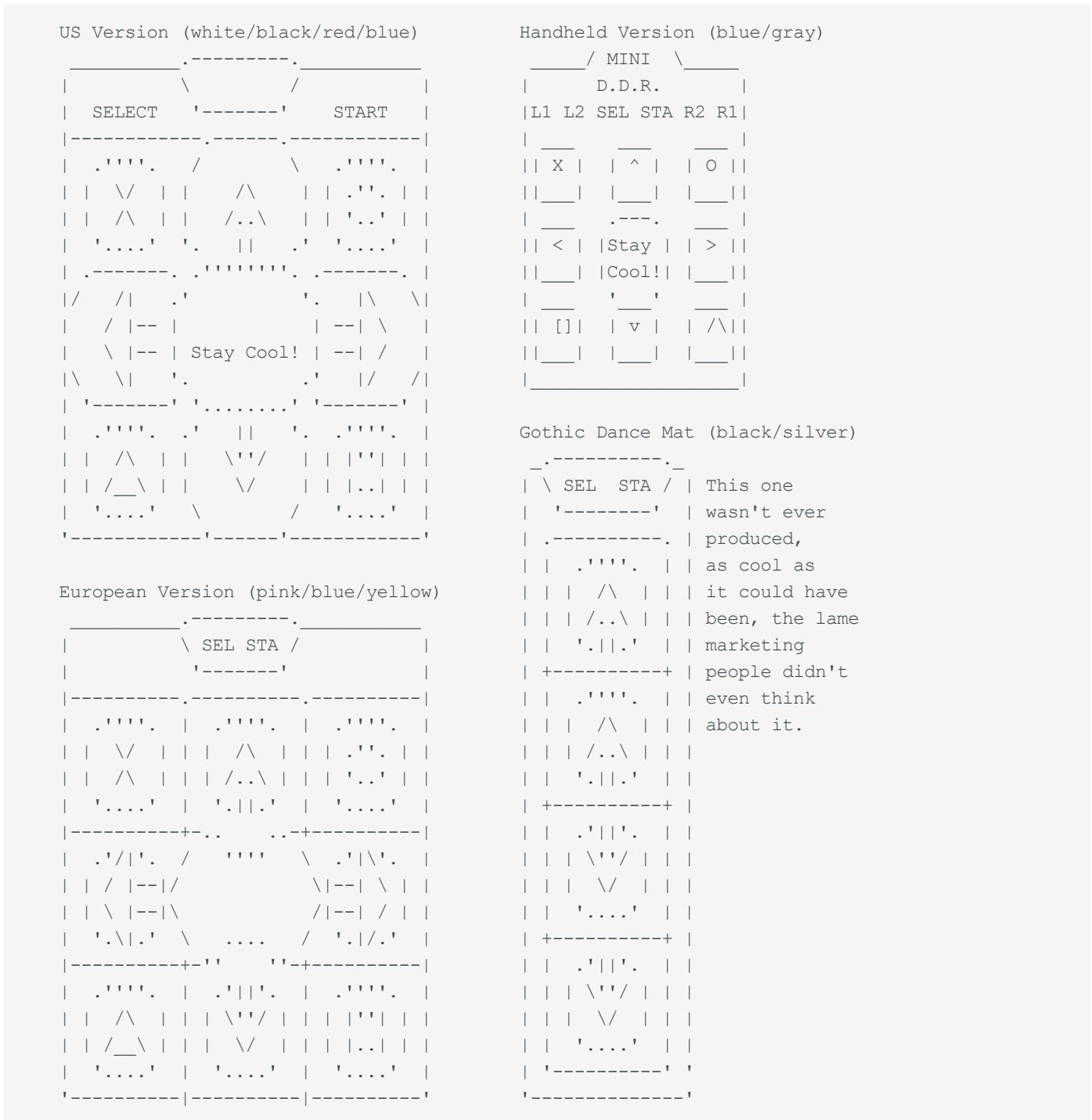
D.D.R. Dance Dance Revolution 2nd Remix
 (and maybe whatever further games)

The mats can be reportedly also used with whatever skateboard games.

Dance Mat Variants

There is the US version (DDR Dance Pad, SLUH-00071), and a slightly different European version (Official Dance Mat, SLEH-00023: shiny latex style with perverted colors, and Start>Select arranged differently). The japanese version (RU017) resembles the US version, but without Triangle/Square symbols drawn in lower left/right edges.

And there is a handheld version (with additional L1/L2/R2/R1 buttons; maybe unlicensed; produced as MINI DDR, and also as Venom Mini Dance Pad).



Stay Cool?

Despite of the "Stay Cool!" slogan, the mat wasn't very cool - not at all! It offered only two steps back-and-forth, and also allowed to do extremely uncool side-steps. Not to mention that it would melt when dropping a burning cigarette on it. Stay Away!

12.15 Controllers - Pop'n Controllers

Controllers used for Konami's Pop'n Music series. At least a few different versions of the controller (Pop'n Controller, Pop'n Controller 2, larger arcade-size version, possibly others and in different color variations) have been released for the PS1 and PS2. Unknown if the controllers released in the PS2 era have any additional commands not present in the original Pop'n Controller, but they are supposedly fully compatible with PS1 Pop'n Music games.

Pop'n Controllers report as digital controllers (ID byte 41h), but the left, right, and down d-pad controls are not connected to any physical buttons and are always reported as pressed (in the first transferred button byte, bits 5-7 are always 0). Pop'n Music games check these bits to determine if a Pop'n Controller is connected and will change the in-game controls accordingly if so.

12.16 Controllers - Fishing Controllers

The fishing rods are (next to lightguns) some of the more openly martial playstation controllers - using the credo that "as long as you aren't using dynamite: it's okay to kill them cause they don't have any feelings."

PSX Fishing Controller Games

```
Action Bass (Syscom Entertainment) (1999) (SLPH-00100)
Bass Landing (ASCII/agetec) (1999) (SLPH-00100, SLUH-00063)
Bass Rise, Fishing Freaks (Bandai) (1999) (BANC-0001)
Bass Rise Plus, Fishing Freaks (Bandai) (2000) (BANC-0001, SLPH-00100)
Breath of Fire IV (Capcom) (SLUH-00063)
Championship Bass (EA Sports) (2000) (SLUH-00063)
Fish On! Bass (Pony Canyon) (1999) (BANC-0001, SLPH-00100)
Fisherman's Bait 2/Exiting Bass2 - Big Ol'Bass (Konami) (SLPH-00100, SLUH-00063)
Fishing Club: (series with 3 titles) (have "headset-logo" on back?)
Lake Masters II (1999) (Dazz/Nexus) (SLPH-00100)
Lake Masters Pro (1999) (Dazz/Nexus) (BANC-0001, SLPH-00100)
Let's Go Bassfishing!: Bass Tsuri ni Ikou! (Banpresto) (1999) (SLPH-00100)
Matsukata Hiroki no World Fishing (BPS The Choice) (1999) (SLPH-00100)
Murakoshi Seikai-Bakuchou Nihon Rettou (Victor) (SLPH-00100)
Murakoshi Masami-Bakuchou Nippon Rettou:TsuriConEdition (1999) (SLPH-00100)
Pakuchikou Seabass Fishing (JP, 03/25/99) (Victor) (SLPH-00100)
Perfect Fishing: Bass Fishing (2000) (Seta) (yellow/green logo)
Perfect Fishing: Rock Fishing (2000) (Seta) (yellow/green logo)
Oyaji no Jikan: Nechan, Tsuri Iku De! (2000) (Visit) (BANC-0001, SLPH-00100)
Reel Fishing II / Fish Eyes II (2000) (Natsume/Victor) (SLPH-00100, SLUH-00063)
Simple 1500 Series Vol. 29: The Tsuri (2000) (yellow/green logo)
```

Suizokukan Project: Fish Hunter e no Michi (1999) (Teichiku) (SLPH-00100)
 Super Bass Fishing (1999) (King) (BANC-0001, SLPH-00100, yellow/green logo)
 Super Black Bass X2 (2000) (Starfish) (SLPH-00100)
 Tsuwadou Keiryuu Mizuumihen (Best Edition) (2000) (ASCII PS1+PS2 controllers?)
 Tsuwadou Seabass Fishing (PlayStation the Best) (1999) (Oz Club) (SLPH-00100)
 Uki Uki Tsuri Tengoku Nagami/Uokami Densetsu Oe (2000) (Teichiku) (SLPH-00100)
 Umi no Nushi Tsuri-Takarajima ni Mukatte (1999) (Victor) (BANC-0001, SLPH-00100)
 Winning Lure (Hori) (2000) (for Hori HPS-97 controller) AKA HPS-98 ?

For more see: <http://www.gamefaqs.com/ps/list-109> (sports->nature->fishing)

Logos on CD Covers

US Fishing games should have a "SLUH-00063" logo. European Fishing games don't have any fishing logos; apparently fishing controllers haven't been officially released/supported in Europe.

Japanese Fishing games can have a bunch of logos: Usually BANC-0001 or SLPH-00100 (or both).

Moreover, some Japanese games have a yellow/green fishing logo with Japanese text (found on Perfect Fishing: Bass Fishing, Perfect Fishing: Rock Fishing, Simple 1500 Series Vol. 29: The Tsuri, Super Bass Fishing) (unknown if that logo refer to other special hardware, or if it means the "normal" BANC-0001 or SLPH-00100 controllers).

And Moreover, some Japanese games have some sort of "headset" logos with Japanese text, these seem to have same meaning as SLPH-00100; as indicated by photos on CD cover of Tsuwadou Keiryuu Mizuumihen (Best Edition) (2000); that CD cover also has a "headset 2" logo, which seems to mean a newer PS2 variant of the SLPH-00100.

PSX Fishing Controllers

ASCII SLPH-00100 (silver)
 ASCII PS2-version? (silver) (similar to SLPH-00100, with new mode switch?)
 agetec SLUS-00063 (silver) (US version of ASCII's SLPH-00100 controller)
 Bandai BANC-0001 (dark gray/blue) (has less buttons than ASCII/agetec)
 Interact Fission (light gray/blue) (similar to ASCII/agetec, 2 extra buttons?)
 Naki (transparent blue) (looks like a clone of the ASCII/agetec controllers)
 Hori HPS-97/HPS-98 (black/gray) (a fishing rod attached to a plastic fish)

Of these, the ASCII/agetec controllers seem to be most popular (and most commonly supported). The Bandai controller is also supported by a couple of games (though the Bandai controller itself seems to be quite rare). The Interact/Naki controllers are probably just clones of the ASCII/agetec ones. The Hori controller is quite rare (and with its string and plastic fish, it's apparently working completely different than the other fishing controllers).

Tech Info (all unknown)

Unknown how to detect fishing controllers.

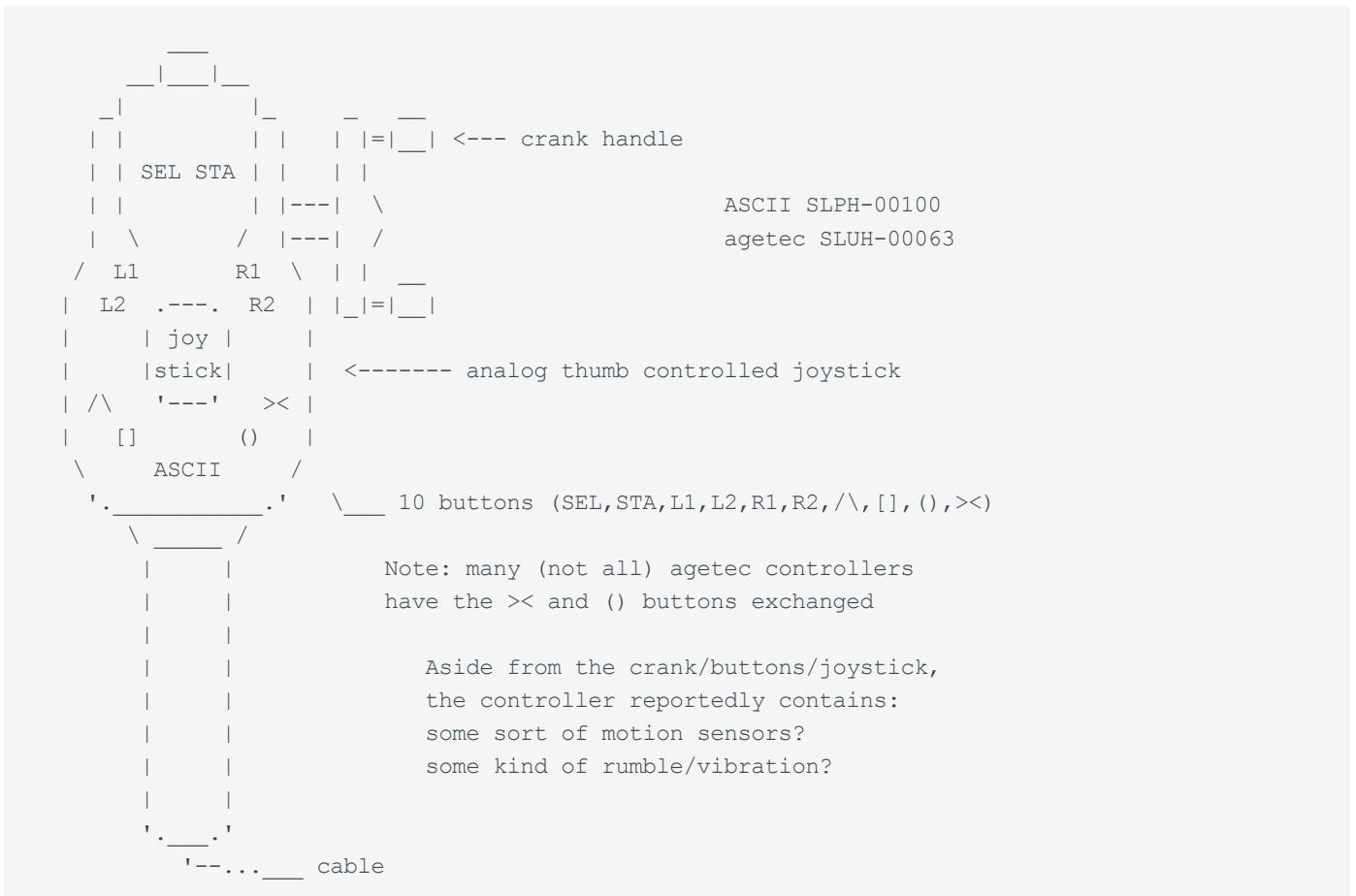
Unknown how to read buttons, joystick, crank, motion sensors.

Unknown how to control rumble/vibration.

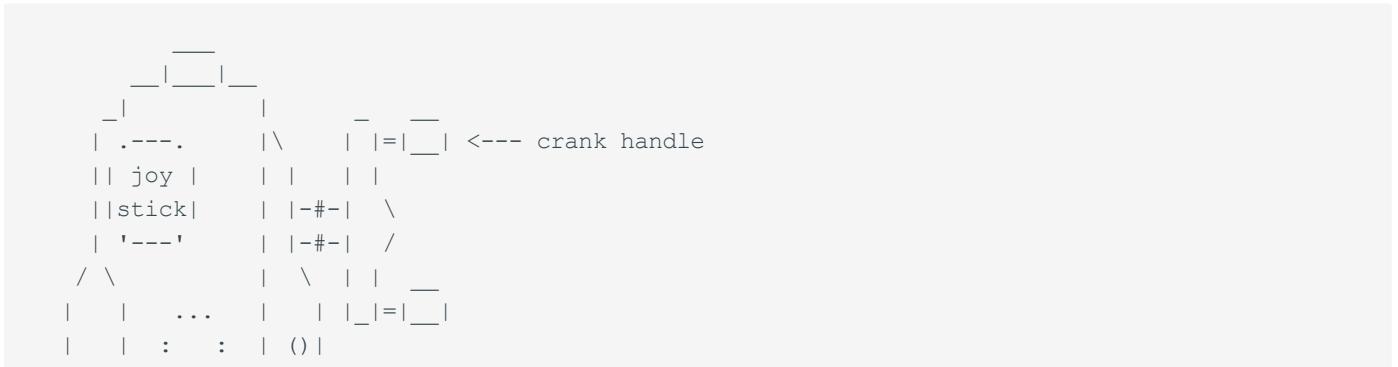
Unknown if/how Bandai differs from ASCII/agetec (aside from less buttons).

Unknown how the Hori thing works.

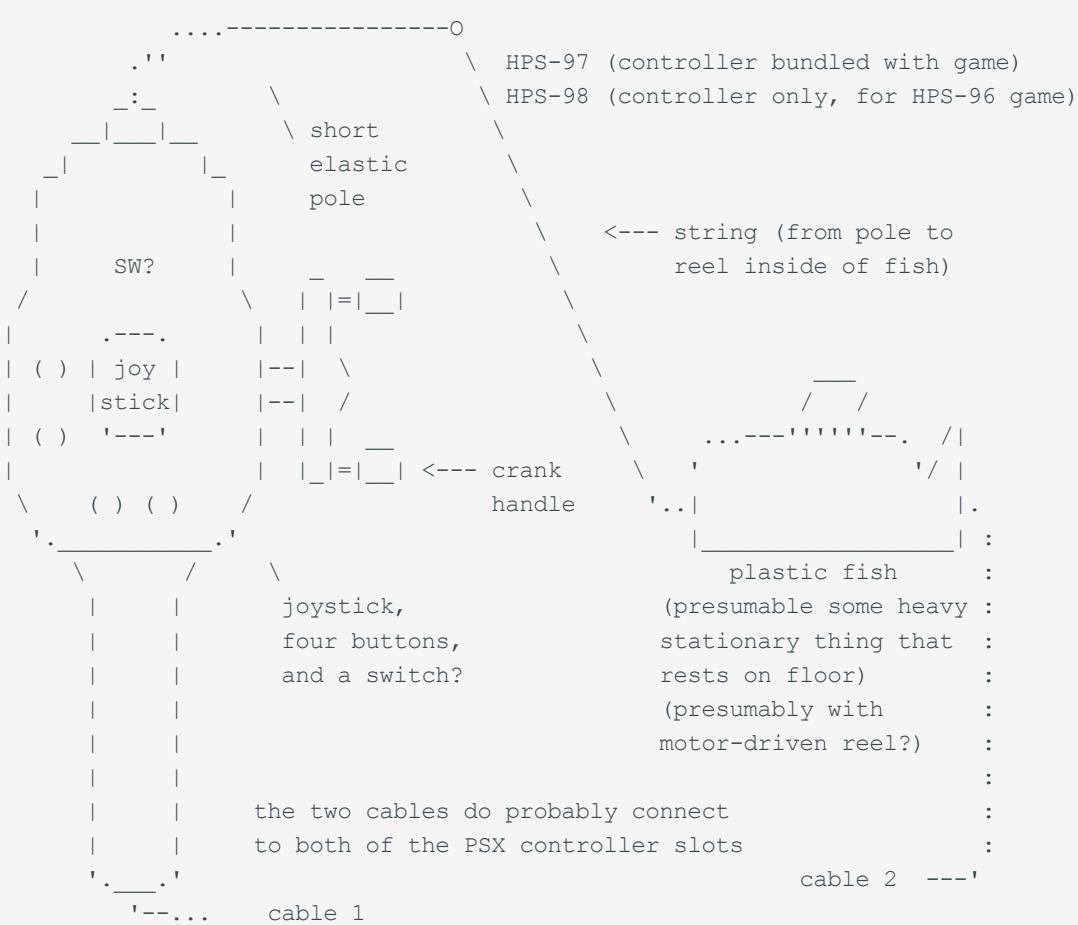
ASCII SLPH-00100 / agetec SLUH-00063 (silver)



Bandai BANC-0001 (dark gray/blue)



Hori HPS-97 / HPS-98 (black/gray)



12.17 Controllers - I-Mode Adaptor (Mobile Internet)

The I-Mode Adaptor cable (SCPH-10180) allows to connect an I-mode compatible mobile phone to the playstation's controller port; granting a mobile internet connection to japanese games.

PSX Games for I-Mode Adaptor (Japan only)

```
Doko Demo Issyo (PlayStation the Best release only) (Sony) 2000
Doko Demo Issyo Deluxe Pack (Bomber eXpress/Sony) 2001
Hamster Club-I (SLPS-03266) (Jorudan) 2002
iMode mo Issyo: Dokodemo Issho Tsuika Disc (Bomber/Sony) 2001
Keitai Eddy (iPC) 2000 (but, phone connects to SIO port on REAR side of PSX?)
Komocchi (Victor) 2001
Mobile Tomodachi (Hamster) 2002
Motto Trump Shiyouyo! i-Mode de Grand Prix (Pure Sound) 2002
One Piece Mansion (Capcom) 2001 (japanese version only)
```

The supported games should have a I-Mode adaptor logo on the CD cover (the logo depicts two plugs: the PSX controller plug, and the smaller I-Mode plug).

Note: "Dragon Quest Monsters 1 & 2" was announced/rumoured to support I-mode (however, its CD cover doesn't show any I-Mode adapter logo).

Tech Details (all unknown)

Unknown how to detect the thing, and how to do the actual data transfers.

The cable does contain a 64pin chip, an oscillator, and some smaller components (inside of the PSX controller port connector).

Hardware Variant

Keitai Eddy seems to have the phone connect to the SIO port (on rear side of the PSX, at least it's depicted like so on the CD cover). This is apparently something different than the SCPH-10180 controller-port cable. Unknown what it is exactly - probably some mobile internet connection too, maybe also using I-mode, or maybe some other protocol.

12.18 Controllers - Additional Inputs

Reset Button

PSX only (not PSone). Reboots the PSX via /RESET signal. Probably including for forcefully getting through the WHOLE BIOS Intro, making it rather useless/annoying? No idea if it clears ALL memory during reboot?

CDROM Shell Open

Status bit of the CDROM controller. Can be used to sense if the shell is opened (and also memorizes if the shell was opened since last check; allowing to sense possible disk changes).

PocketStation

Memory Card with built-in LCD screen and Buttons (which can be used as miniature handheld console). However, when it is connected to the PSX, the buttons are vanishing in the cartridge slot, so the buttons cannot be used as additional inputs for PSX games.

Serial Port PSX only (not PSone)

With an external adaptor (voltage conversion), the serial port can be used (among others) to connect a RS232 Serial Mouse. Although, most or all commercial games with mouse input are probably (?) supporting only Sony's Mouse (on the controller port) (rather than standard RS232 devices on the serial port).

TTY Debug Terminal

If present, the external DUART can be used for external keyboard input, at the BIOS side, this is supported as "std_in".

12.19 Controllers - Misc

Standard Controllers

```
SCPH-1010 digital joypad (with short cable)
SCPH-1080 digital joypad (with longer cable)
SCPH-1030 mouse (with short cable)
SCPH-1090 mouse (with longer cable)
```

```

SCPH-1092 mouse (european?)
SCPH-1110 analog joystick
SCPH-1150 analog joypad (with one vibration motor, with red/green led)
SCPH-1180 analog joypad (without vibration motors, with red/green led)
SCPH-1200 analog joypad (with two vibration motors) (dualshock)
SCPH-110 analog joypad (with two vibration motors) (dualshock for psone)
SCPH-10010 dualshock2 (analog buttons, except L3/R3/Start>Select) (for ps2)
SCPH-1070 multitap

```

Special Controllers

SCPH-4010 VPick (guitar-pick controller) (for Quest for Fame, Stolen Song)

SLPH-0001 (nejicon)

BANDAI "BANC-0002" - 4 Buttons (Triangle, Circle, Cross, Square) (nothing more)

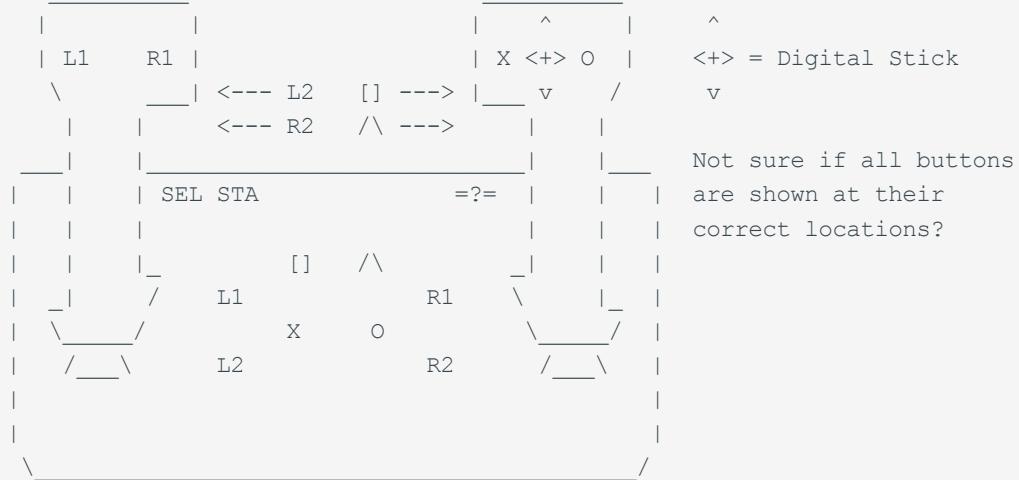
SCPH-2000 Keyboard/Mouse adapter

A PS/2 to PSX controller port adaptor, for educational Lightspan titles.

There are two variants of the adaptor:

Adaptor with short cable to PSX-controller port (and prototype marking)
 Adaptor without cable, directly plugged into controller port (final version?)

Joystick



The thumb buttons on the left act as L1 and R1,
 the trigger is L2, the pinky button is R2
 The thumb buttons on the right act as X and O,
 the trigger is Square and the pinky button is Triangle.
 I find this odd as the triggers should've been L1 and R1,

the pinkies L2 and R2.
 The buttons are redundantly placed on the base as large buttons like what
 you'd see on a fight/arcade stick. Also with Start and Select.
 There is also a physical analog mode switch,
 not a button like on dual shock.

12.20 Memory Card Read/Write Commands

Reading Data from Memory Card

```

Send Reply Comment
81h N/A   Memory Card Access (unlike 01h=Controller access), dummy response
52h FLAG  Send Read Command (ASCII "R"), Receive FLAG Byte
00h 5Ah   Receive Memory Card ID1
00h 5Dh   Receive Memory Card ID2
MSB (00h) Send Address MSB ;\sector number (0..3FFh)
LSB (pre) Send Address LSB ;/
00h 5Ch   Receive Command Acknowledge 1 ;<-- late /ACK after this byte-pair
00h 5Dh   Receive Command Acknowledge 2
00h MSB   Receive Confirmed Address MSB
00h LSB   Receive Confirmed Address LSB
00h ...   Receive Data Sector (128 bytes)
00h CHK   Receive Checksum (MSB xor LSB xor Data bytes)
00h 47h   Receive Memory End Byte (should be always 47h="G"=Good for Read)

```

Non-sony cards additionally send eight 5Ch bytes after the end flag.

When sending an invalid sector number, original Sony memory cards respond with FFFFh as Confirmed Address (and do then abort the transfer without sending any data, checksum, or end flag), third-party memory cards typically respond with the sector number ANDed with 3FFh (and transfer the data for that adjusted sector number).

Writing Data to Memory Card

```

Send Reply Comment
81h N/A   Memory Card Access (unlike 01h=Controller access), dummy response
57h FLAG  Send Write Command (ASCII "W"), Receive FLAG Byte
00h 5Ah   Receive Memory Card ID1
00h 5Dh   Receive Memory Card ID2
MSB (00h) Send Address MSB ;\sector number (0..3FFh)
LSB (pre) Send Address LSB ;/
... (pre) Send Data Sector (128 bytes)
CHK (pre) Send Checksum (MSB xor LSB xor Data bytes)
00h 5Ch   Receive Command Acknowledge 1
00h 5Dh   Receive Command Acknowledge 2
00h 4xh   Receive Memory End Byte (47h=Good, 4Eh=BadChecksum, FFh=BadSector)

```

Get Memory Card ID Command

```

Send Reply Comment
81h N/A   Memory Card Access (unlike 01h=Controller access), dummy response
53h FLAG  Send Get ID Command (ASCII "S"), Receive FLAG Byte
00h 5Ah   Receive Memory Card ID1
00h 5Dh   Receive Memory Card ID2
00h 5Ch   Receive Command Acknowledge 1
00h 5Dh   Receive Command Acknowledge 2
00h 04h   Receive 04h
00h 00h   Receive 00h
00h 00h   Receive 00h
00h 80h   Receive 80h

```

This command is supported only by original Sony memory cards. Not sure if all sony cards are responding with the same values, and what meaning they have, might be number of sectors (0400h) and sector size (0080h) or whatever.

Invalid Commands

```

Send Reply Comment
81h N/A   Memory Card Access (unlike 01h=Controller access), dummy response
xxh FLAG  Send Invalid Command (anything else than "R", "W", or "S")

```

Transfer aborts immediately after the faulty command byte, or, occasionally after one more byte (with response FFh to that extra byte).

FLAG Byte

The initial value of the FLAG byte on power-up (and when re-inserting the memory card) is 08h.

Bit3=1 is indicating that the directory wasn't read yet (allowing to sense memory card changes). For some strange reason, bit3 is NOT reset when reading from the card, but rather when writing to it. To reset the flag, games are usually issuing a dummy write to sector number 003Fh, more or less unnecessarily stressing the lifetime of that sector. Bit2=1 seems to be intended to indicate write errors, however, the write command seems to be always finishing without setting that bit, instead, the error flag may get set on the NEXT command.

Note: Some (not all) non-sony cards also have Bit5 of the FLAG byte set.

Timings

IRQ7 is usually triggered circa 1500 cycles after sending a byte (counted from the begin of the first bit), except, the last byte doesn't trigger IRQ7, and, after the 7th byte of the Read command, an additional delay of circa 31000 cycles occurs before IRQ7 gets triggered (that strange extra delay occurs only on original Sony cards, not on cards from other manufacturers).

There seems to be no extra delays in the Write command, as it seems, the data is written on the fly, and one doesn't need to do any write-busy handling... although, theoretically, the write shouldn't start until verifying the checksum... so it can't be done on the fly at all...?

Notes

Responses in brackets are don't care, (00h) means usually zero, (pre) means usually equal to the previous command byte (eg. the response to LSB is MSB).

Memory cards are reportedly "Flash RAM" which sounds like bullshit, might be battery backed SRAM, or FRAM, or slower EEPROM or FLASH ROM, or vary from card to card...?

12.21 Memory Card Data Format

Data Size

```
Total Memory 128KB = 131072 bytes = 20000h bytes
1 Block 8KB = 8192 bytes = 2000h bytes
1 Frame 128 bytes = 80h bytes
```

The memory is split into 16 blocks (of 8 Kbytes each), and each block is split into 64 sectors (of 128 bytes each). The first block is used as Directory, the remaining 15 blocks are containing Files, each file can occupy one or more blocks.

Header Frame (Block 0, Frame 0)

```
00h-01h Memory Card ID (ASCII "MC")
02h-7Eh Unused (zero)
7Fh      Checksum (all above bytes XORed with each other) (usually 0Eh)
```

Directory Frames (Block 0, Frame 1..15)

```

00h-03h Block Allocation State
    00000051h - In use ;first-or-only block of a file
    00000052h - In use ;middle block of a file (if 3 or more blocks)
    00000053h - In use ;last block of a file (if 2 or more blocks)
    000000A0h - Free ;freshly formatted
    000000A1h - Free ;deleted (first-or-only block of file)
    000000A2h - Free ;deleted (middle block of file)
    000000A3h - Free ;deleted (last block of file)

04h-07h Filesize in bytes (2000h..1E000h; in multiples of 8Kbytes)
08h-09h Pointer to the NEXT block number (minus 1) used by the file
    (ie. 0..14 for Block Number 1..15) (or FFFFh if last-or-only block)
0Ah-1Eh Filename in ASCII, terminated by 00h (max 20 chars, plus ending 00h)
1Fh     Zero (unused)
20h-7Eh Garbage (usually 00h-filled)
7Fh     Checksum (all above bytes XORed with each other)

```

Filesize [04h..07h] and Filename [0Ah..1Eh] are stored only in the first directory entry of a file (ie. with State=51h or A1h), other directory entries have that bytes zero-filled.

Filename Notes

The first some letters of the filename should indicate the game to which the file belongs, in case of commercial games this is conventionally done like so: Two character region code:

"BI"=Japan, "BE"=Europe, "BA"=America

followed by 10 character game code,

in "AAAA-NNNNN" form ;for Pocketstation executables replace "-" by "P"

where the "AAAA" part does imply the region too; (SLPS/SCPS=Japan, SLUS/SCUS=America, SLES/SCES=Europe) (SCxS=Made by Sony, SLxS=Licensed by Sony), followed by up to 8 characters,

"abcdefghijklm"

(which may identify the file if the game uses multiple files; this part often contains a random string which seems to be allowed to contain any chars in range of 20h..7Fh, of course it shouldn't contain "?" and "*" wildcards).

Broken Sector List (Block 0, Frame 16..35)

```
00h-03h Broken Sector Number (Block*64+Frame) (FFFFFFFh=None)
04h-7Eh Garbage (usually 00h-filled) (some cards have [08h..09h]=FFFFh)
7Fh      Checksum (all above bytes XORed with each other)
```

If Block0/Frame(16+N) indicates that a given sector is broken, then the data for that sector is stored in Block0/Frame(36+N).

Broken Sector Replacement Data (Block 0, Frame 36..55)

```
00h-7Fh Data (usually FFh-filled, if there's no broken sector)
```

Unused Frames (Block 0, Frame 56..62)

```
00h-7Fh Unused (usually FFh-filled)
```

Write Test Frame (Block 0, Frame 63)

Reportedly "write test". Usually same as Block 0 ("MC", 253 zero-bytes, plus checksum 0Eh).

Title Frame (Block 1..15, Frame 0) (in first block of file only)

```
00h-01h ID (ASCII "SC")
02h Icon Display Flag
    11h...Icon has 1 frame (static) (same image shown forever)
    12h...Icon has 2 frames (animated) (changes every 16 PAL frames)
    13h...Icon has 3 frames (animated) (changes every 11 PAL frames)
    Values other than 11h..13h seem to be treated as corrupted file
    (causing the file not to be listed in the bootmenu)
03h Block Number (1-15) "icon block count" Uh?
    (usually 01h or 02h... might be block number within
     files that occupy 2 or more blocks)
    (actually, that kind of files seem to HAVE title frames
     in ALL of their blocks; not only in their FIRST block)
    (at least SOME seem to have such duplicated title frame,
     but not all?)
04h-43h Title in Shift-JIS format (64 bytes = max 32 characters)
44h-4Fh Reserved (00h)
50h-5Fh Reserved (00h) ;-- this region is used for the Pocketstation
60h-7Fh Icon 16 Color Palette Data (each entry is 16bit CLUT)
```

For more info on entries [50h..5Fh], see
[Pocketstation File Header/Icons](#)

Icon Frame(s) (Block 1..15, Frame 1..3) (in first block of file only)

```
00h-7Fh  Icon Bitmap (16x16 pixels, 4bit color depth)
```

Note: The icons are shown in the BIOS bootmenu (which appears when starting the PlayStation without a CDROM inserted). The icons are drawn via GP0(2Ch) command, ie. as Textured four-point polygon, opaque, with texture-blending, whereas the 24bit blending color is 808080h (so it's quite the same as raw texture without blending). As semi-transparency is disabled, Palette/CLUT values can be 0000h=FullyTransparent, or 8000h=SolidBlack (the icons are usually shown on a black background, so it doesn't make much of a difference).

Data Frame(s) (Block 1..15, Frame N..63; N=excluding any Title/Icon Frames)

```
00h-7Fh  Data
```

Note: Files that occupy more than one block are having only ONE Title area, and only one Icon area (in the first sector(s) of their first block), the additional blocks are using sectors 0..63 for plain data.

Shift-JIS Character Set (16bit) (used in Title Frames)

Can contain japanese or english text, english characters are encoded like so:

```
81h, 40h      --> SPC
81h, 43h..97h --> punctuation marks
82h, 4Fh..58h --> "0..9"
82h, 60h..79h --> "A..Z"
82h, 81h..9Ah --> "a..z"
```

Titles shorter than 32 characters are padded with 00h-bytes.

Note: The titles are \<usually> in 16bit format (even if they consist of raw english text), however, the BIOS memory card manager does also accept 8bit characters 20h..7Fh (so, in the 8bit form, the title could be theoretically up to 64 characters long, but, nevertheless, the BIOS displays only max 32 chars).

For displaying Titles, the BIOS includes a complete Shift-JIS character set,

[BIOS Character Sets](#)

Shift-JIS is focused on asian languages, and does NOT include european letters (eg. such with accent marks). Although the non-japanese PSX BIOSes DO include a european

character set, the BIOS memory card manager DOESN'T seem to translate any title character codes to that character set region.

12.22 Memory Card Images

There are a lot of different ways to get a save from a memory card onto your PC's hard disk, and these ways sometimes involve sticking some additional information into a header at the beginning of the file.

Raw Memory Card Images (without header) (ie. usually 128K in size)

```
SmartLink .PSM,  
WinPSM .PS,  
DataDeck .DDF,  
FPSX .MCR,  
ePSXe .MCD...
```

don't stick any header on the data at all, so you can just read it in and treat it like a raw memory card.

All of these headers contain a signature at the top of the file. The three most common formats and their signatures are:

```
Connectix Virtual Game Station format (.MEM) : "VgsM", 64 bytes  
PlayStation Magazine format (.PSX) : "PSV", 256 bytes
```

some programs will OMIT any blank or unallocated blocks from the end of the memory card -- if only three save blocks on the card are in use, for example, saving the other twelve is pointless.

Xploder and Action Replay Files (54 byte header)

```
00h..14h Filename in ASCII, terminated by 00h (max 20 chars, plus ending 00h)  
15h..35h Title in ASCII, terminated by 00h (max 32 chars, plus ending 00h)  
36h..    File Block(s) (starting with the Title sector)
```

This format contains only a single file (not a whole memory card). The filename should be the same as used in the Memory Card Directory. The title is more or less don't care; it may be the SHIFT-JIS title from the Title Sector converted to ASCII.

Other

"There exists another single-save format with a 128 byte header containing a raw index frame for the initial block, which must be updated to match the destination card, and the raw save data. I have seen this format once, but I don't remember what it was called or where it came from. You may want to account for this possibility in your format detection logic."

.GME Files (usually 20F40h bytes)

InterAct GME format, produced by the DexDrive.

```

000h 12 ASCII String "123-456-STD",00h
00Ch 4 Usually zerofilled (or meaningless garbage in some files)
010h 5 Always 00h,00h,01h,00h,01h
015h 16 Copy of Sector 0..15 byte[00h] ;"M", followed by allocation states
025h 16 Copy of Sector 0..15 byte[08h] ;00h, followed by next block values
035h 11 Usually zerofilled (or meaningless garbage in some files)
040h F00h Fifteen Description Strings (each one 100h bytes, padded with 00h)
F40h 128K Memory Card Image (128K) (unused sectors 00h or FFh filled)

```

This is a very strange file format, no idea where it comes from. It contains a F40h bytes header (mainly zero-filled), followed by the whole 128K of FLASH memory (mainly zero-filled, too, since it usually contains only a small single executable file).

12.23 Memory Card Notes

Sony PSX Memory Cards

Sony has manufactured only 128KByte memory cards for PSX, no bigger/smaller ones.

Sony PS2 Memory Cards

A special case would be PS2 cards, these are bigger, but PS2 cards won't fit into PSX cards slots (unless when cutting an extra notch in the card edge connector), a PSX game played on a PS2 console could theoretically access PS2 cards (if it supports the different directory structure on that cards).

Third Party Cards with bigger capacity

Some third party cards contain larger memory chips, however, the PSX games/kernel are supporting only regular 128Kbyte cards, so the extra memory can be used only by dividing it into several 128Kbyte memory card images.

Selecting a different memory card image can be done by a switch or button on the card, or via joypad key combinations (joypad/card are sharing the same signals, so the card could watch the traffic on joypad bus, provided that the MIPS CPU is actually reading the joypad).

Third Party Cards with bigger capacity and Data Compression

Some cards are additionally using data compression to increase the card capacity, but that technique is having rather bad reputation and could result in data loss. For example, if a game has allocated four blocks on the memory card, then it'll expect to be able to overwrite that four blocks at any time (without needing to handle "memory card full" errors), however, if the card is full, and if the newly written data has worse compression ratio, then the card will be unable to store the new game position (and may have already overwritten parts of the old game position). As a workaround, such cards may use a LED to warn users when running low on memory (ideally, there should be always at least 128Kbytes of free memory).

Joytech Smart Card Adaptor

The smart card adaptor plugs into memory card slot, and allows to use special credit card-shaped memory cards. There don't seem to be any special features, ie. the hardware setup does just behave like normal PSX memory cards.

Datel VMEM (virtual memory card storage on expansion port)

The Datel/Interact VMEM exists as standalone VMEM cartridge, and some Datel Cheat Devices do also include the VMEM feature. Either way, the VMEM connects to expansion port, and contain some large FLASH memory, for storing multiple memory cards on it. Unknown, how that memory is accessed (maybe it must be copied to a regular memory card, or maybe they've somehow hooked the Kernel (or even the hardware signals?) so that games could directly access the VMEM?

Passwords (instead of Memory Cards)

Some older games are using passwords instead of memory cards to allow the user to continue at certain game positions. That's nice for people without memory card, but unfortunately many of those games are restricted to it - it'd be more user friendly to support both passwords, and, optionally, memory cards.

Yaroze Access Cards (DTL-H3020)

The Yaroze Access Card connects to memory card slot, the card resembles regular memory cards, but it doesn't contain any storage memory. Instead, it does merely support a very basic Access Card detection command:

```
Send Reply Comment  
21h N/A? Probably replies HighZ (ie. probably reads FFh)?  
53h 0xh? Replies unknown 8bit value (upper 4bit are known to be zero)?
```

Ie. when receiving 21h as first byte, it replies by an ACK, and does then output 0xh as response to the next byte.

Without the Access Card, the Yaroze Bootdisc will refuse to work (the disc contains software for transferring data to/from PC, for developing homebrew games).

Pocketstation (Memory Card with built-in LCD screen and buttons)

[Pocketstation](#)

13. Pocketstation

Pocketstation

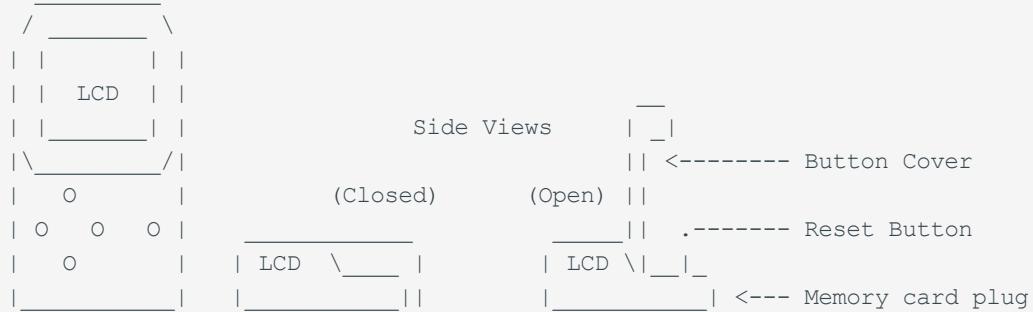
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13.1 Pocketstation Overview

Sony's Pocketstation (SCPH-4000) (1998)

The Pocketstation is a memory card with built-in LCD screen and buttons; aside from using it as memory storage device, it can be also used as miniature handheld console.

CPU	ARM7TDMI (32bit RISC Processor) (variable clock, max 7.995MHz)
Memory	2Kbytes SRAM (battery backed), 16Kbytes BIOS ROM, 128Kbytes FLASH
Display	32x32 pixel LCD (black and white) (without any grayscales)
Sound	Mini Speaker "(12bit PCM) x 1 unit" / "8bit PCM with 12bit range"
Controls	5 input buttons, plus 1 reset button
Infrared	Bi-directional (IrDA based)
Connector	Playstation memory card interface
RTC	Battery backed Real-Time Clock with time/date function
Supply	CR2032 Battery (3VDC) (used in handheld mode, and for SRAM/RTC)



The RTC Problem

The main problem of the Pocketstation seems to be that it tends to reset the RTC to 1st January 1999 with time 00:00:00 whenever possible.

The BIOS contains so many RTC-reset functions, RTC-reset buttons, RTC-reset flags, RTC-reset communication commands, RTC-reset parameters, RTC-reset exceptions, RTC-reset sounds, and RTC-reset animations that it seems as if Sony actually WANTED the Time/Date to be destroyed as often as possible.

The only possible reason for doing this is that the clock hardware is so inaccurate that Sony must have decided to "solve" the problem at software engineering side, by erasing the RTC values before the user could even notice time inaccuracies.

CPU Specs

For details on the ARM7TDMI CPUs opcodes and exceptions, check GBATEK at,
<http://problemkaputt.de/gbatek.htm> (or .txt)

The GBA uses an ARM7TDMI CPU, too.

Thanks to Exophage, Orion, Fezzik, Dr.Hell for Pocketstation info.

13.2 Pocketstation I/O Map

Memory and Memory-Control Registers

00000000h RAM	(2KB RAM) (first 512 bytes reserved for kernel)
02000000h FLASH1	Flash ROM (virtual file-mapped addresses in this region)
04000000h BIOS_ROM	Kernel and GUI (16KB)
06000000h F_CTRL	Control of Flash ROM
06000004h F_STAT	Unknown?
06000008h F_BANK_FLG	FLASH virtual bank mapping enable flags(16 bits) (R/W)
0600000Ch F_WAIT1	waitstates...?
06000010h F_WAIT2	waitstates, and FLASH-Write-Control-and-Status...?
06000100h F_BANK_VAL	FLASH virtual bank mapping addresses (16 words) (R/W)
06000300h F_EXTRA	Extra FLASH (256 bytes, including below F_SN, F_CAL)
06000300h F_SN_LO	Extra FLASH Serial Number LSBs (nocash: 6BE7h)
06000302h F_SN_HI	Extra FLASH Serial Number MSBs (nocash: 426Ch)
06000304h F_?	Extra FLASH Unknown ? (nocash: 05CAh)
06000306h F_UNUSED1	Extra FLASH Unused halfword (nocash: FFFFh)
06000308h F_CAL	Extra FLASH LCD Calibration (nocash: 001Ah)
0600030Ah F_UNUSED2	Extra FLASH Unused halfword (nocash: FFFFh)
0600030Ch F_?	Extra FLASH Unknown ? (nocash: 0010h)
0600030Eh F_UNUSED3	Extra FLASH Unused halfword (nocash: FFFFh)
06000310h F_UNUSED4	Extra FLASH Unused (310..3FFh) (nocash: FFFFh-filled)
08000000h FLASH2	Flash ROM (128KB) (physical addresses in this region)
08002A54h F_KEY1	Flash Unlock Address 1 (W)
080055AAh F_KEY2	Flash Unlock Address 2 (W)

Interrupts and Timers

0A000000h INT_LATCH	Interrupt hold (R)
0A000004h INT_INPUT	Interrupt Status (R)
0A000008h INT_MASK_READ	Read Interrupt Mask (R)
0A000008h INT_MASK_SET	Set Interrupt Mask (W)
0A00000Ch INT_MASK_CLR	Clear Interrupt Mask (W)
0A000010h INT_ACK	Clear Interrupt hold (W)
0A800000h T0_RELOAD	Timer 0 Maximum value
0A800004h T0_COUNT	Timer 0 Current value
0A800008h T0_MODE	Timer 0 Mode
0A800010h T1_RELOAD	Timer 1 Maximum value
0A800014h T1_COUNT	Timer 1 Current value
0A800018h T1_MODE	Timer 1 Mode
0A800020h T2_RELOAD	Timer 2 Maximum value
0A800024h T2_COUNT	Timer 2 Current value
0A800028h T2_MODE	Timer 2 Mode
0B000000h CLK_MODE	Clock control (CPU and Timer Speed) (R/W)
0B000004h CLK_STOP	Clock stop (Sleep Mode)
0B800000h RTC_MODE	RTC Mode

0B800004h RTC_ADJUST	RTC Adjust
0B800008h RTC_TIME	RTC Time (R)
0B80000Ch RTC_DATE	RTC Date (R)

Communication Ports, Audio/Video

0C000000h COM_MODE	Com Mode
0C000004h COM_STAT1	Com Status Register 1 (Bit1=Error)
0C000008h COM_DATA	Com RX Data (R) and TX Data (W)
0C000010h COM_CTRL1	Com Control Register 1
0C000014h COM_STAT2	Com Status Register 2 (Bit0=Ready)
0C000018h COM_CTRL2	Com Control Register 2
0C800000h IRDA_MODE	Infrared Control (R/W)
0C800004h IRDA_DATA	Infrared TX Data
0C80000Ch IRDA_MISC	Infrared Unknown/Reserved
0D000000h LCD_MODE	Video Control (R/W)
0D000004h LCD_CAL	Video Calibration (?)
0D000100h LCD_VRAM	Video RAM (80h bytes; 32x32bit) (R/W)
0D800000h IOP_CTRL	IOP control
0D800004h IOP_STAT	Read Current Start/Stop bits? (R)
0D800004h IOP_STOP	Stop bits? (W)
0D800008h IOP_START	Start bits? (W)
0D80000Ch IOP_DATA	IOP data? (not used by bios)
0D800010h DAC_CTRL	DAC Control (R/W)
0D800014h DAC_DATA	DAC data
0D800020h BATT_CTRL	Battery Monitor Control

BIOS and FLASH can be read only in 16bit and 32bit units (not 8bit).

Upon reset, BIOS ROM is mirrored to address 00000000h (instead of RAM).

For most I/O ports, it is unknown if they are (R), (W), or (R/W)...?

I/O ports are usually accessed at 32bit width, occassionally some ports are (alternately) accessed at 16bit width. A special case are the F_SN registers which seem to be required to be accessed at 16bit (not 32bit).

Memory Access Time

Memory Access Time for Opcode Fetch:

WRAM	1 cycle (for ARM and THUMB)
FLASH	2 cycles (for ARM), or 1 cycle (for THUMB)
BIOS	?

Memory Access Time for Data Read/Write:

WRAM (and some F_xxx ports)	1 cycle
VIRT/PHYS/XTRA_FLASH, BIOS, VRAM, I/O	2 cycles

For data access, it doesn't matter if the access is 8bit/16bit/32bit (unlike as for opcode fetch, where 16bit/thumb can be faster than 32bit/arm). There seems to be no timing differences for sequential/non-sequential access.

Additional memory waitstates can be added via F_WAIT2 (and F_WAIT1 maybe).

Invalid/Unused Memory Locations

00000800h-00FFFFFFh	Mirrors of 0000000h-000007FFh (2K RAM)
01000000h-01FFFFFFh	Invalid (read causes data abort) (unused 16MB area)
020xxxxxh-0201FFFFFFh	Invalid (read causes data abort) (disabled FLASH banks)
02020000h-02FFFFFFh	Invalid (read causes data abort) (no Virt FLASH mirrors)
03000000h-03FFFFFFh	Invalid (read causes data abort) (unused 16MB area)
04004000h-04FFFFFFh	Mirrors of 04000000h-04003FFFh (16K BIOS)
05000000h-05FFFFFFh	Invalid (read causes data abort)
06000014h-060000FFh	Zerofilled (or maybe mirror of a ZERO port?) (F_xxx)
06000140h-060002FFh	Zerofilled (or maybe mirror of a ZERO port?) (F_xxx)
06000400h-06FFFFFFh	Zerofilled (or maybe mirror of a ZERO port?) (F_xxx)
07000000h-07FFFFFFh	Invalid (read causes data abort) (unused 16MB area)
08020000h-08FFFFFFh	Mirrors of 08000000h-0801FFFFh (128K Physical FLASH)
09000000h-09FFFFFFh	Invalid (read causes data abort) (unused 16MB area)
0A000014h-0A7FFFFFFh	Mirrors of 0A000008h-0A0000Bh (INT_MASK_READ) (I_xxx)
0A80000Ch	Mirror of 0A80000h-0A80003h (T0_RELOAD) (T0_xxx)
0A80001Ch	Mirror of 0A80000h-0A80003h (T0_RELOAD) (T1_xxx)
0A80002Ch	Mirror of 0A80000h-0A80003h (T0_RELOAD) (T2_xxx)
0A800030h-0AFFFFFFh	Mirrors of 0A80000h-0A80003h (T0_RELOAD) (T_xxx)
0B000008h-0B7FFFFFFh	Mirrors of ? (CLK_xxx)
0B800010h-0BFFFFFFh	Mirrors of 0B800008h-0B8000Bh (RTC_TIME)
0C00000Ch-0C00000Fh	Zero (COM_xxx)
0C00001Ch-0C7FFFFFFh	Zerofilled (or maybe mirror of a ZERO port?) (COM_xxx)
0C800008h-0CFFFFFFh	? (IRDA_xxx)
0D000008h-0D00000FFh	Zerofilled (or maybe mirror of a ZERO port?) (LCD_xxx)
0D000180h-0D7FFFFFFh	Zerofilled (or maybe mirror of a ZERO port?) (LCD_xxx)
0D800018h	? (DAC_xxx)
0D80001Ch	? (DAC_xxx)
0D800024h-0DFFFFFFh	Zerofilled (or maybe mirror of a ZERO port?) (BATT_xxx)
0E000000h-FFFFFFFFh	Invalid (read causes data abort) (unused 3872MB area)

Unsupported 8bit Reads

02000000h-0201FFFFFFh	VIRT_FLASH ; \
04000000h-04FFFFFFh	BIOS_ROM ; "garbage_byte" (see below)
06000300h-060003FFh	EXTRA_FLASH ;
08000000h-08FFFFFFh	PHYS_FLASH ; /
0A800001h-0AFFFFFFh	Timer area, odd addresses (with A0=1) mirror to 0A800001h
0B800001h-0BFFFFFFh	RTC area, odd addresses (with A0=1) mirror to ...?

Unsupported 16bit Reads

```
0B800002h-0BFFFFFFEh RTC area, odd addresses (with A1=1) mirror to 0B80000Ah
```

garbage_byte (for unsupported 8bit reads)

The "garbage_byte" depends on the LSBs of the read address, prefetched opcodes, and recent data fetches:

```
garbage_word = (prefetch OR (ramdata AND FFFFFFFD0h))
garbage_byte = (garbage_word shr (8*(addr and 3))) AND FFh
```

For ARM code, the "prefetch" is the 2nd next opcode after the LDRB:

```
prefetch.bit0-31 = [curr_arm_opcode_addr+8] ;-eg. from arm LDRB
```

For THUMB code, the "prefetch" is the 2nd next opcode after the LDRB (no matter if that opcode is word-aligned or not), combined with the most recent ARM opcode prefetch (eg. from the BX opcode switched from ARM to THUMB mode; that value may get changed on interrupts):

```
prefetch.bit0-15 = [recent_arm_opcode_addr+8] ;-eg. from arm BX to thumb
prefetch.bit16-31 = [curr_thumb_opcode_addr+4] ;-eg. from thumb LDRB
```

The "ramdata" is related to most recent RAM read (eg. from POP or LDR opcodes that have read data from RAM; however, writes to RAM, or literal pool reads from FLASH don't affect it):

```
ramdata.bit0-31 = [recent_ram_read_addr] ;-eg. from LDR/POP from RAM
```

There might be some more/unknown things that affect the garbage (eg. opcode fetches from RAM instead of FLASH, partial 8bit/16bit data reads from RAM, or reads from I/O areas, current CPU clock speed, or unpredictable things like temperature).

Note: The garbage_byte is "used" by the pocketstation "Rockman" series games.

13.3 Pocketstation Memory Map

Overall Memory Map

```

00000000h RAM      RAM (2K)    (or mirror of BIOS ROM upon reset)
02000000h FLASH1   Flash ROM  (virtual file-mapped addresses in this region)
04000000h BIOS_ROM BIOS (16K) (Kernel and GUI)
06000300h F_SN...   Seems to contain a bunch of additional FLASH bytes?
08000000h FLASH2   Flash ROM (128K) (physical addresses in this region)
0D000100h LCD_VRAM Video RAM (128 bytes) (32x32 pixels, 1bit per pixel)

```

00000000h..000001FFh - Kernel RAM

The first 200h bytes of RAM are reserved for the kernel.

```

0000000h 20h Exception handler opcodes (filled with LDR R15,[$+20h] opcodes)
0000020h 20h Exception handler addresses (in ARM state, no THUMB bit here)
0000040h 80h Sector buffer (and BU command parameter work space)
00000C0h 8   ComFlags (see GetPtrToComFlags(), SWI 06h for details)
00000C8h 2   BU Command FUNC3 Address (see GetPtrToFunc3addr() aka SWI 17h)
00000CAh 1   Value from BU Command_50h, reset by SWI 05h (sense_auto_com)
00000CBh 2   Not used
00000CDh 1   Old Year (BCD, 00h..99h) (for sensing wrapping to new century)
00000CEh 1   Alternate dir_index (when [0D0h]=0) (see SWI 15h and SWI 16h)
00000CFh 1   Current Century (BCD, 00h..99h) (see GetBcdDate() aka SWI 0Dh)
00000D0h 2   Current dir_index (for currently executed file, or 0=GUI)
00000D2h 2   New dir_index (PrepareExecute(flag,dir_index,param), SWI 08h)
00000D4h 4   New param     (PrepareExecute(flag,dir_index,param), SWI 08h)
00000D8h 8   Alarm Setting (see GetPtrToAlarmSetting() aka SWI 13h)
00000E0h 4   Pointer to SWI table (see GetPtrToPtrToSwiTable() aka SWI 14h)
00000E4h 3x4 Memory Card BU Command variables
00000F0h 1   Memory Card FLAG byte (bit3=new_card, bit2=write_error)
00000F1h 1   Memory Card Error offhold (0=none, 1=once)
00000F2h 6   Not used
00000F8h 4x4 Callback Addresses (set via SetCallbacks(index,proc), SWI 01h)
0000108h 4   Snapshot ID (0xh,00h,"SE")
000010Ch 74h IRQ and SWI stack (stacktop at 180h)
0000180h 80h FIQ stack (stacktop at 200h)

```

Although one can modify that memory, one usually shouldn't do that, or at least one must backup and restore the old values before returning control to the GUI or to other executables. Otherwise, the only way to restore the original values would be to press the Reset button (which would erase the RTC time/date).

00000200h..000007FFh - User RAM and User stack (stacktop at 800h)

This region can be freely used by the game. The memory is zerofilled when the game starts.

02000000h - FLASH1 - Flash ROM (virtual file-mapped addresses in this region)

This region usually contains the currently selected file (including its title and icon sectors), used to execute the file in this region, mapped to continuous addresses at 2000000h and up.

08000000h - FLASH2 - Flash ROM (128K) (physical addresses in this region)

This region is used by the BIOS when reading the memory card directory (and when writing data to the FLASH memory). The banking granularity is 2000h bytes (one memory card block), that means that the hardware cannot map Replacement Sectors which may be specified in the for Broken Sector List.

04000000h - BIOS ROM (16K) - Kernel and GUI

```

4000000h 1E00h Begin of Kernel (usually 1E00h bytes)
4000014h 4      BCD Date in YYYYMMDDh format (19981023h for ALL versions)
4001DFCh 4      Core Kernel Version (usually "C061" or "C110")
4001E00h 2200h Begin of GUI (usually 2200h bytes)
4003FFCh 4      Japanese GUI Version (usually "J061" or "J110")

```

The "110" version does contain some patches, but does preserve same function addresses as the "061" version, still it'd be no good to expect the BIOS to contain any code/data at fixed locations (except maybe the GUI version string). Kernel functions can be accessed via SWI OpCodes, and, from the PSX-side, via BU Commands.

Bus-Width Restrictions

FLASH and BIOS ROM seem to be allowed to be read only in 16bit and 32bit units, not in 8bit units? Similar restrictions might apply for some I/O ports...? RAM can be freely read/written in 8bit, 16bit, and 32bit units.

Waitstates

Unknown if and how many waitstates are applied to the different memory regions. The F_WAIT1 and F_WAIT2 registers seem to be somehow waitstate related. FLASH memory

does probably have a 16bit bus, so 32bit data/opcode fetches might be slower then 16bit reads...? Similar delays might happen for other memory and I/O regions...?

13.4 Pocketstation IO Video and Audio

0D000000h - LCD_MODE - LCD control word (R/W)

```

0-2 Draw mode; seems to turn off bits of the screen;
    0: All 32 rows on      ;\
    1: First 8 rows on   ;
    2: Second 8 rows on  ;
    3: Third 8 rows on   ; (these are not necessarily all correct?)
    4: Fourth 8 rows on  ;
    5: First 16 rows on  ;
    6: Middle 16 rows on ;
    7: Bottom 16 rows on /;

3     CPEN      (0=Does some weird fade out of the screen, 1=Normal)

4-5 Refresh rate
    0: Makes a single blue (yes, blue, yes, on a black/white display)
       line appear at the top or middle of the screen - don't use!
    1: 64Hz? (might be 32Hz too, like 2)
    2: 32Hz
    3: 16Hz (results in less intensity on black pixels)

6     Display active      (0=Off, 1=On)

7     Rotate display by 180 degrees (0=For Handheld Mode, 1=For Docked Mode)

8-31 Unknown (should be zero)

```

Software should usually set LCD_MODE.7 equal to INT_INPUT.Bit11 (docking flag). In handheld mode, the button-side is facing towards the player, whilst in Docked mode (when the Pocketstation is inserted into the PSX controller port), the button-side is facing towards the PSX, so the screen coordinates become vice-versa, which can be "undone" by the Rotation flag.

0D000004h - LCD_CAL - LCD Calibration (maybe contrast or so?)

Upon the reset, the kernel sets LCD_CAL = F_CAL AND 0000003Fh. Aside from that, it doesn't use LCD_CAL.

0D000100h..D00017Fh - LCD_VRAM - 32x32 pixels, 1bit color depth (R/W)

This region consists of 32 words (32bit values),

[D000100h]=Top, through [D00017Ch]=Bottom-most scanline

The separate scanlines consist of 32bit each,

Bit0=Left, through Bit31=Right-most Pixel (0=White, 1=Black)

That [D000100h].Bit0=Upper-left arrangement applies if the Rotate bit in LCD_MODE.7 is set up in the conventional way, if it is set the opposite way, then it becomes [D00017Ch].Bit31=Upper-left.

The LCD_VRAM area is reportedly mirrored to whatever locations?

0D800010h - DAC_CTRL - Audio Control (R/W)

0	Audio Enable	enable (0=Off, 1=On)
1-31	Unknown, usually zero	

Note: Aside from the bit in DAC_CTRL, audio must be also enabled/disabled via IOP_STOP/IOP_START bit5. Unknown if/which different purposes that bits have.

0D800014h - DAC_DATA - Audio D/A Converter

Unknown how many bits are passed to the D/A converter, probably bit8-15, ie. 8 bits...?

0-7	Probably unused, usually zero (or fractional part when lowered volume)	
8-15	Signed Audio Outut Level (usually -7Fh..+7Fh) (probably -80h works too)	
16-31	Probably unused, usually sign-expanded from bit15	

The Pocketstation doesn't have any square wave or noise generator (nor a sound DMA channel). So the output levels must be written to DAC_DATA by software, this is usually done via Timer1/IRQ-8 (to reduce CPU load caused by high audio frequencies, it may be much more recommended to use Timer2/FIQ-13, because the FIQ handler doesn't need to push r8-r12).

For example, to produce a 1kHz square wave, the register must be toggled high/low at 2kHz rate. If desired, multiple channels can be mixed by software. High frequencies and multiple voices may require high CPU speed settings, and thus increase battery consumption (aside from that, battery consumption is probably increased anyways when the speaker is enabled).

13.5 Pocketstation IO Interrupts and Buttons

0A000004h - INT_INPUT - Raw Interrupt Signal Levels (R)

Bit	Type	Meaning	
0	IRQ	Button Fire	(0=Released, 1=Pressed)
1	IRQ	Button Right	(0=Released, 1=Pressed)
2	IRQ	Button Left	(0=Released, 1=Pressed)
3	IRQ	Button Down	(0=Released, 1=Pressed)
4	IRQ	Button Up	(0=Released, 1=Pressed)
5	?	Unknown?	(?)
6	FIQ (!)	COM	;for the COM_registers? (via /SEL Pin?)
7	IRQ	Timer 0	
8	IRQ	Timer 1	
9	IRQ	RTC (square wave) (usually 1Hz) (when RTC paused: 4096Hz)	
10	IRQ	Battery Low	(0=Normal, 1=Battery Low)
11	IRQ	Docked ("IOP")	(0=Undocked, 1=Docked to PSX) (via VCC Pin?)
12	IRQ	Infrared Rx	
13	FIQ (!)	Timer 2	
14-15	N/A	Not used	

The buttons are usually read directly from this register (rather than being configured to trigger IRQs) (except in Sleep mode, where the Fire Button IRQ is usually used to wakeup). Also, bit9-11 are often read from this register.

The direction keys seem to be separate buttons, ie. unlike as on a joystick or DPAD, Left/Right (and Up/Down) can be simultaneously pressed...?

0A000008h - INT_MASK_SET - Set Interrupt Mask (W)

0A00000Ch - INT_MASK_CLR - Clear Interrupt Mask (W)

0A000008h - INT_MASK_READ - Read Interrupt Mask (R)

INT_MASK_SET	Enable Interrupt Flags	(0=No change, 1=Enable)	(W)
INT_MASK_CLR	Disable Interrupt Flags	(0=No change, 1=Disable)	(W)
INT_MASK_READ	Current Interrupt Enable Flags	(0=Disabled, 1=Enabled)	(R)

The locations of the separate bits are same as in INT_INPUT (see there).

0A000000h - INT_LATCH - Interrupt Request Flags (R)**0A000010h - INT_ACK - Acknowledge Interrupts (W)**

INT_LATCH	Latched Interrupt Requests (0=None, 1=Interrupt Request)	(R)
INT_ACK	Clear Interrupt Requests (0>No change, 1=Acknowledge)	(W)

The locations of the separate bits are same as in INT_INPUT (see there).

The interrupts seem to be edge-triggered (?), ie. when the corresponding bits in INT_INPUT change from 0-to-1. Unknown if the request bits get set when the corresponding interrupt is disabled in INT_MASK...?

ATTENTION: The GUI doesn't acknowledge Fire Button interrupts on wakeup... so, it seems as if button interrupts are NOT latched... ie. the button "INT_LATCH" bits seem to be just an unlatched mirror of the "INT_INPUT" bits... that might also apply for some other interrupt...?

However, after wakeup, the gui does DISABLE the Fire Button interrupt, MAYBE that does automatically acknowledge it... in that case it might be latched...?

Reading outside the readable region (that is where exactly?) seems to mirror to 0A000008h. Enabling IRQs for the buttons seems to make it impossible to poll them... is that really true?

13.6 Pocketstation IO Timers and Real-Time Clock

Timer and RTC interrupts

INT_INPUT.7	Timer 0 IRQ ;used as 30Hz frame rate IRQ by GUI
INT_INPUT.8	Timer 1 IRQ ;used as Audio square wave IRQ by GUI
INT_INPUT.13	Timer 2 FIQ (this one via FIQ vector, not IRQ vector)
INT_INPUT.9	RTC IRQ (usually 1Hz) (or 4096Hz when RTC paused)

0A800000h - T0_RELOAD - Timer 0 Reload Value**0A800010h - T1_RELOAD - Timer 1 Reload Value****0A800020h - T2_RELOAD - Timer 2 Reload Value**

0-15 Reload Value (when timer becomes less than zero)

Writes to this register are ignored if the timer isn't stopped?

0A800004h - T0_COUNT - Timer 0 Current value

0A800014h - T1_COUNT - Timer 1 Current value

0A800024h - T2_COUNT - Timer 2 Current value

0-15 Current value (decrementing)

Timer interrupts: The timers will automatically raise interrupts if they're enabled, there's no need to set a bit anywhere for IRQs (but you need to enable the respect interrupts in INT_MASK).

0A800008h - T0_MODE - Timer 0 Control

0A800018h - T1_MODE - Timer 1 Control

0A800028h - T2_MODE - Timer 2 Control

0-1 Timer Divider (0=Div2, 1=Div32, 2=Div512, 3=Div2 too)
 2 Timer Enable (0=Stop, 1=Decrement)
 3-15 Unknown (should be zero)

Timers are clocked by the System Clock (usually 4MHz, when CLK_MODE=7), divided by the above divider setting. Note that the System Clock changes when changing the CPU speed via CLK_MODE, so Timer Divider and/or Timer Reload must be adjusted accordingly.

0B800000h - RTC_MODE - RTC control word

0 Pause RTC (0=Run/1Hz, 1=Pause/4096Hz)
 1-3 Select value to be modified via RTC_ADJUST
 4-31 Not used?

The selection bits can be:

```
00h = Second      ; \
01h = Minute      ;
02h = Hour        ; used in combination with RTC_ADJUST
03h = Day of Week ; while RTC is paused
04h = Day          ;
```

05h = Month ;	
06h = Year ;/	
07h = Unknown ;-usually used when RTC isn't paused	

When paused, the RTC IRQ bit in INT_INPUT.9 runs at 4096Hz (instead 1Hz).

0B800004h - RTC_ADJUST - Modify value (write only)

Writing a value here seems to increment the current selected parameter (by the RTC control). What is perhaps (?) clear is that you have to wait for the RTC interrupt signal to go low before writing to this.

0B800008h - RTC_TIME - Real-Time Clock Time (read only) (R)

0-7 Seconds (00h..59h, BCD)	
8-15 Minutes (00h..59h, BCD)	
16-23 Hours (00h..23h, BCD)	
24-31 Day of week (1=Sunday, ..., 7=Saturday)	

Reading RTC_TIME seems to be somewhat unstable: the BIOS uses a read/retry loop, until it has read twice the same value (although it does read the whole 32bit at once by a LDR opcode, the data is maybe passed through a 8bit or 16bit bus; so the LSBs might be a few clock cycles older than the MSBs...?).

0B80000Ch - RTC_DATE - Real-Time Clock Date (read only) (R)

0-7 Day (01h..31h, BCD)	
8-11 Month (01h..12h, BCD)	
16-23 Year (00h..99h, BCD)	
24-31 Unknown? (this is NOT used as century)	

Reading RTC_DATE seems to require the same read/retry method as RTC_TIME (see there). Note: The century is stored in battery-backed RAM (in the reserved kernel RAM region) rather than in the RTC_DATE register. The whole date, including century, can be read via SWI 0Dh, GetBcdDate().

13.7 Pocketstation IO Infrared

The BIOS doesn't contain any IR functions (aside from doing some basic initialization and power-down stuff).

IR is used in Final Fantasy 8's Chocobo World (press Left/Right in the Map screen to go to

the IR menu), and in Metal Gear Solid Integral (Press Up in the main screen), and in PDA Remote 1 & 2 (one-directional TV remote control).

0C800000h - IRDA_MODE - Controlling the protocol - send/recv, etc. (R/W)

0	Transfer Direction (0=Receive, 1=Transmit)
1	Disable IRDA (0=Enable, 1=Disable)
2	Unknown (reportedly IR_SEND_READY, uh?)
3	Unknown (reportedly IR_RECV_READY, uh?)
4-31	Unknown (should be zero)

0C800004h - IRDA_DATA - Infrared TX Data

0	Transmit Data in Send Direction (0=LED Off, 1=LED On)
1-31	Unknown (should be zero)

Bits are usually encoded as long or short ON pulses, separated by short OFF pulses. Where long is usually twice as long as short.

0C80000Ch - IRDA_MISC

Unknown? Reportedly reserved.

INT_INPUT.12 - IRQ - Infrared RX Interrupt

Seems to get triggered on raising or falling (?) edges of incoming data. The interrupt handler seems to read the current counter value from one of the timers (usually Timer 2, with reload=FFFFh) to determine the length of the incoming IR pulse.

IR Notes

Mind that IR hardware usually adopts itself to the normal light conditions, so if it receives an IR signal for a longer period, then it may treat that as the normal light conditions (ie. as "OFF" state). To avoid that, one would usually send a group of ON-OFF-ON-OFF pulses, instead of sending a single long ON pulse:

____-----	One HIGH bit send as SINGLE-LONG-ON pulse (BAD)
--------	One HIGH bit send as MULTIPLE-ON-OFF pulses (OK)

that might be maybe done automatically by the hardware...?

Reportedly, Bit4 of Port 0D80000Ch (IOP_DATA) is also somewhat IR related...?

13.8 Pocketstation IO Memory-Control

06000000h - F_CTRL

0-31 Unknown

Written values are:

00000000h	Used when disabling all virtual flash banks
00000001h	Used before setting new virtual bank values
00000002h	Used after setting virtual bank enable bits
03h	Replace ROM at 00000000h by RAM (used after reset)

The GUI does additionally read from this register (and gets itself trapped in a bizarre endless loop if bit0 was zero). Unknown if it's possible to re-enable ROM at location 00000000h by writing any other values to this register?

06000004h F_STAT

0-31 Unknown

The kernel issues a dummy read from this address (before setting F_CTRL to 00000001h).

06000008h F_BANK_FLG ;FLASH virtual bank mapping enable flags (16 bits)(R/W)

0-15	Enable physical banks 0..15 in virtual region (0=Disable, 1=Enable)
16-31	Unknown (should be zero)

06000100h F_BANK_VAL ;FLASH virtual bank mapping addresses (16 words)(R/W)

This region contains 16 words, the first word at 06000100h for physical bank 0, the last word at 0600013Ch for physical bank 15. Each word is:

0-3	Virtual bank number
4-31	Should be 0

Unused physical banks are usually mapped to 0Fh (and are additionally disabled in the F_BANK_FLG register).

0600000Ch F_WAIT1 ;waitstates...?

```

0..3 Unknown/not tested
4 hangs hardware? but that bit is used in some cases!
5..31 Unknown/not tested

```

Unknown, seems to control some kind of memory waitstates for FLASH (or maybe RAM or BIOS ROM). Normally it is set to the following values:

```

F_WAIT1=00000000h when CPU Speed = 00h..07h
F_WAIT1=00000010h when CPU Speed = 08h..0Fh

```

Note: The kernels Docking/Undocking IRQ-11 handler does additionally do this:
 "F_WAIT1=max(08h,(CLK_MODE AND 0Fh))" (that is a bug, what it actually wants to do is to READ the current F_WAIT.Bit4 setting).

06000010h F_WAIT2 ;waitstates, and FLASH-Write-Control-and-Status...?

```

0 no effect? but that bit is used in some cases! maybe write-enable?
1 hangs hardware?
2 no effect?           READ: indicates 0=write-busy, 1=ready?   (R)
3 hangs hardware?
4 makes FLASH slower?
5 makes WRAM and F_xxx as slow as other memory (0=1 cycle, 1=2 cycles)
6 hangs hardware? but that bit is used in some cases!
7 no effect?
8..31 Unknown/not tested

```

Unknown, seems to control some kind of memory waitstates, maybe for another memory region than F_WAIT1, or maybe F_WAIT2 is for writing, and F_WAIT1 for reading or so. Normally it is set to the following values:

```

F_WAIT2=00000000h when CPU Speed = 00h..07h ;\same as F_WAIT1
F_WAIT2=00000010h when CPU Speed = 08h..0Fh ;/

```

In SWI 0Fh and SWI 10h it is also set to:

```

F_WAIT2=00000021h ;SWI 10h, FlashWritePhysical(sector,src)
F_WAIT2=00000041h ;SWI 0Fh, FlashWriteSerial(serial_number)

```

Before completion, those SWIs do additionally,

```
wait until reading returns F_WAIT2.Bit2 = 1
and then set F_WAIT2=00000000h
```

08002A54h - F_KEY1 - Flash Unlock Address 1 (W)

080055AAh - F_KEY2 - Flash Unlock Address 2 (W)

Unlocks FLASH memory for writing. The complete flowchart for writing sector data (or header values) is:

```
if write_sector ;\
    F_WAIT2=00000021h ; write enable or so
if write_header ;
    F_WAIT2=00000041h ;/
[80055AAh]=FFAAh ;\
[8002A54h]=FF55h ; unlock flash
[80055AAh]=FFA0h ;/
if write_sector ;\
    for i=0 to 3Fh ;
        [8000000h+sector*80h+i*2]=src[i*2] ; write data
if write_header ;
    [8000000h]=new F_SN_LO value ;
    [8000002h]=new F_SN_HI value ;
    [8000008h]=new F_CAL value ;/
first, wait 4000 clock cycles ;\wait
then, wait until F_WAIT2.Bit2=1 ;/
F_WAIT2=00000000h ;-write disable or so
```

During the write operation one can (probably?) not read data (nor opcodes) from FLASH memory, so the above code must be executed either in RAM, or in BIOS ROM (see SWI 03h, SWI 0Fh, SWI 10h).

06000300h - F_SN_LO - Serial Number LSBs

06000302h - F_SN_HI - Serial Number MSBs

06000308h - F_CAL - Calibration value for LCD

```
0-15 Data
```

This seems to be an additional "header" region of the FLASH memory (additionally to the 128K of data). The F_SN registers contain a serial number or so (purpose unknown,

maybe intended as some kind of an "IP" address for more complex infrared network applications), the two LO/HI registers must be read by separate 16bit LDRH opcodes (not by a single 32bit LDR opcode). The F_CAL register contains a 6bit calibration value for LCD_CAL (contrast or so?).

Although only the above 3 halfwords are used by the BIOS, the "header" is unlike to be 6 bytes in size, probably there are whatever number of additional "header" locations at 06000300h and up...?

Note: Metal Gear Solid Integral uses F_SN as some kind of copy protection (the game refuses to run and displays "No copy" if F_SN is different as when the pocketstation file was initially created).

F_BANK_VAL and F_BANK_FLG Notes

Observe that the physical_bank number (p) is used as array index, and that the virtual bank number (v) is stored in that location, ie. table[p]=v, which is unlike as one may have expected it (eg. on a 80386 CPU it'd be vice-versa: table[v]=p).

Due to the table[p]=v assignment, a physical block cannot be mirrored to multiple virtual blocks, instead, multiple physical blocks can be mapped to the same virtual block (unknown what happens in that case, maybe the data becomes ANDed together).

13.9 Pocketstation IO Communication Ports

0C000000h - COM_MODE - Com Mode

0	Data Output Enable (0=None/HighZ, 1=Output Data Bits)
1	/ACK Output Level (0=None/HighZ, 1=Output LOW)
2	Unknown (should be set when expecting a NEW command...?)
3-31	Unknown (should be zero)

0C000008h - COM_DATA - Com RX/TX Data

0-7	Data (Write: to be transmitted to PSX, Read: been received from PSX)
8-31	Unknown

0C000004h - COM_STAT1 - Com Status Register 1 (Bit1=Error)

0	Unknown
1	Error flag or so (0=Okay, 1=Error)
2-31	Unknown

Seems to indicate whatever error (maybe /SEL disabled during transfer, or timeout, or parity error or something else?) in bit1. Meaning of the other bits is unknown. Aside from checking the error flag, the kernel does issue a dummy read at the end of each transfer, maybe to acknowledge something, maybe the hardware simply resets the error bit after reading (although the kernel doesn't handle the bit like so when receiving the 1st command byte).

Aside from the above error flag, one should check if INT_INPUT.11 becomes zero during transfer (which indicates undocking).

0C000014h - COM_STAT2 - Com Status Register 2 (Bit0=Ready)

0	Ready flag (0=Busy, 1=Ready) (when 8bits have been transferred)
1-31	Unknown

0C000010h - COM_CTRL1 - Com Control Register 1

0	Unknown (should be set AT BEGIN OF A NEW command...?)
1	Unknown (0=Disable something, 1=Enable something)
2-31	Unknown (should be zero)

Used values are:

00000000h	= unknown? disable
00000002h	= unknown? enable
00000003h	= unknown? at BEGIN of a new command

When doing the enable thing, Bit1 should be set to 0-then-1...? Bit0 might enable the data shift register... and bit1 might be a master enable and master acknowledge for the COM interrupt... or something else?

0C000018h - COM_CTRL2 - Com Control Register 2

0	Unknown (should be set, probably starts or acknowledges something)
1	Unknown (should be set when expecting a NEW command...?)
2-31	Unknown (should be zero)

Used values are:

00000001h	= unknown? used before AND after each byte-transfer
00000003h	= unknown? used after LAST byte of command (and when init/reset)

Maybe that two bits acknowledge the ready/error bits?

INT_INPUT.6 FIQ (!) COM for the COM_registers? (via /SEL Pin?)

(via FIQ vector, not IRQ vector)

INT_INPUT.11 IRQ Docked ("IOP") (0=Undocked, 1=Docked to PSX)

Probably senses the voltage on the cartridge slots VCC Pin. Becomes zero when Undocked (and probably also when the PSX is switched off).

The Kernel uses IRQ-11 for BOTH sensing docking and undocking, ie. as if the IRQ would be triggered on both 0-to-1 and 1-to-0 transitions... though maybe that feature just relies on switch-bounce. For the same reason (switch bounce), the IRQ-11 handler performs a delay before it checks the new INT_INPUT.11 setting (ie. the delay skips the unstable switch bound period, and allows the signal to stabilize).

IOP_START/IOP_STOP.Bit1

The BIOS adjusts this bit somehow in relation to communication. Unknown when/why/how it must be used. For details on IOP_START/IOP_STOP see Power Control chapter.

Opcode E6000010h (The Undefined Instruction) - Write chr(r0) to TTY

This opcode is used by the SN Systems emulator to write chr(r0) to a TTY style text window. r0 can be ASCII characters 20h and up, or 0Ah for CRLF. Using that opcode is a not too good idea because the default BIOS undef instruction handler simply runs into an endless loop, so games that are using it (eg. Break-Thru by Jason) won't work on real hardware. That, unless the game would change the undef instruction vector at [04h] in Kernel RAM, either replacing it by a MOVS R15,R14 opcode (ignore exception and return to next opcode), or by adding exception handling that outputs the character via IR or via whatever cable connection. Observe that an uninitialized FUNC3 accidentally destroys [04h], so first init FUNC3 handler via SWI 17h, before trying to change [04h], moreover, mind that SWI 05h may reset FUNC3, causing the problem to reappear.

Altogether, it'd be MUCH more stable to write TTY characters to an unused I/O port... only problem is that it's still unknown which I/O ports are unused... ie. which do neither trap data aborts, nor do mirror to existing ports...?

13.10 Pocketstation IO Power Control

0B000000h - CLK_MODE - Clock control (CPU and Timer Speed) (R/W)

0-3	Clock Ratio (01h..08h, see below) (usually 7 = 3.99MHz)	(R/W)
4	Clock Change State (0=Busy, 1=Ready)	(Read-only)
5-15	?	

Allows to change the CPU clock (and Timer clock, which is usually one half of the CPU clock, or less, depending on the Timer Divider). Possible values are:

```

00h = hangs hardware      ;-don't use
01h = 0.063488 MHz        ;\
02h = 0.126976 MHz        ;
03h = 0.253952 MHz        ; 31*8000h / 1,2,4,8,16
04h = 0.507904 MHz        ;
05h = 1.015808 MHz        ;/
06h = 1.998848 MHz        ;\
07h = 3.997696 MHz        ; 61*8000h * 1,2,4
08h = 7.995392 MHz        ;/
09h..0Fh = same as 08h    ;-aliases

```

Before changing CLK_MODE, F_WAIT1 and F_WAIT2 should be adjusted accordingly (see there for details). Note that many memory regions have waitstates, the full CPU speed can be reached mainly with code/data in WRAM.

0B000004h - CLK_STOP - Clock stop (Sleep Mode)

Stops the CPU until an interrupt occurs. The pocketstation doesn't have a power-switch nor standby button, the closest thing to switch "power off" is to enter sleep mode. Software should do that when the user hasn't pressed buttons for 1-2 seconds (that, only in handheld mode, not when docked to the PSX; where it's using the PSX power supply instead of the battery).

```

0     Stop Clock (1=Stop)
1-15 ?

```

Wakeup is usually done by IRQ-0 (Fire Button) and IRQ-11 (Docking). If alarm is enabled, then the GUI also enables IRQ-9 (RTC), and compares RTC_TIME against the

alarm setting each time when it wakes up.

Before writing to CLK_STOP, one should do:

```
DAC_CTRL=0           ;\disable sound
IOP_STOP=20h         ;/
LCD_MODE=0          ;-disable video
IRDA=whatever       ;-disable infrared (if it was used)
BATT_CTRL=BATT_CTRL AND FFFFFFFFCh ;do whatever
INT_MASK_SET=801h   ;enable Docking/Fire wakeup interrupts
```

The GUI uses CLK_STOP only for Standby purposes (not for waiting for its 30Hz "frame rate" timer 0 interrupt; maybe that isn't possible, ie. probably CLK_STOP does completely disable the system clock, and thus does stop Timer0-2...?)

0D800000h - IOP_CTRL - Configures whatever...? (R/W)

```
0-3 Probably Direction for IOP_DATA bit0..3 (0=Input, 1=Output)
4-31 Unknown/Unused (seems to be always zero)
```

Unknown. Set to 0000000Fh by BIOS upon reset. Aside from that, the BIOS does never use that register.

0D800004h - IOP_STAT (R) - Read Current bits? -- No, seems to be always 0

0D800004h - IOP_STOP (W) - Set IOP_DATA Bits

0D800008h - IOP_START (W) - Clear IOP_DATA Bits

These two ports are probably accessing a single register, writing "1" bits to IOP_STOP sets bits in that register, and writing "1" bits to IOP_START clears bits... or vice-versa...?

Writing "0" bits to either port seems to leave that bits unchanged. The meaning of most bits is still unknown:

```
0 Unknown, STARTED by Kernel upon reset
1 Red LED, Communication related (START=Whatever, STOP=Whatelse) (?)
2 Unknown, STARTED by Kernel upon reset
3 Unknown, STARTED by Kernel upon reset
4 Never STARTED nor STOPPED by BIOS (maybe an INPUT, read via IOP_DATA)
5 Sound Enable (START=On, STOP=Off)
6 Unknown, STOPPED by Kernel upon reset
7-31 Unknown, never STARTED nor STOPPED by BIOS
```

Aside from Bit1, it's probably not necessary to change the unknown bits...? Sound is usually disabled by setting IOP_STOP=00000020h. IOP_STAT is rarely used. Although, one piece of code in the BIOS disables sound by setting IOP_STOP=IOP_STAT OR 00000020h, that is probably nonsense, probably intended to keep bits stopped if they are already stopped (which would happen anyways), however, the strange code implies that reading from 0D800004h returns the current status of the register, and that the bits in that register seem to be 0=Started, and 1=Stopped...?

0D80000Ch - IOP_DATA (R)

```

0      ?
1      Red LED (0=On, 1=Off)
2      ?
3      ?
4      Seems to be always 1 (maybe Infrared input?)
5-31 Unknown/Unused (seems to be always zero)

```

Unknown. Not used by the BIOS. Reportedly this register is 0010h if IR Connection...? This register is read by Rewrite ID, and by Harvest Moon. Maybe bit4 doesn't mean \<if> IR connection exist, but rather \<contains> the received IR data level...?

0D800020h - BATT_CTRL - Battery Monitor Control?

Unknown. Somehow battery saving related. Upon reset, and upon leaving sleep mode, the BIOS does set BATT_CTRL=00000000h. Before entering sleep mode, it does set BATT_CTRL=BATT_CTRL AND FFFFFFFFCh, whereas, assuming that BATT_CTRL was 00000000h, ANDing it with FFFFFFFFCh would simply leave it unchanged... unless the hardware (or maybe a game) sets some bits in BATT_CTRL to nonzero values...?

Battery Low Interrupt

INT_INPUT.10	IRQ	Battery Low	(0=Normal, 1=Battery Low)
--------------	-----	-------------	---------------------------

Can be used to sense if the battery is low, if so, one may disable sound output and/or reduce the CPU speed to increase the remaining battery lifetime. Unknown how long the battery lasts, and how much the lifetime is affected by audio, video, infrared, cpu speed, and sleep mode...?

The pocketstation can be also powered through the VCC pin (ie. when docked to the PSX, then it's working even if the battery is empty; or even without battery).

13.11 Pocketstation SWI Function Summary

SWI Function Summary

BIOS functions can be called via SWI opcodes (from both ARM and THUMB mode) (in ARM mode, the SWI function number is in the lower 8bit of the 24bit field; unlike as for example on the GBA, where it'd be in the upper 8bit). Parameters (if any) are passed in r0,r1,r2. Return value is stored in r0 (all other registers are left unchanged).

SWI 00h - Reset()	; don't use	out: everything destroyed
SWI 01h - SetCallbacks(index,proc)		out: old proc
SWI 02h - CustomSwi2(r0..r6,r8..r10)		out: r0
SWI 03h - FlashWriteVirtual(sector,src)		out: 0=okay, 1=failed
SWI 04h - SetCpuSpeed(speed)		out: old_speed
SWI 05h - SenseAutoCom()		out: garbage
SWI 06h - GetPtrToComFlags()		out: ptr (usually 0C0h)
SWI 07h - ChangeAutoDocking(flags.16-18)		out: incoming flags AND 70000h
SWI 08h - PrepareExecute(flag,dir_index,param)		out: dir_index (new or old)
SWI 09h - DoExecute(snapshot_saving_flag)		out: r0=r0 (failed) or r0=param
SWI 0Ah - FlashReadSerial()		out: F_SN
SWI 0Bh - ClearComFlagsBit10()		out: new [ComFlags] (with bit10=0)
SWI 0Ch - SetBcdDateTime(date,time)		out: garbage (RTC_DATE/10000h)
SWI 0Dh - GetBcdDate()		out: date (with century in MSBs)
SWI 0Eh - GetBcdTime()		out: time and day-of-week
SWI 0Fh - FlashWriteSerial(serial_number)		out: garbage (r0=0) ;old BIOS only!
SWI 10h - FlashWritePhysical(sector,src)		out: 0=okay, 1=failed
SWI 11h - SetComOnOff(flag)		out: garbage retadr to swi handler
SWI 12h - TestSnapshot(dir_index)		out: 0=normal, 1=MCX1 with 1,0,"SE"
SWI 13h - GetPtrToAlarmSetting()		out: ptr to alarm_setting
SWI 14h - GetPtrToPtrToSwiTable()		out: ptr-to-ptr to swi_table
SWI 15h - MakeAlternateDirIndex(flag,dir_index)		out: alt_dir_index (new/old)
SWI 16h - GetDirIndex()		out: dir_index (or alternate)
SWI 17h - GetPtrToFunc3Addr()		out: ptr to func3 address
SWI 18h - FlashReadWhateverByte(sector)		out: [8000000h+sector*80h+7Eh]
SWI 19h..FFh - garbage		
SWI 100h..FFFFFh - mirrors of SWI 00h..FFh		

The BIOS uses the same memory region for SWI and IRQ stacks, so both may not occur simultaneously, otherwise one stack would be destroyed by the other (normally that is no problem; IRQs are automatically disabled by the CPU during SWI execution, SWIs aren't used from inside of default IRQ handlers, and SWIs shouldn't be used from inside of hooked IRQ handlers).

13.12 Pocketstation SWI Misc Functions

SWI 01h - SetCallbacks(index,proc)

r0=0	Set SWI 02h callback	(r1=proc, or r1=0=reset/default)
r0=1	Set IRQ callback	(r1=proc, or r1=0=none/default)
r0=2	Set FIQ callback	(r1=proc, or r1=0=none/default)
r0=3	Set Download Notification callback	(r1=proc, or r1=0=bugged/default)

All callbacks are called via BX opcodes (ie. proc.bit0 can be set for THUMB code). SetCallbacks returns the old proc value (usually zero). The callbacks are automatically reset to zero when (re-)starting an executable, or when returning control to the GUI, so there's no need to restore the values by software.

IRQ and FIQ Callbacks

Registers r0,r1,r12 are pushed by the kernels FIQ/IRQ handlers (so the callbacks can use that registers without needing to push them). The FIQ handler can additionally use r8..r11 without pushing them (the CPU uses a separate set of r8..r12 registers in FIQ mode, nevertheless, the kernel DOES push r12 in FIQ mode, without reason). Available stack is 70h bytes for the FIQ callback, and 64h bytes for the IRQ callback.

The callbacks don't receive any incoming parameters, and don't need to respond with a return value. The callback should return to the FIQ/IRQ handler (via normal BX r14) (ie. it should not try to return to User mode).

The kernel IRQ handler does (after the IRQ callback) process IRQ-11 (IOP) (which does mainly handle docking/undocking), and IRQ-9 (RTC) (which increments the century if the year wrapped from 99h to 00h).

And the kernel FIQ handler does (before the FIQ callback) process IRQ-6 (COM) (which does, if ComFlags.Bit9 is set, handle bu_cmd's) (both IRQs and FIQs are disabled, and the main program is stopped until the bu_cmd finishes, or until a joypad command is identified irrelevant, among others that means that sound/timer IRQs aren't processed during that time, so audio output may become distorted when docked).

When docked, the FIQ callback should consist of only a handful of opcodes, eg. it may contain a simple noise, square wave generator, or software based sound "DMA" function, but it should not contain more time-consuming code like sound envelope processing; otherwise IRQ-6 (COM) cannot be executed fast enough to handle incoming commands.

SWI 02h - CustomSwi2(r0..r6,r8..r10) out: r0

Calls the SWI2 callback function (which can be set via SWI 01h). The default callback address is 00000000h (so, by default, it behaves identically as SWI 00h). Any parameters can be passed in r0..r6 and r8..r10 (the other registers aren't passed to the callback function). Return value can be stored in r0 (all other registers are pushed/popped by the swi handler, as usually). Available space on the swi stack is 38h bytes. SWI2 can be useful to execute code in privileged mode (eg. to initialize FIQ registers r8..r12 for a FIQ based sound engine) (which usually isn't possible because the main program runs in non-privileged user mode).

SWI 04h - SetCpuSpeed(speed) out: old_speed

Changes the CPU speed. The BIOS uses it with values in range 01h..07h. Unknown if value 00h can be also used? The function also handles values bigger than 07h, of which, some pieces of BIOS code look as if 08h would be the maximum value...? Before setting the new speed, the function sets F_WAIT1 and F_WAIT2 to 00000000h (or to 00000010h if speed.bit3=1). After changing the speed (by writing the parameter to CLK_MODE) it does wait until the new speed is applied (by waiting for CLK_MODE.bit4 to become zero). The function returns the old value of CLK_MODE, anded with 0Fh.

13.13 Pocketstation SWI Communication Functions

Communication (aka BU Commands, received from the PSX via the memory card slot) can be handled by the pocketstations kernel even while a game is running. However, communications are initially disabled when starting a game, so the game should enable them via SWI 11h, and/or via calling SWI 05h once per frame.

SWI 11h - SetComOnOff(flag)

Can be used to enable/disable communication. When starting an executable, communication is initially disabled, so it'd be a good idea to enable them (otherwise the PSX cannot communicate with the Pocketstation while the game is running). When flag=0, disables communication: Intializes the COM_registers, disables IRQ-6 (COM), and clears ComFlags.9. When flag=1, enables communication: Intializes the COM_registers, enables IRQ-6 (COM), sets ComFlags.9 (when docked), or clears Sys.Flags.9 (when undocked), and sets FAST cpu_speed=7 (only when docked). The function returns garbage (r0=retadr to swi_handler).

SWI 06h - GetPtrToComFlags()

Returns a pointer to the ComFlags word in RAM, which contains several communication related flags (which are either modified upon docking/undocking, or upon receiving certain bu_cmd's). The ComFlags word consists of the following bits:

0-3	Whatever (set/cleared when docked/undocked, and modified by bu_cmd's)
4-7	Not used (should be zero)
8	IRQ-11 (IOP) occurred (set by irq handler, checked/cleared by SWI 05h)
9	Communication Enabled And Docked (0=No, 1=Yes; prevents DoExecute)
10	Reject writes to Broken Sector Region (sector 16..55) (0=No, 1=Yes)
11	Start file request (set by bu_cmd_59h, processed by GUI, not by Kernel)
12-15	Not used (should be zero)
16	Automatically power-down DAC audio on insert/removal (0=No, 1=Yes)
17	Automatically power-down IRDA infrared on insert/removal (0=No, 1=Yes)
18	Automatically adjust LCD screen rotate on insert/removal (0=No, 1=Yes)
19-27	Not used (should be zero)
28	Indicates if a standard bu_cmd (52h/53h/57h) was received (0=No, 1=Yes)
29	Set date/time request (set by bu_cmd FUNC0, processed by BIOS)
30	Destroy RTC and Start GUI request (set by bu_cmd_59h, dir_index=FFFEh)
31	Not used (should be zero)

Bit16-18 can be changed via SWI 07h, ChangeAutoDocking(flags). Bit10 can be cleared by SWI 0Bh, ClearComFlagsBit10().

SWI 07h - ChangeAutoDocking(flags.16-18)

0-15	Not used (should be zero)
16	Automatically power-down DAC audio on insert/removal (0=No, 1=Yes)
17	Automatically power-down IRDA infrared on insert/removal (0=No, 1=Yes)
18	Automatically adjust LCD screen rotate on insert/removal (0=No, 1=Yes)
19-31	Not used (should be zero)

Copies bit16-18 of the incoming parameter to ComFlags.16-18, specifying how the kernel IRQ-11 (IOP) handler shall process docking/undocking from the PSX cartridge slot. The function returns the incoming flags value ANDed with 70000h.

SWI 0Bh - ClearComFlagsBit10()

Resets ComFlags.Bit10, ie. enables bu_cmd_57h (write_sector) to write to the Broken Sector region in FLASH memory (sector 16..55). SWI 0Bh returns the current ComFlags value (the new value, with bit10=0).

Aside from calling SWI 0Bh, ComFlags.10 is also automatically cleared upon IRQ-10 (IOP) (docking/undocking). ComFlags.10 can get set/cleared by the Download Notification callback.

SWI 05h - SenseAutoCom()

Checks if docking/undocking has occurred (by examining ComFlags.8, which gets set by the kernel IRQ-11 (IOP) handler). If that flag was set, then the function does reset it, and does then reset FUNC3=0000h and [0CAh]=00h (both only if docked, not when undocked), and, no matter if docked or undocked, it enables communication; equivalent to SetComOnOff(1); which sets/clears ComFlags.9. The function returns garbage (r0=whatever).

The GUI is calling SWI 05h once per frame. The overall purpose is unknown. It's a good idea to reset FUNC3 and to Enable Communication (although that'd be required only when docked, not when undocked), but SWI 05h is doing that only on (un-)docking transitions (not when it was already docked). In general, it'd make more sense to do proper initializations via SWI 11h and SWI 17h than trusting SWI 05h to do the job. The only possibly useful effect is that SWI 05h does set/clear ComFlags.9 when docked/undocked.

SWI 17h - GetPtrToFunc3addr()

Returns a pointer to a halfword in RAM which contains the FUNC3 address (for bu_cmd_5bh and bu_cmd_5ch). The address is only 16bit, originated at 02000000h in FLASH (ie. it can be only in the first 64K of the file), bit0 can be set for THUMB code. The default address is zero, which behaves bugged: It accidentally sets [00000004h]=00000000h, ie. replaces the Undefined Instruction exception vector by a "andeq r0,r0,r0" opcode, due to that NOP-like opcode, any Undefined Instruction exceptions will run into the SWI vector at [00000008h], and randomly execute an SWI function; with some bad luck that may execute one of the FlashWrite functions and destroy the saved files.

Although setting 0000h acts bugged, one should restore that setting before returning control to GUI or other executables; otherwise the address would still point to the FUNC3 address of the old unloaded executable, which is worse than the bugged effect.

The FUNC3 address is automatically reset to 0000h when (if) SWI 05h (SenseAutoCom) senses new docking.

Download Notification callback

Can be used to mute sound during communication, see SWI 01h, SetCallbacks(index,proc), and BU Command 5Dh for details.

13.14 Pocketstation SWI Execute Functions

SWI 08h - PrepareExecute(flag,dir_index,param)

dir_index should be 0=GUI, or 1..15=First block of game. When calling DoExecute, param is passed to the entrypoint of the game or GUI in r0 register (see notes on GUI \<param> values belows). For games, param may be interpreted in whatever way. When flag=0, the function simply returns the old dir_index value. When flag=1, the new dir_index and param values are stored in Kernel RAM (for being used by DoExecute); the values are stored only if dir_index=0 (GUI), or if dir_index belongs to a file with "SC" and "MCX0" or "MCX1" IDs in it's title sector. If dir_index was accepted, then the new dir_index value is returned, otherwise the old dir_index is returned.

GUI \<param> values - for PrepareExecute(1,0,param)

PrepareExecute(1,0,param) prepares to execute the GUI (rather than a file). When executing the GUI, \<param> consists of the following destructive bits:

0-7	Command number (see below, MSBs=Primary command, LSBs=another dir_index)
8	Do not store Alarm setting in Kernel RAM (0=Normal, 1=Don't store)
9-31	Not used (should be zero)

The command numbers can be:

Command 0xh --> Erase RTC time/date
Command 1xh --> Enter GUI Time Screen with speaker symbol
Command 20h --> Enter GUI Time Screen with alarm symbol
Command 2xh --> Prompt for new Date/Time, then start dir_index (x)
Command 3xh --> Enter GUI File Selection Screen, with dir_index (x) selected
Command xxh --> Erase RTC time/date (same as Command 0xh)

For Command 2xh and 3xh, the lower 4bit of the command (x) must be a valid dir_index of the 1st block of a pocketstation executable, otherwise the BIOS erases the RTC time/date. Bit8 is just a "funny" nag feature, allowing the user to change the alarm setting, but with the changes being ignored (bit8 can be actually useful in BU Command 59h, after FUNC2 was used for changing alarm).

SWI 09h - DoExecute(), or DoExecute(snapshot_saving_flag) for MCX1

Allows to return control to the GUI (when dir_index=0), or to start an executable (when dir_index=1..15). Prior to calling DoExecute, parameters should be set via

`PrepareExecute(1,dir_index,param)`, when not doing that, `DoExecute` would simply restart the current executable (which may be a desired effect in some cases).

The "snapshot_saving_flag" can be omitted for normal (MCX0) files, that parameter is used only for special (MCX1) files (see Snapshot Notes for details).

Caution: `DoExecute` fails (and returns `r0=unchanged`) when `ComFlags.9=1` (which indicates that communications are enabled, and that the Pocketstation is believed to be docked to the PSX). `ComFlags.9` can be forcefully cleared by calling `SetComOnOff(0)`, or it can be updated according to the current docking-state by calling `SetComOnOff(1)` or `SenseAutoCom()`.

SWI 16h - GetDirIndex()

Returns the `dir_index` for the currently executed file. If that value is zero, ie. if there is no file executed, ie. if the function is called by the GUI, then it does instead return the "alternate" `dir_index` (as set via SWI 15h).

SWI 15h - MakeAlternateDirIndex(flag,dir_index) out: alt_dir_index (new/old)

Applies the specified `dir_index` as "alternate" `dir_index` (for being retrieved via SWI 16h for whatever purpose). The `dir_index` is applied only when `flag=1`, and only if `dir_index` is 0=none, or if it is equal to the `dir_index` of the currently executed file (ie. attempts to make other files being the "alternate" one are rejected). If successful, the new `dir_index` is returned, otherwise the old `dir_index` is returned (eg. if `flag=0`, or if the index was rejected).

SWI 12h - TestSnapshot(dir_index)

Tests if the specified file contains a load-able snapshot, ie. if it does have the "SC" and "MCX1" IDs in the title sector, and the 01h,00h,"SE" ID in the snapshot header. If so, it returns `r0=1`, and otherwise returns `r0=0`.

Snapshot Notes (MCX1 Files)

Snapshots are somewhat automatically loaded/saved when calling `DoExecute`:

If the old file (the currently executed file) contains "SC" AND "MCX1" IDs in the title sector, then the User Mode CPU registers and User RAM at 200h..7FFh are automatically saved in the files snapshot region in FLASH memory, with the `snapshot_saving_flag` being applied as bit0 of the 0xh,00h,"SE" ID of the snapshot header).

If the new file (specified in `dir_index`) contains load-able snapshot data (ie. if it has "SC" and "MCX1" IDs in title sector, and 01h,00h,"SE" ID in the snapshot region), then the

BIOS starts the saved snapshot data (instead of restarting the executable at its entrypoint). Not too sure if that feature is really working... the snapshot loader seems to load User RAM from the wrong sectors... and it seems to jump directly to User Mode return address... without removing registers that are still stored on SWI stack... causing the SWI stack to underflow after loading one or two snapshots...?

13.15 Pocketstation SWI Date/Time/Alarm Functions

SWI 0Ch - SetBcdDateTime(date,time)

Sets the time and date, the parameters are having the same format as SWI 0Dh and SWI 0Eh return values (see there). The SWI 0Ch return value contains only garbage ($r0=RTC_DATE/10000h$).

SWI 0Dh - GetBcdDate()

0-7	Day	(01h..31h, BCD)
8-11	Month	(01h..12h, BCD)
16-31	Year	(0000h..9999h, BCD)

Returns the current date, the lower 24bit are read from RTC_DATE, the century in upper 8bit is read from Kernel RAM.

SWI 0Eh - GetBcdTime()

0-7	Seconds	(00h..59h, BCD)
8-15	Minutes	(00h..59h, BCD)
16-23	Hours	(00h..23h, BCD)
24-31	Day of week	(1=Sunday, ..., 7=Saturday)

Returns the current time and day of week, read from RTC_TIME.

SWI 13h - GetPtrToAlarmSetting()

Returns a pointer to a 64bit value in Kernel RAM, the upper word (Bit32-63) isn't actually used by the BIOS, except that, the bu_cmd FUNC3 does transfer the whole 64bits. The meaning of the separate bits is:

0-7	Alarm Minute	(00h..59h, BCD)
8-15	Alarm Hour	(00h..23h, BCD)
16	Alarm Enable	(0=Off, 1=On)

```

17   Button Lock      (0=Normal, 1=Lock) (pressing all 5 buttons in GUI)
18-19 Volume Shift    (0=Normal/Loud, 1=Medium/Div4, 2=Mute/Off)
20-22 Not used       (should be zero)
23   RTC Initialized  (0=Not yet, 1=Yes, was initialized from within GUI)
24-31 Not used       (should be zero)
32-63 Pointer to 8x8 BIOS Charset (characters "0"..."9" plus strange symbols)

```

The RTC hardware doesn't have a hardware-based alarm feature, instead, the alarm values must be compared with the current time by software. Alarm is handled only by the GUI portion of the BIOS. The Kernel doesn't do any alarm handling, so alarm won't occur while a game is executed (unless the game contains code that handles alarm). Games are usually using only the lower 16bit of the charset address, ORed with 04000000h (although the full 32bit is stored in RAM).

```

CHR(00h..09h) = Digits "0..9"
CHR(0Ah) = Space " "
CHR(0Bh) = Colon ":" 
CHR(0Ch) = Button Lock (used by Final Fantasy 8's Chocobo World)
CHR(0Dh) = Speaker Medium; or loud if followed by chr(0Eh)
CHR(0Eh) = Speaker Loud; to be appended to chr(0Dh)
CHR(0Fh) = Speaker Off
CHR(10h) = Battery Low (used by PocketMuuMuu's Cars)
CHR(11h) = Alarm Off
CHR(12h) = Alarm On
CHR(13h) = Memory Card symbol

```

13.16 Pocketstation SWI Flash Functions

SWI 10h - FlashWritePhysical(sector,src)

Writes 80h-bytes at src to the physical sector number (0..3FFh, originated at 08000000h), and does then compare the written data with the source data. Returns 0=okay, or 1=failed.

SWI 03h - FlashWriteVirtual(sector,src)

The sector number (0..3FFh) is a virtual sector number (originated at 02000000h), the function uses the F_BANK_VAL settings to translate it to a physical sector number, and does then write the 80h-bytes at src to that location (via the FlashWritePhysical function). Returns 0=okay, or 1=failed (if the write failed, or if the sector number exceeded the filesize aka the virtually mapped memory region).

SWI 0Ah - FlashReadSerial()

Returns the 32bit value from the two 16bit F_SN registers (see F_SN for details).

SWI 0Fh - FlashWriteSerial(serial_number) ;old BIOS only!

Changes the 32bit F_SN value in the "header" region of the FLASH memory. The function also rewrites the F_CAL value (but it simply rewrites the old value, so it's left unchanged). The function isn't used by the BIOS, no idea if it is used by any games. No return value (always returns r0=0).

This function is supported by the old "061" version BIOS only (the function is padded with jump opcodes which hang the CPU in endless loops on newer "110" version).

SWI 18h - FlashReadWhateverByte(sector)

Returns [8000000h+sector*80h+7Eh] AND 00FFh. Purpose is totally unknown... the actual FLASH memory doesn't contain any relevant information at that locations (eg. the in the directory sectors, that byte is unused, usually zero)... and, reading some kind of status or manufacturer information would first require to command the hardware to output that info...?

13.17 Pocketstation SWI Useless Functions

SWI 00h - Reset() ;don't use, destroys RTC settings

Reboots the pocketstation, similar as when pressing the Reset button. Don't use! The BIOS bootcode does (without any good reason) reset the RTC registers and alarm/century settings in RAM to Time 00:00:00, Date 01 Jan 1999, and Alarm 00:00 disabled, so, after reset, the user would need to re-enter that values.

Aside from the annoying destroyed RTC settings, the function is rather unstable: it does jump to address 00000000h in RAM, which should usually redirect to 04000000h in ROM, however, most pocketstation games are programmed in C language, where "pointer" is usually pronounced "pointer?" without much understanding of whether/why/how to initialize that "strange things", so there's a good probability that one of the recently executed games has accidentally destroyed the reset vector at [00000000h] in battery-backed RAM.

SWI 14h - GetPtrToPtrToSwiTable()

Returns a pointer to a word in RAM, which contains another pointer which usually points to SWI table in ROM. Changing that word could be (not very) useful for setting up a custom SWI table in FLASH or in RAM. When doing that, one must restore the original setting before returning control to the GUI or to another executable (the setting isn't automatically restored).

13.18 Pocketstation BU Command Summary

The Pocketstation supports the standard Memory Card commands (Read Sector, Write Sector, Get Info), plus a couple of special commands.

BU Command Summary

```

50h Change a FUNC 03h related value or so
51h N/A
52h Standard Read Sector command
53h Standard Get ID command
54h N/A
55h N/A
56h N/A
57h Standard Write Sector command
58h Get an ID or Version value or so
59h Prepare File Execution with Dir_index, and Parameter
5Ah Get Dir_index, ComFlags, F_SN, Date, and Time
5Bh Execute Function and transfer data from Pocketstation to PSX
5Ch Execute Function and transfer data from PSX to Pocketstation
5Dh Execute Custom Download Notification Function ;via SWI 01h with r0=3
5Eh Get-and-Send ComFlags.bit1,3,2
5Fh Get-and-Send ComFlags.bit0

```

Commands 5Bh and 5Ch can use the following functions:

```

FUNC 00h - Get or Set Date/Time
FUNC 01h - Get or Set Memory Block
FUNC 02h - Get or Set Alarm/Flags
FUNC 03h - Custom Function 3 ;via SWI 17h, GetPtrToFunc3addr()
FUNC 80h..FFh - Custom Functions 80h..FFh ;via Function Table in File Header

```

13.19 Pocketstation BU Standard Memory Card Commands

For general info on the three standard memory card commands (52h, 53h, 57h), and for info on the FLAG response value, see:

[Memory Card Read/Write Commands](#)

BU Command 52h (Read Sector)

Works much as on normal memory cards, except that, on the Pocketstation, the Read Sector command return 00h as dummy values; instead of the "(pre)" dummies that occur on normal memory cards.

The Read Sector command does reproduce the strange delay (that occurs between 5Ch and 5Dh bytes), similar as on normal original Sony memory cards, maybe original cards did (maybe) actually DO something during that delay period, the pocketstation BIOS simply blows up time in a wait loop (maybe for compatibility with original cards).

BU Command 53h (Get ID)

The Get ID command (53h) returns exactly the same values as normal original Sony memory cards.

BU Command 57h (Write Sector)

The Write Sector command has two new error codes (additonally to the normal 47h="G"=Good, 4Eh="N"=BadChecksum, FFh=BadSector responses). The new error codes are (see below for details):

```
FDh Reject write to Directory Entries of currently executed file
FEh Reject write to write-protected Broken Sector region (sector 16..55)
```

And, like Read Sector, it returns 00h instead of "(pre)" as dummy values.

Write Error Code FDh (Directory Entries of currently executed file)

The FDh error code is intended to prevent the PSX bootmenu (or other PSX games) to delete the currently executed file (which would crash the pocketstation - once when the deleted region gets overwritten by a new file), because the PSX bootmenu and normal PSX games do not recognize the new FDh error code the pocketstation does additionally set FLAG.3 (new card), which should be understood by all PSX programs.

The FDh error code occurs only on directory sectors of the file (not on its data blocks).

However, other PSX games should never modify files that belong to other games (so there should be no compatibility problem with other PSX programs that aren't aware of the file being containing currently executed code).

However, the game that has created the executable pocketstation file must be aware of that situation. If the file is broken into a Pocketstation Executable region and a PSX Gameposition region, then it may modify the Gameposition stuff even while the Executable is running. If the PSX want to overwrite the executable then it must first ensure that it isn't executed (eg. by retrieving the dir_index of the currently executed file via BU Command 5Ah, and comparing it against the first block number in the files FCB at the PSX side; for file handle "fd", the first block is found at "[104h]+fd*2Ch+24h" in PSX memory).

Write Error Code FEh (write-protected Broken Sector region, sector 16..55)

The write-protection is enabled by ComFlags.bit10 (which can be set/cleared via BU Command 5Dh). That bit should be set before writing Pocketstation executables (the Virtual Memory banking granularity is 2000h bytes, which allows to map whole blocks only, but cannot map single sectors, which would be required for files with broken sector replacements).

Unlike Error FDh, this error code doesn't set FLAG.3 for notifying normal PSX programs about the error (which is no problem since normally Error FEh should never occur since ComFlags.10 is usually zero). For more info on ComFlags.10, see SWI 0Bh aka ClearComFlagsBit10(), and BU Command 5Dh.

13.20 Pocketstation BU Basic Pocketstation Commands

BU Command 50h (Change a FUNC 03h related value or so)

```
Send Reply Comment
81h N/A   Memory Card Access
50h FLAG  Send Command 50h
VAL 00h   Send new [0CAh], receive length of following data (00h)
```

Might be somehow related to FUNC 03h...?

BU Command 58h (Get an ID or Version value or so)

```
Send Reply Comment
81h N/A   Memory Card Access
58h FLAG  Send Command 58h
```

(0)	02h	Send dummy/zero, receive length of following data (02h)
(0)	01h	Send dummy/zero, receive whatever value (01h)
(0)	01h	Send dummy/zero, receive another value (01h)

BU Command 59h (Prepare File Execution with Dir_index, and Parameter)

Send	Reply	Comment
81h	N/A	Memory Card Access
59h	FLAG	Send Command 59h
(0)	06h	Send dummy/zero, receive length of following data (06h)
NEW	OLD	Send new dir_index.8-15, receive old dir_index.8-15
NEW	OLD	Send new dir_index.0-7, receive old dir_index.0-7
PAR	(0)	Send exec_parameter.0-7, receive dummy/zero
PAR	(0)	Send exec_parameter.8-15, receive dummy/zero
PAR	(0)	Send exec_parameter.16-23, receive dummy/zero
PAR	(0)	Send exec_parameter.24-31, receive dummy/zero

The new dir_index can be the following:

0000h..000Fh	--> Request to Start GUI or File (with above parameter bits)
0010h..FFFFDh	--> Not used, acts same as FFFFh (see below)
FFFEh	--> Request to Destroy RTC and Start GUI (with parameter 00000000h)
FFFFh	--> Do nothing (transfer all bytes, but don't store the new values)

Upon dir_index=0000h (Start GUI) or 0001..000Fh (start file), a request flag in ComFlags.11 is set, the GUI does handle that request, but the Kernel doesn't handle it (so it must be handled in the game; ie. check ComFlags.11 in your mainloop, and call DoExecute when that bit is set, there's no need to call PrepareExecute, since that was already done by the BU Command).

Caution: When dir_index=0000h, then \<param> should be a value that does NOT erase the RTC time/date (eg. 10h or 20h) (most other values do erase the RTC, see SWI 08h for details).

Upon dir_index=FFFEh, a similar request flag is set in ComFlags.30, and, the Kernel (not the GUI) does handle that request in its FIQ handler (however, the request is: To reset the RTC time/date and to start the GUI with uninitialized irq/svc stack pointers, so this unpleasant and bugged feature shouldn't ever be used). Finally, dir_index=FFFFh allows to read the current dir_index value (which could be also read via BU Command 5Ah).

BU Command 5Ah (Get Dir_index, ComFlags, F_SN, Date, and Time)

Send	Reply	Comment
81h	N/A	Memory Card Access
5Ah	FLAG	Send Command 5Ah
(0)	12h	Send dummy/zero, receive length of following data (12h)

(0)	INDX	Send dummy/zero, receive curr_dir_index.bit8-15	(00h)
(0)	INDX	Send dummy/zero, receive curr_dir_index.bit0-7	(00h..0Fh)
(0)	FLG	Send dummy/zero, receive ComFlags.bit0	(00h or 01h)
(0)	FLG	Send dummy/zero, receive ComFlags.bit1	(00h or 01h)
(0)	FLG	Send dummy/zero, receive ComFlags.bit3	(00h or 01h)
(0)	FLG	Send dummy/zero, receive ComFlags.bit2	(00h or 01h)
(0)	SN	Send dummy/zero, receive F_SN.bit0-7	(whatever)
(0)	SN	Send dummy/zero, receive F_SN.bit8-15	(whatever)
(0)	SN	Send dummy/zero, receive F_SN.bit16-23	(whatever)
(0)	SN	Send dummy/zero, receive F_SN.bit24-31	(whatever)
(0)	DATE	Send dummy/zero, receive BCD Day	(01h..31h)
(0)	DATE	Send dummy/zero, receive BCD Month	(01h..12h)
(0)	DATE	Send dummy/zero, receive BCD Year	(00h..99h)
(0)	DATE	Send dummy/zero, receive BCD Century	(00h..99h)
(0)	TIME	Send dummy/zero, receive BCD Second	(00h..59h)
(0)	TIME	Send dummy/zero, receive BCD Minute	(00h..59h)
(0)	TIME	Send dummy/zero, receive BCD Hour	(00h..23h)
(0)	TIME	Send dummy/zero, receive BCD Day of Week	(01h..07h)

At midnight, the function may accidentally return the date for the old day, and the time for the new day.

BU Command 5Eh (Get-and-Send ComFlags.bit1,3,2)

Send Reply Comment			
81h	N/A	Memory Card Access	
5Eh	FLAG	Send Command 5Eh	
(0)	03h	Send dummy/zero, receive length of following data (03h)	
NEW	OLD	Send new ComFlags.bit1, receive old ComFlags.bit1 (00h or 01h)	
NEW	OLD	Send new ComFlags.bit3, receive old ComFlags.bit3 (00h or 01h)	
NEW	OLD	Send new ComFlags.bit2, receive old ComFlags.bit2 (00h or 01h)	

BU Command 5Fh (Get-and-Send ComFlags.bit0)

Send Reply Comment			
81h	N/A	Memory Card Access	
5Fh	FLAG	Send Command 5Fh	
(0)	01h	Send dummy/zero, receive length of following data (01h)	
NEW	OLD	Send new ComFlags.bit0, receive old ComFlags.bit0 (00h or 01h)	

13.21 Pocketstation BU Custom Pocketstation Commands

BU Command 5Bh (Execute Function and transfer data from Pocketstation to PSX)

Send Reply Comment			
81h	N/A	Memory Card Access	

```

5Bh FLAG Send Command 5Bh
FUNC FFh Send Function Number, receive FFh (indicating variable length)
(0) LEN1 Send dummy/zero, receive length of parameters (depending on FUNC)
... (0) Send parameters (LEN1 bytes), and receive dummy/zero
<----- at this point, the function is executed for the first time
(0) LEN2 Send dummy/zero, receive length of data (depending on FUNC)
(0) ... Send dummy/zero, receive data (LEN2 bytes) from pocketstation
(0) FFh Send dummy/zero, receive FFh
<----- at this point, the function is executed for the second time

```

See below for more info on the FUNC value and the corresponding functions.

BU Command 5Ch (Execute Function and transfer data from PSX to Pocketstation)

```

Send Reply Comment
81h N/A Memory Card Access
5Ch FLAG Send Command 5Ch
FUNC FFh Send Function Number, receive FFh (indicating variable length)
(0) LEN1 Send dummy/zero, receive length of parameters (depending on FUNC)
... (0) Send parameters (LEN1 bytes), and receive dummy/zero
<----- at this point, the function is executed for the first time
(0) LEN2 Send dummy/zero, receive length of data (depending on FUNC)
... (0) Send data (LEN2 bytes) to pocketstation, receive dummy/zero
(0) FFh Send dummy/zero, receive FFh
<----- at this point, the function is executed for the second time

```

See below for more info on the FUNC value and the corresponding functions.

BU Command 5Dh (Execute Custom Download Notification Function)

Can be used to notify the GUI (or games that do support this function) about following "download" operations (or uploads or other BU commands).

BU commands are handled inside of the kernels FIQ handler, that means both IRQs and FIQs are disabled during a BU command transmission, so any IRQ or FIQ based audio frequency generators will freeze during BU commands. To avoid distorted noise, it's best to disable sound for the duration specified in bit0-7. If the PSX finishes before the originally specified duration has expired, then it can resend this command with bit8=1 to notify the pocketstation that the "download" has completed.

```

Send Reply Comment
81h N/A Memory Card Access
5Dh FLAG Send Command 5Dh
(0) 03h Send dummy/zero, receive length of following data (03h)
VAL (0) Send receive value.16-23 (whatever), receive dummy/zero
VAL (0) Send receive value.8-15 (download flags), receive dummy/zero
VAL (0) Send receive value.0-7 (download duration), receive dummy/zero

```

The Download Notification callback address can be set via SWI 01h, SetCallbacks(3,proc), see there for details. At kernel side, the function execution is like so:

```
If value.8-15 = 00h, then ComFlags.bit10=1, else ComFlags.bit10=0.  
If download_callback<>0 then call download_callback with r0=value.0-23.
```

In the GUI, the bu_cmd_5dh_hook/callback handles parameter bits as so (and games should probably handle that bits in the same fashion, too):

```
bit0-7 download duration (in whatever units... 30Hz, RTC, seconds...?)  
bit8 download finished (0=no, 1=yes, cancel any old/busy duration)  
bit9-23 not used by gui
```

If PSX games send any of the standard commands (52h,53h,57h) to access the memory card without using command 5Dh, then GUI automatically sets the duration to 01h (and pauses sound only for that short duration).

FUNC 00h - Get or Set Date/Time (FUNC0)

LEN1 is 00h (no parameters), and LEN2 is 08h (eight data bytes):

DATE	Get or Send BCD Day	(01h..31h)
DATE	Get or Send BCD Month	(01h..12h)
DATE	Get or Send BCD Year	(00h..99h)
DATE	Get or Send BCD Century	(00h..99h)
TIME	Get or Send BCD Second	(00h..59h)
TIME	Get or Send BCD Minute	(00h..59h)
TIME	Get or Send BCD Hour	(00h..23h)
TIME	Get or Send BCD Day of Week	(01h..07h)

At midnight, the function may accidentally return the date for the old day, and the time for the new day.

FUNC 01h - Get or Set Memory Block (FUNC1)

LEN1 is 05h (five parameters bytes):

ADDR	Send Pocketstation Memory Address.bit0-7
ADDR	Send Pocketstation Memory Address.bit8-15
ADDR	Send Pocketstation Memory Address.bit16-23
ADDR	Send Pocketstation Memory Address.bit24-31
LEN2	Send Desired Data Length (00h..80h, automatically clipped to max=80h)

LEN2 is variable (using the 5th byte of the above parameters):

```
... Get or Send LEN2 Data byte(s), max 80h bytes
```

Can be used to write to RAM (and eventually also to I/O ports; when you know what you are doing). In the read direction it can read almost anything: RAM, BIOS ROM, I/O Ports, Physical and Virtual FLASH memory. Of which, trying to read unmapped Virtual FLASH does probably (?) cause a Data Abort exception (and crash the Pocketstation), so that region may be read only if a file is loaded (check that dir_index isn't zero, via BU Command 5Ah, and, take care not to exceed the filesize of that file).

BUG: When sending more than 2 data bytes in the PSX-to-Pocketstation direction, then ADDR must be word-aligned (the BIOS tries to handle odd destination addresses, but when doing that, it messes up the alignment of another internal pointer).

FUNC 02h - Get or Set Alarm/Flags (FUNC2)

LEN1 is 00h (no parameters), and LEN2 is 08h (eight data bytes):

```
DATA Get or Send Alarm.bit0-7, Alarm Minute (00h..59h, BCD)
DATA Get or Send Alarm.bit8-15, Alarm Hour (00h..23h, BCD)
DATA Get or Send Alarm.bit16-23, Flags, see SWI 13h, GetPtrToAlarmSetting()
DATA Get or Send Alarm.bit24-31, Not used (usually 00h)
DATA Get or Send Alarm.bit32-39, BIOS Charset Address.0-7
DATA Get or Send Alarm.bit40-47, BIOS Charset Address.8-15
DATA Get or Send Alarm.bit48-55, BIOS Charset Address.16-23
DATA Get or Send Alarm.bit56-63, BIOS Charset Address.24-31
```

Changing the alarm value while the GUI is running works only with some trickery: For a sinister reason, the GUI copies the alarm setting to User RAM when it gets started, that copy isn't affected by FUNC2, so the GUI believes that the old alarm setting does still apply (and writes that old values back to Kernel RAM when leaving the GUI). The only workaround is:

Test if the GUI is running, if so, restart it via Command 59h (with dir_index=0, and param=0120h or similar, ie. with param.bit8 set), then execute FUNC2, then restart the GUI again (this time with param.bit8 zero).

FUNC 03h - Custom Function 3 (aka FUNC3)

LEN1 is 04h (fixed) (four parameters bytes):

```
VAL Send Parameter Value.bit0-7
VAL Send Parameter Value.bit8-15
```

```
VAL Send Parameter Value.bit16-23
VAL Send Parameter Value.bit24-31
```

LEN2 is variable (depends on the return value of the 1st function call):

```
... Get or Send LEN2 Data byte(s)
```

The function address can be set via SWI 17h, GetPtrToFunc3addr(), see there for details. Before using FUNC 03h one must somehow ensure that the desired file is loaded (and that it does have initialized the function address via SWI 17h, otherwise the pocketstation would crash).

The FUNC3 address is automatically reset to 0000h when (if) SWI 05h (SenseAutoCom) senses new docking.

Note: The POC-XBOO circuit uses FUNC3 to transfer TTY debug messages.

FUNC 80h..FFh - Custom Function 80h..FFh

LEN1 is variable (depends on the LEN1 value in Function Table in File Header):

```
... Send LEN1 Parameter Value(s), max 80h bytes (destroys Kernel when >80h)
```

LEN2 is variable (depends on the return value of the 1st function call):

```
... Get or Send LEN2 Data byte(s), max 80h bytes (clipped to max=80h)
```

The function addresses (and LEN1 values) are stored in the Function Table FLASH memory (see Pocketstation File Header for details).

```
;above LEN1 should be 00h..80h (the parameters are stored
;in a 80h-byte buffer in kernel RAM, so len LEN1=81h..FFh would
;destroy the kernel RAM that is located after that buffer)
```

Before using FUNC 80h..FFh one must somehow ensure that the desired file is loaded (ie. that the function table with the desired functions is mapped to flash memory; otherwise the pocketstation would crash).

First Function Call (Pre-Data)

Incoming parameters on 1st Function Call:

```
r0=flags (09h=Pre-Data to PSX, or 0Ah=Pre-Data from PSX)
r1=pointer to parameter buffer (which contains LEN1 bytes) (in Kernel RAM)
```

Return Value on 1st Function Call:

```
r0 = Pointer to 64bit memory location (or r0=00000000h=Failed)
```

That 64bits are:

```
0-31    BUF2 address of data buffer (src/dst)
32-63    LEN2 (00000000h..00000080h) (clipped to max 00000080h if bigger)
```

dst is written in 8bit units

src is read in 16bit units (and then split to 8bit units)

Second Function Call (Post-Data)

Incoming parameters on 2nd Function Call:

```
r0=flags (11h=Post-Data to PSX, 12h=Post-Data from PSX; plus 04h if Bad-Data)
r1=pointer to data buffer (which contains LEN2 bytes) (BUF2 address)
```

Return Value on 2nd Function Call:

```
There's no return value required on 2nd call (although the kernel
functions seem to return the same stuff as on 1st call).
```

Function flags (r0)

For each function, there is only one single function vector which is called for both To- and From-PSX, and both Pre- and Post-Data, and also on errors. The function must decipher the flags in r0 to figure out which of that operations it should handle:

```
0    To-PSX  (when used by Command 5Bh)
1    From-PSX (when used by Command 5Ch)
2    Error occurred during Data transfer
3    Pre-Data
4    Post-Data
5-31 Not used (zero)
```

There are only six possible flags combinations:

```
09h Pre-Data to PSX
0Ah Pre-Data from PSX
11h Post-Data to PSX
12h Post-Data from PSX
15h Post-Bad-Data to PSX
16h Post-Bad-Data from PSX
```

The kernel doesn't call FUNC 03h if the Error bit is set (ie. Post-Bad-Data needs to be handled only by FUNC 80h..FFh, not by FUNC 03h.)

13.22 Pocketstation File Header/Icons

Pocketstation File Content

Pocketstation files consists of the following elements (in that order):

```
PSX Title Sector ;80h bytes
PSX Colored Icon(s) ;(hdr[02h] AND 0Fh)*80h bytes
Pocketstation Saved Snapshot ;800h bytes if hdr[52h]=="MCX1", else 0 bytes
Pocketstation Function Table ;(hdr[57h]*8+7Fh) AND NOT 7Fh bytes
Pocketstation File Viewer Mono Icon ;hdr[50h]*80h bytes
Pocketstation Executable Mono Icon List ;hdr[56h]*8 bytes
Body (Pocketstation Executable Code/Data, PSX Game Position, Exec-Icons)
```

The Title sector contains some information about the size of the above regions, but not about their addresses (ie. to find a given region, one must compute the size of the preceding regions).

Special "P" Filename in Directory Sector

For pocketstation executables, the 7th byte of the filename must be a "P" (for other files that location does usually contain a "-", assuming the file uses a standard filename, eg. "BESLES-12345abcdefgh" for a Sony licensed european title).

Special Pocketstation Entries in the Title Sector at [50h..5Fh]

```
50h 2 Number of File Viewer Mono Icon Frames (or 0000h=Use Exec-Icons)
52h 4 Pocketstation Identifier ("MCX0"=Normal, "MCX1"=With Snapshot)
56h 1 Number of entries in Executable Mono Icon List (01h..FFh)
57h 1 Number of BU Command 5Bh/5Ch Get/Set Functions (00h..7Fh, usually 00h)
```

58h 4	Reserved (zero)
5Ch 4	Entrypoint in FLASH1 (ie. Fileoffset plus 02000000h) (bit0=THUMB)

In normal PSX files, the region at 50h..5Fh is usually zerofilled. For more info on the standard entries in the Title Sector (and for info on Directory Entries), see:

[Memory Card Data Format](#)

Snapshot Region (in "MCX1" Files only)

For a loadable snapshot the Snapshot ID must be 01h,00h,"SE", the Kernel uses snapshots only once (after loading a snapshot, it forcefully changes the ID to 00h, 00h,"SE" in FLASH memory).

000h	r1..r12 (ie. without r0)
030h	r13_usr (sp_usr)
034h	r14_usr (lr_usr)
038h	r15 (pc)
03Ch	psr_fc
040h	Snapshot ID (0xh,00h,"SE")
044h	unused (3Ch bytes)
200h	Copy of user RAM at 200h..7FFh

For MCX1 files, snapshots can be automatically loaded and saved via the SWI 09h, DoExecute function (the snapshot handling seems to be bugged though; see SWI 09h for details).

Function Table (FUNC 80h..FFh)

The table can contain 00h..7Fh entries, for FUNC 80h..FFh. Each entry occupies 8 bytes:

00h 4	LEN1 (00000000h..00000080h) (destroys Kernel RAM if bigger)
04h 4	Function Address (bit0 can be set for THUMB code)

If the number of table entries isn't a multiple of 10h, then the table should be zero-padded to a multiple of 80h bytes (the following File Viewer Mono Icon data is located on the next higher 80h-byte boundary after the Function Table).

For details see BU Commands 5Bh and 5Ch.

File Viewer Mono Icon

Animation Length (0001h..any number) (icon frames) is stored in hdr[50h], for the File Viewer Icon, the Animation Delay is fixed (six 30Hz units per frame).

The File Viewer Icon is shown in the Directory Viewer (which is activated when holding

the Down-button pressed for some seconds in the GUI screen with the speaker and memory card symbols, and which shows icons for all files, including regular PSX game positions, whose colored icons are converted without any contrast optimizations to unidentify-able dithered monochrome icons). If the animation length of the File Viewer Icon is 0000h, then the Directory Viewer does instead display the first Executable Mono Icon.

Each icon frame is 32x32 pixels with 1bit color depth (32 words, =128 bytes),

```
1st word = top-most scanline, 31st word = bottom-most scanline
bit0 = left-most pixel, bit31 = right-most pixel (0=white, 1=black)
```

A normal icon occupies 80h bytes, animated icons have more than one frame and do occupy N*80h bytes.

Executable Mono Icon List

The number of entries in the Executable Mono Icon List is specified in `hdr[56h]` (usually 01h). Each entry in the Icon List occupies 8 bytes:

```
00h 2 Animation Length (0001h..any number) (icon frames)
02h 2 Animation Delay (N 30Hz units per icon frame)
04h 4 Address of icon frame(s) in Virtual FLASH (at 02000000h and up)
```

The icon frame(s) can be anywhere on a word-aligned location in the file Body (as specified in the above Address entry), the format of the frame(s) is the same as for File Viewer Mono Icons (see there).

The Executable Icons are shown in the Executable File Selection Menu (which occurs when pressing Left/Right buttons in the GUI). Pressing Fire button in that menu starts the selected executable. If the Icon List has more than 1 entry, then pressing Up/Down buttons moves to the previous/next entry (this just allows to view the corresponding icons, but doesn't have any other purpose, namely, the current list index is NOT passed to the game when starting it).

The Executable Mono Icon List is usually zero-padded to 80h-bytes size (although that isn't actually required, the following file Body could start at any location).

Entrypoint

The whole file (including the header and icons) gets mapped to 02000000h and up. The entrypoint can be anywhere in the file Body, and it gets called with a parameter value in r0 (when started by the GUI, that parameter is always zero, but it may be nonzero when

the executable was started by a game, ie. the \<param> from SWI 08h, PrepareExecute, or the \<param> from BU Command 59h).

Caution: Games (and GUI) are started with the ARM CPU running in Non-privileged User Mode (however, there are several ways to hook IRQ/FIQ handlers, and from there one can switch to Privileged System Mode).

Returning to the GUI

Games should always include a way to return to the GUI (eg. an option in the game over screen, a key combination, a watchdog timer, and/or the docking signal) (conventionally, games should prompt Exit/Continue when holding Fire pressed for 5 seconds), otherwise it wouldn't be possible to start other games - except by pushing the Reset button (which is no good idea since the bizarre BIOS reset handler does reset the RTC time for whatever reason).

The kernel doesn't pass any return address to the entrypoint (neither in R14, nor on stack). To return control to the GUI, use SWI functions

PrepareExecute(1,0,GetDirIndex() + 30h), and then DoExecute(0).

13.23 Pocketstation File Images

Pocketstation files are normally stored in standard Memory Card images,
[Memory Card Images](#)

Pocketstation specific files

Aside from that standard formats, there are two Pocketstation specific formats, the "SC" and "SN" variants. Both contain only the raw file, without any Directory sectors, and thus not including a "BESLESP12345"-style filename string. The absence of the filename means that a PSX game couldn't (re-)open these files via filenames, so they are suitable only for "standalone" pocketstation games.

Pocketstation .BIN Files ("SC" variant)

Contains the raw Pocketstation Executable (ie. starting with the "SC" bytes in the title sector, followed by icons, etc.), the filesize should be padded to a 2000h-byte block boundary.

Pocketstation .BIN Files ("SN" variant)

This is a strange incomplete .BIN file variant which starts with a 4-byte ID ("SN",00h, 00h), which is directly followed by executable code, without any title sector, and without any icons.

It seems as if the file (including the 4-byte ID) is intended to be mapped to address 02000000h, and that the entrypoint is fixed at 02000004h (in ARM state).

Since the File doesn't have a valid file header with "SC" and "MCXn" IDs, it won't be recognized by real hardware, the PSX BIOS would treat it as a corrupted/deleted file, the Pocketstation BIOS would treat it as a non-executable file.

So, that fileformat is apparently working only on whatever emulators, apparently on the one developed by SN Systems.

If one should want to use that files on real hardware, one could add a 2000h byte stub at the begin of the file; with valid headers, and with a small executable that remaps the "SN" stuff to 02000000h via the F_BANK_VAL registers.

Ah, and the "SN" files seem to access RAM at 01000000h and up, unknown if RAM is mirrored to that location on real hardware, reportedly that region is unused... and doesn't contain RAM...?

Some games use The Undefined Instruction for TTY Output.

Most games do strange 8bit writes to LCD_MODE+0 and LCD_MODE+1

The games usually don't allow to return to the GUI (except by Reset).

The filesize is don't care (no padding to block, sector, word, or halfword boundaries required).

13.24 Pocketstation XBOO Cable

This circuit allows to connect a pocketstation to PC parallel port, allowing to upload executables to real hardware, and also allowing to download TTY debug messages (particulary useful as the 32x32 pixel LCD screen is ways too small to display any detailed status info).

POC-XBOO Circuit

Use a standard parallel port cable (with 36pin centronics connector or 25pin DB connector) and then build a small adaptor like this:

Pin	CNTR	DB25	Pocketstation	
ACK	10	10	-----	1 JOYDTA
D0	2	2	-----	2 JOYCMD
GND	19-30	18-25	-----	4 GND

9	7	6	5	4	3	2	1	CARD
_____	_____	_____	_____	_____	_____	_____	_____	_____

```

D1 3 3 ----- 6 /JOYSEL
D2 4 4 ----- 7 JOYCLK
PE 12 12 ----- 9 /JOYACK (/IRQ7) | 9 8 7 | 6 5 4 | 3 2 1 | PAD
NC ----- 8 /JOYGUN (/IRQ10) \_____|_____|_____|/
NC ----- 3 7.5V (rumble.supply)
SUPPLY.5V --|>|---|>|--- 5 3.5V (VCC) (eg. PC's +5V via two 1N4001 diodes)
SUPPLY.0V ----- 4 GND (not needed when same as GND on CNTR/DB25)

```

The circuit is same as for "Direct Pad Pro" (but using a memory card connector instead of joypad connector, and needing +5V from PC power supply instead of using parallel port D3..D7 as supply). Note: IRQ7 is optional (for faster/early timeout).

POC-XBOO Upload

The upload function is found in no\$gba "Utility" menu. It does upload the executable and autostart it via standard memory card/pocketstation commands (ie. it doesn't require any special transmission software installed on the pocketstation side).

Notes: Upload is overwriting ALL files on the memory card, and does then autostart the first file. Upload is done as "read and write only if different", this provides faster transfers and higher lifetime.

POC-XBOO TTY Debug Messages

TTY output is conventionally done by executing the ARM CPU's Undefined Opcode with an ASCII character in R0 register (for that purpose, the undef opcode handler should simply point to a MOVS PC,LR opcode).

That kind of TTY output works in no\$gba's pocketstation emulation. It can be also used via no\$gba's POC-XBOO cable, but requires some small customization in the executable: First of, the executable needs "TTY+" ID in some reserved bytes of the title sector (telling the xboo uploader to stay in transmission mode and to keep checking for TTY messages after the actual upload):

```
TitleSector[58h] = "TTY+"
```

With that ID, and with the XBOO-hardware being used, the game will be started with with "TTY+" in R0 (notifying it that the XBOO hardware is present, and that it needs to install special transmission handlers):

```

;-----
.data?
.org 200h
...
tty_bufsiz equ 128 ;max=128=fastest (can be smaller if you are short of RAM)

```

```

func3_info:                                ;\ ;\
func3_buf_base    dd 0      ;fixed="func3_buf"      ; ;  func3_info+00h
func3_buf_len     dd 0      ;range=0..128          ;/ ;  func3_info+04h
func3_stack       dd 0      ;                         ;  func3_info+08h
func3_buffer:      defs tty_bufsiz           ;/ func3_info+0Ch
ptr_to_comflags   dd 0

...
.code
...
;-----
tty_wrchr:   ;in: r0=char
  dd      0e6000010h ;=undef opcode             ;-Write chr(r0) to TTY
  bx      lr

;-----
init_tty:   ;in: r0=param (from entrypoint)
  ldr    r1,=2B595454h ;"TTY+"                  ;\check if xboo-cable present
  cmp    r1,r0          ; (r0=incoming param from
  beq    @@tty_by_xboo_cable ;/executable's entrypoint)
;-- -
  mov    r1,0            ;\dummy und_handler
  ldr    r2,=0e1b0f00eh  ;=movs r15,r14        ; (just return from exception,
  str    r2,[r1,04h]    ;und_handler           ;/for normal cable-less mode)
  b     @@finish

;---
@@tty_by_xboo_cable:
  swi    17h  ;GetPtrToFunc3addr()             ;\
  ldr    r1,=(tty_func3_handler AND 0ffffh)  ; init FUNC3 aka TTY handler
  strh  r1,[r0]                      ;/
  ldr    r1,=func3_info                ;\
  mov    r0,0            ;\ ; mark TTY as len=empty
  str    r0,[r1,4]      ;func3_buf_len    ;/ ; and
  add    r0,r1,0ch      ;=func3_buffer      ;\ ; init func3 base
  str    r0,[r1,0]      ;func3_buf_base   ;/ ;/
  mov    r1,0            ;\
  ldr    r2,=0e59ff018h  ;=ldr r15,[pc,NN]   ;
  str    r2,[r1,04h]    ;und_handler         ; special xboo und_handler
  add    r2,=tty_xboo_und_handler      ;
  str    r2,[r1,24h]    ;und_vector        ;/
@@finish:
  swi    06h ;GetPtrToComFlags()             ;\
  ldr    r1,=ptr_to_comflags            ; get ptr to ComFlags
  str    r0,[r1]                      ;/
  bx    lr

;-----
tty_xboo_und_handler: ;in: r0=char
  ldr    r13,=func3_info ;aka sp_und          ;-base address (in sp_und)
  str    r12,[r13,8]  ;func3_stack          ;-push r12
@@wait_if_buffer_full:
  ldr    r12,=ptr_to_comflags             ;\ ;exit if execute file request
  ldr    r12,[r12]  ;ptr to ComFlags        ; ; ComFlg.Bit11 ("bu_cmd_59h"),
  ldr    r12,[r12]  ;read ComFlags        ; ; ie. allow that flag to be
  tst    r12,1 shl 11 ;test bit11        ; ; processed by main program,
  bne    @@exit                    ; ;/without hanging here
  ldrb   r12,[r13,4] ;func3_buf_len      ; wait if buffer full

```

```

cmp    r12,tty_bufsiz           ; (until drained by FIQ)
beq    @@wait_if_buffer_full   ;/
mov    r12,1bh+0c0h ;mode=und, FIQ/IRQ=off ;\disable FIQ (no COMMUNICATION
mov    cpsr_ctl,r12            ;/interrupt during buffer write)
ldrb   r12,[r13,4]  ;func3_buf_len      ;\
add    r12,1       ;raise len        ; write char to buffer
strb   r12,[r13,4]  ;func3_buf_len      ; and raise buffer length
add    r12,0ch-1   ;=func3_buffer+INDEX  ;
strb   r0,[r13,r12] ;append char to buf  ;/
@@exit:
ldr    r12,[r13,8]  ;func3_stack      ;-pop r12
movs   r15,r14        ;return from exception (and restore old IRQ/FIQ state)
;-----
tty_func3_handler: ;in: r0=flags, r1=ptr
tst    r0,10h ;test if PRE/POST data (pre: Z, post: NZ)
;ldreq  r1,[r1]  ;read 32bit param (aka the four LEN1 bytes of FUNC3)
ldr    r0,=func3_info ;ptr to two 32bit values (FUNC3 return value)
movne  r1,0          ;\for POST data: mark buffer empty
strne  r1,[r0,4]  ;func3_buf_len=0   ;/
bx    lr             ;-for PRE data: return r0=func3_info

```

Usage: Call "init_tty" at the executable's entrypoint (with incoming R0 passed on). Call "tty_wrchr" to output ASCII characters.

Note: The TTY messages are supported only in no\$gba debug version (not no\$gba gaming version).

14. Serial Port (SIO)

1F801050h SIO_TX_DATA (W)

0-7	Data to be sent
8-31	Not used

Writing to this register starts transmit (if, or as soon as, TXEN=1 and CTS=on and SIO_STAT.2=Ready). Writing to this register while SIO_STAT.0=Busy causes the old value to be overwritten.

The "TXEN=1" condition is a bit more complex: Writing to SIO_TX_DATA latches the current TXEN value, and the transfer DOES start if the current TXEN value OR the latched TXEN value is set (ie. if TXEN gets cleared after writing to SIO_TX_DATA, then the transfer may STILL start if the old latched TXEN value was set; this appears for SIO transfers in Wipeout 2097).

1F801050h SIO_RX_DATA (R)

0-7	Received Data	(1st RX FIFO entry) (oldest entry)
8-15	Preview	(2nd RX FIFO entry)
16-23	Preview	(3rd RX FIFO entry)
24-31	Preview	(4th RX FIFO entry) (5th..8th cannot be previewed)

A data byte can be read when SIO_STAT.1=1. Data should be read only via 8bit memory access (the 16bit/32bit "preview" feature is rather unusable).

1F801054h SIO_STAT (R)

0	TX Ready Flag 1	(1=Ready/Started) (depends on CTS) (TX requires CTS)
1	RX FIFO Not Empty	(0=Empty, 1=Not Empty)
2	TX Ready Flag 2	(1=Ready/Finished) (depends on TXEN and on CTS)
3	RX Parity Error	(0=No, 1=Error; Wrong Parity, when enabled) (sticky)
4	RX FIFO Overrun	(0=No, 1=Error; Received more than 8 bytes) (sticky)
5	RX Bad Stop Bit	(0=No, 1=Error; Bad Stop Bit) (when RXEN) (sticky)
6	RX Input Level	(0=Normal, 1=Inverted) ;only AFTER receiving Stop Bit
7	DSR Input Level	(0=Off, 1=On) (remote DTR) ;DSR not required to be on
8	CTS Input Level	(0=Off, 1=On) (remote RTS) ;CTS required for TX
9	Interrupt Request	(0=None, 1=IRQ) (sticky)
10	Unknown	(always zero)
11-25	Baudrate Timer	(15bit timer, decrementing at 33MHz)
26-31	Unknown	(usually zero, sometimes all bits set)

Note: Bit0 gets cleared after sending the Startbit, Bit2 gets cleared after sending all bits up to including the Stopbit.

1F801058h SIO_MODE (R/W) (eg. 004Eh --> 8N1 with Factor=MUL16)

0-1	Baudrate Reload Factor (1=MUL1, 2=MUL16, 3=MUL64) (or 0=STOP)
2-3	Character Length (0=5bits, 1=6bits, 2=7bits, 3=8bits)
4	Parity Enable (0=No, 1=Enable)
5	Parity Type (0=Even, 1=Odd) (seems to be vice-versa...?)
6-7	Stop bit length (0=Reserved/1bit, 1=1bit, 2=1.5bits, 3=2bits)
8-15	Not used (always zero)

1F80105Ah SIO_CTRL (R/W)

0	TX Enable (TXEN) (0=Disable, 1=Enable, when CTS=On)
1	DTR Output Level (0=Off, 1=On)
2	RX Enable (RXEN) (0=Disable, 1=Enable) ;Disable also clears RXFIFO
3	TX Output Level (0=Normal, 1=Inverted, during Inactivity & Stop bits)
4	Acknowledge (0=No change, 1=Reset SIO_STAT.Bits 3,4,5,9) (W)
5	RTS Output Level (0=Off, 1=On)
6	Reset (0=No change, 1=Reset most SIO_registers to zero) (W)
7	Unknown? (read/write-able when FACTOR non-zero) (otherwise always zero)
8-9	RX Interrupt Mode (0..3 = IRQ when RX FIFO contains 1,2,4,8 bytes)
10	TX Interrupt Enable (0=Disable, 1=Enable) ;when SIO_STAT.0-or-2 ;Ready
11	RX Interrupt Enable (0=Disable, 1=Enable) ;when N bytes in RX FIFO
12	DSR Interrupt Enable (0=Disable, 1=Enable) ;when SIO_STAT.7 ;DSR=On
13-15	Not used (always zero)

1F80105Ch SIO_MISC (R/W)

This is an internal register, which usually shouldn't be accessed by software. Messing with it has rather strange effects: After writing a value "X" to this register, reading returns "X ROR 8" eventually "ANDed with 1F1Fh and ORed with C0C0h or 8080h" (depending on the character length in SIO_MODE).

1F80105Eh SIO_BAUD (R/W) (eg. 00DCh --> 9600 bauds; when Factor=MUL16)

0-15	Baudrate Reload value for decrementing Baudrate Timer
------	---

The Baudrate is calculated (based on SIO_BAUD, and on Factor in SIO_MODE):

$$\text{BitsPerSecond} = (44100\text{Hz} * 300\text{h}) / \text{MIN}((\text{Reload} * \text{Factor}) \text{ AND NOT } 1, \text{Factor})$$

SIO_TX_DATA Notes

The hardware can hold (almost) 2 bytes in the TX direction (one being currently transferred, and, once when the start bit was sent, another byte can be stored in SIO_TX_DATA). When writing to SIO_TX_DATA, both SIO_STAT.0 and SIO_STAT.2 become zero. As soon as the transfer starts, SIO_STAT.0 becomes set (indicating that one can write a new byte to SIO_TX_DATA; although the transmission is still busy). As soon as the transfer of the most recently written byte ends, SIO_STAT.2 becomes set.

SIO_RX_DATA Notes

The hardware can hold 8 bytes in the RX direction (when receiving further byte(s) while the RX FIFO is full, then the last FIFO entry will be overwritten by the new byte, and SIO_STAT.4 gets set; the hardware does NOT automatically disable RTS when the FIFO becomes full).

Data can be read from SIO_RX_DATA when SIO_STAT.1 is set, that flag gets automatically cleared after reading from SIO_RX_DATA (unless there are still further bytes in the RX FIFO). Note: The hardware does always store incoming data in RX FIFO (even when Parity or Stop bits are invalid).

Note: A 16bit read allows to read two FIFO entries at once; nevertheless, it removes only ONE entry from the FIFO. On the contrary, a 32bit read DOES remove FOUR entries (although, there's nothing that'd indicate if the FIFO did actually contain four entries).

Reading from Empty RX FIFO returns either the most recently received byte or zero (the hardware stores incoming data in ALL unused FIFO entries; eg. if five entries are used, then the data gets stored thrice, after reading 6 bytes, the FIFO empty flag gets set, but nevertheless, the last byte can be read two more times, but doing further reads returns 00h).

Interrupt Acknowledge Notes

First reset I_STAT.8, then set SIO_CTRL.4 (when doing it vice-versa, the hardware may miss a new IRQ which may occur immediately after setting SIO_CTRL.4) (and I_STAT.8 is edge triggered, so that bit can be reset even while SIO_STAT.9 is still set).

When acknowledging via SIO_CTRL.4 with the enabled condition(s) in SIO_CTRL.10-12 still being true (eg. the RX FIFO is still not empty): the IRQ does trigger again (almost) immediately (it goes off only for a very short moment; barely enough to allow I_STAT.8 to sense a edge).

SIO_BAUD Notes

Timer reload occurs when writing to SIO_BAUD, and, automatically when the Baudrate Timer reaches zero. There should be two 16bit SIO timers (for TX and RX), the upper 15bit of one of those timers can be read from SIO_STAT (not sure which one, and no idea if there's a way to read the other timer, too).

Or... maybe there is only ONE timer, and RX/TX are separated only by separate "timer elapsed" counters, in that case the MUL1 factor won't work properly, but, with the MUL16 or MUL64 factors, RX could start anytime (eg. when TX has already elapsed a bunch of times)...?

The maximum baud rate may vary depending on the length and quality of the cable, whether and how many inverters and anti-inverters are used (on the mainboard and in external adaptor, and on whether signals are externally converted to +/-12V levels)... anyways, rates up to 9600 baud should be working in all cases.

However, running in no\$psx, Wipeout 2097 seems to use about 2 million bauds... although, in older no\$psx versions, I believe I did see it using some kind of baudrate detection, where it did try different rates in steps of 200 bauds or so...?

SIO Ports vs JOY Ports

SIO uses I/O Addresses 1F801050h..1F80105Fh, which seem to be organized similar to the Controller/Memory Card registers at 1F801040h..1F80104Fh, though not identical, and with an additional register at 1F80105Ch, which has no corresponding port at 1F80104Ch.

SIO_BAUD is \<effectively> same as for JOY_BAUD, but, \<internally> they are a bit different:

JOY_BAUD is multiplied by Factor, and does then ellapse "2" times per bit.
 SIO_BAUD is NOT multiplied, and, instead, ellapses "2*Factor" times per bit.

Unlike for the Controller/Memory Card ports, the data is transferred without CLK signal, instead, it's using RS232 format, ie. the transfer starts with a start bit, and is then transferred at a specific baudrate (which must be configured identically at the receiver side). For RS232, data is usually 8bit, and may optionally end with a parity bit, and one or two stop bits.

Note

For SIO Pinouts, PSone SIO upgrading, and for building RS232 adaptors, see:
[Pinouts - SIO Pinouts](#)

Aside from the internal SIO port, the PSX BIOS supports two additional external serial ports, connected to the expansion port,

[EXP2 Dual Serial Port \(for TTY Debug Terminal\)](#)

SIO Games

The serial port is used (for 2-player link) by Wipeout 2097 (that game accidentally assumes BAUDs based on $64*1024*1025$ Hz rather than on $600h*44100$ Hz).

Ridge Racer Revolution is also said to support 2P link.

Keitai Eddy seems to allow to connect a mobile phone to the SIO port (the games CD cover suggests so; this seems to be something different than the "normal" I-Mode adaptor, which would connect to controller port, not to SIO port).

8251A Note

The Playstation Serial Port is apparently based/inspired on the Intel 8251A USART chip; which has very similar 8bit Mode/Command/Status registers.

15. Expansion Port (PIO)

Expansion Port can contain ROM, RAM, I/O Ports, etc. For ROM, the first 256 bytes would contain the expansion ROM header.

For region 1, the CPU outputs a chip select signal (CPU Pin 98, /EXP).

For region 2, the CPU doesn't produce a chip select signal (the region is intended to contain multiple I/O ports, which require an address decoder anyways, that address decoder could treat any /RD or /WR with A13=Hi and A23=Hi and A22=Lo as access to expansion region 2 (for /WR, A22 may be ignored; assuming that the BIOS is read-only)).

Size/Bus-Width

The BIOS initializes Expansion Region 1 to 512Kbyte with 8bit bus, and Region 2 to 128 bytes with 8bit bus. However, the size and data bus-width of these regions can be changed, see:

[Memory Control](#)

For Region 1, 32bit reads are supported even in 8bit mode (eg. 32bit opcode fetches are automatically processed as four 8bit reads).

For Region 2, only 8bit access seems to be supported (except that probably 16bit mode allows 16bit access), anyways, larger accesses seem to cause exceptions... not sure if that can be disabled...?

Expansion 1 - EXP1 - Intended to contain ROM

[EXP1 Expansion ROM Header](#)

Expansion 2 - EXP2 - Intended to contain I/O Ports

[EXP2 Dual Serial Port \(for TTY Debug Terminal\)](#)

[EXP2 DTL-H2000 I/O Ports](#)

[EXP2 Post Registers](#)

[EXP2 Nocash Emulation Expansion](#)

Expansion 3 - EXP3 - Intended to contain RAM

Not used by BIOS nor by any games. Seems to contain 1Mbyte RAM with 16bit databus (ie. 512Kx16) in DTL-H2000.

Other Expansions

Aside from the above, the Expansion regions can be used for whatever purpose, however, mind that the BIOS is reading from the ROM header region, and is writing to the POST register (so 1F000000h-1F0000FFh and 1F802041h should be used only if the hardware isn't disturbed by those accesses).

Missing Expansion Port

The expansion port is installed only on older PSX boards, newer PSX boards and all PSone boards don't have that port. However, the CPU should still output all expansion signals, and there should be big soldering points on the board, so it'd be easy to upgrade the console.

Latched Address Bus

Note that A0..A23 are latched outputs, so they can be used as general purpose 24bit outputs, provided that the system bus isn't used for other purposes (such like /BIOS, /SPU, /CD accesses) (A0..A23 are not affected by Main RAM and GPU addressing, nor by internal I/O ports like Timer and IRQ registers).

15.1 EXP1 Expansion ROM Header

Expansion 1 - ROM Header (accessed with 8bit databus setting)

Address	Size	Content
1F000000h	4	Post-Boot Entrypoint (eg. 1F000100h and up)
1F000004h	2Ch	Post-Boot ID ("Licensed by Sony Computer Entertainment Inc.")
1F000030h	50h	Post-Boot TTY Message (must contain at least one 00h byte)
1F000080h	4	Pre-Boot Entrypoint (eg. 1F000100h and up)
1F000084h	2Ch	Pre-Boot ID ("Licensed by Sony Computer Entertainment Inc.")
1F0000B0h	50h	Not used (should be zero, but may contain code/data/io)
1F000100h ..		Code, Data, I/O Ports, etc.

The entrypoints are called if their corresponding ID strings are present, return address to BIOS is passed in R31, so the expansion ROM may return control to BIOS, if that should be desired.

Aside from verifying the IDs, the BIOS will also display the Post-Boot ID string (and the following message string) via TTY (done right before calling the Post-Boot Entrypoint).

Pre-Boot Function

The Pre-Boot function is called almost immediately after Reset, with only some Memory Control registers initialized, the BIOS function vectors at A0h, B0h, and C0h are NOT yet initialized, so the Pre-Boot function can't use them.

Post-Boot Function

The Post-Boot function gets called while showing the "PS" logo, but before loading the .EXE file. The BIOS function vectors at A0h, B0h, and C0h are already installed and can be used by the Post-Boot Function.

Note that the Post-Boot Function is called ONLY when the "PS" logo is shown (ie. not if the CDROM drive is empty, or if it contains an Audio CD).

Mid-Boot Hook

One common trick to hook the Kernel after BIOS initialization, but before CDROM loading is to use the Pre-Boot handler to set a COP0 opcode fetch hardware breakpoint at 80030000h (after returning from the Pre-Boot handler, the Kernel will initialize important things like A0h/B0h/C0h tables, and will then break again when starting the GUI code at 80030000h) (this trick is used by Action Replay v2.0 and up).

Note

Expansion ROMs are most commonly used in cheat devices,
[Cheat Devices](#)

15.2 EXP2 Dual Serial Port (for TTY Debug Terminal)

SCN2681 Dual Asynchronous Receiver/Transmitter (DUART)

The PSX/PSone retail BIOS contains some TTY Debug Terminal code; using an external SCN2681 chip which can be connected to the expansion port.

Whilst supported by all PSX/PSone retail BIOSes on software side, there aren't any known PSX consoles/devboards/expansions actually containing DUARTs on hardware side.

1F802023h/Read - RHRA - DUART Rx Holding Register A (FIFO) (R)**1F80202Bh/Read - RHRB - DUART Rx Holding Register B (FIFO) (R)****1F802023h/Write - THRA - DUART Tx Holding Register A (W)****1F80202Bh/Write - THRΒ - DUART Tx Holding Register B (W)**

7-0	Data (aka Character)
-----	----------------------

The hardware can hold max 2 Tx characters per channel (1 in the THR register, and one currently processed in the Tx Shift Register), and max 4 Rx characters (3 in the RHR FIFO, plus one in the Rx Shift Register) (when receiving a 5th character, the "old newest" value in the Rx Shift Register is lost, and the overrun flag is set).

1F802020h/FirstAccess - MR1A - DUART Mode Register 1.A (R/W)**1F802028h/FirstAccess - MR1B - DUART Mode Register 1.B (R/W)**

7	RxRTS Control	(0=No, 1=Yes)
6	RxINT Select	(0=RxDY, 1=FFULL)
5	Error Mode	(0=Char, 1=Block)
4-3	Parity Mode	(0=With Parity, 1=Force Parity, 2=No Parity, 3=Multidrop)
2	Parity Type	(0=Even, 1=Odd)
1-0	Bits per Character	(0=5bit, 1=6bit, 2=7bit, 3=8bit)

Note: In block error mode, block error conditions must be cleared by using the error reset command (command 4) or a receiver reset (command 2).

1F802020h/SecondAccess - MR2A - DUART Mode Register 2.A (R/W)**1F802028h/SecondAccess - MR2B - DUART Mode Register 2.B (R/W)**

7-6	Channel Mode	(0=Normal, 1=Auto-Echo, 2=Local loop, 3=Remote loop)
5	TxRTS Control	(0=No, 1=Yes) (when 1 --> OPO=RTSA / OP1=RTSB)
4	CTS Enable	(0=No, 1=Yes) (when 1 --> IPO=CTSA / IP1=CTSB)
3-0	Tx Stop Bit Length	(00h..0Fh = see below)

Stop Bit Lengths:

0=0.563	1=0.625	2=0.688	3=0.750	4=0.813	5=0.875	6=0.938	7=1.000
8=1.563	9=1.625	A=1.688	B=1.750	C=1.813	D=1.875	E=1.938	F=2.000

Add 0.5 to values shown for 0..7 if channel is programmed for 5 bits/char.

1F802021h/Write - CSRA - DUART Clock Select Register A (W)

1F802029h/Write - CSRB - DUART Clock Select Register B (W)

```
7-4 Rx Clock Select (0..0Ch=See Table, 0Dh=Timer, 0Eh=16xIP, 0Fh=1xIP)
3-0 Tx Clock Select (0..0Ch=See Table, 0Dh=Timer, 0Eh=16xIP, 0Fh=1xIP)
```

The 2681 has some sets of predefined baud rates (set1/set2 selected via ACR.7), additionally, in BRG Test Mode, set3/set4 are used instead of set1/set2), the baud rates for selections 00h..0Dh are:

Rate	00h	01h	02h	03h	04h	05h	06h	07h	08h	09h	0Ah	0Bh	0Ch
Set1	50	110	134.5	200	300	600	1200	1050	2400	4800	7200	9600	38400
Set2	75	110	134.5	150	300	600	1200	2000	2400	4800	1800	9600	19200
Set3	4800	880	1076	19200	28800	57600	115200	1050	57600	4800	57600	9600	38400
Set4	7200	880	1076	14400	28800	57600	115200	2000	57600	4800	14400	9600	19200

Selection 0Eh/0Fh are using an external clock source (derived from IP3,IP4,IP5,IP6 pins; for TxA,RxA,TxB,RxB respectively).

1F802022h/Write - CRA - DUART Command Register A (W)

1F80202Ah/Write - CRB - DUART Command Register B (W)

```
7 Not used (should be 0)
6-4 Miscellaneous Commands (0..7 = see below)
3 Disable Tx (0=No change, 1=Disable)
2 Enable Tx (0=No change, 1=Enable) ;Don't use with Command 3 (Reset Rx)
1 Disable Rx (0=No change, 1=Disable)
0 Enable Rx (0=No change, 1=Enable) ;Don't use with Command 2 (Reset Tx)
```

The command values for CRA (or CRB) are:

```
0 No command ;no effect
1 Reset MR pointer ;force "FirstAccess" state for MR1A (or MR1B) access
2 Reset receiver ;reset RxA (or RxB) registers, disable Rx, flush Fifo
3 Reset transmitter ;reset TxA (or TxB) registers
4 Reset Error Flags ;reset SRA.7-4 (or SRB.7-4) to zero
5 Reset Break-Change IRQ Flag ;reset ISR.2 (or ISR.6) to zero
6 Start break ;after current char, pause Tx with TxDI=Low (or TxDI=Low)
7 Stop break ;output one High bit, then continue Tx (ie. undo pause)
```

Access to the upper four bits of the command register should be separated by 3 edges of the X1 clock. A disabled transmitter cannot be loaded.

1F802025h/Read - ISR - DUART Interrupt Status Register (R)

1F802025h/Write - IMR - DUART Interrupt Mask Register (W)

7	Input Port Change	(0=No, 1=Yes) (Ack via reading IPCR) ;see ACR.3-0
6	Break Change B	(0=No, 1=Yes) (Ack via CRB/Command5)
5	RxRDYB/FFULLB	(0=No, 1=Yes) (Ack via reading data) ;see MR1B.6
4	THR _B Empty (TxRDYB)	(0=No, 1=Yes) (Ack via writing data) ;same as SRB.2
3	Counter Ready	(0=No, 1=Yes) (Ack via CT_STOP)
2	Break Change A	(0=No, 1=Yes) (Ack via CRA/Command5)
1	RxDYB/FFULLA	(0=No, 1=Yes) (Ack via reading data) ;see MR1A.6
0	THR _A Empty (TxRDYA)	(0=No, 1=Yes) (Ack via writing data) ;same as SRA.2

1F802021h/Read - SRA - DUART Status Register A (R)

1F802029h/Read - SRB - DUART Status Register B (R)

7	Rx Received Break*	(0=No, 1=Yes) ;received 00h without stop bit
6	Rx Framing Error*	(0=No, 1=Yes) ;received data without stop bit
5	Rx Parity Error*	(0=No, 1=Yes) ;received data with bad parity
4	Rx Overrun Error	(0=No, 1=Yes) ;Rx FIFO full + RxShiftReg full
3	Tx Underrun (TxEMT)	(0=No, 1=Yes) ;both TxShiftReg and THR empty
2	Tx THR Empty (TxRDY)	(0=No, 1=Yes) ;same as ISR.0 / ISR.4
1	Rx FIFO Full (FFULL)	(0=No, 1=Yes) ;set upon 3 or more characters
0	Rx FIFO Not Empty (RxRDY)	(0=No, 1=Yes) ;set upon 1 or more characters

Bit7-5 are appended to the corresponding data character in the receive FIFO. A read of the status provides these bits (7:5) from the top of the FIFO together with bits (4:0). These bits are cleared by a "reset error status" command. In character mode they are discarded when the corresponding data character is read from the FIFO. In block error mode, block error conditions must be cleared by using the error reset command (command 4x) or a receiver reset.

1F802024h/Write - ACR - DUART Aux. Control Register (W)

7	Select Baud Rate Generator (BRG) Set	(0=Set1/Set3, 1=Set2/Set4)
6-4	Counter/Timer Mode and Source	(see below)
3-0	IP3..IP0 Change Interrupt Enable Flags	(0=Off, 1=On)

Counter/Timer Mode and Clock Source Settings:

Num	Mode	Clock Source
0h	Counter	External (IP2)
1h	Counter	TxCA - 1x clock of Channel A transmitter
2h	Counter	TxCB - 1x clock of Channel B transmitter
3h	Counter	Crystal or external clock (x1/CLK) divided by 16
4h	Timer	External (IP2)
5h	Timer	External (IP2) divided by 16
6h	Timer	Crystal or external clock (x1/CLK)
7h	Timer	Crystal or external clock (x1/CLK) divided by 16

In Counter Mode, the Counter Ready flag is set on any underflow, and the counter wraps to FFFFh and keeps running (but may get stopped by software).

In Timer Mode, automatic reload occurs on any underflow, the counter flag (which can be output to OP3) is toggled on any underflow, but the Counter Ready flag is set only on each 2nd underflow (unlike as in Counter mode).

1F802024h/Read - IPCR - DUART Input Port Change Register (R)

```
7-4 IP3..IP0 Change Occured Flags (0=No, 1=Yes) ;auto reset after read
3-0 Current IP3-IP0 Input states (0=Low, 1=High) ;Same as IP.3-0
```

Reading from this register automatically resets IPCR.7-4 and ISR.7.

1F80202Dh/Read - IP - DUART Input Port (R)

```
7 Not used (always 1)
6-0 Current IP6-IP0 Input states (0=Low, 1=High) ;LSBs = Same as IPCR.3-0
```

IP0-6 can be used as general purpose inputs, or for following special purposes:

```
IP6 External RxB Clock ;see CSRB.7-4
IP5 External TxB Clock ;see CSRB.3-0
IP4 External RxA Clock ;see CSRA.7-4
IP3 External TxA Clock ;see CSRA.3-0
IP2 External Timer Input ;see AUX.6-4
IP1 Clear to Send B (CTSB) ;see MR2B.5
IP0 Clear to Send A (CTSA) ;see MR2A.5
```

Note: The 24pin chip doesn't have any inputs, the 28pin chip has only one input (IP2), the 40pin/44pin chips have seven inputs (IP0-IP6).

1F80202Eh/Write - DUART Set Output Port Bits Command (Set means Out=LOW)**1F80202Fh/Write - DUART Reset Output Port Bits Command (Reset means Out=HIGH)**

```
7-0 Change "OPR" OP7-OP0 Output states (0=No change, 1=Set/Reset)
```

Note: The 24pin chip doesn't have any outputs, the 28pin chip has only two outputs (OP0,OP1), the 40pin/44pin chips have eight outputs (OP0-OP7).

1F80202Dh/Write - OPCR - DUART Output Port Configuration Register (W)

7	OP7	(0=OPR.7, 1=TxDYB)
6	OP6	(0=OPR.6, 1=TxDYA)
5	OP5	(0=OPR.5, 1=RxDY/FFULLB)
4	OP4	(0=OPR.4, 1=RxDY/FFULLA)
3-2	OP3	(0=OPR.3, 1=Clock/Timer Output, 2=TxCB(1x), 3=RxCB(1x))
1-0	OP2	(0=OPR.2, 1=TxCA(16x), 2=TxCA(1x), 3=RxCA(1x))

Additionally, the OP0 and OP1 outputs are controlled via MR2A.5 and MR2B.5.

1F802022h/Read - - DUART Toggle Baud Rate Generator Test Mode (Read=Strobe)**1F80202Ah/Read - - DUART Toggle 1X/16X Test Mode (Read=Strobe)**

```
7-0 Not used (just issue a dummy-read to toggle the test mode on/off)
```

BGR Test switches between Baud Rate Set1/Set2 and Set3/Set4.

1X/16X Test switches between whatever...?

1F80202Eh/Read - CT_START - DUART Start Counter Command (Read=Strobe)**1F80202Fh/Read - CT_STOP - DUART Stop Counter Command (Read=Strobe)**

```
7-0 Not used (just issue a dummy-read to strobe start/stop command)
```

Start: Forces reload (copies CTR/CTUR to CTL/CTU), and starts the timer.

Stop-in-Counter-Mode: Resets ISR.3, and stops the timer.

Stop-in-Timer-Mode: Resets ISR.3, but doesn't stop the timer.

1F802026h/Read - CTU - DUART Counter/Timer Current Value, Upper/Bit15-8 (R)**1F802027h/Read - CTL - DUART Counter/Timer Current Value, Lower/Bit7-0 (R)****1F802026h/Write - CTUR - DUART Counter/Timer Reload Value, Upper/Bit15-8 (W)****1F802027h/Write - CTLR - DUART Counter/Timer Reload Value, Lower/Bit7-0 (W)**

The CTLR/CTUR reload value is copied to CTL/CTU upon Start Counter Command. In Timer mode (not in Counter mode), it is additionally copied automatically when the timer undeflows.

1F80202Ch - N/A - DUART Reserved Register (neither R nor W)

Reserved.

Chip versions

The SCN2681 is manufactured with 24..44 pins, the differences are:

24pin basic cut-down version	;without IP0-1/OP0-1 = without CTS/RTS
28pin additional IP2,OP0,OP1,X2	;without IP0-1 = without CTS
40pin additional IP0-IP6,OP0-OP7,X2	;full version
44pin same as 40pin with four NC pins	;full version (SMD)

Unknown which of them is supposed to be used with the PSX?

Note: The Motorola 68681 should be the same as the Philips/Signetics 2681.

Notes

Unknown if the Interrupt signal is connected to the PSX... there seems to be no spare IRQ for it, though it \<might> share an IRQ with whatever other hardware...?

The BIOS seems to use only one of the two channels; for the std_io functions:

[BIOS TTY Console \(std_io\)](#)

Aside from the external DUART, the PSX additionally contains an internal UART,
[Serial Port \(SIO\)](#)

The DTL-H2000 devboard uses a non-serial "ATCONS" channel for TTY stuff,

[EXP2 DTL-H2000 I/O Ports](#)

15.3 EXP2 DTL-H2000 I/O Ports

The DTL-H2000 contains extended 8Mbyte Main RAM (instead of normal 2Mbyte), plus additional 1MByte RAM in Expansion Area at 1FA00000h, plus some I/O ports at 1F8020xxh:

1F802000h - DTL-H2000: EXP2: - ATCONS STAT (R)

0	Unknown, used for something
1	Unknown/unused
2	Unknown, used for something
3	TTY/Atcons TX Ready (0=Busy, 1=Ready)
4	TTY/Atcons RX Available (0=None, 1=Yes)
5-7	Unknown/unused

1F802002h - DTL-H2000: EXP2: - ATCONS DATA (R and W)

0-7	TTY/Atcons RX/TX Data
-----	-----------------------

TTY channel for message output (TX) and debug console keyboard input (RX). The DTL-H2000 is using this "ATCONS" stuff instead of the DUART stuff used in retail console BIOSes ("CONS" seems to refer to "Console", and "AT" might refer to PC/AT or whatever).

1F802004h - DTL-H2000: EXP2: - 16bit - ?

0-15	Data...?
------	----------

1F802030h - DTL-H2000: Secondary IRQ10 Controller (IRQ Flags)

This register does expand IRQ10 (Lightgun) to more than one IRQ source. The register contains only Secondary IRQ Flags (there seem to be no Secondary IRQ Enable bits; at least not for Lightguns).

0	... used for something
1	Lightgun IRQ (write: 0=No change, 1=Acknowledge) (read: 0=None, 1=IRQ)
2-3	Unknown/unused (write: 0=Normal)
4	... acknowledged at 1FA00B04h, otherwise unused
5	... TTY RX ?
6-7	Unknown/unused (write: 0=Normal)
8-31	Not used by DTL-H2000 BIOS (but Lightgun games write 0 to these bits)

Retail games that support IRQ10-based "Konami" Lightguns are containing code for detecting and accessing port 1F802030h. The detection works by examining a value in the BIOS ROM like so:

```
IF [BFC00104h]=00002000h then Port 1F802030h does exist      (DTL-H2000)
IF [BFC00104h]=00002500h then Port 1F802030h does NOT exist
IF [BFC00104h]=00000003h then Port 1F802030h does NOT exist (default)
IF [BFC00104h]= <other> then Port 1F802030h does NOT exist
```

Normal consoles don't include Port 1F802030h, and IRQ10 is wired directly to the controller port, and the value at [BFC00104h] is always 00000003h. Accordingly, one cannot upgrade the console just by plugging a Secondary IRQ10 controller to the expansion port (instead, one would need to insert the controller between the CPU and controller plug, and to install a BIOS with [BFC00104h]=00002000h).
The DTL-H2000 BIOS accesses 1F802030h with 8bit load/store opcodes, however, the Lightgun games use 32bit load/store - which is theoretically overlapping port 1F802032h, though maybe the memory system does ignore the upper bits.

1F802032h - DTL-H2000: EXP2: - maybe IRQ enable?

0	Used for something (Cleared on some occasions)
1-3	Unknown/unused
4	Used for something (Set on some occasions)
5-7	Unknown/unused

1F802040h - DTL-H2000: EXP2: 1-byte - DIP Switch?

0-7	DIP Value (00h..FFh, but should be usually 00h..02h)
-----	--

This register selects the DTL-H2000 boot mode, for whatever reason it's called "DIP Switch" register, although the DTL-H2000 boards don't seem to contain any such DIP Switches (instead, it's probably configured via some I/O ports on PC side). Possible values are:

DIP=0 --> .. long delay before TTY?	with "PSX>" prompt, throws CDROM cmds
DIP=1 --> .. long delay before TTY?	no "PSX>" prompt
DIP=2 --> .. instant TTY?	with "PSX>" prompt
DIP=3 --> Lockup	
DIP=04h..FFh --> Lockup with POST=04h..FFh	

1F802042h - DTL-H2000: EXP2: POST/LED (R/W)**EXP2 Post Registers**

15.4 EXP2 Post Registers

1F802041h - POST - External 7-segment Display (W)

0-3	Current Boot Status (00h..0Fh)
4-7	Not used by BIOS (always set to 0)

During boot, the BIOS writes incrementing values to this register, allowing to display the current boot status on an external 7 segment display (much the same as Port 80h used in PC BIOSes).

1F802042h - DTL-H2000: EXP2: POST/LED (R/W)

0-7	Post/LED value
-----	----------------

8bit wide, otherwise same as POST 1F802041h on retail consoles.

1F802070h - POST2 - Unknown? (W) - PS2

Might be a configuration port, or it's another POST register (which is used prior to writing the normal POST bytes to 1FA00000h).

The first write to 1F802070h is 32bit, all further writes seem to be 8bit.

1FA00000h - POST3 - External 7-segment Display (W) - PS2

Similar to POST, but PS2 BIOS uses this address.

15.5 EXP2 Nocash Emulation Expansion

1F802060h Emu-Expansion ID1 "E" (R)

1F802061h Emu-Expansion ID2 "X" (R)

1F802062h Emu-Expansion ID3 "P" (R)

1F802063h Emu-Expansion Version (01h) (R)

Contains ID and Version.

1F802064h Emu-Expansion Enable1 "O" (R/W)

1F802065h Emu-Expansion Enable2 "N" (R/W)

Activates the Halt and Turbo Registers (when set to "ON").

1F802066h Emu-Expansion Halt (R)

When enabled (see above), doing an 8bit read from this address stops the CPU emulation unless/until an Interrupt occurs (when "CAUSE AND SR AND FF00h" becomes nonzero). Can be used to reduce power consumption, and to make the emulation faster.

1F802067h Emu-Expansion Turbo Mode Flags (R/W)

When enabled (see above), writing to this register activates/deactivates "turbo" mode, which is causing new data to arrive immediately after acknowledging the previous interrupt.

0	CDROM Turbo	(0=Normal, 1=Turbo)
1	Memory Card Turbo	(0=Normal, 1=Turbo)
2	Controller Turbo	(0=Normal, 1=Turbo)
3-7	Reserved	(must be zero)

16. Memory Control

The Memory Control registers are initialized by the BIOS, and, normally software doesn't need to change that settings. Some registers are useful for expansion hardware (allowing to increase the memory size and bus width).

1F801000h - Expansion 1 Base Address (usually 1F000000h)

1F801004h - Expansion 2 Base Address (usually 1F802000h)

0-23	Base Address	(Read/Write)
24-31	Fixed	(Read only, always 1Fh)

For Expansion 1, the address is forcefully aligned to the selected expansion size (see below), ie. if the size is bigger than 1 byte, then the lower bit(s) of the base address are ignored.

For Expansion 2, trying to use ANY other value than 1F802000h seems to disable the Expansion 2 region, rather than mapping it to the specified address (ie. Port 1F801004h doesn't seem to work).

For Expansion 3, the address seems to be fixed (1FA00000h).

1F801008h - Expansion 1 Delay/Size (usually 0013243Fh) (512Kbytes, 8bit bus)

1F80100Ch - Expansion 3 Delay/Size (usually 00003022h) (1 byte)

1F801010h - BIOS ROM Delay/Size (usually 0013243Fh) (512Kbytes, 8bit bus)

1F801014h - SPU Delay/Size (200931E1h) (use 220931E1h for SPU-RAM reads)

1F801018h - CDROM Delay/Size (00020843h or 00020943h)

1F80101Ch - Expansion 2 Delay/Size (usually 00070777h) (128 bytes, 8bit bus)

0-3	Write Delay	(00h..0Fh=01h..10h Cycles)
4-7	Read Delay	(00h..0Fh=01h..10h Cycles)
8	Recovery Period	(0=No, 1=Yes, uses COM0 timings)
9	Hold Period	(0=No, 1=Yes, uses COM1 timings)
10	Floating Period	(0=No, 1=Yes, uses COM2 timings)
11	Pre-strobe Period	(0=No, 1=Yes, uses COM3 timings)

```

12  Data Bus-width      (0=8bits, 1=16bits)
13  Auto Increment     (0=No, 1=Yes)
14-15 Unknown (R/W)
16-20 Memory Window Size (1 SHL N bytes) (0..1Fh = 1 byte ... 2 gigabytes)
21-23 Unknown (always zero)
24-27 DMA timing override
28  Address error flag. Write 1 to it to clear it.
29  DMA timing select  (0=use normal timings, 1=use bits 24-27)
30  Wide DMA           (0=use bit 12, 1=override to full 32 bits)
31  Wait                (1=wait on external device before being ready)

```

When booting, all these registers are using the maximum cycle delays for both reads and writes. When booting, the BIOS will immediately select a faster read access delay, resulting in a visible speed up when booting. The effects aren't immediate however. The BIOS boots using the following instructions:

```

bfc00000    lui      $t0, 0x0013
bfc00004    ori      $t0, 0x243f
bfc00008    lui      $at, 0x1f80
bfc0000c    sw       $t0, 0x1010($at)
bfc00010    nop
bfc00014    li       $t0, 0x0b88
bfc00018    lui      $at, 0x1f80
bfc0001c    sw       $t0, 0x1060($at)
bfc00020    nop

```

When using a logic analyzer to monitor the boot sequence, the instruction at bfc00014 is still read using the old timings since reset, and then the instruction at bfc00018 is finally read using the sped up timings.

Reads and writes access times aren't symmetrical, and are each controlled with their own values. By default, EXP1 will be set to 16 cycles when writing, which is the slowest possible. If the programmer wants to write to a flash chip on EXP1, or communicate with a computer, speeding up write access is recommended.

The fastest a port could go would be by setting the lowest 16 bits to zero, which will result in 3 CPU cycles for a single byte access.

!CS always goes active at least one cycle before !WR or !RD go active. The various timing changes are between all the events inside the data read/write waveform. The whole

formula for computing the total access time is fairly complex overall, and difficult to properly describe.

- The pre-strobe period will add delays between the moment the data bus is set, and the moment !CS goes active.
- The hold period will keep the data in the data bus for some more cycles after !WR goes inactive, and before !CS goes inactive. The accessed device is supposed to sample the data bus during this interval.
- The floating period will keep the data bus floating for some more cycles after !RD goes inactive, and before !CS goes inactive. The accessed device is supposed to stop driving the data bus during this interval. The CPU will sample the data bus somewhere before or exactly when !CS goes inactive.
- The recovery period will add delays between two operations.

The data bus width will influence if the CPU does full 16 bits reads, or only 8 bits. When doing 32 bits operations, the CPU will issue 2 16-bits operations, or 4 8-bits operations, keeping !CS active the whole time, and strobing !WR or !RD accordingly. When doing these sequences, the address bus will also increment automatically between each operation, if the auto-increment bit is active.

This means it is possible to slightly shorten the read time of 4 bytes off the same address by disabling auto-increment, and reading a full word. The CPU will then read 4 bytes off the same address, and place them all into each byte of the loaded register.

The DMA timing override portion will replace the access timing when doing DMA, only if the DMA override flag is set.

The Wide DMA flag will enable full 32 bits DMA operations on the bus, by reusing the low 16-bits address signals as the high 16-bits data. This means that if the CPU is doing Wide DMA reads, the low 16-bits of the address bus will become inputs.

Trying to access addresses that exceed the selected size causes a bus exception. Maximum size would be Expansion 1 = 17h (8MB), BIOS = 16h (4MB), Expansion 2 = 0Dh (8KB), Expansion 3 = 15h (2MB). Trying to select larger sizes would overlap the internal I/O ports, and crash the PSX. The Size bits seem to be ignored for SPU/CDROM. The SPU timings seem to be applied for both the 200h-byte SPU region at 1F801C00h and for the 200h-byte unknown region at 1F801E00h.

1F801020h - COM_DELAY / COMMON_DELAY (00031125h or 0000132Ch or 00001325h)

```

0-3  COM0 - Recovery period cycles
4-7  COM1 - Hold period cycles
8-11 COM2 - Floating release cycles
12-15 COM3 - Strobe active-going edge delay
16-31 Unknown/unused (read: always 0000h)

```

This register contains clock cycle offsets that can be added to the Access Time values in Port 1F801008h..1Ch. Works (somehow) like so:

```

1ST=0, SEQ=0, MIN=0
IF Use_COM0 THEN 1ST=1ST+COM0-1, SEQ=SEQ+COM0-1
IF Use_COM2 THEN 1ST=1ST+COM2,   SEQ=SEQ+COM2
IF Use_COM3 THEN MIN=COM3
IF 1ST<6 THEN 1ST=1ST+1 ;(somewhat like so)
1ST=1ST+AccessTime+2, SEQ=SEQ+AccessTime+2
IF 1ST<(MIN+6) THEN 1ST=(MIN+6)
IF SEQ<(MIN+2) THEN SEQ=(MIN+2)

```

The total access time is the sum of First Access, plus any Sequential Access(es), eg. for a 32bit access with 8bit bus: Total=1ST+SEQ+SEQ+SEQ.

If the access is done from code in (uncached) RAM, then 0..4 cycles are added to the Total value (the exact number seems to vary depending on the used COMx values or so).

1F801060h - RAM_SIZE (R/W) (usually 00000B88h) (or 00000888h)

```

0-2  Unknown (no effect)
3    Crashes when zero (except PU-7 and EARLY-PU-8, which <do> set bit3=0)
4-6  Unknown (no effect)
7    Delay on simultaneous CODE+DATA fetch from RAM (0=None, 1=One Cycle)
8    Unknown (no effect) (should be set for 8MB, cleared for 2MB)
9-11 Define 8MB Memory Window (first 8MB of KUSEG,KSEG0,KSEG1)
12-15 Unknown (no effect)
16-31 Unknown (Garbage)

```

Possible values for Bit9-11 are:

```

0 = 1MB Memory + 7MB Locked
1 = 4MB Memory + 4MB Locked
2 = 1MB Memory + 1MB HighZ + 6MB Locked
3 = 4MB Memory + 4MB HighZ
4 = 2MB Memory + 6MB Locked          ;<-- would be correct for PSX
5 = 8MB Memory                      ;<-- default by BIOS init
6 = 2MB Memory + 2MB HighZ + 4MB Locked ;<-- HighZ = Second /RAS
7 = 8MB Memory

```

The BIOS initializes this to setting 5 (8MB) (ie. the 2MB RAM repeated 4 times), although the "correct" would be setting 4 (2MB, plus other 6MB Locked). The remaining memory, after the first 8MB, and up to the Expansion/IO/BIOS region seems to be always Locked. The HighZ regions are FFh-filled, that even when grounding data lines on the system bus (ie. it is NOT a mirror of the PIO expansion region).

Locked means that the CPU generates an exception when accessing that area.

Note: Wipeout uses a BIOS function that changes RAM_SIZE to 00000888h (ie. with corrected size of 2MB, and with the unknown Bit8 cleared). Gundam Battle Assault 2 does actually use the "8MB" space (with stacktop in mirrored RAM at 807FFFxxh).

Clearing bit7 causes many games to hang during CDROM loading on both EARLY-PU-8 and LATE-PU-8 (but works on PU-18 through PM-41).

FFFE0130h Cache Control (R/W)

0-2	Unknown (Read/Write)	(R/W)
3	Scratchpad Enable 1 (0=Disable, 1=Enable when Bit7 is set, too)	(R/W)
4-5	Unknown (Read/Write)	(R/W)
6	Unknown (read=always zero)	(R) or (W) or unused..?
7	Scratchpad Enable 2 (0=Disable, 1=Enable when Bit3 is set, too)	(R/W)
8	Unknown	(R/W)
9	Crash (0=Normal, 1=Crash if code-cache enabled)	(R/W)
10	Unknown (read=always zero)	(R) or (W) or unused..?
11	Code-Cache Enable (0=Disable, 1=Enable)	(R/W)
12-31	Unknown	(R/W)

Used by BIOS to initialize cache (in combination with COP0), like so:

```

Init Cache Step 1:
[FFFE0130h]=00000804h, then set cop0_sr=00010000h, then
zerofill each FOURTH word at [0000..0FFFh], then set cop0_sr=zero.

Init Cache Step 2:
[FFFE0130h]=00000800h, then set cop0_sr=00010000h, then
zerofill ALL words at [0000h..0FFFh], then set cop0_sr=zero.

Finish Initialization:
read 8 times 32bit from [A0000000h], then set [FFFE0130h]=0001E988h

```

Note: FFFE0130h is described in LSI's "L64360" datasheet, chapter 14 (and probably also in their LR33300/LR33310 datasheet, if it were available in internet).

17. Unpredictable Things

Normally, I/O ports should be accessed only at their corresponding size (ie. 16bit read/write for 16bit ports), and of course, only existing memory and I/O addresses should be used. When not recursing that rules, some more or less (un-)predictable things may happen...

I/O Write Datasize

Address	Content	W.8bit	W.16bit	W.32bit	
00000000h-00xFFFFFh	Main RAM	OK	OK	OK	
1F800000h-1F8003FFh	Scratchpad	OK	OK	OK	
1F801000h-1F801023h	MEMCTRL	(w32)	(w32)	OK	
1F80104xh	JOY_xxx	(w16)	OK	CROP	
1F80105xh	SIO_xxx	(w16)	OK	CROP	
1F801060h-1F801063h	RAM_SIZE	(w32)	(w32)	OK	(with crash)
1F801070h-1F801077h	IRQCTRL	(w32)	(w32)	OK	
1F8010x0h-1F8010x3h	DMAx.ADDR	(w32)	(w32)	OK	
1F8010x4h-1F8010x7h	DMAx.LEN	OK	OK	OK	
1F8010x8h-1F8010xFh	DMAx.CTRL/MIRR	(w32)	(w32)	OK	
1F8010F0h-1F8010F7h	DMA.DPCR/DICR	(w32)	(w32)	OK	
1F8010F8h-1F8010FFh	DMA.unknown	IGNORE	IGNORE	IGNORE	
1F801100h-1F80110Bh	Timer 0	(w32)	(w32)	OK	
1F801110h-1F80110Bh	Timer 1	(w32)	(w32)	OK	
1F801120h-1F80110Bh	Timer 2	(w32)	(w32)	OK	
1F801800h-1F801803h	CDROM	OK	?	?	
1F801810h-1F801813h	GPU.GP0	?	?	OK	
1F801814h-1F801817h	GPU.GP1	?	?	OK	
1F801820h-1F801823h	MDEC.CMD/DTA	?	?	OK	
1F801824h-1F801827h	MDEC.CTRL	?	?	OK	
1F801C00h-1F801E7Fh	SPU	(i16)	OK	OK	
1F801E80h-1F801FFFh	SPU.UNUSED	IGNORE	IGNORE	IGNORE	
1F802020h-1F80202Fh	DUART	OK	?	?	
1F802041h	POST	OK	?	?	
FFFE0130h-FFFE0133h	CACHE.CTRL	(i32)	(i32)	OK	

Whereas,

```

OK      works
(w32) write full 32bits (left-shifted if address isn't word-aligned)
(w16) write full 16bits (left-shifted if address isn't halfword-aligned)
(i32) write full 32bits (ignored if address isn't word-aligned)
(i16) write full 16bits (ignored if address isn't halfword-aligned)
CROP   write only lower 16bit (and leave upper 16bit unchanged)

```

It's somewhat "legit" to use 16bit writes on 16bit registers like RAM_SIZE, I_STAT, I_MASK, and Timer 0-2.

Non-4-byte aligned 8bit/16bit writes to RAM_SIZE do crash (probably because the "(w32)" effect is left-shifting the value, so lower 8bit become zero).

Results on unaligned I/O port writes (via SWL/SWR opcodes) are unknown.

I/O Read Datasize

In most cases, I/O ports can be read in 8bit, 16bit, or 32bit units, regardless of their size, among others allowing to read two 16bit ports at once with a single 32bit read. If there's only one 16bit port within a 32bit region, then 32bit reads often return garbage in the unused 16bits. Also, 8bit or 16bit VRAM data reads via GPUREAD probably won't work? Expansion 2 Region can be accessed only via 8bit reads, and 16bit/32bit reads seem to cause exceptions (or rather: no such exception!) (except, probably 16bit reads are allowed when the region is configured to 16bit databus width).

There are at least some special cases:

```
FFFE0130h-FFFE0133h  8bit (+16bit?)  read works ONLY from word-aligned address
```

Cache Problems

The functionality of the Cache is still widely unknown. Not sure if DMA transfers are updating or invalidating cache. Cached Data within KSEG0 should be automatically also cached at the corresponding mirrored address in KUSEG and vice versa. Mirrors within KSEG1 (or within KUSEG) may be a different thing, eg. when using addresses spread across the first 8MB region to access the 2MB RAM. Same problems may occur for Expansion and BIOS mirrors, although, not sure if that regions are cached.

Writebuffer Problems

The writebuffer seems to be disabled for the normal I/O area at 1F801000h, however, it appears to be enabled for the Expansion I/O region at 1F802000h (after writing to 1F802041h, the BIOS issues 4 dummy writes to RAM, apparently (?) in order to flush the writebuffer). The same might apply for Expansion Memory region at 1F000000h, although usually that region would contain ROM, so it'd be don't care whether it is write-buffered or not.

CPU Load/Store Problems

XXcpuREG ---> applies ONLY to LOAD (not to store)

Memory read/write opcodes take a 1-cycle delay until the data arrives at the destination, ie. the next opcode should not use the destination register (or more unlikely, the destination memory location) as source operand. Usually, when trying to do so, the second opcode would receive the OLD value - however, if an exception occurs between the two opcodes, then the read/write operation may finish, and the second opcode would probably receive the NEW value.

CPU Register Problems - R1 (AT), R26 (K0), R29 (SP)

Exception handlers cannot preserve all registers, before returning, they must load the return address into a general purpose register (conventionally R26 aka K0), so be careful not to use that register, unless you are 100% sure that no interrupts and no other exceptions can occur. Some exception handlers might also destroy R27 aka K1 (though exception handler in the PSX Kernel leaves that register unchanged).

Some assemblers (not a22i in nocash syntax mode) are internally using R1 aka AT as scratch register for some pseudo opcodes, including for a "sw rx,imm32" pseudo opcode (which is nearly impossible to separate from the normal "sw rx,imm16" opcode), be careful not to use R1, unless you can trust your assembler not to destroy that register behind your back.

The PSX Kernel uses "Full-Decrementing-Wasted-Stack", where "Wasted" means that when calling a sub-function with N parameters, then the caller must pre-allocate N words on stack, and the sub-function may freely use and destroy these words; at [SP+0..N*4-1].

Locked Locations in Memory and I/O Area

```

00800000h      ;-when Main RAM configured to end at 7FFFFFFh
1F080000h 780000h ;-when Expansion 1 configured to end at 7FFFFFFh
1F800400h C00h   ;-region after Scratchpad
1F801024h 1Ch    ;\
1F801064h 0Ch    ;
1F801078h 08h    ;
1F801140h 6C0h   ; gaps in I/O region
1F801804h 0Ch    ;
1F801818h 08h    ;
1F801828h 3D8h   ;/
1F802080h 3FDF80h ;-when Expansion 2 configured to end at 7Fh
1FC80000h 60380000h ;-when BIOS ROM configured to end at 7FFFFFFh
C0000000h 1FFE0000h ;\

```

```
FFFE0020h E0h      ; gaps in KSEG2 (cache control region)
FFFE0140h 1FEC0h  ;/
```

Trying to access these locations generates an exception. For KSEG0 and KSEG1, locked regions are same as for first 512MB of KUSEG.

Mirrors in I/O Area

```
1F80108Ch+N*10h - D#_CHCR Mirrors - (N=0..6, for DMA channel 0..6)
```

Read/writeable mirrors of DMA Control registers at 1F801088h+N*10h.

Garbage Locations in I/O Area

```
1F801062h (2 bytes) ;\
1F801072h (2 bytes) ; unused addresses in Memory and Interrupt Control area
1F801076h (2 bytes) ;/
1F801102h (2 bytes) ;\
1F801106h (2 bytes) ; unused addresses in Timer 0 area
1F80110Ah (6 bytes) ;/
1F801112h (2 bytes) ;\
1F801116h (2 bytes) ; unused addresses in Timer 1 area
1F80111Ah (6 bytes) ;/
1F801122h (2 bytes) ;\
1F801126h (2 bytes) ; unused addresses in Timer 2 area and next some bytes
1F80112Ah (22 bytes) ;/
1F801820h (4 bytes) ;-read MDEC Data-Out port (if there is no data)
FFFE0000h (32 bytes) ;\
FFFE0100h (48 bytes) ; unused addresses in Cache control area
FFFE0132h (2 bytes) ; (including write-only upper 16bit of Port FFFE0130h)
FFFE0134h (12 bytes) ;/
```

Unlike all other unused I/O addresses, these addresses are unlocked (ie. they do not trigger exceptions on access), however they do not seem to contain anything useful. The BIOS never seems to use them. Writing any values to them seems to have no effect. And reading acts somewhat unstable:

Usually returns zeros in most cases. Except that, the first byte on a 10h-byte boundary often returns the lower 8bit of the memory address (eg. [FFFE0010h]=10h). And, when [FFFE0130h].Bit11=0, then reading from these registers does return the 32bit opcode that is to be executed next (or at some locations, the opcode thereafter).

PSX as Abbreviation for Playstation 1

In gaming and programming scene, "PSX" is most commonly used as abbreviation for the original Playstation series (occasionally including PSone). Sony has never officially used that abbreviation, however, the Playstation BIOS contains the ASCII strings "PSX" and "PS-X" here and there. The letters "PS" are widely believed to stand for PlayStation, and the meaning of the "X" is totally unknown (although, actually it may stand for POSIX.1, see below).

PSX as Abbreviation for POSIX.1

According to JMI Software Systems, "PSX" is a trademark of themselves, and stands for "single-user, single-group, subset of POSIX.1" (POSIX stands for something commonly used by HLL programmers under UNIX or so). That "PSX" kernel from JMI is available for various processors, including MIPS processors, and like the playstation, it does include functions like "atoi", and does support TTY access via Signetics 2681 DUART chips. The DTL-H2000 does also have POSIX-style "PSX>" prompt. So, altogether, it's quite possible that Sony has licensed the kernel from JMI.

PSX as Abbreviation for an Extended Playstation 2

As everybody agrees, PSX should be used only as abbreviation for Playstation 1, and nobody should never ever use it for the Playstation 2. Well, nobody, except Sony... despite of the common use as abbreviation for Playstation 1 (and despite of the JMI trademark)... in 2003, Sony has have released a "Playstation 2 with built-in HDD/DVD Videorecorder" and called that thing "PSX" for the best of confusion.

18. CPU Specifications

CPU

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System Control Coprocessor (COP0)

[COP0 - Register Summary](#)

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[COP0 - Debug Registers](#)

18.1 CPU Registers

All registers are 32bit wide.

Name	Alias	Common Usage
(R0)	zero	Constant (always 0) (this one isn't a real register)
R1	at	Assembler temporary (destroyed by some pseudo opcodes!)
R2-R3	v0-v1	Subroutine return values, may be changed by subroutines
R4-R7	a0-a3	Subroutine arguments, may be changed by subroutines
R8-R15	t0-t7	Temporaries, may be changed by subroutines
R16-R23	s0-s7	Static variables, must be saved by subs
R24-R25	t8-t9	Temporaries, may be changed by subroutines
R26-R27	k0-k1	Reserved for kernel (destroyed by some IRQ handlers!)
R28	gp	Global pointer (rarely used)
R29	sp	Stack pointer
R30	fp(s8)	Frame Pointer, or 9th Static variable, must be saved
R31	ra	Return address (used so by JAL,BLTZAL,BGEZAL opcodes)
-	pc	Program counter
-	hi,lo	Multiply/divide results, may be changed by subroutines

R0 is always zero.

R31 can be used as general purpose register, however, some opcodes are using it to store

the return address: JAL, BLTZAL, BGEZAL. (Note: JALR can optionally store the return address in R31, or in R1..R30. Exceptions store the return address in cop0r14 - EPC).

R29 (SP) - Full Decrementing Wasted Stack Pointer

The CPU doesn't explicitly have stack-related registers or opcodes, however, conventionally, R29 is used as stack pointer (SP). The stack can be accessed with normal load/store opcodes, which do not automatically increase/decrease SP, so the SP register must be manually modified to (de-)allocate data.

The PSX BIOS is using "Full Decrementing Wasted Stack".

Decrementing means that SP gets decremented when allocating data (that's common for most CPUs) - Full means that SP points to the first ALLOCATED word on the stack, so the allocated memory is at SP+0 and above, free memory at SP-1 and below, Wasted means that when calling a sub-function with N parameters, then the caller must pre-allocate N words on stack, and the sub-function may freely use and destroy these words; at [SP+0..N*4-1].

For example, "push ra,r16,r17" would be implemented as:

```
sub  sp,20h
mov  [sp+14h],ra
mov  [sp+18h],r16
mov  [sp+1Ch],r17
```

where the allocated 20h bytes have the following purpose:

[sp+00h..0Fh]	wasted stack (may, or may not, be used by sub-functions)
[sp+10h..13h]	8-byte alignment padding (not used)
[sp+14h..1Fh]	pushed registers

18.2 CPU Opcode Encoding

Primary opcode field (Bit 26..31)

00h=SPECIAL	08h=ADDI	10h=COP0	18h=N/A	20h=LB	28h=SB	30h=LWC0	38h=SWC0
01h=BcondZ	09h=ADDIU	11h=COP1	19h=N/A	21h=LH	29h=SH	31h=LWC1	39h=SWC1
02h=J	0Ah=SLTI	12h=COP2	1Ah=N/A	22h=LWL	2Ah=SWL	32h=LWC2	3Ah=SWC2
03h=JAL	0Bh=SLTIU	13h=COP3	1Bh=N/A	23h=LW	2Bh=SW	33h=LWC3	3Bh=SWC3
04h=BEQ	0Ch=ANDI	14h=N/A	1Ch=N/A	24h=LB	2Ch=N/A	34h=N/A	3Ch=N/A
05h=BNE	0Dh=ORI	15h=N/A	1Dh=N/A	25h=LHU	2Dh=N/A	35h=N/A	3Dh=N/A
06h=BLEZ	0Eh=XORI	16h=N/A	1Eh=N/A	26h=LWR	2Eh=SWR	36h=N/A	3Eh=N/A
07h=BGTZ	0Fh=LUI	17h=N/A	1Fh=N/A	27h=N/A	2Fh=N/A	37h=N/A	3Fh=N/A

Secondary opcode field (Bit 0..5) (when Primary opcode = 00h)

00h=SLL	08h=JR	10h=MFHI	18h=MULT	20h=ADD	28h=N/A	30h=N/A	38h=N/A
01h=N/A	09h=JALR	11h=MTHI	19h=MULTU	21h=ADDU	29h=N/A	31h=N/A	39h=N/A
02h=SRL	0Ah=N/A	12h=MFLO	1Ah=DIV	22h=SUB	2Ah=SLT	32h=N/A	3Ah=N/A
03h=SRA	0Bh=N/A	13h=MTLO	1Bh=DIVU	23h=SUBU	2Bh=SLTU	33h=N/A	3Bh=N/A
04h=SLLV	0Ch=SYSCALL	14h=N/A	1Ch=N/A	24h=AND	2Ch=N/A	34h=N/A	3Ch=N/A
05h=N/A	0Dh=BREAK	15h=N/A	1Dh=N/A	25h=OR	2Dh=N/A	35h=N/A	3Dh=N/A
06h=SRLV	0Eh=N/A	16h=N/A	1Eh=N/A	26h=XOR	2Eh=N/A	36h=N/A	3Eh=N/A
07h=SRAV	0Fh=N/A	17h=N/A	1Fh=N/A	27h=NOR	2Fh=N/A	37h=N/A	3Fh=N/A

Opcode/Parameter Encoding

31..26		25..21		20..16		15..11		10..6		5..0	
6bit		5bit		5bit		5bit		6bit			
<hr/>											
000000		N/A		rt		rd		imm5		0000xx	shift-imm
000000		rs		rt		rd		N/A		0001xx	shift-reg
000000		rs		N/A		N/A		N/A		001000	jr
000000		rs		N/A		rd		N/A		001001	jalr
000000		<----comment20bit---->						00110x		sys/brk	
000000		N/A		N/A		rd		N/A		0100x0	mfhi/mflo
000000		rs		N/A		N/A		N/A		0100x1	mthi/mtlo
000000		rs		rt		N/A		N/A		0110xx	mul/div
000000		rs		rt		rd		N/A		10xxxx	alu-reg
000001		rs		00000		<--immediate16bit-->				bltz	
000001		rs		00001		<--immediate16bit-->				bgez	
000001		rs		10000		<--immediate16bit-->				bltzal	
000001		rs		10001		<--immediate16bit-->				bgezal	
00001x		<-----immediate26bit----->						j/jal			
00010x		rs		rt		<--immediate16bit-->				beq/bne	
00011x		rs		N/A		<--immediate16bit-->				blez/bgtz	
001xxx		rs		rt		<--immediate16bit-->				alu-imm	
001111		N/A		rt		<--immediate16bit-->				lui-imm	
100xxx		rs		rt		<--immediate16bit-->				load rt, [rs+imm]	

```
101xxx | rs    | rt    | <--immediate16bit--> | store rt,[rs+imm]
x1xxxx | <-----coprocessor specific-----> | coprocessor (see below)
```

Coprocessor Opcode/Parameter Encoding

31..26	25..21 20..16 15..11 10..6	5..0		
6bit	5bit 5bit 5bit 5bit 6bit			
0100nn	0 0000 rt	rd	N/A	000000 MFCn rt,rd_dat ;rt = dat
0100nn	0 0010 rt	rd	N/A	000000 CFCn rt,rd_cnt ;rt = cnt
0100nn	0 0100 rt	rd	N/A	000000 MTCn rt,rd_dat ;dat = rt
0100nn	0 0110 rt	rd	N/A	000000 CTCn rt,rd_cnt ;cnt = rt
0100nn	0 1000 00000 <--immediate16bit-->	BCnF target ;jump if false		
0100nn	0 1000 00001 <--immediate16bit-->	BCnT target ;jump if true		
0100nn	1 <-----immediate25bit----->	COPn imm25		
010000	1 0000 N/A	N/A	N/A	000001 COP0 01h ;=TLBR
010000	1 0000 N/A	N/A	N/A	000010 COP0 02h ;=TLBWI
010000	1 0000 N/A	N/A	N/A	000110 COP0 06h ;=TLBWR
010000	1 0000 N/A	N/A	N/A	001000 COP0 08h ;=TLBP
010000	1 0000 N/A	N/A	N/A	010000 COP0 10h ;=RFE
1100nn	rs	rt	<--immediate16bit-->	LWCn rt_dat,[rs+imm]
1110nn	rs	rt	<--immediate16bit-->	SWCn rt_dat,[rs+imm]

Illegal Opcodes

All opcodes that are marked as "N/A" in the Primary and Secondary opcode tables are causing a Reserved Instruction Exception (excode=0Ah).
The unused operand bits (eg. Bit21-25 for LUI opcode) should be usually zero, but do not necessarily trigger exceptions if set to nonzero values.

18.3 CPU Load/Store Opcodes

Load instructions

movbs rt,[imm+rs]	lb rt,imm(rs)	rt=[imm+rs] ;byte sign-extended
movb rt,[imm+rs]	lbu rt,imm(rs)	rt=[imm+rs] ;byte zero-extended
movhs rt,[imm+rs]	lh rt,imm(rs)	rt=[imm+rs] ;halfword sign-extended
movh rt,[imm+rs]	lhu rt,imm(rs)	rt=[imm+rs] ;halfword zero-extended
mov rt,[imm+rs]	lw rt,imm(rs)	rt=[imm+rs] ;word

Load instructions can read from the data cache (if the data is not in the cache, or if the memory region is uncached, then the CPU gets halted until it has read the data) (however, the PSX doesn't have a data cache).

Caution - Load Delay

The loaded data is NOT available to the next opcode, ie. the target register isn't updated until the next opcode has completed. So, if the next opcode tries to read from the load destination register, then it would (usually) receive the OLD value of that register (unless an IRQ occurs between the load and next opcode, in that case the load would complete during IRQ handling, and so, the next opcode would receive the NEW value).

Store instructions

```
movb [imm+rs],rt    sb  rt,imm(rs)      [imm+rs]=(rt AND FFh) ;store 8bit
movh [imm+rs],rt    sh  rt,imm(rs)      [imm+rs]=(rt AND FFFFh) ;store 16bit
mov  [imm+rs],rt    sw  rt,imm(rs)      [imm+rs]=rt           ;store 32bit
```

Store operations are passed to the write-buffer, so they can execute within a single clock cycle (unless the write-buffer was full, in that case the CPU gets halted until there's room in the buffer). But, the PSX doesn't have a writebuffer...?

Load/Store Alignment

Halfword addresses must be aligned by 2, word addresses must be aligned by 4, trying to access mis-aligned addresses will cause an exception. There's no alignment restriction for bytes.

Unaligned Load/Store

```
lwr  rt,imm(rs)      load right bits of rt from memory (usually imm+0)
lwl  rt,imm(rs)      load left   bits of rt from memory (usually imm+3)
swr  rt,imm(rs)      store right bits of rt to memory (usually imm+0)
swl  rt,imm(rs)      store left   bits of rt to memory (usually imm+3)
```

There's no delay required between lwl and lwr, so you can use them directly following each other, eg. to load a word anywhere in memory without regard to alignment:

```
lwl  r2,$0003(t0)  ;\no delay required between these
lwr  r2,$0000(t0)  ;/(although both access r2)
nop
and  r2,r2,0ffffh  ;-requires load delay HERE (before reading from r2)
                  ;-access r2 (eg. reducing it to unaligned 16bit data)
```

Unaligned Load/Store (Details)

LWR/SWR transfers the right (=lower) bits of Rt, up-to 32bit memory boundary:

lwr/swr [N*4+0]	transfer whole 32bit of Rt to/from [N*4+0..3]
lwr/swr [N*4+1]	transfer lower 24bit of Rt to/from [N*4+1..3]
lwr/swr [N*4+2]	transfer lower 16bit of Rt to/from [N*4+2..3]
lwr/swr [N*4+3]	transfer lower 8bit of Rt to/from [N*4+3]

LWL/SWL transfers the left (=upper) bits of Rt, down-to 32bit memory boundary:

lwl/swl [N*4+0]	transfer upper 8bit of Rt to/from [N*4+0]
lwl/swl [N*4+1]	transfer upper 16bit of Rt to/from [N*4+0..1]
lwl/swl [N*4+2]	transfer upper 24bit of Rt to/from [N*4+0..2]
lwl/swl [N*4+3]	transfer whole 32bit of Rt to/from [N*4+0..3]

The CPU has four separate byte-access signals, so, within a 32bit location, it can transfer all fragments of Rt at once (including for odd 24bit amounts). The transferred data is not zero- or sign-expanded, eg. when transferring 8bit data, the other 24bit of Rt and [mem] will remain intact.

Note: The aligned variant can also be misused for blocking memory access on aligned addresses (in that case, if the address is known to be aligned, only one of the opcodes are needed, either LWL or LWR).... Uhuhhhhhm, OR is that NOT allowed... more PROBABLY that doesn't work?

18.4 CPU ALU Opcodes

arithmetic instructions

addt rd,rs,rt	add rd,rs,rt	rd=rs+rt (with overflow trap)
add rd,rs,rt	addu rd,rs,rt	rd=rs+rt
subt rd,rs,rt	sub rd,rs,rt	rd=rs-rt (with overflow trap)
sub rd,rs,rt	subu rd,rs,rt	rd=rs-rt
addt rt,rs,imm	addi rt,rs,imm	rt=rs+(-8000h..+7FFFh) (with ov.trap)
add rt,rs,imm	addiu rt,rs,imm	rt=rs+(-8000h..+7FFFh)

The opcodes "with overflow trap" do trigger an exception (and leave rd unchanged) in case of overflows.

comparison instructions

```

setlt slt    rd,rs,rt  if rs<rt then rd=1 else rd=0 (signed)
setb sltu   rd,rs,rt  if rs<rt then rd=1 else rd=0 (unsigned)
setlt slti   rt,rs,imm if rs<(-8000h..+7FFFh)  then rt=1 else rt=0 (signed)
setb sltiu  rt,rs,imm if rs<(FFFF8000h..7FFFh) then rt=1 else rt=0(unsigned)

```

logical instructions

and	rd,rs,rt	and	rd,rs,rt	rd = rs AND rt
or	rd,rs,rt	or	rd,rs,rt	rd = rs OR rt
xor	rd,rs,rt	xor	rd,rs,rt	rd = rs XOR rt
nor	rd,rs,rt	nor	rd,rs,rt	rd = FFFFFFFFh XOR (rs OR rt)
and	rt,rs,imm	andi	rt,rs,imm	rt = rs AND (0000h..FFFFh)
or	rt,rs,imm	ori	rt,rs,imm	rt = rs OR (0000h..FFFFh)
xor	rt,rs,imm	xori	rt,rs,imm	rt = rs XOR (0000h..FFFFh)

shifting instructions

shl	rd,rt,rs	sllv	rd,rt,rs	rd = rt SHL (rs AND 1Fh)
shr	rd,rt,rs	srlv	rd,rt,rs	rd = rt SHR (rs AND 1Fh)
sar	rd,rt,rs	sraw	rd,rt,rs	rd = rt SAR (rs AND 1Fh)
shl	rd,rt,imm	sll	rd,rt,imm	rd = rt SHL (00h..1Fh)
shr	rd,rt,imm	srl	rd,rt,imm	rd = rt SHR (00h..1Fh)
sar	rd,rt,imm	sra	rd,rt,imm	rd = rt SAR (00h..1Fh)
mov	rt,i*10000h	lui	rt,imm	rt = (0000h..FFFFh) SHL 16

Unlike many other opcodes, shifts use 'rt' as second (not third) operand.
The hardware does NOT generate exceptions on SHL overflows.

Multiply/divide

smul	rs,rt	mult	rs,rt	hi:lo = rs*rt (signed)
umul	rs,rt	multu	rs,rt	hi:lo = rs*rt (unsigned)
sdiv	rs,rt	div	rs,rt	lo = rs/rt, hi=rs mod rt (signed)
udiv	rs,rt	divu	rs,rt	lo = rs/rt, hi=rs mod rt (unsigned)
mov	rd,hi	mfhi	rd	rd=hi ;move from hi
mov	rd,lo	mflo	rd	rd=lo ;move from lo
mov	hi,rs	mthi	rs	hi=rs ;move to hi
mov	lo,rs	mtlo	rs	lo=rs ;move to lo

The mul/div opcodes are starting the multiply/divide operation, starting takes only a single clock cycle, however, trying to read the result from the hi/lo registers while the mul/div operation is busy will halt the CPU until the mul/div has completed. For multiply,

the execution time depends on rs (ie. "small*large" can be much faster than "large*small").

```

__umul_execution_time_____
Fast  (6 cycles)    rs = 00000000h..000007FFh
Med   (9 cycles)    rs = 00000800h..000FFFFFh
Slow  (13 cycles)   rs = 00100000h..FFFFFFFh
__smul_execution_time_____
Fast  (6 cycles)    rs = 00000000h..000007FFh, or rs = FFFF800h..FFFFFFFh
Med   (9 cycles)    rs = 00000800h..000FFFFFh, or rs = FFF00000h..FFFFF801h
Slow  (13 cycles)   rs = 00100000h..7FFFFFFFh, or rs = 80000000h..FFF00001h
__udiv/sdiv_execution_time_____
Fixed (36 cycles)  no matter of rs and rt values

```

For example, when executing "umul 123h,12345678h" and "mov r1,lo", one can insert up to six (cached) ALU opcodes, or read one value from PSX Main RAM (which has 6 cycle access time) between the "umul" and "mov" opcodes without additional slowdown. The hardware does NOT generate exceptions on divide overflows, instead, divide errors are returning the following values:

Opcode	Rs	Rd	Hi/Remainder	Lo/Result
udiv	0..FFFFFFFh	0	--> Rs	FFFFFFFh
sdiv	0..+7FFFFFFFh	0	--> Rs	-1
sdiv	-80000000h..-1	0	--> Rs	+1
sdiv	-80000000h	-1	--> 0	-80000000h

For udiv, the result is more or less correct (as close to infinite as possible). For sdiv, the results are total garbage (about farthest away from the desired result as possible). Note: After accessing the lo/hi registers, there seems to be a strange rule that one should not touch the lo/hi registers in the next 2 cycles or so... not yet understood if/when/how that rule applies...?

18.5 CPU Jump Opcodes

jumps and branches

Note that the instruction following the branch will always be executed.

```

jmp dest      j      dest      pc=(pc and F0000000h)+(imm26bit*4)
call dest     jal    dest      pc=(pc and F0000000h)+(imm26bit*4),ra=$+8
jmp rs        jr     rs       pc=rs
call rs,ret=rd jalr  (rd,)rs(,rd) pc=rs, rd=$+8 ;see caution
je  rs,rt,dest beq   rs,rt,dest if rs=rt  then pc=$+4+(-8000h..+7FFFh)*4
jne rs,rt,dest bne   rs,rt,dest if rs<>rt then pc=$+4+(-8000h..+7FFFh)*4

```

js	rs,dest	bltz	rs,dest	if rs<0	then pc=\$+4+(-8000h..+7FFFh)*4
jns	rs,dest	bgez	rs,dest	if rs>=0	then pc=\$+4+(-8000h..+7FFFh)*4
jgtz	rs,dest	bgtz	rs,dest	if rs>0	then pc=\$+4+(-8000h..+7FFFh)*4
jlez	rs,dest	blez	rs,dest	if rs<=0	then pc=\$+4+(-8000h..+7FFFh)*4
calls	rs,dest	bltzal	rs,dest	if rs<0	then pc=\$+4+(..)*4, ra=\$+8
callns	rs,dest	bgezal	rs,dest	if rs>=0	then pc=\$+4+(..)*4, ra=\$+8

JALR cautions

Caution: The JALR source code syntax varies (IDT79R3041 specs say "jalr rs,rd", but MIPS32 specs say "jalr rd,rs"). Moreover, JALR may not use the same register for both operands (eg. "jalr r31,r31") (doing so would destroy the target address; which is normally no problem, but it can be a problem if an IRQ occurs between the JALR opcode and the following branch delay opcode; in that case BD gets set, and EPC points "back" to the JALR opcode, so JALR is executed twice, with destroyed target address in second execution).

exception opcodes

Unlike for jump/branch opcodes, exception opcodes are immediately executed (ie. without executing the following opcode).

syscall	imm20	generates a system call exception
break	imm20	generates a breakpoint exception

The 20bit immediate doesn't affect the CPU (however, the exception handler may interprete it by software; by examining the opcode bits at [epc-4]).

18.6 CPU Coprocessor Opcodes

Coprocessor Instructions (COP0..COP3)

mov	rt,cop#Rd(0-31)	mfc# rt,rd	; rt = cop#datRd ;data regs
mov	rt,cop#Rd(32-63)	cfc# rt,rd	; rt = cop#cntRd ;control regs
mov	cop#Rd(0-31),rt	mtc# rt,rd	; cop#datRd = rt ;data regs
mov	cop#Rd(32-63),rt	ctc# rt,rd	; cop#cntRd = rt ;control regs
mov	cop#cmd,imm25	cop# imm25	; exec cop# command 0..1FFFFFFh
mov	cop#Rt(0-31),[rs+imm]	lwc# rt,imm(rs)	; cop#dat_rt = [rs+imm] ;word
mov	[rs+imm],cop#Rt(0-31)	swc# rt,imm(rs)	; [rs+imm] = cop#dat_rt ;word
jf	cop#flg,dest	bc#f dest	; if cop#flg=false then pc=\$+disp
jt	cop#flg,dest	bc#t dest	; if cop#flg=true then pc=\$+disp
rfe		rfe	; return from exception (COP0)
tlb<xx>		tlb<xx>	; virtual memory related (COP0)

Unknown if any tlb-opcodes (tlbr,tlbwi,tlbwr,tlbp) are implemented in the psx?

Caution - Load Delay

When reading from a coprocessor register, the next opcode cannot use the destination register as operand (much the same as the Load Delays that occur when reading from memory; see there for details).

Reportedly, the Load Delay applies for the next TWO opcodes after coprocessor reads, but, that seems to be nonsense (the PSX does finish both COP0 and COP2 reads after ONE opcode).

Caution - Store Delay

In some cases, a similar delay occurs when writing to a coprocessor register. COP0 is more or less free of store delays (eg. one can read from a cop0 register immediately after writing to it), the only known exception is the cop2 enable bit in cop0r12.bit30 (setting that cop0 bit acts delayed, and cop2 isn't actually enabled until after 2 clock cycles or so). Writing to cop2 registers has a delay of 2..3 clock cycles. In most cases, that is probably (?) only 2 cycles, but special cases like writing to IRGB (which does additionally affect IR1,IR2,IR3) take 3 cycles until the result arrives in all registers).

Note that Store Delays are counted in numbers of clock cycles (not in numbers of opcodes). For 3 cycle delay, one must usually insert 3 cached opcodes (or one uncached opcode).

18.7 CPU Pseudo Opcodes

Pseudo instructions (native/spasm)

```

nop           ;alias for sll r0,r0,0
move rd,rs    ;alias for addu rd,rs,r0
la  rx,imm32  ;load address (alias for lui rx / addiu rx)
li  rx,imm32  ;load immediate (alias for lui rx / ori rx)
li  rx,imm16   ;load immediate (alias for ori, range 0..FFFFh)
li  rx,-imm15  ;load immediate (alias for addiu, range -1..-8000h)
li  rx,imm16*10000h ;load immediate (alias for lui)
lw   rx,imm32  ;load from address (lui rx / lw rx,rx)
sw   rx,imm32  ;store to address (lui r1 / sw rx,r1) (destroys r1!)
lb,lh,lwl,lwr,lbu,lhu;as above pseudo lw
sb,sh,swl,swr  ;as above pseudo sw (ie. also destroys r1!)
alu rx,op      ;alias for alu rx,rx,op
alu(u) rx,rx,imm ;alias for alui(u) rx,rx,imm
jalr rx       ;alias for jalr (RA,) rx(,RA)

```

```

subi(u) rt,rs,imm      ;alias for addi(u) rt,rs,-imm
beqz rx,dest           ;alias for beq rx,r0,dest
bnez rx,dest           ;alias for bne rx,r0,dest
b dest                 ;alias for beq r0,r0,dest (jump relative/spasm)
bra dest               ;alias for ...? (jump relative/gnu)
bal dest               ;alias for ...? (call relative/spasm)

```

Pseudo instructions (nocash/a22i)

```

mov  rx,NNNN0000h      ;alias for lui  rx,NNNNh
mov  rx,0000NNNNh     ;alias for or   rx,r0,NNNNh ;max +FFFFh
mov  rx,-imm15         ;alias for add  rx,r0,-NNNNh ;min -8000h
mov  rx,ry              ;alias for or   rx,ry,0  (or "addiu")
nop                   ;alias for shl  r0,r0,0
jrel dest             ;alias for blez R0,dest ;relative jump
crel dest             ;alias for callns R0,dest ;relative call
jz   rx,dest           ;alias for je   rx,R0,dest
jnz  rx,dest           ;alias for jne  rx,R0,dest
call rx                ;alias for call rx,ret=RA
ret                   ;alias for jmp  ra
subt rt,rs,imm        ;alias for addt rt,rs,-imm
sub  rt,rs,imm        ;alias for add  rt,rs,-imm
alu  rx,op              ;alias for alu  rx,rx,op
neg(t) rx,ry           ;alias for sub(t) rx,R0,ry
not   rx,ry             ;alias for nor   rx,R0,ry
neg(t)/not rx          ;alias for neg(t)/not rx,rx
setz rx,ry             ;alias for setb rx,ry,1  (set if zero)
setnz rx,ry            ;alias for setb rx,R0,ry (set if nonzero)
syscall/break         ;alias for syscall/break 000000h

```

Below are pseudo instructions combined of two 32bit opcodes...

```

movp rx,imm32          ;alias for lui  rx,imm16 -plus- or rx,rx,imm16)
mov(bhs)p rx,[imm32]    ;load from address (lui rx,imm16 / mov rx,[rx+imm16])
movu [rs+imm]           ;alias for lwr/swr [rs+imm] plus lwl/swl [rs+imm+3]
reti                   ;alias for jmp k0 plus rfe

```

Below are pseudo instructions combined of two or more 32bit opcodes...

```

push rlist              ;alias for sub sp,n*4 -- mov [sp+(1..n)*4],r1..rn
pop  rlist              ;alias for mov r1..rn,[sp+(1..n)*4] -- add sp,n*4
pop  pc,rlist           ;alias for pop ra,rlist -- jmp ra

```

Possible more Pseudos...

```

call x0000000h ;call y0000000h (could be half-working for mem mirrors?)
setae, setge    ;--> setb, setlt with swapped operands

```

Directives (nocash)

```
.mips      ;select MIPS instruction set (alternately .hc05 for MC68HC05)
.bios      ;create a .ROM file (instead of .EXE)
.auto_nop   ;append NOPs to jumps ;unless next opcode starts with a +
org imm    ;assume following code to be originated at address "imm"
db n(,n(..)) ;define 8bit data values(s) or quoted ASCII strings
dw n(,n(..)) ;define 16bit data values(s) (not 32bit data!)
dd n(,n(..)) ;define 32bit data values(s)
.align imm
0          ;alias for immediate 0 and register R0 (whichever fits)
```

Directives (native)

```
org imm      ;self-explaining (but, default=$80010000 for spasm!)
align imm    ;self-explaining (probably zeropadded?)
db n(,n(..)) ;define 8bit data values(s) or quoted ASCII strings
dh n(,n(..)) ;define 16bit data values(s)
dw n(,n(..)) ;define 32bit data values(s) (not 16bit data!)
dcb len,value ;fill <len> bytes by <value> (different as DCB on ARM CPUs)
xyz         ;define label "xyz" at current address (without colon)
xyz equ n    ;assign value n to xyz
xyz = n     ;probably same/similar as "equ"
;xyz        ;comments invoked with semicolon (spasm)
incbin file.bin ;import binary file
include file.asm ;import asm file
zero         ;alias for r0
>imm32       ;alias for (i-(i AND 8000h))/10000h, and/or i/10000h ?
<imm32       ;alias for (i AND 0FFFFh), used for SW(+/-) and ORI(+) ?
end         ;N/A ;no "end" or ".end" directive needed/used by spasm
r1 aka at ;N/A ;some assemblers may (optionally) reject to use r1/at
```

Syntax for unknown assembler (for pad.s)

It uses "0x" for HEX values (but doesn't use "\$" for registers).

It uses "#" instead of ";" for comments.

It uses ":" for labels (fortunately).

The assembler has at least one directive: ".byte" (equivalent to "db" on other assemblers).

I've no clue which assembler is used for that syntax... could that be the Psy-Q assembler?

18.8 COP0 - Register Summary

COP0 Register Summary

cop0r0-r2	- N/A
cop0r3	- BPC - Breakpoint on execute (R/W)
cop0r4	- N/A
cop0r5	- BDA - Breakpoint on data access (R/W)
cop0r6	- JUMPDEST - Randomly memorized jump address (R)
cop0r7	- DCIC - Breakpoint control (R/W)
cop0r8	- BadVaddr - Bad Virtual Address (R)
cop0r9	- BDAM - Data Access breakpoint mask (R/W)
cop0r10	- N/A
cop0r11	- BPCM - Execute breakpoint mask (R/W)
cop0r12	- SR - System status register (R/W)
cop0r13	- CAUSE - (R) Describes the most recently recognised exception
cop0r14	- EPC - Return Address from Trap (R)
cop0r15	- PRID - Processor ID (R)
cop0r16-r31	- Garbage
cop0r32-r63	- N/A - None such (Control regs)

18.9 COP0 - Exception Handling

cop0r13 - CAUSE - (Read-only, except, Bit8-9 are R/W)

Describes the most recently recognised exception

0-1	-	Not used (zero)
2-6	-	Excode Describes what kind of exception occurred:
	00h	INT Interrupt
	01h	MOD Tlb modification (none such in PSX)
	02h	TLBL Tlb load (none such in PSX)
	03h	TLBS Tlb store (none such in PSX)
	04h	AdEL Address error, Data load or Instruction fetch
	05h	AdES Address error, Data store
	06h-0Fh	The address errors occur when attempting to read outside of KUseg in user mode and when the address is misaligned. (See also: BadVaddr register)
	06h	IBE Bus error on Instruction fetch
	07h	DBE Bus error on Data load/store
	08h	Syscall Generated unconditionally by syscall instruction
	09h	BP Breakpoint - break instruction
	0Ah	RI Reserved instruction
	0Bh	CpU Coprocessor unusable
	0Ch	Ov Arithmetic overflow
	0Dh-1Fh	Not used
7	-	Not used (zero)
8-15	Ip	Interrupt pending field. Bit 8 and 9 are R/W, and

	contain the last value written to them. As long as any of the bits are set they will cause an interrupt if the corresponding bit is set in IM.
16-27 -	Not used (zero)
28-29 CE	Contains the coprocessor number if the exception occurred because of a coprocessor instruction for a coprocessor which wasn't enabled in SR.
30 -	Not used (zero)
31 BD	Is set when last exception points to the branch instruction instead of the instruction in the branch delay slot, where the exception occurred.

cop0r12 - SR - System status register (RW)

0	IEc Current Interrupt Enable (0=Disable, 1=Enable) ;rfe pops IUp here
1	KUc Current Kernal/User Mode (0=Kernel, 1=User) ;rfe pops KUp here
2	IEp Previous Interrupt Disable ;rfe pops IUo here
3	KUp Previous Kernal/User Mode ;rfe pops KUo here
4	IEo Old Interrupt Disable ;left unchanged by rfe
5	KUo Old Kernal/User Mode ;left unchanged by rfe
6-7 -	Not used (zero)
8-15 Im	8 bit interrupt mask fields. When set the corresponding interrupts are allowed to cause an exception.
16	Isc Isolate Cache (0=No, 1=Isolate) When isolated, all load and store operations are targetted to the Data cache, and never the main memory. (Used by PSX Kernel, in combination with Port FFFE0130h)
17	Swc Swapped cache mode (0=Normal, 1=Swapped) Instruction cache will act as Data cache and vice versa. Use only with Isc to access & invalidate Instr. cache entries. (Not used by PSX Kernel)
18	PZ When set cache parity bits are written as 0.
19	CM Shows the result of the last load operation with the D-cache isolated. It gets set if the cache really contained data for the addressed memory location.
20	PE Cache parity error (Does not cause exception)
21	TS TLB shutdown. Gets set if a programm address simultaneously matches 2 TLB entries. (initial value on reset allows to detect extended CPU version?)
22	BEV Boot exception vectors in RAM/ROM (0=RAM/KSEG0, 1=ROM/KSEG1)
23-24 -	Not used (zero)
25	RE Reverse endianness (0=Normal endianness, 1=Reverse endianness) Reverses the byte order in which data is stored in memory. (lo-hi -> hi-lo) (Has affect only to User mode, not to Kernel mode) (?) (The bit doesn't exist in PSX ?)
26-27 -	Not used (zero)
28	CU0 COP0 Enable (0=Enable only in Kernal Mode, 1=Kernal and User Mode)
29	CU1 COP1 Enable (0=Disable, 1=Enable) (none such in PSX)
30	CU2 COP2 Enable (0=Disable, 1=Enable) (GTE in PSX)
31	CU3 COP3 Enable (0=Disable, 1=Enable) (none such in PSX)

cop0r14 - EPC - Return Address from Trap (R)

```
0-31  Return Address from Exception
```

This address is the instruction at which the exception took place, unless BD is set in CAUSE, then the instruction was at EPC+4.

Interrupts should always return to EPC+0, no matter of the BD flag. That way, if BD=1, the branch gets executed again, that's required because EPC stores only the current program counter, but not additionally the branch destination address.

Other exceptions may require to handle BD. In simple cases, when BD=0, the exception handler may return to EPC+0 (retry execution of the opcode), or to EPC+4 (skip the opcode that caused the exception). Note that jumps to faulty memory locations are executed without exception, but will trigger address errors and bus errors at the target location, ie. EPC (and BadVAddr, in case of address errors) point to the faulty address, not to the opcode that has jumped to that address).

Interrupts vs GTE Commands

If an interrupt occurs "on" a GTE command (cop2cmd), then the GTE command is executed, but nevertheless, the return address in EPC points to the GTE command. So, if the exception handler would return to EPC as usually, then the GTE command would be executed twice. In best case, this would be a waste of clock cycles, in worst case it may lead to faulty result (if the results from the 1st execution are re-used as incoming parameters in the 2nd execution). To fix the problem, the exception handler must do:

```
if (cause AND 7Ch)=00h           ;if excode=interrupt
  if ([epc] AND FE000000h)=4A000000h ;and opcode=cop2cmd
    epc=epc+4                      ;then skip that opcode
```

Note: The above exception handling is working only in newer PSX BIOSes, but in very old PSX BIOSes, it is only incompletely implemented (see "BIOS Patches" chapter for common workarounds; or write your own exception handler without using the BIOS). Of course, the above exception handling won't work in branch delays (where BD gets set to indicate that EPC was modified) (best workaround is not to use GTE commands in branch delays).

cop0cmd=10h - RFE opcode - Prepare Return from Exception

The RFE opcode moves some bits in cop0r12 (SR): bit2-3 are copied to bit0-1, and bit4-5 are copied to bit2-3, all other bits (including bit4-5) are left unchanged.

The RFE opcode does NOT automatically jump to EPC. Instead, the exception handler must copy EPC into a register (usually R26 aka K0), and then jump to that address. Because of branch delays, that would look like so:

```
mov k0, epc ;get return address
push k0      ;save epc in memory (if you expect nested exceptions)
...
pop k0      ;restore from memory (if you expect nested exceptions)
jmp k0      ;jump to K0 (after executing the next opcode)
+rfe       ;move SR bit4/5 --> bit2/3 --> bit0/1
```

If you expect exceptions to be nested deeply, also push/pop SR. Note that there's no way to leave all registers intact (ie. above code destroys K0).

cop0r8 - BadVaddr - Bad Virtual Address (R)

Contains the address whose reference caused an exception. Set on any MMU type of exceptions, on references outside of kuseg (in User mode) and on any misaligned reference. BadVaddr is updated ONLY by Address errors (Excode 04h and 05h), all other exceptions (including bus errors) leave BadVaddr unchanged.

Exception Vectors (depending on BEV bit in SR register)

Exception	BEV=0	BEV=1
Reset	BFC00000h	BFC00000h (Reset)
UTLB Miss	80000000h	BFC00100h (Virtual memory, none such in PSX)
COP0 Break	80000040h	BFC00140h (Debug Break)
General	80000080h	BFC00180h (General Interrupts & Exceptions)

Note: Changing vectors at 800000xxh (kseg0) seems to be automatically reflected to the instruction cache without needing to flush cache (at least it worked SOMETIMES in my test proggy... but NOT always? ...anyways, it'd be highly recommended to flush cache when changing any opcodes), whilst changing mirrors at 000000xxh (kuseg) seems to require to flush cache.

The PSX uses only the BEV=0 vectors (aside from the reset vector, the PSX BIOS ROM doesn't contain any of the BEV=1 vectors).

Exception Priority

Reset At any time (highest)	; -reset
AdEL Memory (Load instruction)	; \
AdES Memory (Store instruction)	; memory (data load/store)
DBE Memory (Load or store)	; /

```

MOD ALU (Data TLB)           ; \
TLBL ALU (DTLB Miss)        ; none such
TLBS ALU (DTLB Miss)        ;/
Ovf ALU                      ;-overflow
Int ALU                      ;-interrupt
Sys RD (Instruction Decode) ; \
Bp RD (Instruction Decode)  ;
RI RD (Instruction Decode)  ;
CpU RD (Instruction Decode) ; /
TLBL I-Fetch (ITLB Miss)    ; -none such
AdEL IVA (Instruction Virtual Address) ; \memory (opcode fetch)
IBE RD (end of I-Fetch, lowest)   ; /

```

18.10 COP0 - Misc

cop0r15 - PRID - Processor ID (R)

0-7	Revision
8-15	Implementation
16-31	Not used

For a Playstation with CXD8606CQ CPU, the PRID value is 00000002h.
Unknown if/which other Playstation CPU versions have other values...?

cop0r6 - JUMPDEST - Randomly memorized jump address (R)

The is a rather strange totally useless register. After certain exceptions, the CPU does memorize a jump destination address in the register. Once when it has memorized an address, the register becomes locked, and the memorized value won't change until it becomes unlocked by a new exception. Exceptions that do unlock the register are Reset and Interrupts (cause.bit10). Exceptions that do NOT unlock the register are syscall/break opcodes, and software generated interrupts (eg. cause.bit8).

In the unlocked state, the CPU does more or less randomly memorize one of the next some jump destinations - eg. the destination from the second jump after reset, or from a jump that occurred immediately before executing the IRQ handler, or from a jump inside of the IRQ handler, or even from a later jump that occurs shortly after returning from the IRQ handler.

The register seems to be read-only (although the Kernel initialization code writes 0 to it for whatever reason).

cop0r0..r2, cop0r4, cop0r10, cop0r32..r63 - N/A

Registers 0,1,2,4,10 control virtual memory on some MIPS processors (but there's none such in the PSX), and Registers 32..63 (aka "control registers") aren't used in any MIPS processors. Trying to read any of these registers causes a Reserved Instruction Exception (excode=0Ah).

cop0cmd=01h,02h,06h,08h - TLBR,TLBWI,TLBWR,TLBP

The PSX supports only one cop0cmd (cop0cmd=10h aka RFE). Trying to execute the TLBxx opcodes causes a Reserved Instruction Exception (excode=0Ah).

jf/jt cop0flg,dest - conditional cop0 jumps**mov [mem],cop0reg / mov cop0reg,[mem] - coprocessor cop0 load/store**

Not supported by the CPU. Trying to execute these opcodes causes a Coprocessor Unusable Exception (excode=0Bh, ie. unlike above, not 0Ah).

cop0r16-r31 - Garbage

Trying to read these registers returns garbage (but does not trigger an exception). When reading one of the garbage registers shortly after reading a valid cop0 register, the garbage value is usually the same as that of the valid register. When doing the read later on, the return value is usually 00000020h, or when reading much later it returns 00000040h, or even 00000100h. No idea what is causing that effect...?

Note: The garbage registers can be accessed (without causing an exception) even in "User mode with cop0 disabled" (SR.Bit1=1 and SR.Bit28=0); accessing any other existing cop0 registers (or executing the rfe opcode) in that state is causing Coprocessor Unusable Exceptions (excode=0Bh).

18.11 COP0 - Debug Registers

The COP0 debug registers seem to be PSX specific, normal R30xx CPUs like IDT's R3041 and R3051 don't have anything similar.

cop0r7 - DCIC - Breakpoint control (R/W)

0	Automatically set by hardware upon Any break	(R/W)
1	Automatically set by hardware upon BPC Code break	(R/W)

```

2    Automatically set by hardware upon BDA Data break      (R/W)
3    Automatically set by hardware upon BDA Data-Read break (R/W)
4    Automatically set by hardware upon BDA Data-Write break (R/W)
5    Automatically set by hardware upon any-jump break      (R/W)
6-11  Not used (always zero)
12-13 Jump Redirection (0=Disable, 1..3=Enable) (see note) (R/W)
14-15 Unknown? (R/W)
16-22 Not used (always zero)
23    Super-Master Enable 1 for bit24-29
24    Execution breakpoint (0=Disabled, 1=Enabled) (see BPC, BPCM)
25    Data access breakpoint (0=Disabled, 1=Enabled) (see BDA, BDAM)
26    Break on Data-Read (0=No, 1=Break/when Bit25=1)
27    Break on Data-Write (0=No, 1=Break/when Bit25=1)
28    Break on any-jump (0=No, 1=Break on branch/jump/call/etc.)
29    Master Enable for bit28 (...and/or exec-break at address>=80000000h?)
30    Master Enable for bit24-27
31    Super-Master Enable 2 for bit24-29

```

When a breakpoint address match occurs the PSX jumps to 80000040h (ie. unlike normal exceptions, not to 80000080h). The Excode value in the CAUSE register is set to 09h (same as BREAK opcode), and EPC contains the return address, as usually. One of the first things to be done in the exception handler is to disable breakpoints (eg. if the any-jump break is enabled, then it must be disabled BEFORE jumping from 80000040h to the actual exception handler).

cop0r7.bit12-13 - Jump Redirection Note

If one or both of these bits are nonzero, then the PSX seems to check for the following opcode sequence,

```

mov rx, [mem] ;load rx from memory
...           ;one or more opcodes that do not change rx
jmp/call rx  ;jump or call to rx

```

if it does sense that sequence, then it sets PC=[00000000h], but does not store any useful information in any cop0 registers, namely it does not store the return address in EPC, so it's impossible to determine which opcode has caused the exception. For the jump target address, there are 31 registers, so one could only guess which of them contains the target value; for "POP PC" code it'd be usually R31, but for "JMP [vector]" code it may be any register. So far the feature seems to be more or less unusable...?

cop0r5 - BDA - Breakpoint on Data Access Address (R/W)**cop0r9 - BDAM - Breakpoint on Data Access Mask (R/W)**

Break condition is " $((addr \text{ XOR } BDA) \text{ AND } BDAM)=0$ ".

cop0r3 - BPC - Breakpoint on Execute Address (R/W)**cop0r11 - BPCM - Breakpoint on Execute Mask (R/W)**

Break condition is " $((PC \text{ XOR } BPC) \text{ AND } BPCM)=0$ ".

Note (BREAK Opcode)

Additionally, the BREAK opcode can be used to create further breakpoints by patching the executable code. The BREAK opcode uses the same Excode value (09h) in CAUSE register. However, the BREAK opcode jumps to the normal exception handler at 80000080h (not 80000040h).

Note (LibCrypt)

The debug registers are mis-used by "Legacy of Kain: Soul Reaver" (and maybe also other games) for storing libcrypt copy-protection related values (ie. just as a "hidden" location for storing data, not for actual debugging purposes).

[CDROM Protection - LibCrypt](#)**Note (Cheat Devices/Expansion ROMs)**

The Expansion ROM header supports only Pre-Boot and Post-Boot vectors, but no Mid-Boot vector. Cheat Devices are often using COP0 breaks for Mid-Boot Hooks, either with BPC=BFC06xxxh (break address in ROM, used in older cheat firmwares), or with BPC=80030000h (break address in RAM aka relocated GUI entrypoint, used in later cheat firmwares). Moreover, aside from the Mid-Boot Hook, the Xplorer cheat device is also supporting a special cheat code that uses the COP0 break feature.

Note (Datasheet)

Note: COP0 debug registers are described in LSI's "L64360" datasheet, chapter 14. And in their LR33300/LR33310 datasheet, chapter 4.

19. Kernel (BIOS)

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19.1 BIOS Overview

BIOS CDROM Boot

The main purpose of the BIOS is to boot games from CDROM, unfortunately, before doing that, it displays the Sony intro. It's also doing some copy protection and region checks, and refuses to boot unlicensed games, or illegal copies, or games for other regions.

BIOS Bootmenu

The bootmenu shows up when starting the Playstation without CDROM inserted. The menu allows to play Audio CDs, and to erase or copy game positions on Memory Cards.

BIOS Functions

The BIOS contains a number of more or less useful, and probably more or less inefficient functions that can be used by software.

No idea if it's easy to take full control of the CPU, ie. to do all hardware access and interrupt handling by software, without using the BIOS at all?

Eventually the BIOS functions for accessing the CDROM drive are important, not sure how complicated/compatible it'd be to access the CDROM drive directly via I/O ports... among others, there might be different drives used in different versions of the Playstation, which aren't fully compatible with each other?

BIOS Memory

The BIOS occupies 512Kbyte ROM with 8bit address bus (so the BIOS ROM is rather slow, for faster execution, portions of it are relocated to the first 64K of RAM). For some very strange reason, the original PSX BIOS executes all ROM functions in uncached ROM, which is incredible slow (nocash BIOS uses cached ROM, which does work without problems).

The first 64Kbyte of the 2Mbyte Main RAM are reserved for the BIOS (containing exception handlers, jump tables, other data, and relocated code). That reserved region does unfortunately include the "valuable" first 32Kbytes (valuable because that memory could be accessed directly via [R0+immediate], without needing to use R1..R31 as base register).

19.2 BIOS Memory Map

BIOS ROM Map (512Kbytes)

```
BFC00000h Kernel Part 1 (code/data executed in uncached ROM)
BFC10000h Kernel Part 2 (code/data relocated to cached RAM)
BFC18000h Intro/Bootmenu (code/data decompressed and relocated to RAM)
BFC64000h Character Sets
```

BIOS ROM Header/Footer

```
BFC00100h Kernel BCD date (YYYYMMDDh)
BFC00104h Console Type (see Port 1F802030h, Secondary IRQ10 Controller)
BFC00108h Kernel Maker/Version Strings (separated by one or more 00h bytes)
BFC7FF32h GUI Version/Copyright Strings (if any) (separated by one 00h byte)
```

BIOS RAM Map (1st 64Kbytes of RAM) (fixed addresses mainly in 1st 500h bytes)

00000000h 10h	Garbage Area (see notes below)
00000010h 30h	Unused/reserved
00000040h 20h	COP0 debug-break vector (not used by Kernel) (in KSEG0)
00000060h 4	RAM Size (in megabytes) (2 or 8)
00000064h 4	Unknown (set to 00000000h)
00000068h 4	Unknown (set to 000000FFh)
0000006Ch 14h	Unused/reserved
00000080h 10h	Exception vector (actually in KSEG0, ie. at 80000080h)
00000090h 10h	Unused/reserved
000000A0h 10h	A(nnh) Function Vector
000000B0h 10h	B(nnh) Function Vector
000000C0h 10h	C(nnh) Function Vector
000000D0h 30h	Unused/reserved
00000100h 58h	Table of Tables (BIOS Control Blocks) (see below)
00000158h 28h	Unused/reserved
00000180h 80h	Command line argument from SYSTEM.CNF; BOOT = fname argument
00000200h 300h	A(nnh) Jump Table
00000500h ...	Kernel Code/Data (relocated from ROM)
0000Cxxxh ...	Unused/reserved
0000DF80h 80h	Used for BIOS Patches (ie. used by games, not used by BIOS)
0000DFFCh 4	Response value from Intro/Bootmenu
0000E000h 2000h	Kernel Memory; ExCBs, EvCBs, and TCBs allocated via B(00h)

User Memory (not used by Kernel)

00010000h ...	Begin of User RAM (Exefile, Data, Heap, Stack, etc.)
001FFF00h ...	Default Stacktop (usually in KSEG0)
1F800000h 400h	Scratchpad (Data-Cache mis-used as Fast RAM)

Table of Tables (see BIOS Control Blocks for details)

Each table entry consists of two 32bit values; containing the base address, and total size (in bytes) of the corresponding control blocks.

00000100h	ExCB	Exception Chain Entrypoints	(addr=var, size=4*08h)
00000108h	PCB	Process Control Block	(addr=var, size=1*04h)
00000110h	TCB	Thread Control Blocks	(addr=var, size=N*C0h)
00000118h	-	Unused/reserved	
00000120h	EvCB	Event Control Blocks	(addr=var, size=N*1Ch)
00000128h	-	Unused/reserved	
00000130h	-	Unused/reserved	
00000138h	-	Unused/reserved	
00000140h	FCB	File Control Blocks	(addr=fixed, size=10h*2Ch)
00000148h	-	Unused/reserved	
00000150h	DCB	Device Control Blocks	(addr=fixed, size=0Ah*50h)

File handles (fd=00h..0Fh) can be simply converted as fcb=[140h]+fd*2Ch.

Event handles (event=F10000xxh) as evcb=[120h]+(event AND FFFFh)*1Ch.

Garbage Area at Address 00000000h

The first some bytes of memory address 00000000h aren't actually used by the Kernel, except for storing some garbage at that locations. However, this garbage is actually important for bugged games like R-Types and Fade to Black (ie. games that do read from address 00000000h due to using uninitialized pointers).

Initially, the garbage area is containing a copy of the 16-byte exception handler at address 80h, but the first 4-bytes are typically smashed (set to 00000003h from some useless dummy writes in some useless CDROM delays). Ie. the 16-bytes should have these values:

```
[00000000h]=3C1A0000h ;<-- but overwritten by 00000003h after soon
[00000004h]=275A0C80h ;<-- or 275A0C50h (in older BIOS)
[00000008h]=03400008h
[0000000Ch]=00000000h
```

For R-Types, the halfword at [0] must non-zero (else the game will do a DMA to address 0, and thereby destroy kernel memory). Fade to Black does several garbage reads from [0..9], a wrong byte value at [5] can cause the game to crash with an invalid memory access exception upon memory card access.

19.3 BIOS Function Summary

Parameters, Registers, Stack

Argument(s) are passed in R4,R5,R6,R7,[SP+10h],[SP+14h],etc.

Caution: When calling a sub-function with N parameters, the caller MUST always allocate N words on the stack, and, although the first four parameters are passed in registers rather than on stack, the sub-function is allowed to use/destroy these words at [SP+0..N*4-1].

BIOS Functions (and custom callback functions) are allowed to destroy registers R1-R15, R24-R25, R31 (RA), and HI/LO. Registers R16-R23, R29 (SP), and R30 (FP) must be left unchanged (if the function uses that registers, then it must push/pop them). R26 (K0) is reserved for exception handler and should be usually not used by other functions. R27 (K1) and R28 (GP) are left more or less unused by the BIOS, so one can more or less freely use them for whatever purpose.

The return value (if any) is stored in R2 register.

A-Functions (Call 00A0h with function number in R9 Register)

```

A(00h) or B(32h) FileOpen(filename,accessmode)
A(01h) or B(33h) FileSeek(fd,offset,seektype)
A(02h) or B(34h) FileRead(fd,dst,length)
A(03h) or B(35h) FileWrite(fd,src,length)
A(04h) or B(36h) FileClose(fd)
A(05h) or B(37h) FileIoctl(fd,cmd,arg)
A(06h) or B(38h) exit(exitcode)
A(07h) or B(39h) FileGetDeviceFlag(fd)
A(08h) or B(3Ah) FileGetc(fd)
A(09h) or B(3Bh) FilePutc(char,fd)
A(0Ah) todigit(char)
A(0Bh) atof(src)      ;Does NOT work - uses (ABSENT) cop1 !!!
A(0Ch) strtoul(src,src_end,base)
A(0Dh) strtol(src,src_end,base)
A(0Eh) abs(val)
A(0Fh) labs(val)
A(10h) atoi(src)
A(11h) atol(src)
A(12h) atob(src,num_dst)
A(13h) setjmp(buf)
A(14h) longjmp(buf,param)
A(15h) strcat(dst,src)
A(16h) strncat(dst,src,maxlen)
A(17h) strcmp(str1,str2)
A(18h) strncmp(str1,str2,maxlen)
A(19h) strcpy(dst,src)
A(1Ah) strncpy(dst,src,maxlen)

```

```

A(1Bh) strlen(src)
A(1Ch) index(src,char)
A(1Dh) rindex(src,char)
A(1Eh) strchr(src,char) ;exactly the same as "index"
A(1Fh) strrchr(src,char) ;exactly the same as "rindex"
A(20h) strpbrk(src,list)
A(21h) strspn(src,list)
A(22h) strcspn(src,list)
A(23h) strtok(src,list) ;use strtok(0,list) in further calls
A(24h) strstr(str,substr) - buggy
A(25h) toupper(char)
A(26h) tolower(char)
A(27h) bcopy(src,dst,len)
A(28h) bzero(dst,len)
A(29h) bcmp(ptr1,ptr2,len) ;Bugged
A(2Ah) memcpy(dst,src,len)
A(2Bh) memset(dst,fillbyte,len)
A(2Ch) memmove(dst,src,len) ;Bugged
A(2Dh) memcmp(src1,src2,len) ;Bugged
A(2Eh) memchr(src,scanbyte,len)
A(2Fh) rand()
A(30h) srand(seed)
A(31h) qsort(base,nel,width,callback)
A(32h) strtod(src,src_end) ;Does NOT work - uses (ABSENT) cop1 !!!
A(33h) malloc(size)
A(34h) free(buf)
A(35h) lsearch(key,base,nel,width,callback)
A(36h) bsearch(key,base,nel,width,callback)
A(37h) calloc(sizx,sizy) ;SLOW!
A(38h) realloc(old_buf,new_siz) ;SLOW!
A(39h) InitHeap(addr,size)
A(3Ah) SystemErrorExit(exitcode)
A(3Bh) or B(3Ch) std_in_getchar()
A(3Ch) or B(3Dh) std_out_putchar(char)
A(3Dh) or B(3Eh) std_in_gets(dst)
A(3Eh) or B(3Fh) std_out_puts(src)
A(3Fh) printf(txt,param1,param2,etc.)
A(40h) SystemErrorUnresolvedException()
A(41h) LoadExeHeader(filename,headerbuf)
A(42h) LoadExeFile(filename,headerbuf)
A(43h) DoExecute(headerbuf,param1,param2)
A(44h) FlushCache()
A(45h) init_a0_b0_c0_vectors
A(46h) GPU_dw(Xdst,Ydst,Xsiz,Ysiz,src)
A(47h) gpu_send_dma(Xdst,Ydst,Xsiz,Ysiz,src)
A(48h) SendGP1Command(gp1cmd)
A(49h) GPU_cw(gp0cmd) ;send GP0 command word
A(4Ah) GPU_cwp(src,num) ;send GP0 command word and parameter words
A(4Bh) send_gpu_linked_list(src)
A(4Ch) gpu_abort_dma()
A(4Dh) GetGPUStatus()
A(4Eh) gpu_sync()
A(4Fh) SystemError
A(50h) SystemError

```

```

A(51h) LoadAndExecute(filename,stackbase,stackoffset)
A(52h) SystemError ----OR---- "GetSyssSp()" ?
A(53h) SystemError ;PS2: set_ioabort_handler(src)
A(54h) or A(71h) CdInit()
A(55h) or A(70h) _bu_init()
A(56h) or A(72h) CdRemove() ;does NOT work due to SysDqIntRP bug
A(57h) return 0
A(58h) return 0
A(59h) return 0
A(5Ah) return 0
A(5Bh) dev_tty_init() ;PS2: SystemError
A(5Ch) dev_tty_open(fcb, and unused:"path\nname", accessmode) ;PS2: SystemError
A(5Dh) dev_tty_in_out(fcb, cmd) ;PS2: SystemError
A(5Eh) dev_tty_ioctl(fcb, cmd, arg) ;PS2: SystemError
A(5Fh) dev_cd_open(fcb, "path\nname", accessmode)
A(60h) dev_cd_read(fcb, dst, len)
A(61h) dev_cd_close(fcb)
A(62h) dev_cd_firstfile(fcb, "path\nname", direntry)
A(63h) dev_cd_nextfile(fcb, direntry)
A(64h) dev_cd_chdir(fcb, "path")
A(65h) dev_card_open(fcb, "path\nname", accessmode)
A(66h) dev_card_read(fcb, dst, len)
A(67h) dev_card_write(fcb, src, len)
A(68h) dev_card_close(fcb)
A(69h) dev_card_firstfile(fcb, "path\nname", direntry)
A(6Ah) dev_card_nextfile(fcb, direntry)
A(6Bh) dev_card_erase(fcb, "path\nname")
A(6Ch) dev_card_undelete(fcb, "path\nname")
A(6Dh) dev_card_format(fcb)
A(6Eh) dev_card_rename(fcb1, "path\nname1", fcb2, "path\nname2")
A(6Fh) ? ;card ;[r4+18h]=00000000h ;card_clear_error(fcb) or so
A(70h) or A(55h) _bu_init()
A(71h) or A(54h) CdInit()
A(72h) or A(56h) CdRemove() ;does NOT work due to SysDqIntRP bug
A(73h) return 0
A(74h) return 0
A(75h) return 0
A(76h) return 0
A(77h) return 0
A(78h) CdAsyncSeekL(src)
A(79h) return 0 ;DTL-H: Unknown?
A(7Ah) return 0 ;DTL-H: Unknown?
A(7Bh) return 0 ;DTL-H: Unknown?
A(7Ch) CdAsyncGetStatus(dst)
A(7Dh) return 0 ;DTL-H: Unknown?
A(7Eh) CdAsyncReadSector(count,dst,mode)
A(7Fh) return 0 ;DTL-H: Unknown?
A(80h) return 0 ;DTL-H: Unknown?
A(81h) CdAsyncSetMode(mode)
A(82h) return 0 ;DTL-H: Unknown?
A(83h) return 0 ;DTL-H: Unknown?
A(84h) return 0 ;DTL-H: Unknown?
A(85h) return 0 ;DTL-H: Unknown?, or reportedly, CdStop (?)
A(86h) return 0 ;DTL-H: Unknown?

```

```

A(87h) return 0           ;DTL-H: Unknown?
A(88h) return 0           ;DTL-H: Unknown?
A(89h) return 0           ;DTL-H: Unknown?
A(8Ah) return 0           ;DTL-H: Unknown?
A(8Bh) return 0           ;DTL-H: Unknown?
A(8Ch) return 0           ;DTL-H: Unknown?
A(8Dh) return 0           ;DTL-H: Unknown?
A(8Eh) return 0           ;DTL-H: Unknown?
A(8Fh) return 0           ;DTL-H: Unknown?

A(90h) CdromIoIrqFunc1()
A(91h) CdromDmaIrqFunc1()
A(92h) CdromIoIrqFunc2()
A(93h) CdromDmaIrqFunc2()
A(94h) CdromGetInt5errCode(dst1,dst2)
A(95h) CdInitSubFunc()
A(96h) AddCDROMDevice()
A(97h) AddMemCardDevice() ;DTL-H: SystemError
A(98h) AddDuartTtyDevice() ;DTL-H: AddAdconsTtyDevice ;PS2: SystemError
A(99h) AddDummyTtyDevice()
A(9Ah) SystemError       ;DTL-H: AddMessageWindowDevice
A(9Bh) SystemError       ;DTL-H: AddCdromSimDevice
A(9Ch) SetConf(num_EvCB,num_TCB,stacktop)
A(9Dh) GetConf(num_EvCB_dst,num_TCB_dst,stacktop_dst)
A(9Eh) SetCdromIrqAutoAbort(type,flag)
A(9Fh) SetMemSize(megabytes)

```

Below functions A(A0h..B4h) not supported on pre-retail DTL-H2000 devboard:

```

A(A0h) WarmBoot()
A(A1h) SystemErrorBootOrDiskFailure(type,errorcode)
A(A2h) EnqueueCdIntr() ;with prio=0 (fixed)
A(A3h) DequeueCdIntr() ;does NOT work due to SysDeqIntRP bug
A(A4h) CdGetLbn(filename) ;get 1st sector number (or garbage when not found)
A(A5h) CdReadSector(count,sector,buffer)
A(A6h) CdGetStatus()
A(A7h) bu_callback_okay()
A(A8h) bu_callback_err_write()
A(A9h) bu_callback_err_busy()
A(AAh) bu_callback_err_eject()
A(ABh) _card_info(port)
A(ACh) _card_async_load_directory(port)
A(ADh) set_card_auto_format(flag)
A(AEh) bu_callback_err_prev_write()
A(AFh) card_write_test(port) ;CEX-1000: jump_to_00000000h
A(B0h) return 0           ;CEX-1000: jump_to_00000000h
A(B1h) return 0           ;CEX-1000: jump_to_00000000h
A(B2h) ioabort_raw(param) ;CEX-1000: jump_to_00000000h
A(B3h) return 0           ;CEX-1000: jump_to_00000000h
A(B4h) GetSystemInfo(index) ;CEX-1000: jump_to_00000000h
A(B5h..BFh) N/A ;jump_to_00000000h

```

B-Functions (Call 00B0h with function number in R9 Register)

```

B(00h) alloc_kernel_memory(size)
B(01h) free_kernel_memory(buf)
B(02h) init_timer(t,reload,flags)
B(03h) get_timer(t)
B(04h) enable_timer_irq(t)
B(05h) disable_timer_irq(t)
B(06h) restart_timer(t)
B(07h) DeliverEvent(class, spec)
B(08h) OpenEvent(class,spec,mode,func)
B(09h) CloseEvent(event)
B(0Ah) WaitEvent(event)
B(0Bh) TestEvent(event)
B(0Ch) EnableEvent(event)
B(0Dh) DisableEvent(event)
B(0Eh) OpenThread(reg_PC,reg_SP_FP,reg_GP)
B(0Fh) CloseThread(handle)
B(10h) ChangeThread(handle)
B(11h) jump_to_00000000h
B(12h) InitPad(buf1,siz1,buf2,siz2)
B(13h) StartPad()
B(14h) StopPad()
B(15h) OutdatedPadInitAndStart(type,button_dest,unused,unused)
B(16h) OutdatedPadGetButtons()
B(17h) ReturnFromException()
B(18h) SetDefaultExitFromException()
B(19h) SetCustomExitFromException(addr)
B(1Ah) SystemError ;PS2: return 0
B(1Bh) SystemError ;PS2: return 0
B(1Ch) SystemError ;PS2: return 0
B(1Dh) SystemError ;PS2: return 0
B(1Eh) SystemError ;PS2: return 0
B(1Fh) SystemError ;PS2: return 0
B(20h) UnDeliverEvent(class,spec)
B(21h) SystemError ;PS2: return 0
B(22h) SystemError ;PS2: return 0
B(23h) SystemError ;PS2: return 0
B(24h) jump_to_00000000h
B(25h) jump_to_00000000h
B(26h) jump_to_00000000h
B(27h) jump_to_00000000h
B(28h) jump_to_00000000h
B(29h) jump_to_00000000h
B(2Ah) SystemError ;PS2: return 0
B(2Bh) SystemError ;PS2: return 0
B(2Ch) jump_to_00000000h
B(2Dh) jump_to_00000000h
B(2Eh) jump_to_00000000h
B(2Fh) jump_to_00000000h
B(30h) jump_to_00000000h
B(31h) jump_to_00000000h
B(32h) or A(00h) FileOpen(filename,accessmode)

```

```

B(33h) or A(01h) FileSeek(fd,offset,seektype)
B(34h) or A(02h) FileRead(fd,dst,length)
B(35h) or A(03h) FileWrite(fd,src,length)
B(36h) or A(04h) FileClose(fd)
B(37h) or A(05h) FileIoctl(fd,cmd,arg)
B(38h) or A(06h) exit(exitcode)
B(39h) or A(07h) FileGetDeviceFlag(fd)
B(3Ah) or A(08h) FileGetc(fd)
B(3Bh) or A(09h) FilePutc(char,fd)
B(3Ch) or A(3Bh) std_in_getchar()
B(3Dh) or A(3Ch) std_out_putchar(char)
B(3Eh) or A(3Dh) std_in_gets(dst)
B(3Fh) or A(3Eh) std_out_puts(src)
B(40h) chdir(name)
B(41h) FormatDevice(devicename)
B(42h) firstfile(filename,direntry)
B(43h) nextfile(direntry)
B(44h) FileRename(old_filename,new_filename)
B(45h) FileDelete(filename)
B(46h) FileUndelete(filename)
B(47h) AddDevice(device_info) ;subfunction for AddXxxDevice functions
B(48h) RemoveDevice(device_name_lowercase)
B(49h) PrintInstalledDevices()

```

Below functions B(4Ah..5Dh) not supported on pre-retail DTL-H2000 devboard:

```

B(4Ah) InitCard(pad_enable) ;uses/destroys k0/k1 !!!
B(4Bh) StartCard()
B(4Ch) StopCard()
B(4Dh) _card_info_subfunc(port) ;subfunction for "_card_info"
B(4Eh) write_card_sector(port,sector,src)
B(4Fh) read_card_sector(port,sector,dst)
B(50h) allow_new_card()
B(51h) Krom2RawAdd(shiftjis_code)
B(52h) SystemError ;PS2: return 0
B(53h) Krom2Offset(shiftjis_code)
B(54h) GetLastError()
B(55h) GetLastFileError(fd)
B(56h) GetC0Table
B(57h) GetB0Table
B(58h) get_bu_callback_port()
B(59h) testdevice(devicename)
B(5Ah) SystemError ;PS2: return 0
B(5Bh) ChangeClearPad(int)
B(5Ch) get_card_status(slot)
B(5Dh) wait_card_status(slot)
B(5Eh..FFh) N/A ;jump_to_00000000h ;CEX-1000: B(5Eh..F6h) only
B(100h....) N/A ;garbage ;CEX-1000: B(F7h.....) and up

```

C-Functions (Call 00C0h with function number in R9 Register)

```

C(00h) EnqueueTimerAndVblankIrqs(priority) ;used with prio=1
C(01h) EnqueueSyscallHandler(priority) ;used with prio=0
C(02h) SysEnqIntRP(priority,struc) ;bugged, use with care
C(03h) SysDeqIntRP(priority,struc) ;bugged, use with care
C(04h) get_free_EvCB_slot()
C(05h) get_free_TCB_slot()
C(06h) ExceptionHandler()
C(07h) InstallExceptionHandlers() ;destroys/uses k0/k1
C(08h) SysInitMemory(addr,size)
C(09h) SysInitKernelVariables()
C(0Ah) ChangeClearRCnt(t,flag)
C(0Bh) SystemError ;PS2: return 0
C(0Ch) InitDefInt(priority) ;used with prio=3
C(0Dh) SetIrqAutoAck(irq,flag)
C(0Eh) return 0 ;DTL-H2000: dev_sio_init
C(0Fh) return 0 ;DTL-H2000: dev_sio_open
C(10h) return 0 ;DTL-H2000: dev_sio_in_out
C(11h) return 0 ;DTL-H2000: dev_sio_ioctl
C(12h) InstallDevices(ttyflag)
C(13h) FlushStdInOutPut()
C(14h) return 0 ;DTL-H2000: SystemError
C(15h) tty_cdevinput(circ,char)
C(16h) tty_cdevscan()
C(17h) tty_circgetc(circ) ;uses r5 as garbage txt for ioabort
C(18h) tty_circputc(char,circ)
C(19h) ioabort(txt1,txt2)
C(1Ah) set_card_find_mode(mode) ;0=normal, 1=find deleted files
C(1Bh) KernelRedirect(ttyflag) ;PS2: ttyflag=1 causes SystemError
C(1Ch) AdjustA0Table()
C(1Dh) get_card_find_mode()
C(1Eh..7Fh) N/A ;jump_to_00000000h
C(80h.....) N/A ;mirrors to B(00h.....)

```

SYS-Functions (Syscall opcode with function number in R4 aka A0 Register)

```

SYS(00h) NoFunction()
SYS(01h) EnterCriticalSection()
SYS(02h) ExitCriticalSection()
SYS(03h) ChangeThreadSubFunction(addr) ;syscall with r4=03h, r5=addr
SYS(04h..FFFFFFFFFFh) calls DeliverEvent(F0000010h,4000h)

```

The 20bit immediate in the "syscall imm" opcode is unused (should be zero).

BREAK-Functions (Break opcode with function number in opcode's immediate)

BRK opcodes may be used within devkits, however, the standard BIOS simply calls DeliverEvent(F0000010h,1000h) and SystemError_A_40h upon any BRK opcodes (as well as on any other unresolved exceptions).

```
BRK(1C00h) Division by zero (commonly checked/invoked by software)
BRK(1800h) Division overflow (-80000000h/-1, sometimes checked by software)
```

Below breaks are used in DTL-H2000 BIOS:

```
BRK(1h) Whatever lockup or so?
BRK(101h) PCInit() Inits the fileserver.
BRK(102h) PCCreat(filename, fileattributes)
BRK(103h) PCOpen(filename, accessmode)
BRK(104h) PCClose(filehandle)
BRK(105h) PCRead(filehandle, length, memory_destination_address)
BRK(106h) PCWrite(filehandle, length, memory_source_address)
BRK(107h) PClSeek(filehandle, file_offset, seekmode)
BRK(3C400h) User has typed "break" command in debug console
```

The break functions have argument(s) in A1,A2,A3 (ie. unlike normal BIOS functions not in A0,A1,A2), and TWO return values (in R2, and R3). These functions require a commercial/homebrew devkit... consisting of a Data Cable (for accessing the PC's harddisk)... and an Expansion ROM (for handling the BREAK opcodes)... or so?

19.4 BIOS File Functions

A(00h) or B(32h) - FileOpen(filename, accessmode) - Opens a file for IO

```
out: V0 File handle (00h..0Fh), or -1 if error.
```

Opens a file on the target device for io. Accessmode is set like this:

```
bit0 1=Read ;\These bits aren't actually used by the BIOS, however, at
bit1 1=Write ;/least 1 should be set; won't work when all 32bits are zero
bit2 1=Exit without waiting for incoming data (when TTY buffer empty)
bit9 0=Open Existing File, 1/Create New file (memory card only)
bit15 1=Asynchronous mode (memory card only; don't wait for completion)
bit16-31 Number of memory card blocks for a new file on the memory card
```

The PSX can have a maximum of 16 files open at any time, of which, 2 handles are always reserved for std_io, so only 14 handles are available for actual files. Some

functions (chdir, testdevice, FileDelete, FileUndelete, FormatDevice, firstfile, FileRename) are temporarily allocating 1 filehandle (FileRename tries to use 2 filehandles, but, it does accidentally use only 1 handle, too). So, for example, FileDelete would fail if more than 13 file handles are opened by the game.

A(01h) or B(33h) - FileSeek(fd, offset, seektype) - Move the file pointer

```
seektype 0 = from start of file      (with positive offset)
           1 = from current file pointer (with positive/negative offset)
           2 = Bugs. Should be from end of file.
```

Moves the file pointer the number of bytes in A1, relative to the location specified by A2. Movement from the eof is incorrect. Also, movement beyond the end of the file is not checked.

A(02h) or B(34h) - FileRead(fd, dst, length) - Read data from an open file

```
out: V0 Number of bytes actually read, -1 if failed.
```

Reads the number of bytes from the specified open file. If length is not specified an error is returned. Read per \$0080 bytes from memory card (bu:) and per \$0800 from cdrom (cdrom:).

A(03h) or B(35h) - FileWrite(fd, src, length) - Write data to an open file

```
out: V0 Number of bytes written.
```

Writes the number of bytes to the specified open file. Write to the memory card per \$0080 bytes. Writing to the cdrom returns 0.

A(04h) or B(36h) - FileClose(fd) - Close an open file

Returns r2=fd (or r2=-1 if failed).

A(08h) or B(3Ah) - FileGetc(fd) - read one byte from file

```
out: R2=character (sign-expanded) or FFFFFFFFh,error
```

Internally redirects to "FileRead(fd,tempbuf,1)". For some strange reason, the returned character is sign-expanded; so, a return value of FFFFFFFFh could mean either character FFh, or error.

A(09h) or B(3Bh) - FilePutc(char,fd) - write one byte to file

Observe that "fd" is the 2nd parameter (not the 1st parameter as usually).

```
out: R2=Number of bytes actually written, -1 if failed
```

Internally redirects to "FileWrite(fd,tempbuf,1)".

B(40h) - chdir(name) - Change the current directory on target device

Changes the current directory on the specified device, which should be "cdrom:" (memory cards don't support directories). The PSX supports only a current directory, but NOT a current device (ie. after chdir, the directory name may be omitted from filenames, but the device name must be still included in all filenames).

```
in: A0 Pointer to new directory path (eg. "cdrom:\path")
```

Returns 1=okay, or 0=failed.

The function doesn't verify if the directory exists. Caution: For cdrom, the function does always load the path table from the disk (even if it was already stored in RAM, so chdir is causing useless SLOW read/seek delays).

B(42h) - firstfile(filename,direntry) - Find first file to match the name

Returns r2=direntry (or r2=0 if no matching files).

Searches for the first file to match the specified filename; the filename may contain "?" and "*" wildcards. "*" means to ignore ALL following characters; accordingly one cannot specify any further characters after the "*" (eg. "DATA*" would work, but "*DAT" won't work). "?" is meant to ignore a single character cell. Note: The "?" wildcards (but not "*") can be used also in all other file functions; causing the function to use the first matching name (eg. FileDelete "?????" would erase the first matching file, not all matching files).

Start the name with the device you want to address. (ie. pcdrv:) Different drives can be accessed as normally by their drive names (a:, c:, huh?) if path is omitted after the

device, the current directory will be used.

A direntry structure looks like this:

```

00h 14h Filename, terminated with 00h
14h 4   File attribute (always 0 for cdrom) (50h=norm or A0h=del for card)
18h 4   File size
1Ch 4   Pointer to next direntry? (not used?)
20h 4   First Sector Number
24h 4   Reserved (not used)

```

BUG: If "?" matches the ending 00h byte of a name, then any further characters in the search expression are ignored (eg. "FILE?.DAT" would match to "FILE2.DAT", but accidentally also to "FILE").

BUG: For CDROM, the BIOS includes some code that is intended to realize disk changes during firstfile/nextfile operations, however, that code is so bugged that it does rather ensure that the BIOS does NOT realize new disks being inserted during firstfile/nextfile.

BUG: firstfile/nextfile is internally using a FCB. On the first call to firstfile, the BIOS is searching a free FCB, and does apply that as "search fcb", but it doesn't mark that FCB as allocated, so other file functions may accidentally use the same FCB. Moreover, the BIOS does memorize that "search fcb", and, even when starting a new search via another call to firstfile, it keeps using that FCB for search (without checking if the FCB is still free). A possible workaround is not to have any files opened during firstfile/nextfile operations.

B(43h) - nextfile(direntry) - Searches for the next file to match the name

Returns r2=direntry (or r2=0 if no more matching files).

Uses the settings of a previous firstfile/nextfile command.

B(44h) - FileRename(old_filename, new_filename)

Returns 1=okay, or 0=failed.

B(45h) - FileDelete(filename) - Delete a file on target device

Returns 1=okay, or 0=failed.

B(46h) - FileUndelete(filename)

Returns 1=okay, or 0=failed.

B(41h) - FormatDevice(devicename)

Erases all files on the device (ie. for formatting memory cards).

Returns 1=okay, or 0=failed.

B(54h) - GetLastError()

Indicates the reason of the most recent file function error (FileOpen, FileSeek, FileRead, FileWrite, FileClose, GetLastFileError, FileIoctl, chdir, testdevice, FileDelete, FileUndelete, FormatDevice, FileRename). Use GetLastError() ONLY if an error has occured (the error code isn't reset to zero by functions that are passing okay). firstfile/nextfile do NOT affect GetLastError(). See below list of File Error Numbers for more info.

B(55h) - GetLastFileError(fd)

Basically same as B(54h), but allowing to specify a file handle for which error information is to be received; accordingly it doesn't work for functions that do use 'hidden' internal file handles (eg. FileDelete, or unsuccessful FileOpen). Returns FCB[18h], or FFFFFFFFh if the handle is invalid/unused.

A(05h) or B(37h) FileIoctl(fd,cmd,arg)

Used only for TTY.

A(07h) or B(39h) FileGetDeviceFlag(fd)

Returns bit1 of the file's DCB flags. That bit is set only for Duart/TTY, and is cleared for Dummy/TTY, Memory Card, and CDROM.

B(59h) - testdevice(devicename)

Whatever. Checks the devicename, and if it's accepted, calls a device specific function. For the existing devices (cdrom,bu,tty) that specific function simply returns without doing anything. Maybe other devices (like printers or modems) would do something more interesting.

File Error Numbers for B(54h) and B(55h)

```
00h okay (though many successful functions leave old error code unchanged)
02h file not found
06h bad device port number (tty2 and up)
09h invalid or unused file handle
```

```

10h general error (physical I/O error, unformatted, disk changed for old fcb)
11h file already exists error (create/undelete/rename)
12h tried to rename a file from one device to another device
13h unknown device name
16h sector alignment error, or fpos>=filesize, unknown seektype or ioctl cmd
18h not enough free file handles
1Ch not enough free memory card blocks
FFFFFFFFFFh invalid or unused file handle passed to B(55h) function

```

19.5 BIOS File Execute and Flush Cache

A(41h) - LoadExeHeader(filename, headerbuf)

Loads the 800h-byte exe file header to an internal sector buffer, and does then copy bytes [10h..4Bh] of that header to headerbuf[00h..3Bh].

A(42h) - LoadExeFile(filename, headerbuf)

Same as LoadExeHeader (see there for details), but additionally loads the body of the executable (using the size and destination address in the file header), and does call FlushCache. The exe can be then started via DoExecute (this isn't done automatically by LoadExeFile). Unlike "LoadAndExecute", the "LoadExeFile/DoExecute" combination allows to return the new exe file to return to the old exe file (instead of restarting the boot executable).

BUG: Uses the unstable FlushCache function (see there for details).

A(43h) - DoExecute(headerbuf, param1, param2)

Can be used to start a previously loaded executable. The function saves R16,R28,R30,SP,RA in the reserved region of headerbuf (rather than on stack), more or less slowly zerofills the memfill region specified in headerbuf, reads the stack base and offset values and sets SP and FP to base+offset (or leaves them unchanged if base=0), reads the GP value from headerbuf and sets GP to that value. Then calls the executable's entrypoint, with param1 and param2 passed in r4,r5.

If the executable (should) return, then R16,R28,R30,SP,RA are restored from headerbuf, and the function returns with r2=1.

A(51h) - LoadAndExecute(filename, stackbase, stackoffset)

This is a rather bizarre function. In short, it does load and execute the specified file, and thereafter, it (tries to) reload and restart to boot executable.

Part1: Takes a copy of the filename, with some adjustments: Everything up to the first ":" or 00h byte is copied as is (ie. the device name, if it does exist, or otherwise the whole path\filename.ext;ver), the remaining characters are copied and converted to uppercase (ie. the path\filename.ext;ver part, or none if the device name didn't exist), finally, checks if a ";" exists (ie. the version suffix), if there's none, then it appends ";1" as default version. CAUTION: The BIOS allocates ONLY 28 bytes on stack for the copy of the filename, that region is followed by 4 unused bytes, so the maximum length would be 32 bytes (31 characters plus EOL) (eg. "device:\pathname\filename.ext;1",00h).

Part2: Enables IRQs via ExitCriticalSection, memorizes the stack base/offset values from the previously loaded executable (which should have been the boot executable, unless LoadAndExecute should have been used in nested fashion), does then use LoadExeFile to load the desired file, replaces the stack base/offset values in its headerbuf by the LoadAndExecute parameter values, and does then execute it via DoExecute(headerbuf, 1,0).

Part3: If the exefile returns, or if it couldn't be loaded, then the boot file is (unsuccessfully) attempted to be reloaded: Enables IRQs via ExitCriticalSection, loads the boot file via LoadExeFile, replaces the stack base/offset values in its headerbuf by the values memorized in Part2 (which \<should> be the boot executable's values from SYSTEM.CNF, unless the nesting stuff occurred), and does then execute the boot file via DoExecute(headerbuf,1,0).

Part4: If the boot file returns, or if it couldn't be loaded, then the function looks up in a "JMP \$" endless loop (normally, returning from the boot exe causes SystemErrorBootOrDiskFailure("B",38Ch), however, after using LoadAndExecute, this functionality is replaced by the "JMP \$" lockup.

BUG: Uses the unstable FlushCache function (see there for details).

BUG: Part3 accidentally treats the first 4 characters of the exename as memory address (causing an invalid memory address exception on address 6F726463h, for "cdrom:filename.exe").

A(9Ch) - SetConf(num_EvCB, num_TCB, stacktop)

Changes the number of EvCBs and TCBs, and the stacktop. That values are usually initialized from the settings in the SYSTEM.CNF file, so using this function usually shouldn't ever be required.

The function deallocates all old ExCBs, EvCBs, TCBs (so all Exception handlers, Events, and Threads (except the current one) are lost, and all other memory that may have been allocated via alloc_kernel_memory(size) is deallocated, too. It does then allocate the new

control blocks, and enqueue the default handlers. Despite of the changed stacktop, the current stack pointer is kept intact, and the function returns to the caller.

A(9Dh) - GetConf(num_EvCB_dst, num_TCB_dst, stacktop_dst)

Returns the number of EvCBs, TCBs, and the initial stacktop. There's no return value in the R2 register, instead, the three 32bit return values are stored at the specified "dst" addresses.

A(44h) - FlushCache()

Flushes the Code Cache, so opcodes are ensured to be loaded from RAM. This is required when loading program code via DMA (ie. from CDROM) (the cache controller apparently doesn't realize changes to RAM that are caused by DMA). The LoadExeFile and LoadAndExecute functions are automatically calling FlushCache (so FlushCache is required only when loading program code via "FileRead" or via "CdReadSector"). FlushCache may be also required when relocating or modifying program code by software (the cache controller doesn't seem to realize modifications to memory mirrors, eg. patching the exception handler at 80000080h seems to work without FlushCache, but patching the same bytes at 00000080h doesn't).

Note: The PSX doesn't have a Data Cache (or actually, it has, but it's misused as Fast RAM, mapped to a fixed memory region, and which isn't accessible by DMA), so FlushCache isn't required for regions that contain data.

BUG: The FlushCache function contains a handful of opcodes that do use the k0 register without having IRQs disabled at that time, if an IRQ occurs during those opcodes, then the k0 value gets destroyed by the exception handler, causing FlushCache to get trapped in an endless loop.

One workaround would be to disable all IRQs before calling FlushCache, however, the BIOS does internally call the function without IRQs disabled, that applies to:

```
load_file A(42h)
load_exec A(51h)
add_device B(47h) (and all "add_xxx_device" functions)
init_card B(4Ah)
and by intro/boot code
```

for load_file/load_exec, IRQ2 (cdrom) and IRQ3 (dma) need to be enabled, so the "disable all IRQs" workaround cannot be used for that functions, however, one can/should disable as many IRQs as possible, ie. everything except IRQ2/IRQ3, and all DMA interrupts except DMA3 (cdrom).

Executable Memory Allocation

LoadExeFile and LoadAndExecute are simply loading the file to the address specified in the exe file header. There's absolutely no verification whether that memory is (or isn't) allocated via malloc, or if it is used by the boot executable, or by the kernel, or if it does contain RAM at all.

When using the "malloc" function combined with loading exe files, it may be recommended not to pass all memory to InitHeap (ie. to keep a memory region being reserved for loading executables).

Note

For more info about EXE files and their headers, see
[CDROM File Formats](#)

19.6 BIOS CDROM Functions

General File Functions

CDROMs are basically accessed via normal file functions, with device name "cdrom:" (which is an abbreviation for "cdrom0:", anyways, the port number is ignored).

[BIOS File Functions](#)

[BIOS File Execute and Flush Cache](#)

Before starting the boot executable, the BIOS automatically calls CdInit(), so the game doesn't need to do any initializations before using CDROM file functions.

Absent CD-Audio Support

The Kernel doesn't include any functions for playing Audio tracks. Also, there's no BIOS function for setting the XA-ADPCM file/channel filter values. So CD Audio can be used only by directly programming the CDROM I/O ports.

Asynchronous CDROM Access

The normal File functions are always using synchronous access for CDROM (ie. the functions do wait until all data is transferred) (unlike as for memory cards, accessmode.bit15 cannot be used to activate asynchronous cdrom access). However, one can read files in asynchronous fashion via CdGetLbn, CdAsyncSeekL, and

CdAsyncReadSector. CDROM files are non-fragmented, so they can be read simply from incrementing sector numbers.

A(A4h) - CdGetLbn(filename)

Returns the first sector number used by the file, or -1 in case of error.

BUG: The function accidentally returns -1 for the first file in the directory (the first file should be a dummy entry for the current or parent directory or so, so that bug isn't much of a problem), if the file is not found, then the function accidentally returns garbage (rather than -1).

A(A5h) - CdReadSector(count,sector,buffer)

Reads \<count> sectors, starting at \<sector>, and writes data to \<buffer>. The read is done in mode=80h (double speed, 800h-bytes per sector). The function waits until all sectors are transferred, and does then return the number of sectors (ie. count), or -1 in case of error.

A(A6h) - CdGetStatus()

Retrieves the cdrom status via CdAsyncGetStatus(dst) (see there for details; especially for cautions on door-open flag). The function waits until the event indicates completion, and does then return the status byte (or -1 in case of error).

A(78h) - CdAsyncSeekL(src)

Issues Setloc and SeekL commands. The parameter (src) is a pointer to a 3-byte sector number (MM,SS,FF) (in BCD format).

The function returns 0=failed, or 1=okay. Completion is indicated by events (class=F0000003h, and spec=20h, or 8000h).

A(7Ch) - CdAsyncGetStatus(dst)

Issues a GetStat command. The parameter (dst) is a pointer to a 1-byte location that receives the status response byte.

The function returns 0=failed, or 1=okay. Completion is indicated by events (class=F0000003h, and spec=20h, or 8000h).

Caution: The command acknowledges the door-open flag, but doesn't automatically reload the path table (which is required if a new disk is inserted); if the door-open flag was set, one should call a function that does forcefully load the path table (like chdir).

A(7Eh) - CdAsyncReadSector(count,dst,mode)

Issues SetMode and ReadN (when mode.bit8=0), or ReadS (when mode.bit8=1) commands. count is the number of sectors to be read, dst is the destination address in RAM, mode.bit0-7 are passed as parameter to the SetMode command, mode.bit8 is the ReadN/ReadS flag (as described above). The sector size (for DMA) depends on the mode value: 918h-bytes (bit4=1, bit5=X), 924h-bytes (bit4=0, bit5=1), or 800h-bytes (bit4,5=0).

Before CdAsyncReadSector, the sector number should be set via CdAsyncSeekL(src). The function returns 0=failed, or 1=okay. Completion is indicated by events (class=F0000003h, and spec=20h, 80h, or 8000h).

A(81h) - CdAsyncSetMode(mode)

Similar to CdAsyncReadSector (see there for details), but issues only the SetMode command, without any following ReadN/ReadS command.

A(94h) - CdromGetInt5errCode(dst1,dst2)

Returns the first two response bytes from the most recent INT5 error: [dst1]=status, [dst2]=errorcode. The BIOS doesn't reset these values in case of successful completion, so the values are quite useless.

A(54h) or A(71h) - CdInit()

A(56h) or A(72h) - CdRemove() ;does NOT work due to SysDeqIntRP bug

A(90h) - CdromIolrqFunc1()

A(91h) - CdromDmalrqFunc1()

A(92h) - CdromIolrqFunc2()

A(93h) - CdromDmalrqFunc2()

A(95h) - CdInitSubFunc() ;subfunction for CdInit()

A(9Eh) - SetCdromIrqAutoAbort(type,flag)

A(A2h) - EnqueueCdIntr() ;with prio=0 (fixed)

A(A3h) - DequeueCdIntr() ;does NOT work due to SysDeqIntRP bug

Internally used CDROM functions for initialization and IRQ handling.

19.7 BIOS Memory Card Functions

General File Functions

Memory Cards aka Backup Units (bu) are basically accessed via normal file functions, with device names "bu00:" (Slot 1) and "bu10:" (Slot 2),

[BIOS File Functions](#)

Before using the file functions for memory cards, first call InitCard(pad_enable), then StartCard(), and then _bu_init().

File Header, Filesize, and Sector Alignment

The first 100h..200h bytes (2..4 sectors) of the file must contain the title and icon bitmap(s). For details, see:

[Memory Card Data Format](#)

The filesize must be a multiple of 2000h bytes (one block), the maximum size would be 1E000h bytes (when using all 15 blocks on the memory card). The filesize must be

specified when creating the file (ie. accessmode bit9=1, and bit16-31=number of blocks). Once when the file is created, the BIOS does NOT allow to change the filesize (unless by deleting and re-creating the file).

When reading/writing files, the amount of data must be a multiple of 80h bytes (one sector), and the file position must be aligned to a 80h-byte boundary, too. There's no restriction on fragmented files (ie. one may cross 2000h-byte block boundaries within the file).

Poor Memcard Performance

PSX memory card accesses are typically super-slow. That, not so much because the hardware would be slow, but rather because of improper inefficient code at the BIOS side. The original BIOS tries to synchronize memory card accesses with joypad accesses simply by accessing only one sector per frame (although it could access circa two sectors). To the worst, the BIOS accesses Slot 1 only on each second frame, and Slot 2 only each other frame (although in 99% of all cases only one slot is accessed at once, so the access time drops to 0.5 sectors per frame).

Moreover, the memory card id, directory, and broken sector list do occupy 26 sectors (although the whole information would fit into 4 or 5 sectors) (a workaround would be to read only the first some bytes, and to skip the additional unused bytes - though that'd also mean to skip the checksums which are unfortunately stored at the end of the sector).

And, anytime when opening a file (in synchronous mode), the BIOS does additionally read sector 0 (which is totally useless, and gets especially slow when opening a bunch of files; eg. when extracting the title/icon from all available files on the card).

Asynchronous Access

The BIOS supports synchronous and asynchronous memory card access. Synchronous means that the BIOS function doesn't return until the access has completed (which means, due to the poor performance, that the function spends about 75% of the time on inactivity) (except in nocash PSX bios, which has better performance), whilst asynchronous access means that the BIOS function returns immediately after invoking the access (which does then continue on interrupt level, and does return an event when finished).

The file "FileRead" and "FileWrite" functions act asynchronous when accessmode bit15 is set when opening the file. Additionally, the A(ACh) _card_async_load_directory(port) function can be used to tell the BIOS to load the directory entries and broken sector list to its internal RAM buffers (eg. during the games title screen, so the BIOS doesn't need to

load that data once when the game enters its memory card menu). All other functions like FileDelete or FormatDevice always act synchronous. The FileOpen/findfirst/findnext functions do normally complete immediately without accessing the card at all (unless the directory wasn't yet read; in that case the directory is loading in synchronous fashion). Unfortunately, the asynchronous response doesn't rely on a single callback event, but rather on a bunch of different events which must be all allocated and tested by the game (and of which, one event is delivered on completion) (which one depends on whether function completed okay, or if an error occurred).

Multitap Support (and Multitap Problems)

The BIOS does have some partial support for accessing more than two memory cards (via Multitap adaptors). Device/port names "bu01:", "bu02:", "bu03:" allow to access extra memory carts in slot1 (and "bu11:", "bu12:", "bu13:" in slot2). Namely, those names will send values 82h, 83h, 84h to the memory card slot (instead of the normal 81h value).

However, the BIOS directory_buffer and broken_sector_list do support only two memory cards (one in slot1 and one in slot2). So, trying to access more memory cards may cause great data corruption (though there might be a way to get the BIOS to reload those buffers before accessing a different memory card).

Aside from that problem, the BIOS functions are very-very-very slow even when accessing only two memory cards. Trying to use the BIOS to access up to eight memory cards would be very-extremly-very slow, which would be more annoying than useful.

B(4Ah) - InitCard(pad_enable) ;uses/destroys k0/k1 !!!

B(4Bh) - StartCard()

B(4Ch) - StopCard()

A(55h) or A(70h) - _bu_init()

--- Below are some lower level memory card functions ---

A(ABh) - _card_info(port)**B(4Dh) - _card_info_subfunc(port) ;subfunction for "_card_info"**

Can be used to check if the most recent call to write_card_sector has completed okay. Issues an incomplete dummy read command (similar to B(4Fh) - read_card_sector). The read command is aborted once when receiving the status byte from the memory card (the actual data transfer is skipped).

A(AFh) - card_write_test(port) ;not supported by old CEX-1000 version

Resets the card changed flag. For some strange reason, this flag isn't automatically reset after reading the flag, instead, the flag is reset upon sector writes. To do that, this function issues a dummy write to sector 3Fh.

B(50h) - allow_new_card()

Normally any memory card read/write functions fail if the BIOS senses the card change flag to be set. Calling this function tells the BIOS to ignore the card change flag on the next read/write operation (the function is internally used when loading the "MC" ID from sector 0, and when calling the card_write_test function to acknowledge the card change flag).

B(4Eh) - write_card_sector(port,sector,src)**B(4Fh) - read_card_sector(port,sector,dst)**

Invokes asynchronous reading/writing of a single sector. The function returns 1=okay, or 0=failed (on invalid sector numbers). The actual I/O is done on IRQ level, completion of the I/O command transmission can be checked, among others, via get/wait_card_status(slot) functions (with slot=port/10h).

In case of the write function, completion of the \<transmission> does NOT mean that the actual \<writing> has completed, instead, write errors are indicated upon completion of the \<next sector> read/write transmission (or, if there are no further sectors to be accessed; one can use _card_info to verify completion of the last written sector).

The sector number should be in range of 0..3FFh, for some strange reason, probably a BUG, the function also accepts sector 400h. The specified sector number is directly accessed (it is NOT parsed through the broken sector replacement list).

B(5Ch) - get_card_status(slot)**B(5Dh) - wait_card_status(slot)**

Returns the status of the most recent I/O command, possible values are:

```
01h=ready
02h=busy/read
04h=busy/write
08h=busy/info
11h=failed/timeout (eg. when no cartridge inserted)
21h=failed/general error
```

get_card_status returns immediately, wait_card_status waits until a non-busy state occurs.

A(A7h) - bu_callback_okay()**A(A8h) - bu_callback_err_write()****A(A9h) - bu_callback_err_busy()****A(AAh) - bu_callback_err_eject()****A(AEh) - bu_callback_err_prev_write()**

These five callback functions are internally used by the BIOS, notifying other BIOS functions about (un-)successful completion of memory card I/O commands.

B(58h) - get_bu_callback_port()

This is a subfunction for the five bu_callback_xxx functions (indicating whether the callback occurred for a slot1 or slot2 access).

A(ACh) - _card_async_load_directory(port)

Invokes asynchronous reading of the memory card directory. The function isn't too useful because the BIOS tends to read the directory automatically in various places in synchronous mode, so there isn't too much chance to replace the automatic synchronous reading by asynchronous reading.

A(ADh) - set_card_auto_format(flag)

Can be used to enable/disable auto format (0=off, 1=on). The _bu_init function initializes auto format as disabled. If auto format is enabled, then the BIOS does automatically format memory cards if it has failed to read the "MC" ID bytes on sector 0. Although potentially useful, activating this feature is rather destructive (for example, read errors on sector 0 might occur accidentally due to improperly inserted cards with dirty contacts, so it'd be better to prompt the user whether or not to format the card, rather than doing that automatically).

C(1Ah) - set_card_find_mode(mode)**C(1Dh) - get_card_find_mode()**

Allows to get/set the card find mode (0=normal, 1=find deleted files), the mode setting affects only the firstfile/nextfile functions. All other file functions are used fixed mode settings (always mode=0 for FileOpen, FileRename, FileDelete, and mode=1 for FileUndelete).

19.8 BIOS Interrupt/Exception Handling

The Playstation's Kernel uses an incredible inefficient and unstable exception handler; which may have been believed to be very powerful and flexible.

Inefficiency

For a maximum of slowness, it does always save and restore all CPU registers (including such that aren't used in the exception handler). It does then go through a list of installed interrupt handlers - and executes ALL of them. For example, a Timer0 IRQ is first passed to the Cdrom and Vblank handlers (which must reject it, no thanks), before it does eventually reach the Timer0 handler.

Unstable IRQ Handling

A fundamental mistake in the exception handler is that it doesn't memorize the incoming IRQ flags. So the various interrupt handlers must check Port 1F801070h one after each other. That means, if a high priority handler has rejected IRQ processing (because the desired IRQ flag wasn't set at that time), then a lower priority handler may process it (assuming that the IRQ flag got set in the meantime), and, in worst case it may even

acknowledge it (so the high priority handler does never receive it).

To avoid such problems, there should be only ONE handler installed for each IRQ source. However, that isn't always possible because the Kernel automatically installs some predefined handlers. Most noteworthy, the totally bugged DefaultInterruptHandlers is always installed (and cannot be removed), so it does randomly trigger Events. Fortunately, it does not acknowledge the IRQs (unless SetIrqAutoAck was used to enable that fatal behaviour).

B(18h) - SetDefaultExitFromException()

Applies the default "Exit" structure (which consists of a pointer to ReturnFromException, and the Kernel's exception stacktop (minus 4, for whatever reason), and zeroes for the R16..R23,R28,R30 registers. Returns the address of that structure.

See SetCustomExitFromException for details.

B(19h) - SetCustomExitFromException(addr)

addr points to a structure (with same format as for the SaveState function):

```

00h 4    r31/ra,pc ;usually ptr to ReturnFromException function
04h 4    r28/sp     ;usually exception stacktop, minus 4, for whatever reason
08h 4    r30/fp     ;usually 0
0Ch 4x8   r16..r23 ;usually 0
2Ch 4    r28/gp     ;usually 0

```

The hook function is executed only if the ExceptionHandler has been fully executed (after processing an IRQ, many interrupt handlers are calling ReturnFromException to abort further exception handling, and thus do skip the hook function). Once when the hook function has finished, it should execute ReturnFromException. The hook function is called with r2=1 (that is important if the hook address was recorded with SaveState, where it "returns" to the SaveState caller, with r2 as "return value").

Priority Chains

The Kernel's exception handler has four priority chains, each may contain one or more Interrupt or Exception handlers. The default handlers are:

Prio	Chain	Content
0		CdromDmaIrq, CdromIoIrq, SyscallException
1		CardSpecificIrq, VblankIrq, Timer2Irq, Timer1Irq, Timer0Irq
2		PadCardIrq
3		DefInt

The exception handler calls all handlers, starting with the first element in the priority 0 chain (ie. usually CdromDmaIrq). The separate handlers must check if they want to process the IRQ (eg. CdromDmaIrq would process only CDROM DMA IRQs, but not joypad IRQs or so). If it has processed and acknowledged the IRQ, then the handler may execute ReturnFromException, which causes the handlers of lower priority to be skipped (if there are still other unacknowledged IRQs pending, then the hardware will re-enter the exception handler as soon as the RFE opcode in ReturnFromException does re-enable interrupts).

C(02h) - SysEnqIntRP(priority,struc) ;bugged, use with care

Inserts a new element in the specified priority chain. The new element is inserted at the begin of the chain, so (within that priority chain) the new element has highest priority.

```

00h 4 pointer to next element      (0=none) ;this pointer is inserted by BIOS
04h 4 pointer to SECOND function (0=none) ;executed if func1 returns r2<>0
08h 4 pointer to FIRST   function (0=none) ;executed first
0Ch 4 Not used (usually zero)

```

BUG: SysDeqIntRP can remove only the first element in the chain (see there for details), so adding new chain elements may cause OTHER functions to be unable to remove their chain elements. The BIOS seems to be occasionally adding/removing the "CardSpecificIrq" and "PadCardIrq" (with priority 1 and 2), so using those priorities may cause the BIOS to be unable to remove that IRQ handlers. Using priority 0 and 3 should work (as long as the software takes care to remove only the newest elements) (but there should be no conflicts with the BIOS which does never remove priority 0 and 3 elements) (leaving apart that DequeueCdIntr and CdRemove try to remove priority 0 elements, but those functions won't work anyways; due to the same bug).

C(03h) - SysDeqIntRP(priority,struc) ;bugged, use with care

Removes the specified element from the specified priority chain.

BUG: The function tries to search the whole chain (and to remove the element if it finds it). However, it does only check the first element properly, and, thereafter it reads a garbage value from an uninitialized stack location, and acts more or less unpredictable. So, it can remove only the first element in the chain, ie. it should be called only if you are SURE that there's no newer element in the chain, and only if you are SURE that the element IS in the chain.

SYS(01h) - EnterCriticalSection() ;syscall with r4=01h

Disables interrupts by clearing SR (cop0r12) Bit 2 and 10 (of which, Bit2 gets copied to Bit0 once when returning from the syscall exception). Returns 1 if both bits were set, returns 0 if one or both of the bits were already zero.

SYS(02h) - ExitCriticalSection() ;syscall with r4=02h

Enables interrupts by set SR (cop0r12) Bit 2 and 10 (of which, Bit2 gets copied to Bit0 once when returning from the syscall exception). There's no return value (all registers except SR and K0 are unchanged).

C(0Dh) - SetIrqAutoAck(irq,flag)

Specifies if the DefaultInterruptHandler shall automatically acknowledge IRQs. The "irq" parameter is the number of the interrupt, ie. 00h..0Ah = IRQ0..IRQ10. The "flag" value should be 0 to disable AutoAck, or non-zero to enable AutoAck. By default, AutoAck is disabled for all IRQs.

Mind that the DefaultInterruptHandler is totally bugged. Especially the AutoAck feature doesn't work very well: It may cause higher priority handlers to miss their IRQ, and it may even cause the DefaultInterruptHandler to miss its own IRQs.

C(06h) - ExceptionHandler()

The C(06h) vector points to the exception handler, ie. to the function that is invoked from the 4 opcodes at address 80000080h, that opcodes jump directly to the exception handler, so patching the C(06h) vector has no effect.

Reading the C(06h) entry can be used to let a custom 80000080h handler pass control back to the default handler (that, by a "direct" jump, not by the usual "MOV R9,06h / CALL 0C0h" method, which would destroy main programs R9 register).

Also, reading C(06h) may be useful for patching the exception handler (which contains a bunch of NOP opcodes, which seem to be intended to insert additional opcodes, such like debugger exception handling) (Note: some of that NOPs are reserved for Memory Card IRQ handling).

BUG: Early BIOS versions did try to examine a copy of cop0r13 in r2 register, but did forgot cop0r13 to r2 (so they examined garbage), this was fixed in newer BIOS versions, additionally, most commercial games still include patches for compatibility with the old BIOS.

B(17h) - ReturnFromException()

Restores the CPU registers (R1-R31,HI,LO,SR,PC) (except R26/K0) from the current TCB. This function is usually executed automatically at the end of the ExceptionHandler, however, functions in the exception chain may call ReturnFromException to return immediately, without processing chain elements of lower priority.

C(00h) - EnqueueTimerAndVblankIrqs(priority) ;used with prio=1**C(01h) - EnqueueSyscallHandler(priority) ;used with prio=0****C(0Ch) - InitDefInt(priority) ;used with prio=3**

Internally used to add some default IRQ and Exception handlers.

No Nested Exceptions

The Kernel doesn't support nested exceptions, that would require a decreasing exception stack, however, the kernel saves the incoming CPU registers in the current TCB, and an exception stack with fixed start address for internal push/pop during exception handling. So, nesting would overwrite these values. Do not enable IRQs, and don't trap other exceptions (like break or syscall opcodes, or memory or overflow errors) during exception handling.

Note: The exception stack has a fixed size of 1000h bytes (and is located somewhere in the first 64Kbytes of memory).

19.9 BIOS Event Functions

B(08h) - OpenEvent(class, spec, mode, func)

Adds an event structure to the event table.

```
class,spec - triggers if BOTH values match
mode - (1000h=execute function/stay busy, 2000h=no func/mark ready)
func - Address of callback function (0=None) (used only when mode=1000h)
out: R2 = Event descriptor (F1000000h and up), or FFFFFFFFh if failed
```

Opens an event, should be called within a critical section. The return value is used to identify the event to the other event functions. A list of event classes, specs and modes is at the end of this section. Initially, the event is disabled.

Note: The desired max number of events can be specified in the SYSTEM.CNF boot file (the default is "EVENT = 10" (which is a HEX number, ie. 16 decimal; of which 5 events are internally used by the BIOS for CDROM functions, so, of the 16 events, only 11 events are available to the game). A bigger amount of events will slowdown the DeliverEvent function (which always scans all EvCBs, even if all events are disabled).

B(09h) - CloseEvent(event) - releases event from the event table

Always returns 1 (even if the event handle is unused or invalid).

B(0Ch) - EnableEvent(event) - Turns on event handling for specified event

Always returns 1 (even if the event handle is unused or invalid).

B(0Dh) - DisableEvent(event) - Turns off event handling for specified event

Always returns 1 (even if the event handle is unused or invalid).

B(0Ah) WaitEvent(event)

Returns 0 if the event is disabled. Otherwise hangs in a loop until the event becomes ready, and returns 1 once when it is ready (and automatically switches the event back to busy status). Callback events (mode=1000h) do never set the ready flag (and thus WaitEvent would hang forever).

The main program simply hangs during the wait, so when using multiple threads, it may be more recommended to create an own waitloop that checks TestEvent, and to call ChangeThread when the event is busy.

BUG: The return value is unstable (sometimes accidentally returns 0=disabled if the event status changes from not-ready to ready shortly after the function call).

B(0Bh) TestEvent(event)

Returns 0 if the event is busy or disabled. Otherwise, when it is ready, returns 1 (and automatically switches the event back to busy status). Callback events (mode=1000h) do never set the ready flag.

B(07h) DeliverEvent(class, spec)

This function is usually called by the kernel, it triggers all events that are enabled/busy, and that have the specified class and spec values. Depending on the mode, either the

callback function is called (mode=1000h), or the event is marked as enabled/ready (mode=2000h).

B(20h) UnDeliverEvent(class, spec)

This function is usually called by the kernel, undelivers all events that are enabled/ready, and that have mode=2000h, and that have the specified class and spec values. Undeliver means that the events are marked as enabled/busy.

C(04h) get_free_EvCB_slot()

A subfunction for OpenEvent.

Event Classes

File Events:

```
0000000xh memory card (for file handle fd=x)
```

Hardware Events:

```
F0000001h IRQ0 VBLANK
F0000002h IRQ1 GPU
F0000003h IRQ2 CDROM Decoder
F0000004h IRQ3 DMA controller
F0000005h IRQ4 RTC0 (timer0)
F0000006h IRQ5/IRQ6 RTC1 (timer1 or timer2)
F0000007h N/A Not used (this should be timer2)
F0000008h IRQ7 Controller (joypad/memcard)
F0000009h IRQ9 SPU
F000000Ah IRQ10 PIO ;uh, does the PIO have an IRQ signal? (IRQ10 is joypad)
F000000Bh IRQ8 SIO
F0000010h Exception ;CPU crashed (BRK,BadSyscall,Overflow,MemoryError, etc.)
F0000011h memory card (lower level BIOS functions)
F0000012h memory card (not used by BIOS; maybe used by Sony's devkit?)
F0000013h memory card (not used by BIOS; maybe used by Sony's devkit?)
```

Event Events:

```
F1xxxxxxh event (not used by BIOS; maybe used by Sony's devkit?)
```

Root Counter Events (Timers and Vblank):

F2000000h Root counter 0 (Dotclock)	(hardware timer)
F2000001h Root counter 1 (horizontal retrace?)	(hardware timer)

```
F2000002h Root counter 2 (one-eighth of system clock) (hardware timer)
F2000003h Root counter 3 (vertical retrace?) (this is a software timer)
```

User Events:

```
F3xxxxxxh user (not used by BIOS; maybe used by games and/or Sony's devkit?)
```

BIOS Events (including such that have nothing to do with BIOS):

```
F4000001h memory card (higher level BIOS functions)
F4000002h libmath (not used by BIOS; maybe used by Sony's devkit?)
```

Thread Events:

```
FFxxxxxxh thread (not used by BIOS; maybe used by Sony's devkit?)
```

Event Specs

```
0001h counter becomes zero
0002h interrupted
0004h end of i/o
0008h file was closed
0010h command acknowledged
0020h command completed
0040h data ready
0080h data end
0100h time out
0200h unknown command
0400h end of read buffer
0800h end of write buffer
1000h general interrupt
2000h new device
4000h system call instruction ;SYS(04h..FFFFFFFFFFh)
8000h error happened
8001h previous write error happened
0301h domain error in libmath
0302h range error in libmath
```

Event modes

```
1000h Execute callback function, and stay busy (do NOT mark event as ready)
2000h Do NOT execute callback function, and mark event as ready
```

19.10 BIOS Event Summary

Below is a list of all events (class,spec values) that are delivered and/or undelivered by the BIOS in one way or another. The BIOS does internally open five events for cdrom (class=F0000003h with spec=10h,20h,40h,80h,8000h). The various other class/spec's are only delivered by the BIOS (but not received by the BIOS) (ie. a game may open/enable memory card events to receive notifications from the BIOS).

CDROM Events

```
F0000003h,10h cdrom DMA finished (all sectors finished)
F0000003h,20h cdrom ?
F0000003h,40h cdrom dead feature (delivered only by unused functions)
F0000003h,80h cdrom INT4 (reached end of disk)
F0000003h,100h      n/a ? ;undelivered, but not opened, nor delivered
F0000003h,200h      ;undelivered, but not opened
F0000003h,8000h
```

Memory Card - Higher Level File/Device Events

```
0000000xh,4      card file handle (x=fd) done okay
F4000001h,4      card done okay (len=0)
F4000001h,100h   card err busy ;A(A9h)
F4000001h,2000h  card err eject ;A(AAh) or unformatted (bad "MC" id)
F4000001h,8000h  card err write ;A(A8h) or A(AEh) or general error
```

Memory Card - Lower Level Hardware I/O Events

```
F0000011h,4      finished okay
F0000011h,100h   err busy
F0000011h,200h   n/a ?
F0000011h,2000h  err
F0000011h,8000h  err
F0000011h,8001h  err (this one is NOT undelivered!)
```

Timer/Vblank Events

```
F2000000h,2      Timer0 (IRQ4)
F2000001h,2      Timer1 (IRQ5)
F2000002h,2      Timer2 (IRQ6)
F2000003h,2      Vblank (IRQ0) (unstable since IRQ0 is also used for joypad)
```

Default IRQ Handler Events (very unstable, don't use)

```
F0000001h,1000h ;IRQ0  (VBLANK)
F0000002h,1000h ;IRQ1  (GPU)
F0000003h,1000h ;IRQ2  (CDROM)
F0000004h,1000h ;IRQ3  (DMA)
F0000005h,1000h ;IRQ4  (TMR0)
F0000006h,1000h ;IRQ5  (TMR1)
F0000006h,1000h ;IRQ6  (TMR2) (accidentally uses same event as TMR1)
F0000008h,1000h ;IRQ7  (joypad/memcard)
F0000009h,1000h ;IRQ9  (SPU)
F000000Ah,1000h ;IRQ10 (Joypad and PIO)
F000000Bh,1000h ;IRQ8  (SIO)
```

Unresolved Exception Events

```
F0000010h,1000h unknown exception ;neither IRQ nor SYSCALL
F0000010h,4000h unknown syscall   ;syscall(04h..FFFFFFFFFFh)
```

19.11 BIOS Thread Functions

B(0Eh) OpenThread(reg_PC,reg_SP_FP,reg_GP)

Searches a free TCB, marks it as used, and stores the initial program counter (PC), global pointer (GP aka R28), stack pointer (SP aka R29), and frame pointer (FP aka R30) (using the same value for SP and FP). All other registers are left uninitialized (eg. may contain values from an older closed thread, that includes the SR register, see note).

The return value is the new thread handle (in range FF000000h..FF000003h, assuming that 4 TCBs are allocated) or FFFFFFFFh if there's no free TCB. The function returns to the old current thread, use "ChangeThread" to switch to the new thread.

Note: The desired max number of TCBs can be specified in the SYSTEM.CNF boot file (the default is "TCB = 4", one initially used for the boot executable, plus 3 free threads).

BUG - Uninitialized SR Register

OpenThread does NOT initialize the SR register (cop0r12) of the new thread. Upon powerup, the bootcode zerofills the TCB memory (so, the SR of new threads will be initially zero; ie. Kernel Mode, IRQ's disabled, and COP2 disabled). However, when closing/reopening threads, the SR register will have the value of the old closed thread (so it may get started with IRQs enabled, and, in worst case, if the old thread should have

switched to User Mode, even without access to KSEG0, KSEG1 memory).
Or, ACTUALLY, the memory is NOT zerofilled on powerup... so SR is total random?

B(0Fh) CloseThread(handle)

Marks the TCB for the specified thread as unused. The function can be used for any threads, including for the current thread.

Closing the current thread doesn't terminate the current thread, so it may cause problems once when opening a new thread, however, it should be stable to execute the sequence "DisableInterrupts, CloseCurrentThread, ChangeOtherThread".

The return value is always 1 (even if the handle was already closed).

B(10h) ChangeThread(handle)

Pauses the current thread, and activates the selected new thread (or crashes if the specified handle was unused or invalid).

The return value is always 1 (stored in the R2 entry of the TCB of the old thread, so the return value will be received once when changing back to the old thread).

Note: The BIOS doesn't automatically switch from one thread to another. So, all other threads remain paused until the current thread uses ChangeThread to pass control to another thread.

Each thread is having its own CPU registers (R1..R31, HI, LO, SR, PC), the registers are stored in the TCB of the old thread, and restored when switching back to that thread.

Mind that other registers (I/O Ports or GTE registers aren't stored automatically, so, when needed, they need to be pushed/popped by software before/after ChangeThread).

C(05h) get_free_TCB_slot()

Subfunction for OpenThread, returns the number of the first free TCB (usually in range 0..3) or FFFFFFFFh if there's no free TCB.

SYS(03h) ChangeThreadSubFunction(addr) ;syscall with r4=03h, r5=addr

Subfunction for ChangeThread, R5 contains the address of the new TCB, just like all exceptions, the syscall exception is saving the CPU registers in the current TCB, but does then apply the new TCB as current TCB, and so, it does then enter the new thread when returning from the exception.

19.12 BIOS Timer Functions

Timers (aka Root Counters)

The three hardware timers aren't internally used by any BIOS functions, so they can be freely used by the game, either via below functions, or via direct I/O access.

Vblank

Some of the below functions are allowing to use Vblank IRQs as a fourth "timer". However, Vblank IRQs are internally used by the BIOS for handling joypad and memory card accesses. One could theoretically use two separate Vblank IRQ handlers, one for joypad, and one as "timer", but the BIOS is much too unstable for such "shared" IRQ handling (it may occassionally miss one of the two handlers). So, although Vblank IRQs are most important for games, the PSX BIOS doesn't actually allow to use them for purposes other than joypad access. A possible workaround is to examine the status byte in one of the joypad buffers (ie. the `InitPad(buf1,22h,buf2,22h)` buffers). Eg. a `wait_for_vblank` function could look like so: set `buf1[0]=55h`, then wait until `buf1[0]=00h` or `buf1[0]=FFh`.

B(02h) init_timer(t,reload,flags)

When $t=0..2$, resets the old timer mode by setting $[1F801104h+t*16]=0000h$, applies the reload value by $[1F801108h+t*16]=\text{reload}$, computes the new mode:

```
if flags.bit4=0 then mode=0048h else mode=0049h
if flags.bit0=0 then mode=mode OR 100h
if flags.bit12=1 then mode=mode OR 10h
```

and applies it by setting $[1F801104h+t*16]=\text{mode}$, and returns 1. Does nothing and returns zero for $t>2$.

B(03h) get_timer(t)

Reads the current timer value: Returns halfword $[1F801100h+t*16]$ for $t=0..2$. Does nothing and returns zero for $t>2$.

B(04h) enable_timer_irq(t)**B(05h) disable_timer_irq(t)**

Enables/disables timer or vblank interrupt enable bits in [1F801074h], bit4,5,6 for t=0,1,2, or bit0 for t=3, or random/garbage bits for t>3. The enable function returns 1 for t=0..2, and 0 for t=3. The disable function returns always 1.

B(06h) restart_timer(t)

Sets the current timer value to zero: Sets [1F801100h+t*16]=0000h and returns 1 for t=0..2. Does nothing and returns zero for t>2.

C(0Ah) - ChangeClearRCnt(t,flag) ;root counter (aka timer)

Selects what the kernel's timer/vblank IRQ handlers shall do after they have processed an IRQ (t=0..2: timer 0..2, or t=3: vblank) (flag=0: do nothing; or flag=1: automatically acknowledge the IRQ and immediately return from exception). The function returns the old (previous) flag value.

19.13 BIOS Joypad Functions

Pad Input

Joypads should be initialized via InitPad(buf1,22h,buf2,22h), and StartPad(). The main program can read the pad data from the buf1/buf2 addresses (including Status, ID1, button states, and any kind of analogue inputs). For more info on ID1, Buttons and analogue inputs, see

[Controllers and Memory Cards](#)

Note: The BIOS doesn't include any functions for sending custom data to the pads (such like for controlling rumble motors).

B(12h) - InitPad(buf1, siz1, buf2, siz2)

Memorizes the desired buf1/buf2 addresses, zerofills the buffers by using the siz1/siz2 buffer size values (which should be 22h bytes each). And does some initialization on the PadCardIrq element (but doesn't enqueue it, that must be done by a following call to StartPad), and does set the "pad_enable_flag", that flag can be also set/cleared via

`InitCard(pad_enable)`, where it selects if the Pads are kept handled together with Memory Cards. `buf1/buf2` are having the following format:

00h	Status (00h=okay, FFh=timeout/wrong ID2)
01h	ID1 (eg. 41h=digital_pad, 73h=analogue_pad, 12h=mouse, etc.)
02h..21h	Data (max 16 halfwords, depending on lower 4bit of ID1)

Note: `InitPad` does initially zerofill the buffers, so, until the first IRQ is processed, the initial status is 00h=okay, with buttons=0000h (all buttons pressed), to fix that situation, change the two status bytes to FFh after calling `InitPad` (or alternately, reject ID1=00h). Once when the `PadCardIrq` is enqueued via `StartPad`, and while "pad_enable_flag" is set, the data for (both) Pad1 and Pad2 is read on Vblank interrupts, and stored in the buffers, the IRQ handler stores up to 22h bytes in the buffer (regardless of the siz1/siz2 values) (eg. a Multitap adaptor uses all 22h bytes).

B(13h) - StartPad()

Should be used after `InitPad`. Enqueues the `PadCardIrq` handler, and does additionally initialize some flags.

B(14h) - StopPad()

Dequeues the `PadCardIrq` handler. Note that this handler is also used for memory cards, so it'll "stop" cards, too.

B(15h) - OutdatedPadInitAndStart(type, button_dest, unused, unused)

This is an extremely bizarre and restrictive function - don't use! The function fails unless type is 20000000h or 20000001h (the type value has no other function). The function uses "buf1/buf2" addresses that are located somewhere "hidden" within the BIOS variables region, the only way to read from that internal buffers is to use the ugly "`OutdatedPadGetButtons()`" function. For some strange reason it FFh-fills buf1/buf2, and does then call `InitPad(buf1,22h,buf2,22)` (which does immediately 00h-fill the previously FFh-filled buffers), and does then call `StartPad()`.

Finally, it does memorize the "button_dest" address (see `OutdatedPadGetButtons()` for details on that value). The two unused parameters have no function, however, they are internally written back to the stack locations reserved for parameter 2 and 3, ie. at [SP+08h] and [SP+0Ch] on the caller's stack, so the function MUST be called with all four parameters allocated on stack. Return value is 2 (or 0 if type was disliked).

B(16h) - OutdatedPadGetButtons()

This is a very ugly function, using the internal "buf1/buf2" values from "OutdatedPadInitAndStart" and the "button_dest" value that was passed to that function. If "button_dest" is non-zero, then this function is automatically called by the PadCardIrq handler, and stores its return value at [button_dest] (where it may be read by the main program). If "button_dest" is zero, then it isn't called automatically, and it \<can> be called manually (with return value in R2), however, it does additionally write the return value to [button_dest], ie. to [00000000h] in this case, destroying that memory location.

The return value itself is useless garbage: The lower 16bit contain the pad1 buttons, the upper 16bit the pad2 buttons, of which, both values have reversed byte-order (ie. the first button byte in upper 8bit). The function works only with controller IDs 41h (digital joypad) and 23h (nonstandard device). For ID=23h, the halfword is ORed with 07C7h, and bit6,7 are then cleared if the analogue inputs are greater than 10h. For ID=41h the data is left intact. Any other ID values, or disconnected joypads, cause the halfword to be set to FFFFh (same as when no buttons are pressed), that includes newer analogue pads (unless they are switched to "digital" mode).

19.14 BIOS GPU Functions

A(48h) - SendGP1Command(gp1cmd)

Writes [1F801814h]=gp1cmd. There's no return value (r2 is left unchanged).

A(49h) - GPU_cw(gp0cmd) ;send GP0 command word

Calls gpu_sync(), and does then write [1F801810h]=gp0cmd. Returns the return value from the gpu_sync() call.

A(4Ah) - GPU_cwp(src,num) ;send GP0 command word and parameter words

Calls gpu_sync(), and does then copy "num" words from [src and up] to [1F801810h], src should usually point to a command word, followed by num-1 parameter words. Transfer is done by software (without DMA). Always returns 0.

A(4Bh) - send_gpu_linked_list(src)

Transfer an OT via DMA. Calls gpu_sync(), and does then write [1F801814h]=4000002h, [1F8010F4h]=0, [1F8010F0h]=[1F8010F0h] OR 800h, [1F8010A0h]=src, [1F8010A4h]=0, [1F8010A8h]=1000401h. The function does additionally output a bunch of TTY status messages via printf. The function doesn't wait until the DMA is completed. There's no return value.

A(4Ch) - gpu_abort_dma()

Writes [1F8010A8h]=401h, [1F801814h]=4000000h, [1F801814h]=2000000h, [1F801814h]=1000000h. Ie. stops GPU DMA, and issues GP1(4), GP1(2), GP1(1). Returns 1F801814h, ie. the I/O address.

A(4Dh) - GetGPUStatus()

Reads [1F801814h] and returns that value.

A(46h) - GPU_dw(Xdst,Ydst,Xsiz,Ysiz,src)

Waits until GPUSTAT.Bit26 is set (unlike gpu_sync, which waits for Bit28), and does then [1F801810h]=A0000000h, [1F801810h]=YdstXdst, [1F801810h]=YsizXsiz, and finally transfers "N" words from [src and up] to [1F801810h], where "N" is "Xsiz*Ysiz/2". The data is transferred by software (without DMA) (by code executed in the uncached BIOS region with high waitstates, so the data transfer is very SLOW).

Caution: If "Xsiz*Ysiz" is odd, then the last halfword is NOT transferred, so the GPU stays waiting for the last data value.

Returns [SP+04h]=Ydst, [SP+08h]=Xsiz, [SP+0Ch]=Ysiz, [SP+10h]=src+N*4, and R2=src=N*4.

A(47h) - gpu_send_dma(Xdst,Ydst,Xsiz,Ysiz,src)

Calls gpu_sync(), writes [1F801810h]=A0000000h, [1F801814h]=4000002h, [1F8010F0h]=[1F8010F0h] OR 800h, [1F8010A0h]=src, [1F8010A4h]=N*10000h+10h (where N="Xsiz*Ysiz/32"), [1F8010A8h]=1000201h.

Caution: If "Xsiz*Ysiz" is not a multiple of 32, then the last halfword(s) are NOT transferred, so the GPU stays waiting for that values.

Returns R2=1F801810h, and [SP+04h]=Ydst, [SP+08h]=Xsiz, [SP+0Ch]=Ysiz.

A(4Eh) - gpu_sync()

If DMA is off (when GPUSTAT.Bit29-30 are zero): Waits until GPUSTAT.Bit28=1 (or until timeout).

If DMA is on: Waits until D2_CHCR.Bit24=0 (or until timeout), and does then wait until GPUSTAT.Bit28=1 (without timeout, ie. may hang forever), and does then turn off DMA via GP1(04h).

Returns 0 (or -1 in case of timeout, however, the timeout values are very big, so it may take a LOT of seconds before it returns).

19.15 BIOS Memory Allocation

A(33h) - malloc(size)

Allocates size bytes on the heap, and returns the memory handle (aka the address of the allocated memory block). The address of the block is guaranteed to be aligned to 4-byte memory boundaries. Size is rounded up to a multiple of 4 bytes. The address may be in KUSEG, KSEG0, or KSEG1, depending on the address passed to InitHeap.

Caution: The BIOS (tries to) initialize the heap size to 0 bytes (actually it accidentally overwrites that initial setting by garbage during relocation), so any call to malloc will fail, unless InitHeap has been used to initialize the address/size of the heap.

A(34h) - free(buf)

Deallocates the memory block. There's no return value, and no error checking. The function simply sets [buf-4]=[buf-4] OR 00000001h, so if buf is an invalid handle it may destroy memory at [buf-4], or trigger a memory exception (for example, when buf=0).

A(37h) - calloc(sizx, sisy) ;SLOW!

Allocates xsiz*ysiz bytes by calling malloc(xsiz*ysiz), and, unlike malloc, it does additionally zerofill the memory via SLOW "bzero" function. Returns the address of the memory block (or zero if failed).

A(38h) - realloc(old_buf, new_size) ;SLOW!

If "old_buf" is zero, executes malloc(new_size), and returns r2=new_buf (or 0=failed). Else, if "new_size" is zero, executes free(old_buf), and returns r2=garbage. Else, executes malloc(new_size), bcopy(old_buf,new_buf,new_size), and free(old_buf), and

returns r2=new_buf (or 0=failed).

Caution: The bcopy function is SLOW, and realloc does accidentally copy "new_size" bytes from old_buf, so, if the old_size was smaller than new_size then it'll copy whatever garbage data - in worst case, if it exceeds the top of the 2MB RAM region, it may crash with a locked memory exception, although that'd happen only if SetMemSize(2) was used to restrict RAM to 2MBs.

A(39h) - InitHeap(addr, size)

Initializes the address and size of the heap - the BIOS does not automatically do this, so, before using the heap, InitHeap must be called by software. Usually, the heap would be memory region between the end of the boot executable, and the bottom of the executable's stack. InitHeap can be also used to deallocate all memory handles (eg. when a new exe file has been loaded, it may use it to deallocate all old memory).

The heap is used only by malloc/realloc/calloc/free, and by the "qsort" function.

B(00h) alloc_kernel_memory(size)

B(01h) free_kernel_memory(buf)

Same as malloc/free, but, instead of the heap, manages the 8kbyte control block memory at A000E000h..A000FFFFh. This region is used by the kernel to allocate ExCBs (4x08h bytes), EvCBs (N*1Ch bytes), TCBs (N*0C0h bytes), and the process control block (1x04h bytes). Unlike the heap, the BIOS does automatically initialize this memory region via SysInitMemory(addr,size), and does automatically allocate the above data (where the number of EvCBs and TCBs is as specified in the SYSTEM.CNF file). Note: FCBs and DCBs are located elsewhere, at fixed locations in the kernel variables area.

Scratchpad Note

The kernel doesn't include any allocation functions for the scratchpad (nor do any kernel functions use that memory area), so the executable can freely use the "fast" memory at 1F800000h..1F8003FFh.

A(9Fh) - SetMemSize(megabytes)

Changes the effective RAM size (2 or 8 megabytes) by manipulating port 1F801060h, and additionally stores the size in megabytes in RAM at [00000060h].

Note: The BIOS bootcode accidentally sets the RAM value to 2MB (which is the correct physical memory size), but initializes the I/O port to 8MB (which mirrors the physical 2MB

within that 8MB region), so the initial values don't match up with each other.

Caution: Applying the correct size of 2MB may cause the "realloc" function to crash (that function may accidentally access memory above 2MB).

19.16 BIOS Memory Fill/Copy/Compare (SLOW)

Like most A(NNh) functions, below functions are executed in uncached BIOS ROM, the ROM has very high waitstates, and the 32bit opcodes are squeezed through an 8bit bus. Moreover, below functions are restricted to process the data byte-by-byte. So, they are very-very-very slow, don't even think about using them.

Of course, that applies also for most other BIOS functions. But it's becoming most obvious for these small functions; memcpy takes circa 160 cycles per byte (reasonable would be less than 4 cycles), and bzero takes circa 105 cycles per byte (reasonable would be less than 1 cycles).

A(2Ah) - **memcpy(dst, src, len)**

Copies len bytes from [src..src+len-1] to [dst..dst+len-1]. Refuses to copy any data when dst=00000000h or when len>7FFFFFFFh. The return value is always the incoming "dst" value.

A(2Bh) - **memset(dst, fillbyte, len)**

Fills len bytes at [dst..dst+len-1] with the fillbyte value. Refuses to fill memory when dst=00000000h or when len>7FFFFFFFh. The return value is the incoming "dst" value (or zero, when len=0 or len>7FFFFFFFh).

A(2Ch) - **memmove(dst, src, len) - bugged**

Same as memcpy, but (attempts) to support overlapping src/dst regions, by using a backwards transfer when src\<dst (and, for some reason, only when dst>=src+len). **BUG:** The backwards variant accidentally transfers len+1 bytes from [src+len..src] down to [dst+len..dst].

A(2Dh) - **memcmp(src1, src2, len) - bugged**

Compares len bytes at [src1..src1+len-1] with [src2..src2+len-1], and (attempts) to return the difference between the first mismatching bytes, ie. [src1+N]-[src2+N], or 0 if there are no mismatches. Refuses to compare data when src1 or src2 is 00000000h, and

returns 0 in that case.

BUG: Accidentally returns the difference between the bytes AFTER the first mismatching bytes, ie. $[src1+N+1]-[src2+N+1]$.

That means that a return value of 0 can mean absolutely anything: That the memory blocks are identical, or that a mismatch has been found (but that the NEXT byte after the mismatch does match), or that the function has failed (due to src1 or src2 being 00000000h).

A(2Eh) - memchr(src, scanbyte, len)

Scans $[src..src+len-1]$ for the first occurrence of scanbyte. Refuses to scan any data when $src=00000000h$ or when $len>7FFFFFFFh$. Returns the address of that first occurrence, or 0 if the scanbyte wasn't found.

A(27h) - bcopy(src, dst, len)

Same as "memcpy", but with "src" and "dst" exchanged. That is, the first parameter is "src", the refuse occurs when "src" is 00000000h, and, returns the incoming "src" value (whilst "memcpy" uses "dst" in that place).

A(28h) - bzero(dst, len)

Same as memset, but uses 00h as fixed fillbyte value.

A(29h) - bcmp(ptr1, ptr2, len) - bugged

Same as "memcmp", with exactly the same bugs.

19.17 BIOS String Functions

A(15h) - strcat(dst, src)

Appends src to the end of dst. Searches the ending 00h byte in dst, and copies src to that address, up to including the ending 00h byte in src. Returns the incoming dst value. Refuses to do anything if src or dst is 00000000h (and returns 0 in that case).

A(16h) - strncat(dst, src, maxlen)

Same as "strcat", but clipped to "MaxSrc=(min(0,maxlen)+1)" characters, ie. the total length is max "length(dst)+min(0,maxlen)+1". If src is longer or equal to "MaxSrc", then

only the first "MaxSrc" chars are copied (with the last byte being replaced by 00h). If src is shorter, then everything up to the ending 00h byte gets copied, but without additional padding (unlike as in "strncpy").

A(17h) - strcmp(str1, str2)

Compares the strings up to including ending 00h byte. Returns 0 if they are identical, or otherwise $[str1+N]-[str2+N]$, where N is the location of the first mismatch, the two bytes are sign-expanded to 32bits before doing the subtraction. The function rejects str1/str2 values of 00000000h (and returns 0=both are zero, -1=only str1 is zero, and +1=only str2 is zero).

A(18h) - strncmp(str1, str2, maxlen)

Same as "strcmp" but stops after comparing "maxlen" characters (and returns 0 if they did match). If the strings are shorter, then comparison stops at the ending 00h byte (exactly as for strcmp).

A(19h) - strcpy(dst, src)

Copies data from src to dst, up to including the ending 00h byte. Refuses to copy anything if src or dst is 00000000h. Returns the incoming dst address (or 0 if copy was refused).

A(1Ah) - strncpy(dst, src, maxlen)

Same as "strcpy", but clipped to "maxlen" characters. If src is longer or equal to maxlen, then only the first "maxlen" chars are copied (but without appending an ending 00h byte to dst). If src is shorter, then the remaining bytes in dst are padded with 00h bytes.

A(1Bh) - strlen(src)

Returns the length of the string up to excluding the ending 00h byte (or 0 when src is 00000000h).

A(1Ch) - index(src, char)**A(1Dh) - rindex(src, char)****A(1Eh) - strchr(src, char) ;exactly the same as "index"****A(1Fh) - strrchr(src, char) ;exactly the same as "rindex"**

Scans for the first (index) or last (rindex) occurrence of char in the string. Returns the memory address of that occurrence (or 0 if there's no occurrence, or if src is 00000000h). Char may be 00h (returns the end address of the string). Note that, despite of the function names, the return value is always a memory address, NOT an index value relative to src.

A(20h) - strpbrk(src, list)

Scans for the first occurrence of a character that is contained in the list. The list contains whatever desired characters, terminated by 00h.

Returns the address of that occurrence, or 0 if there was none. BUG: If there was no occurrence, it returns 0 only if src[0]=00h, and otherwise returns the incoming "src" value (which is the SAME return value as when a occurrence did occur on 1st character).

A(21h) - strspn(src, list)**A(22h) - strcspn(src, list)**

Scans for the first occurrence of a character that is (strspn), or that isn't (strcspn) contained in the list. The list contains whatever desired characters, terminated by 00h. Returns the index (relative to src) of that occurrence. If there was no occurrence, then it returns the length of src. That silly return values do not actually indicate if an occurrence has been found or not (unless one checks for [src+index]=00h or so).

"The strcspn() function shall compute the length (in bytes) of the maximum initial segment of the string pointed to by s1 which consists entirely of bytes not from the string pointed to by s2."

"The strspn() function shall compute the length (in bytes) of the maximum initial segment of the string pointed to by s1 which consists entirely of bytes from the string pointed to by s2."

Hmmmm, that'd be vice-versa?

A(23h) - strtok(src, list) ;first call

A(23h) - strtok(0, list) ;further call(s)

Used to split a string into fragments, list contains a list of characters that are to be treated as separators, terminated by 00h.

The first call copies the incoming string to a buffer in the BIOS variables area (the buffer size is 100h bytes, so the string should be max 255 bytes long, plus the ending 00h byte, otherwise the function destroys other BIOS variables), it does then search the first fragment, starting at the begin of the buffer. Further calls (with src=00000000h) are searching further fragments, starting at the buffer address from the previous call. The internal buffer is used only for strtok, so its contents (and the returned string fragments) remain intact until a new first call to strtok takes place.

The separate fragments are processed by searching the first separator, starting at the current buffer address, the separator is then replaced by a 00h byte, and the old buffer address is returned to the caller. Moreover, the function tries to skip all continuously following separators, until reaching a non-separator, and does memorize that address for the next call (due to that skipping further calls won't return empty fragments, the first call may do so though). That skipping seems to be bugged, if list contains two or more different characters, then additional separators aren't skipped.

```
",,TEXT,,,END" with list="," returns "", "TEXT", "END"
",,TEXT,,,END" with list=".." returns "", "", "TEXT", "", "", "END"
```

Once when there are no more fragments, then 00000000h is returned.

A(24h) - strstr(str, substr) - buggy

Scans for the first occurrence of substr in the string. Returns the memory address of that occurrence (or 0 if it was unable to find an occurrence).

BUG: After rejecting incomplete matches, the function doesn't fallback to the old str address plus 1, but does rather continue at the current str address. Eg. it doesn't find substr="aab" in str="aaab" (in that example, it does merely realize that "aab"\<>"aaa" and then that "aab"\<>"b").

19.18 BIOS Number/String/Character Conversion

A(0Eh) - abs(val)

A(0Fh) - labs(val) ;exactly same as "abs"

Returns the absolute value (if val\<0 then R2=-val, else R2=val).

A(0Ah) - todigit(char)

Takes the incoming character, ANDed with FFh, and returns 0..9 for characters "0..9" and 10..35 for "A..Z" or "a..z", or 0098967Fh (9,999,999 decimal) for any other 7bit characters, or garbage for characters 80h..FFh.

A(25h) - toupper(char)

A(26h) - tolower(char)

Returns the incoming character, ANDed with FFh, with letters "A..Z" converted to uppercase/lowercase format accordingly. Works only for char 00h..7Fh (some characters in range 80h..FFh are left unchanged, others are randomly "adjusted" by adding/subtracting 20h, and by sign-expanding the result to 32bits).

A(0Dh) - strtol(src, src_end, base)

Converts a string to a number. The function skips any leading "blank" characters (that are, 09h..0Dh, and 20h) (ie. TAB, CR, LF, SPC, and some others) (some characters in range 80h..FFh are accidentally treated as "blank", too).

The incoming base value should be in range 2..11, although the function does also accept the buggy values in range of 12..36 (for values other than 2..36 it defaults to decimal/base10). The used numeric digits are "0..9" and "A..Z" (or less when base is smaller than 36).

The string may have a negative sign prefix "-" (negates the result) (a "+" is NOT recognized; and will be treated as the end of the string). Additionally, the string may contain prefixes "0b" (binary/base2), "0x" (hex/base16), or "o" (octal/base8) (only "o", not "Oo"), allowing to override the incoming "base" value.

BUG: Incoming base values greater than 11 don't work due to the prefix feature (eg. base=16 with string "0b11" will be treated as 11 binary, and base=36 with string "o55" will be treated as 55 octal) (the only workaround would be to add/remove leading "0"

characters, ie. "b11" or "00b11" or "0o55" would work okay).

Finally, the function initializes result=0, and does then process the digits as "result=result*base+digit" (without any overflow checks) unless/until it reaches an unknown digit (or when digit>=base) (ie. the string may end with 00h, or with any other unexpected characters).

The function accepts both uppercase and lowercase characters (both as prefixes, and as numeric digits). The function returns R2=result, and [src_end]=end_address (ie. usually the address of the ending 00h byte; or of any other unexpected end-byte). If src points to 00000000h, then the function returns r2=0, and leaves [src_end] unchanged.

A(0Ch) - strtoul(src, src_end, base)

Same as "strtol" except that it doesn't recognize the "-" sign prefix (ie. works only for unsigned numbers).

A(10h) - atoi(src)

A(11h) - atol(src) ;exactly same as "atoi" (but slightly slower)

Same as "strtol", except that it doesn't return the string end address in [src_end], and except that it defaults to base=10, but still supports prefixes, allowing to use base2,8,16. CAUTION: For some super bizarre reason, this function treats "0" (a leading ZERO digit) as OCTAL prefix (unlike strtol, which uses the "o" letter as octal prefix) (the "0x" and "0b" prefixes are working as usually).

A(12h) - atob(src, num_dst)

Calls "strtol(str,src_end,10)", and does then exchange the two return values (ie. sets R2=[src_end], and [num_dst]=value_32bit).

A(0Bh) - atof(src) ;USES (ABSENT) COP1 FPU !!!

A(32h) - strtod(src, src_end) ;USES (ABSENT) COP1 FPU !!!

These functions are intended to convert strings to floating point numbers, however, the functions are accidentally compiled for MIPS processors with COP1 floating point unit (which is not installed in the PSX, nor does the BIOS support a COP1 software emulation), so calling these functions will produce a coprocessor exception, causing the PSX to lockup via A(40h) SystemErrorUnresolvedException.

Note

On other systems (eg. 8bit computers), "abs/atoi" (integer) and "labs/atol" (long) may act differently. However, on the Playstation, both use signed 32bit values.

19.19 BIOS Misc Functions

A(2Fh) - rand()

Advances the random generator as " $x=x*41C64E6Dh+3039h$ " (aka plus 12345 decimal), and returns a 15bit random value " $R2=(x/10000h) \text{ AND } 7FFFh$ ".

A(30h) - srand(seed)

Changes the current 32bit value of the random generator.

A(B4h) - GetSystemInfo(index) ;not supported by old CEX-1000 version

Returns a word, halfword, or string, depending on the selected index value:

00h	Get Kernel BCD Date	(eg. 19951204h) (YYYYMMDDh)
01h	Get Kernel Flags or so	(usually/always 00000003h)
02h	Get Kernel Version String	(eg. "CEX-3000/1001/1002 by K.S.",0)
03h	Get whatever halfword	(usually 0) ;PS2: returns cop0r15
04h	Get whatever halfword	(usually 0)
05h	Get RAM Size in kilobytes	(usually 2048) ;=[00000060h] SHL 10
06h..0Eh	Get whatever halfwords	(usually 0,400h,0,200h,0,0,1,1,1)
0Fh	N/A (returns zero) ;PS2: returns 0000h	(effectively = same as zero)
10h..FFFFFFFh	Not used	(returns zero)

Note: The Date/Version are referring to the Kernel (in the first half of the BIOS). The Intro and Bootmenu (in the second half of the BIOS) may have a different version, there's no function to retrieve info on that portion, however, a version string for it can be usually found at BFC7FF32h (eg. "System ROM Version 4.5 05/25/00 E",0) (in many bios versions, the last letter of that string indicates the region, but not in all versions) (the old SCPH1000 does not include that version string at all).

B(56h) GetC0Table()**B(57h) GetB0Table()**

Retrieves the address of the jump lists for B(NNh) and C(NNh) functions, allowing to patch entries in that lists (however, the BIOS does often jump directly to the function addresses, rather than indirectly via the list, so patching may have little effect in such cases). Note: There's no function to retrieve the address of the A(NNh) jump list, however, that list is usually/always at 00000200h.

A(31h) - qsort(base, nel, width, callback)

Sorts an array, using a super-slow implementation of the "quick sort" algorithm. base is the address of the array, nel is the number of elements in the array, width is the size in bytes of each element, callback is a function that receives pointers to two elements which need to be compared; callback should return zero if the elements are identical, or a positive/negative number to indicate which element is bigger.

The qsort function rearranges the contents of the array, ie. depending on the callback result, it may swap the contents of the two elements, for some bizarre reason it doesn't swap them directly, but rather stores one of the elements temporarily on the heap (that means, qsort works only if the heap was initialized with InitHeap, and only if "width" bytes are free). There's no return value.

A(35h) - lsearch(key, base, nel, width, callback)**A(36h) - bsearch(key, base, nel, width, callback)**

Searches an element in an array (key is the pointer to the searched element, the other parameters are same as for "qsort"). "lsearch" performs a slow linear search in an unsorted array, by simply comparing one array element after each other. "bsearch" assumes that the array contains sorted elements (eg. via qsort), which is allowing to skip some elements, and to jump back and forth in the array, until it has found the desired element (or the location where it'd be, if it'd be in the array). Both functions return the address of the element (or 0 if it wasn't found).

C(19h) - ioabort(txt1,txt2)

Displays the two strings on the TTY (in some cases the BIOS does accidentally pass garbage instead of the 2nd string though). And does then execute ioabort_raw(1), see there for more details.

A(B2h) - ioabort_raw(param) ;not supported by old CEX-1000 version

Executes "RestoreState(ioabortbuffer,param)". Internally used to recover from failed I/O operations, param should be nonzero to notify the SaveState caller that the abort has occurred.

A(13h) - setjmp(buf)

This is a somewhat incomplete implementation of posix's setjmp, by storing the ABI-saved CPU registers in the specified buffer (30h bytes):

```

00h 4      r31 (ra)  (aka caller's pc)
04h 4      r29 (sp)
08h 4      r30 (fp)
0Ch 4x8    r16..r23
2Ch 4      r28 (gp)

```

That type of buffer can be used with "ioabort", "RestoreState", and also "SetCustomExitFromException(addr)".

The "setjmp" function returns 0 when called directly. However, it may return again - to the same return address, and the same stack pointer - with another return value (which should be usually non-zero, to indicate that the state has been restored (eg. ioabort passes 1 as return value)).

Also noteworthy from what a compliant setjmp implementation should be doing is the absence of saving the state of cop0 and cop2, thus making this slightly unsuitable for a typical coroutine system implementation.

A(14h) - longjmp(buf, param)

Restores the R16-R23,GP,SP,FP,RA registers from a previously recorded jmp_buf buffer, and "returns" to that new RA address (rather than to the caller of the longjmp function). The "param" value is passed as "return value" to the code at RA, ie. usually to the caller of the original setjmp call. Noteworthy difference from a conformant longjmp implementation is that the "param" value won't be clamped to 1 if you pass 0 to it. So since setjmp returns 0 on the first call, the caller of longjmp must take care that "param" is non-zero, so the callsite of setjmp can make the difference between the first call and a rollback. See setjmp for further details.

A(53h) - set_ioabort_handler(src) ;PS2 only ;PSX: SystemError

Normally the ioabort handler is changed only internally during booting, with this new function, games can install their own ioabort handler. src is pointer to a 30h-byte "savestate" structure, which will be copied to the actual ioabort structure.

A(06h) or B(38h) - exit(exitcode)

Terminates the program and returns control to the BIOS; which does then lockup itself via A(3Ah) SystemErrorExit.

A(A0h) - WarmBoot()

Performs a warmboot (resets the kernel and reboots from CDROM). Unlike the normal coldboot procedure, it doesn't display the "\<S>" and "PS" intro screens (and doesn't verify the "PS" logo in the ISO System Area), and, doesn't enter the bootmenu (even if the disk drive is empty, or if it contains an Audio disk). And, it doesn't reload the SYSTEM.CNF file, so the function works only if the same disk is still inserted (or another disk with identical SYSTEM.CNF, such like Disk 2 of the same game).

A(B5h..BFh) B(11h,24h..29h,2Ch..31h,5Eh..FFh) C(1Eh..7Fh) - N/A - Jump 0

These functions jump to address 00000000h. For whatever reason, that address does usually contain a copy of the exception handler (ie. same as at address 80000080h). However, since there's no return address stored in EPC register, the functions will likely crash when returning from the exception handler.

A(57h..5Ah,73h..77h,79h..7Bh,7Dh,7Fh..80h,82h..8Fh,B0h..B1h,B3h), and**C(0Eh..11h,14h) - N/A - Returns 0**

No function. Simply returns with r2=00000000h.

Reportedly, A(85h) is CdStop, but that seems to be nonsense?

SYS(00h) - NoFunction()

No function. Simply returns without changing any registers or memory locations (except that, of course, the exception handler destroys k0).

SYS(04h..FFFFFFFFFFh) - calls DeliverEvent(F0000010h,4000h)

These are syscalls with invalid function number in R4. For whatever reason that is handled by issuing DeliverEvent(F0000010h,4000h). Thereafter, the syscall returns to the main program (ie. it doesn't cause a SystemError).

A(3Ah) - SystemErrorExit(exitcode)**A(40h) - SystemErrorUnresolvedException()****A(A1h) - SystemErrorBootOrDiskFailure(type,errorcode) ;type "B"=Boot,"D"=Disk**

These are used "SystemError" functions. The functions are repeatedly jumping to themselves, causing the system to hang. Possibly useful for debugging software which may hook that functions.

A(4Fh,50h,52h,53h,9Ah,9Bh) B(1Ah..1Fh,21h..23h,2Ah,2Bh,52h,5Ah) C(0Bh) - N/A

These are additional "SystemError" functions, but they are never used. The functions are repeatedly jumping to themselves, causing the system to hang.

Note: A(52h) is reportedly "GetSysSp()", but that seems to be nonsense?

BRK(1C00h) - Division by zero (commonly checked/invoked by software)**BRK(1800h) - Division overflow (-80000000h/-1, sometimes checked by software)**

The CPU does not generate any exceptions upon divide overflows, because of that, the Kernel code and many games are commonly checking if the divider is zero (by software), and, if so, execute a BRK 1C00h opcode. The default BIOS exception handler doesn't handle BRK exceptions, and does simply redirect them to SystemErrorUnresolvedException().

19.20 BIOS Internal Boot Functions

A(45h) - init_a0_b0_c0_vectors

Copies the three default four-opcode handlers for the A(NNh),B(NNh),C(NNh) functions to A00000A0h..A00000CFh.

C(07h) - InstallExceptionHandlers() ;destroys/uses k0/k1

Copies the default four-opcode exception handler to the exception vector at 80000080h..8000008Fh, and, for whatever reason, also copies the same opcodes to 80000000h..8000000Fh.

C(08h) - SysInitMemory(addr,size)

Initializes the address (A000E000h) and size (2000h) of the allocate-able Kernel Memory region, and, seems to deallocate any memory handles which may have been allocated via B(00h).

C(09h) - SysInitKernelVariables()

Zerofills all Kernel variables; which are usually at [00007460h..0000891Fh].

Note: During the boot process, the BIOS accidentally overwrites the first opcode of this function (by the last word of the A0h table), so, thereafter, this function won't work anymore (nor would it be of any use).

C(12h) - InstallDevices(ttyflag)

Initializes the size and address of the File and Device Control Blocks (FCBs and DCBs). Adds the TTY device by calling "KernelRedirect(ttyflag)", and the CDROM and Memory Card devices by calling "AddCDROMDevice()" and "AddMemCardDevice()".

C(1Ch) - AdjustA0Table()

Copies the B(32h..3Bh) and B(3Ch..3Fh) function addresses to A(00h..09h) and A(3Bh..3Eh). Apparently Sony's compiler/linker can't insert the addresses in the A0h table directly at compilation time, so this function is used to insert them during execution of the boot code.

19.21 BIOS More Internal Functions

Below are mainly internally used device related subfunctions.

Internal Device Stuff

```
A(5Bh) dev_tty_init()                                ;PS2: SystemError
A(5Ch) dev_tty_open(fcb, and unused:"path\name", accessmode) ;PS2: SystemError
```

```

A(5Dh) dev_tty_in_out(fcb,cmd) ;PS2: SystemError
A(5Eh) dev_tty_ioctl(fcb,cmd,arg) ;PS2: SystemError
A(5Fh) dev_cd_open(fcb,"path\name",accessmode)
A(60h) dev_cd_read(fcb,dst,len)
A(61h) dev_cd_close(fcb)
A(62h) dev_cd_firstfile(fcb,"path\name",direntry)
A(63h) dev_cd_nextfile(fcb,direntry)
A(64h) dev_cd_chdir(fcb,"path")
A(65h) dev_card_open(fcb,"path\name",accessmode)
A(66h) dev_card_read(fcb,dst,len)
A(67h) dev_card_write(fcb,src,len)
A(68h) dev_card_close(fcb)
A(69h) dev_card_firstfile(fcb,"path\name",direntry)
A(6Ah) dev_card_nextfile(fcb,direntry)
A(6Bh) dev_card_erase(fcb,"path\name")
A(6Ch) dev_card_undelete(fcb,"path\name")
A(6Dh) dev_card_format(fcb)
A(6Eh) dev_card_rename(fcb1,"path\name1",fcb2,"path\name2")
A(6Fh) ? ;card ;[r4+18h]=00000000h ;card_clear_error(fcb) or so
A(96h) AddCDROMDevice()
A(97h) AddMemCardDevice()
A(98h) AddDuartTtyDevice() ;PS2: SystemError
A(99h) AddDummyTtyDevice()
B(47h) AddDevice(device_info) ;subfunction for AddXxxDevice functions
B(48h) RemoveDevice(device_name_lowercase)
B(5Bh) ChangeClearPad(int) ;pad AND card (ie. used also for Card)
C(15h) tty_cdevinput(circ,char)
C(16h) tty_cdevscan()
C(17h) tty_circgetc(circ) ;uses r5 as garbage txt for ioabort
C(18h) tty_circputc(char,circ)

```

Device Names

Device Names are case-sensitive (usually lowercase, eg. "bu" for memory cards). In filenames, the device name may be followed by a hexadecimal 32bit non-case-sensitive port number (eg. "bu00:" for selecting the first memory card slot). Accordingly, the device name should not end with a hexdigit (eg. "usb:" would be treated as device "us" with port number 0Bh).

Standard device names are "cdrom:", "bu00:", "bu10:", "tty00:". Other, nonstandard devices are:

```

Castlevania is trying to access an unknown device named "sim:".
Caetla (a firmware replacement for Cheat Devices) supports "pcdrv:" device.

```

19.22 BIOS PC File Server

DTL-H2000

Below BRK's are internally used in DTL-H2000 BIOS for two devices: "mwin:" (Message Window) and "sim:" (CDROM Sim).

Caetla Blurb

Caetla (a firmware replacement for Cheat Devices) supports "pcdrv:" device, the SN systems (=what?) device extension to access files on the drive of the pc. This fileserver can be accessed by using the kernel functions, with the "pcdrv:" device name prefix to the filenames or using the SN system calls.

The following SN system calls for the fileserver are provided. Accessed by setting the registers and using the break command with the specified field.

The break functions have argument(s) in A1,A2,A3 (ie. unlike normal BIOS functions not in A0,A1,A2), and TWO return values (in V0, and V1).

BRK(101h) - PCInit() - Inits the fileserver

No parameters.

BRK(102h) - PCCreat(filename, fileattributes) - Creates a new file on PC

```
out: V0  0 = success, -1 = failure
      V1  file handle or error code if V0 is negative
```

Attributes Bits (standard MSDOS-style):

bit0	Read only file (R)
bit1	Hidden file (H)
bit2	System file (S)
bit3	Not used (zero)
bit4	Directory (D)
bit5	Archive file (A)
bit6-31	Not used (zero)

BRK(103h) - PCOpen(filename, accessmode) - Opens a file on the PC

```
out: V0  0 = success, -1 = failure
      V1  file handle or error code if V0 is negative
```

BRK(104h) - PCClose(filehandle) - Closes a file on the PC

```
out: V0  0 = success, -1 = failure
V1  0 = success, error code if V0 is negative
```

BRK(105h) - PCRead(filehandle, length, memory_destination_address)

```
out: V0  0 = success, -1 = failure
V1  number of read bytes or error code if V0 is negative.
```

Note: PCRead does not stop at EOF, so if you set more bytes to read than the filelength, the fileservr will pad with zero bytes. If you are not sure of the filelength obtain the filelength by PCISeek (A2=0, A3=2, V1 will return the length of the file, don't forget to reset the file pointer to the start before calling PCread!)

BRK(106h) - PCWrite(filehandle, length, memory_source_address)

```
out: V0  0 = success, -1 = failure
V1  number of written bytes or error code if V0 is negative.
```

BRK(107h) - PCISeek(filehandle, file_offset, seekmode) - Change Filepos

seekmode may be from 0=Begin of file, 1=Current fpos, or 2=End of file.

```
out: V0  0 = success, -1 = failure
V1  file pointer
```

19.23 BIOS TTY Console (std_io)

A(3Fh) - Printf(txt,param1,param2,etc.) - Print string to console

in: A0	Pointer to 0 terminated string
A1,A2,A3,[SP+10h..]	Argument(s)

Prints the specified string to the TTY console. Printf does internally use "std_out_putchar" to output the separate characters (and expands char 09h and 0Ah accordingly). The string can contain C-style escape codes (prefixed by "%" each):

c	display ASCII character
s	display ASCII string

i,d,D	display signed Decimal number (d/i=default32bit, D=force32bit)
u,U	display unsigned Decimal number (u=default32bit, U=force32bit)
o,O	display unsigned Octal number (o=default32bit, O=force32bit)
p,x,X	display unsigned Hex number (p=lower/force32bit, x=lower, X=upper)
n	write 32bit/16bit string length to [parameter] (default32bit)

Additionally, following prefixes (inserted between "%" and escape code):

+ or SPC	show leading plus or space character in positive signed numbers
NNN	fixed width (for padding or so) (first digit must be 1..9) (not 0)
.NNN	fixed width (for clipping or so)
*	variable width (using one of the parameters) (negative=ending_spc)
.*	variable width
-	force ending space padding (in case of width being specified)
#	show leading "0x" or "0X" (hex), or ensure 1 leading zero (octal)
0	show leading zero's
L	unknown/no effect?
h,l	force 16bit (h=halfword), or 32bit (l=long/word)

The force32bit codes (D,U,O,p,l) are kinda useless since the PSX defaults to 32bit parameters anyways. The force16bit code (h) may be useful as "%hn" (writeback 16bit value), otherwise it's rather useless, unless signed 16bit parameters have garbage in upper 16bit, for unsigned 16bit parameters it doesn't work at all (accidentally sign-expands 16bit to 32bit, and then displays that signed 32bit value as giant unsigned value). Printf supports only octal, decimal, and hex (but not binary).

A(3Eh) or B(3Fh) std_out_puts(src) - Write string to TTY

```
in: R4=address of string (terminated by 00h)
```

Like "printf", but doesn't resolve any "%" operands. Empty strings are handled in a special way: If R4 points to a 00h character then nothing is output (as one would expect it), but, if R4 is 00000000h then "\<NULL>" is output (only that six letters; without appending any CR or LF).

A(3Dh) or B(3Eh) std_in_gets(dst) - Read string from TTY (keyboard input)

```
in: r4=dst (pointer to a 128-byte buffer) - out: r2=dst (same as incoming r4)
```

Internally uses "std_in_getchar" to receive the separate characters (which are thus masked by 7Fh). The received characters are stored in the buffer, and are additionally sent back as echo to the TTY via std_out_putc.

The following characters are handled in a special way: 09h (TAB) is replaced by a single

SPC. 08h or 7FH (BS or DEL) are removing the last character from the buffer (unless it is empty) and send 08h,20h,08h (BS,SPC,BS) to the TTY. 0Dh or 0Ah (CR or LF) do terminate the input (append 00h to the buffer, send 0Ah to the TTY, which is expanded to 0Dh,0Ah by the std_out_putc function, and do then return from the std_in_gets function).

The sequence 16h,NNh forces NNh to be stored in the buffer (even if NNh is a special character like 00h..1Fh or 7Fh). If the buffer is full (circa max 125 chars, plus one extra byte for the ending 00h), or if an unknown control code in range of 00h..1Fh is received without the 16h prefix, then 07h (BELL) is sent to the TTY.

A(3Bh) or B(3Ch) std_in_getchar() - Read character from TTY

Reads one character from the TTY console, by internally redirecting to "FileRead(0,tempbuf,1)". The returned character is ANDed by 7Fh (so, to read a fully intact 8bit character, "FileRead(0,tempbuf,1)" must be used instead of this function).

A(3Ch) or B(3Dh) std_out_putchar(char) - Write character to TTY

Writes the character to the TTY console, by internally redirecting to "FileWrite(1,tempbuf,1)". Char 09h (TAB) is expanded to one or more SPC characters, until reaching the next tabulation boundary (every 8 characters). Char 0Ah (LF) is expanded to 0Dh,0Ah (CR,LF). Other special characters (which should be handled at the remote terminal side) are 08h (BS, backspace, move cursor one position to the left), and 07h (BELL, produce a short beep sound).

C(13h) FlushStdInOutPut()

Closes and re-opens the std_in (fd=0) and std_out (fd=1) file handles.

C(1Bh) KernelRedirect(ttyflag) ;PS2: ttyflag=1 causes SystemError

Removes, re-mounts, and flushes the TTY device, the parameter selects whether to mount the real DUART-TTY device (r4=1), or a Dummy-TTY device (r4=0), the latter one sends any std_out to nowhere. Values other than r4=0 or r4=1 do remove the device, but do not re-mount it (which might result in problems).

Caution: Trying to use r4=1 on a PSX that does not have the DUART hardware installed causes the BIOS to hang (so one should first detect the DUART hardware, eg. by writing two different bytes to Port 1F802020h.1st/2nd access, and the read and verify that two bytes).

Activating std_io

The std_io functions can be enabled via C(1Bh) KernelRedirect(ttyflag), the BIOS is unable to detect the presence of the TTY hardware, by default the BIOS bootcode disables std_io by setting the initial KernelRedirect value at [A000B9B0h] to zero, this is hardcoded shortly after the POST(E) output:

```
call    output_post_r4      ;\output POST(E)
+mov    r4,0Eh               ;/
mov    r1,A00010000h         ;\set [0A000B9B0h]=0 ;TTY=dummy/off
call    reset_cont_d_3       ; and call reset_cont_d_3
+mov    [r1-4650h],0          ;/
```

assuming that R28=A0010FF0h, the last 3 opcodes of above code can be replaced by:

```
mov    r1,1h                 ;\set [0A000B9B0h]=1 ;TTY=duart/on
call   reset_cont_d_3        ; and call reset_cont_d_3
+mov   [r28-4650h-0ff0h],r1  ;/
```

with that patch, the BIOS bootcode (and many games) are sending debug messages to the debug terminal, via expansion port, see:

[EXP2 Dual Serial Port \(for TTY Debug Terminal\)](#)

Note: The nocash BIOS automatically detects the DUART hardware, and activates TTY if it is present.

B(49h) PrintInstalledDevices()

Uses printf to display the long and short names from the DCB of the currently installed devices. Doesn't do anything else. There's no return value.

Note

Several BIOS functions are internally using printf to output status information, timeout, and error messages, etc. So, trying to close the TTY file handles (fd=0 and fd=1) would cause such functions to work unstable.

19.24 BIOS Character Sets

B(51h) Krom2RawAdd(shiftjis_code)

```
In: r4 = 16bit Shift-JIS character code
Out: r2 = address in BIOS ROM of the desired character (or -1 = error)
```

r4 should be 8140h..84BEh (charset 2), or 889Fh..9872h (charset 3).

B(53h) Krom2Offset(shiftjis_code)

```
In: r4 = 16bit Shift-JIS character code
Out: r2 = offset within charset (without charset base address)
```

This is a subfunction for B(51h) Krom2RawAdd(shiftjis_code).

Character Sets in ROM (112Kbytes)

The character sets are located at BFC64000h and up, intermixed with some other stuff:

BFC64000h	Charset 1 (16x15 pix, letters with accent marks)	(NOT in JAPAN)
BFC65CB6h	Garbage (four-and-a-half reverb tables, ioports, printf strings)	
BFC66000h	Charset 2 (16x15 pix, various alphabets, english, greek, etc.)	
BFC69D68h	Charset 3 (16x15 pix, japanese or chinese symbols or so)	
BFC7F8DEh	Charset 4 (8x15 pix, mainly ASCII letters)	
BFC7FE6Fh	Charset 5 (8x15 pix, additional punctuation marks)	(NOT in PS2)
BFC7FF32h	Version (Version and Copyright strings)	(NOT in SCPH1000)
BFC7FF8Ch	Charset 6 (8x15 pix, seven-and-a-half japanese chars)	(NOT in PS2)
BFC80000h	End (End of 512kBYTE BIOS ROM)	

Charset 1 (and Garbage) is NOT included in japanese BIOSes (in the SCPH1000 version that region contains uncompressed program code, in newer japanese BIOSes that regions are zero-filled)

Charset 1 symbols are as defined in JIS-X-0212 char(2661h..2B77h), and EUC-JP char(8FA6E0h..8FABF7h).

Version (and Copyright) string is NOT included in SCPH1000 version (that BIOS includes further japanese 8x15 pix chars in that region).

For charset 2 and 3 it may be recommended to use the B(51h)

Krom2RawAdd(shiftjis_code) to obtain the character addresses. Not sure if that BIOS function (or another BIOS function) allows to retrieve charset 1, 4, 5, and 6 addresses?

19.25 BIOS Control Blocks

Exception Control Blocks (ExCB) (4 blocks of 8 bytes each)

```
00h 4    ptr to first element of exception chain
04h 4    not used (zero)
```

Event Control Blocks (EvCB) (usually 16 blocks of 1Ch bytes each)

```
00h 4    class   (events are triggered when class and spec match)
04h 4    status   (0=free,1000h=disabled,2000h=enabled/busy,4000h=enabled/ready)
08h 4    spec    (events are triggered when class and spec match)
0Ch 4    mode    (1000h=execute function/stay busy, 2000h=no func/mark ready)
10h 4    ptr to function to be executed when ready (or 0=none)
14h 8    not used (uninitialized)
```

Thread Control Blocks (TCB) (usually 4 blocks of 0C0h bytes each)

```
00h 4    status      (1000h=Free TCB, 4000h=Used TCB)
04h 4    not used   (set to 1000h by OpenThread) (not for boot executable?)
08h 80h r0..r31   (entries for r0/zero and r26/k0 are unused)
88h 4    cop0r14/epc (aka r26/k0 and pc when returning from exception)
8Ch 8    hi,lo      (the mul/div registers)
94h 4    cop0r12/sr (stored/restored by exception, NOT init by OpenThread)
98h 4    cop0r13/cause (stored when entering exception, NOT restored on exit)
9Ch 24h not used  (uninitialized)
```

Process Control Block (1 block of 4 bytes)

```
00h 4    ptr to TCB of current thread
```

The PSX supports only one process, and thus only one Process Control Block.

File Control Blocks (FCB) (16 blocks of 2Ch bytes each)

```
00h 4    status (0=Free FCB) (nonzero=accessmode)
04h 4    cdrom: disk_id (checksum across path table of the corresponding disk),
           memory card: port number (00h=slot1, 10h=slot2)
08h 4    transfer address (for dev_in_out function)
0Ch 4    transfer length (for dev_in_out function)
10h 4    current file position
14h 4    device flags (copy of DCB[04h])
18h 4    error ;used by B(55h) - GetLastFileError(fd)
1Ch 4    Pointer to DCB for the file
20h 4    filesize
```

```

24h 4 logical block number (start of file) (for cdrom: at least)
28h 4 file control block number (simply 0..15 for FCB number 0..15)

```

Device Control Blocks (DCB) (10 blocks of 50h bytes each)

```

00h 4 ptr to lower-case short name ("cdrom", "bu", "tty") (or 0=Free DCB)
04h 4 device flags (cdrom=14h, bu=14h, tty/dummy=1, tty/duart=3)
08h 4 sector size (cdrom=800h, bu=80h, tty=1)
0Ch 4 ptr to upper-case long name ("CD-ROM", "MEMORY CARD", "CONSOLE")
10h 4 ptr to init() (TTY only)
14h 4 ptr to open(fcb,"path\name",accessmode)
18h 4 ptr to in_out(fcb,cmd) (TTY only)
1Ch 4 ptr to close(fcb)
20h 4 ptr to ioctl(fcb,cmd,arg) (TTY only)
24h 4 ptr to read(fcb,dst,len)
28h 4 ptr to write(fcb,src,len)
2Ch 4 ptr to erase(fcb,"path\name")
30h 4 ptr to undelete(fcb,"path\name")
34h 4 ptr to firstfile(fcb,"path\name",direntry)
38h 4 ptr to nextfile(fcb,direntry)
3Ch 4 ptr to format(fcb)
40h 4 ptr to chdir(fcb,"path") (CDROM only)
44h 4 ptr to rename(fcb1,"path\name1",fcb2,"path\name2")
48h 4 ptr to remove()
4Ch 4 ptr to testdevice(fcb,"path\name")

```

19.26 BIOS Versions

Kernel Versions

For the actual kernel, there seem to be only a few different versions. Most PSX/PSone's are containing the version from 1995 (which is kept 1:1 the same in all consoles; without any PAL/NTSC related customizations).

```

28-Jul-1994  "DTL-H2000"          ;v0.x (pre-retail devboard)
22-Sep-1994  "CEX-1000 KT-3 by S.O." ;v1.0 through v2.0
no-new-date   "CEX-3000 KT-3 by K.S."  ;v2.1 only (old Port 1F801060h)
04-Dec-1995   "CEX-3000/1001/1002 by K.S." ;v2.2 through v4.5 (except v4.0)
29-May-1997   "CEX-7000/-7001 by K.S.    " ;v4.0 only (new Port 1F801010h)
17-Jan-2000   "PS compatible mode by M.T." ;v5.0 (Playstation 2)

```

The date and version string can be retrieved via GetSystemInfo(index).

The "CEX-7000/-7001" version was only "temporarily" used (when the kernel/gui grew too large they changed the ROM size from 512K to 1024K; but did then figure out that they could use a self-decompressing GUI to squeeze everything into 512K; but they did

accidentally still use the 1024K setting) (newer consoles fixed that and switched back to the old version from 1995) (aside from the different date/version string, the only changed thing is the opcode at BFC00000h, which initializes port 1F801010h to BIOS ROM size of 1MB, instead of 512KB; no idea if that BIOS does actually contain additional data?). The "CEX-3000 KT-3" version is already almost same as "CEX-3000/1001/1002", aside from version/date, the only differences are at offset BFC00014h..1Fh, and BFC003E0h (both related to Port 1F801060h).

Bootmenu/Intro Versions

This portion was updated more often. It's customized for PAL/NTSC displays, japanese/english language, and (maybe?) region/licence string checks. The SCPH1000 uses uncompressed Bootmenu/Intro code with "\<S>" intro, but without "PS" intro (or, "PS" is shown only on region matches?), newer versions are using selfdecompressing code, with both intro screens. The GUI in older PSX models looks like a drawing program for children, the GUI in newer PSX models and in PSone's looks more like a modernized bathroom furniture, unknown how the PS2 GUI looks like?

Games are communicating only with the Kernel, so the differences in the Bootmenu/Intro part should have little or effect on compatibility (although some I/O ports might be initialized differently, and although some games might (accidently) read different (garbage) values from the ROM).

Ver	CRC32	Used in	System ROM Version	Kernel
0.xj	18D0F7D8	DTL-H2000	(no version string)	dtlh2000
1.0j	3B601FC8	SCPH-1000 and DTL-H1000	(no version string)	cex1000
1.1j	3539DEF6	SCPH-3000 and DTL-H1000H	"1.1 01/22/95"	""
2.0a	55847D8C	DTL-H1001	"2.0 05/07/95 A"	""
2.0e	9BB87C4B	SCPH-1002 and DTL-H1002	"2.0 05/10/95 E"	""
2.1j	BC190209	SCPH-3500	"2.1 07/17/95 J"	cex3000
2.1a	AFF00F2F	SCPH-1001 and DTL-H1101	"2.1 07/17/95 A"	""
2.1e	86C30531	SCPH-1002 and DTL-H1102	"2.1 07/17/95 E"	""
2.2j	24FC7E17	SCPH-5000 and DTL-H1200	"2.2 12/04/95 J"	cex3000/100x
2.2a	37157331	SCPH-1001 and DTL-H1201/3001	"2.2 12/04/95 A"	""
2.2e	1E26792F	SCPH-1002 and DTL-H1202/3002	"2.2 12/04/95 E"	""
2.2v	446EC5B2	SCPH-5903 (VCD, 1Mbyte)	"2.2 12/04/95 J"	""
2.2d	DECB22F5	DTL-H1100	"2.2 03/06/96 D"	""
3.0j	FF3EEB8C	SCPH-5500	"3.0 09/09/96 J"	""
3.0a	8D8CB7E4	SCPH-5501/7003	"3.0 11/18/96 A"	""
3.0e	D786F0B9	SCPH-5502/5552	"3.0 01/06/97 E"	""
4.0j	EC541C00	SCPH-7000/9000	"4.0 08/18/97 J"	cex7000
4.1w	B7C43DAD	SCPH-7000W	...XXX...	
4.1a	502224B6	SCPH-7001/7501/7503/9001	"4.1 12/16/97 A"	cex3000/100x
4.1e	318178BF	SCPH-7002/7502/9002	"4.1 12/16/97 E"	""
4.3j	F2AF798B	SCPH-100 (PSone)	"4.3 03/11/00 J"	""
4.4a	6A0E22A0	SCPH-101 (PSone)	"4.4 03/24/00 ..XXX..	
4.4e	0BAD7EA9	SCPH-102 (PSone)	"4.4 03/24/00 E"	""

4.5a 171BDCEC SCPH-101 (PSone)	"4.5 05/25/00 A"	""
4.5e 76B880E5 SCPH-102 (PSone)	"4.5 05/25/00 E"	""
5.0t B7EF81A9 SCPH10000 (Playstation 2)	"5.0 01/17/00 T"	PS compatible

The System ROM Version string can be found at BFC7FF32h (except in v1.0).

v2.2j/a/e use exactly the same GUI as v2.1 (only the kernel was changed). v2.2d is almost same as v2.2j (but with some GUI patches or so).

v4.1 and v4.5 use exactly the same GUI code for "A" and "E" regions (the only difference is the last byte of the version string; which does specify whether the GUI shall use PAL or NTSC).

v5.0 is playstation 2 bios (4MB) with more or less backwards compatible kernel.

Character Set Versions

The 16x15 pixel charsets at BFC66000h and BFC69D68h are included in all BIOSes, however, the 16x15 portion for letters with accent marks at BFC64000h is included only in non-japanese BIOSes, and in some newer japanese BIOSes (not included in v4.0j, but they are included in v4.3j).

The 8x15 pixel charset with characters 21h..7Fh is included in all BIOSes. In the SCPH1000, this region is followed by additional 8x15 punctuation marks at char 80h and up, however, this region is missing in PS2 BIOS. Moreover, some BIOSes include an incomplete 8x15 japanese character set (which ends abruptly at BF7FFFFFh), in newer BIOSes, some of theses chars are replaced by the version string at BFC7FF32h, and, the remaining 8x15 japanese chars were removed in the PS2 BIOS version.

19.27 BIOS Patches

The original PSX Kernel mainly consists of messy and unstable compiler generated code, and, to the worst, the \<same> author seems to have attempted to use assembler code in some places. In result, most commercial games are causing a greater mess by inserting patches in the kernel code...

Which has been a nasty surprise when making the nocash PSX bios; which obviously wasn't compatible with these patches. The only solutions would have been to insert hundreds of NOPs to make my bios \<exactly> as bloated as the original bios (which I really didn't want to do), or to create anti-patch-patches.

Patches and Anti-Patch-Patches

As shown below, all known patches are invoked by a B(56h) or B(57h) function call. In the nocash PSX bios, these two functions are examining the following opcodes, if the opcodes are a known patch, then the BIOS reproduces the desired behaviour, and does then continue normal execution after those opcodes. If the opcodes are unknown, then the BIOS simply locks up; and shows an error message with the address of that opcodes in the TTY window; info about any such unknown opcodes would be welcome!

Compatibility

If you want to (or need to) use patches, please use byte-identical opcodes as commercial games do (as shown below; only the "xxxx" address digits are don't care), so the nocash PSX bios (or other homebrewn BIOSes) can detect and reproduce them. Or alternately, don't use the BIOS, and access I/O ports directly, which is much better and faster anyways.

patch_missing_cop0r13_in_exception_handler:

In newer Kernel version, the exception handler reads cop0r13/cause to r2, examines the Excode value in r2, and if the exception was caused by an interrupt, and if the next opcode (at EPC) is a GTE/COP2 command, then it does increment EPC by 4. The GTE commands are executed even if an interrupt occurs simultaneously, so, without adjusting EPC, the command would be executed twice. With some commands that'd just waste some clock cycles, with other commands it may cause data to be written twice to the GTE FIFOs, or may re-use the result from the 1st command execution as input to the 2nd execution.

The old "CEX-1000 KT-3" Kernel version did examine r2, but it "forgot" to previously load cop0r13 to r2, so it did randomly examine a garbage value. The patch inserts the missing opcode, used in elo2 at 80033740h, and in Pandemonium II at 8007F3FCh:

```

240A00B0 mov r10,0B0h          ;\ 00000000 nop
0140F809 call r10             ;: 00000000 nop
24090056 +mov r9,56h          ;/ 241A0100 mov k0,100h
3C0Axxxx mov r10,xxxx0000h    ;\ 8F5A0008 mov k0,[k0+8h]
3C09xxxx mov r9,xxxx0000h    ;: 00000000 nop
8C420018 mov r2,[r2+06h*4] ;=C(06h) ;: 8F5A0000 mov k0,[k0]
254Axxxx add r10,xxxxh ;=@new_data ;: 00000000 nop
2529xxxx add r9,xxxxh ;=@new_data_end ;/ 235A0008 addt k0,8h
      @@copy_lop: ;\ AF410004 mov [k0+4h],r1
8D430000 mov r3,[r10]          ;: AF420008 mov [k0+8h],r2
254A0004 add r10,4h           ;: AF43000C mov [k0+0Ch],r3
24420004 add r2,4h           ;: AF5F007C mov [k0+7Ch],ra

```

```

1549FFFC jne r10,r9,@@copy_lop ; 40026800 mov r2,cop0r13
AC43FFFC +mov [r2-4h],r3 ;/ 00000000 nop

```

Alternately, same as above, but using k0/k1 instead of r10/r9, used in Ridge Racer at 80047B14h:

```

240A00B0 mov r10,0B0h ; \
0140F809 call r10 ; \
24090056 +mov r9,56h ; / 241A0100 mov k0,100h
3C1Axxxx mov k0,xxxx0000h ; \
3C1Bxxxx mov k1,xxxx0000h ; / 8F5A0008 mov k0,[k0+8h]
8C420018 mov r2,[r2+06h*4] ;=C(06h) ; \
275Axxxx add k0,xxxxh ;=@new_data ; / 8F5A0000 mov k0,[k0]
277Bxxxx add k1,xxxxh ;=@new_data_end ; \
    @@copy_lop: ; / 235A0008 addt k0,8h
8F430000 mov r3,[k0] ; \
275A0004 add k0,4h ; / AF410004 mov [k0+4h],r1
24420004 add r2,4h ; / AF420008 mov [k0+8h],r2
175BFFFC jne k0,k1,@@copy_lop ; / AF43000C mov [k0+0Ch],r3
AC43FFFC +mov [r2-4h],r3 ; / AF5F007C mov [k0+7Ch],ra

```

Alternately, slightly different code used in metal_gear_solid at 80095CC0h, and in alone1 at 800A3ECCh:

```

24090056 mov r9,56h ; \
240A00B0 mov r10,0B0h ; / B(56h) GetC0Table
0140F809 call r10 ;
00000000 +nop ; /
8C420018 mov r2,[r2+06h*4] ;=00000C80h = exception_handler = C(06h)
00000000 nop
24420028 add r2,28h
00407821 mov r15,r2
3C0Axxxx lui r10,xxxxh ;@ori_data ; \
254Axxxx add r10,xxxxh ; / ;
3C09xxxx lui r9,xxxxh ;@ori_data_end ; @ori_data:
2529xxxx add r9,xxxxh ; / ; AF410004 mov [k0+4h],r1
    @@verify_lop: ; / AF420008 mov [k0+8h],r2
8D430000 mov r3,[r10] ; / AF43000C mov [k0+0Ch],r3
8C4B0000 mov r11,[r2] ; / AF5F007C mov [k0+7Ch],ra
254A0004 add r10,4h ; / 40037000 mov r3,cop0r14
146B000E jne r3,r11,@@verify_mismatch ; / 00000000 nop
24420004 +add r2,4h ;
1549FFFA jne r10,r9,@@verify_lop ; /
00000000 +nop ; /
01E01021 mov r2,r15
3C0Axxxx lui r10,xxxxh ;@new_data ; \
254Axxxx add r10,xxxxh ; / ;
3C09xxxx lui r9,xxxxh ;@new_data_end ; @new_data:
2529xxxx add r9,xxxxh ; / ; AF410004 mov [k0+4h],r1
    @@copy_lop: ; / AF420008 mov [k0+8h],r2
8D430000 mov r3,[r10] ; / 40026800 mov r2,cop0r13

```

```

00000000 nop ; AF43000C mov [k0+0Ch],r3
AC430000 mov [r2],r3 ; 40037000 mov r3,cop0r14
254A0004 add r10,4h ; AF5F007C mov [k0+7Ch],ra
1549FFFF jne r10,r9,@@copy_lop ;
24420004 +add r2,4h ;/
@@verify_mismatch:

```

Alternately, a bugged/nonfunctional homebrew variant (used by Hitmen's "minimum" demo):

```

;BUG1: 8bit "movb r6" should be 32bit "mov r6"
;BUG2: @@copy_lop should transfer 6 words (not 7 words)
;BUG3: and, asides, the minimum demo works only with PAL BIOS (not NTSC)
0xxxxxxxx call xxxxxxxxh ;\B(56h) GetC0Table
00000000 +nop ;/(mov r8,0B0h, jmp r8, +mov r9,56h)
3C04xxxx mov r4,xxxx0000h ;@@ori_data
2484xxxx add r4,xxxxh ;/
90460018 movb r6,[r2+06h*4] ;BUG1 ;exception_handler = C(06h)
24870018 add r7,r4,18h ;@ori_end ;\
24C50028 add r5,r6,28h ;C(06h)+28h ;
00A03021 mov r6,r5 ;@@ori_data:
    @@verify_lop: ; 80086520 AF410004 mov [k0+4h],r1
8CA30000 mov r3,[r5] ; 80086524 AF420008 mov [k0+8h],r2
8C820000 mov r2,[r4] ; 80086528 AF43000C mov [k0+0Ch],r3
00000000 nop ; 8008652C AF5F007C mov [k0+7Ch],ra
1462000C jne r3,r2,@@verify_mismatch ; 80086530 40037000 mov r3,cop0r14
24840004 +add r4,4h ; 80086534 00000000 nop
1487FFFA jne r4,r7,@@verify_lop ;@@ori_end:
24A50004 +add r5,4h ;/
00C02821 mov r5,r6 ;\@@new_data:
3C04xxxx mov r4,xxxx0000h ;@@new_data; 80086538 AF410004 mov [k0+4h],r1
2484xxxx add r4,xxxxh ;/ ; 8008653C AF420008 mov [k0+8h],r2
2483001C add r3,r4,1Ch ;@bugged_end ; 80086540 40026800 mov r2,cop0r13
    @@copy_lop: ; 80086544 AF43000C mov [k0+0Ch],r3
8C820000 mov r2,[r4] ; 80086548 40037000 mov r3,cop0r14
24840004 add r4,4h ; 8008654C AF5F007C mov [k0+7Ch],ra
ACA20000 mov [r5],r2 ;@@new_end:
1483FFFC jne r4,r3,@@copy_lop ; 80086550 00000000 nop ;BUG2
24A50004 +add r5,4h ;/ @@bugged_end:
    @@verify_mismatch:

```

early_card_irq_patch:

Because of a hardware glitch the card IRQ cannot be acknowledged while the external IRQ signal is still LOW, making it necessary to insert a delay that waits until the signal gets HIGH before acknowledging the IRQ.

The original BIOS is so inefficient that it takes hundreds of clock cycles between the interrupt request and the IRQ acknowledge, so, normally, it doesn't require an additional delay.

However, the central mistake in the IRQ handler is that it doesn't memorize which IRQ has originally triggered the interrupt. For example, it may get triggered by a timer IRQ, but a newer card IRQ may occur during IRQ handling, in that case, the card IRQ may get processed and acknowledged without the required delay.

Used in Metal Gear Solid at 8009AA5Ch, and in alone1 at 800AE2F8h:

```

24090056 mov r9,56h ;\ ; @new_data:
240A00B0 mov r10,0B0h ; B(56h) GetC0Table ;3C02A001 lui r2,0A001h
0140F809 call r10 ; ;2442DFAC sub r2,2054h
00000000 +nop ;/ ;00400008 jmp r2 ;=@new_cont_d
8C420018 mov r2,[r2+06h*4] ;\get C(06h) ;00000000 +nop ;=A000DFACCh
00000000 nop ;/ ;00000000 nop
8C430070 mov r3,[r2+70h] ;\ ; @new_data_end:
00000000 nop ; get ; @new_cont_d:
3069FFFF and r9,r3,0FFFFh ; early_card ;8C621074 mov r2,[r3+1074h]
00094C00 shl r9,10h ; irq_handler ;00000000 nop
8C430074 mov r3,[r2+74h] ; ;30420080 and r2,80h ;I_STAT.7
00000000 nop ; ;1040000B jz r2,@ret
306AFFFF and r10,r3,0FFFFh ;/ ;00000000 +nop
012A1821 add r3,r9,r10 ; @wait_lop:
24620028 add r2,r3,28h ;=early+28h ;8C621044 mov r2,[r3+1044h]
3C0AXXXX lui r10,xxxxh ;@new_data ;00000000 nop
254Axxxx sub r10,xxxxh ;/ ;30420080 and r2,80h ;JOY_STAT.7
3C09xxxx lui r9,xxxxh ;@new_data_end ;1440FFFC jnz r2,@wait_lop
2529xxxx sub r9,xxxxh ;/ ;00000000 +nop
    @@copy_lop:
8D430000 mov r3,[r10] ;3C020001 lui r2,0001h
00000000 nop ;8C42DFFC mov r2,[r2-2004h]
AC430000 mov [r2],r3 ;00400008 jmp r2 ;=[0000DFFCh]
254A0004 add r10,4h ;00000000 +nop
1549FFFF bne r10,r9,@@copy_lop ; @ret:
24420004 +add r2,4h ;03E00008 ret
3C010001 lui r1,0001h ;\[DFFCh]=r2 ;00000000 +nop
0xxxxxxxx call xxxxxxxxh ; and call ... ;
AC22DFFC +mov [r1-2004h],r2 ;/
;
```

Alternately, elo2 uses slightly different code at 8003961Ch:

```

240A00B0 mov r10,0B0h ;\ ; @new_data:
0140F809 call r10 ; B(56h) GetC0Table ;3C02xxxx lui r2,8xxxxh
24090056 +mov r9,56h ;/ ;2442xxxx sub r2,xxxxh
8C420018 mov r2,[r2+06h*4] ;\get C(06h) ;00400008 jmp r2 ;=@new_cont_d
00000000 nop ;/ ;00000000 +nop ;=xxxxxxxxh
8C430070 mov r3,[r2+70h] ;\ ; @new_data_end:
00000000 nop ; get ; @new_cont_d:
3069FFFF and r9,r3,0FFFFh ; early_card ;8C621074 mov r2,[r3+1074h]
8C430074 mov r3,[r2+74h] ; irq_handler ;00000000 nop
00094C00 shl r9,10h ; ;30420080 and r2,80h ;I_STAT.7
306AFFFF and r10,r3,0FFFFh ; ;1040000B jz r2,@ret
012A1821 add r3,r9,r10 ;/
;
```

```

3C0Axxxx mov r10,xxxx0000h ;00000000 +nop
3C09xxxx mov r9,xxxx0000h ;        @@wait_lop:
24620028 add r2,r3,28h ;=early+28h ;8C621044 mov r2,[r3+1044h]
254Axxxx sub r10,xxxxh ;=@new_data ;00000000 nop
2529xxxx sub r9,xxxxh ;=@new_data_end ;30420080 and r2,80h ;JOY_STAT.7
    @@copy_lop: ;1440FFFC jnz r2,@@wait_lop
8D430000 mov r3,[r10] ;00000000 +nop
254A0004 add r10,4h ;3C02xxxx lui r2,8xxxx
24420004 add r2,4h ;8C42xxxx mov r2,[r2-xxxxh]
1549FFFC jne r10,r9,@@copy_lop ;00000000 nop
AC43FFFF +mov [r2-4h],r3 ;00400008 jmp r2 ;=[8xxxxxxxxh]
3C018xxx mov r1,8xxx0000h ;\[...]=r2, ;00000000 +nop
0xxxxxxxx call xxxxxxxxxxxh ; and call ... ;        @@ret:
AC22xxxx +mov [r1+xxxxh],r2 ;/ ;03E00008 ret
    ...

```

Note: The above @@wait_lop's should be more preferably done with timeouts (else they may hang endless if a Sony Mouse is newly connected; the mouse does have /ACK stuck LOW on power-up).

patch_uninstall_early_card_irq_handler:

Used to uninstall the "early_card_irq_vector" (the BIOS installs that vector from inside of B(4Ah) InitCard(pad_enable), and, without patches, the BIOS doesn't allow to uninstall it thereafter).

Used in Breath of Fire III (SLES-01304) at 8017E790, and also in Ace Combat 2 (SLUS-00404) at 801D23F4:

```

240A00B0 mov r10,0B0h      ;\
0140F809 call r10          ; B(56h) GetC0Table
24090056 +mov r9,56h      ;/
3C0Axxxx mov r10,xxxx0000h
3C09xxxx mov r9,xxxx0000h
8C420018 mov r2,[r2+06h*4] ;=00000C80h = exception_handler = C(06h)
254Axxxx add r10,xxxxh ;@new_data
2529xxxx add r9,xxxxh ;@new_data_end
    @@copy_lop:             ;\  @new_data:
8D430000 mov r3,[r10]      ; 00000000 nop
254A0004 add r10,4h       ; 00000000 nop
24420004 add r2,4h       ; 00000000 nop
1549FFFC jne r10,r9,@@copy_lop ; @new_data_end:
AC43006C +mov [r2+70h-4],r3 ;/

```

Alternately, more inefficient, used in Blaster Master-Blasting Again (SLUS-01031) at 80063FF4h, and Raiden DX at 80029694h:

```

24090056 mov r9,56h      ;\
240A00B0 mov r10,0B0h      ; B(56h) GetC0Table

```

```

0140F809 call r10          ;
00000000 +nop             ;/
8C420018 mov  r2,[r2+06h*4] :=00000C80h = exception_handler = C(06h)
3C0Axxxx mov  r10,xxxx0000h ;\@@new_data
254Axxxx add   r10,xxxxh    ;/
3C09xxxx mov  r9,xxxx0000h ;\@@new_data_end
2529xxxx add   r9,xxxxh    ;/
    @@copy_lop:           ;\
8D430000 mov  r3,[r10]       ;    @@new_data:
00000000 nop              ;    00000000 nop
AC430070 mov  [r2+70h],r3    ;    00000000 nop
254A0004 add   r10,4h ;src  ;    00000000 nop
1549FFFFB jne  r10,r9,@@copy_lop ;    @@new_data_end:
24420004 +add  r2,4h ;dst  ;/

```

Note: the above code is same as "patch_install_lightgun_irq_handler", except that it writes to r2+70h, instead of r2+80h.

patch_card_specific_delay:

Same purpose as the "early_card_irq_patch" (but for the command/status bytes rather than for the data bytes). The patch looks buggy since it inserts the delay AFTER the acknowledge, but it DOES work (the BIOS accidentally acknowledges the IRQ twice; and the delay occurs PRIOR to 2nd acknowledge).

Used in Metal Gear Solid at 8009AAF0h, and in Legacy of Kain at 801A56D8h, and in alone1 at 800AE38Ch:

```

24090057 mov  r9,57h ;\           ;    @@new_data:
240A00B0 mov  r10,0B0h ; B(57h) GetB0Table ; 3C08A001 lui  r8,0A001h
0140F809 call r10      ;/           ; 2508DF80 sub  r8,2080h
00000000 +nop             ;    0100F809 call r8 ;=A000DF80h
8C42016C mov  r2,[r2+5Bh*4] ;B(5Bh) ; 00000000 +nop
00000000 nop              ;    00000000 nop
8C4309C8 mov  r3,[r2+9C8h] ;blah   ;    @@new_data_end:
3C0Axxxx lui   r10,xxxxh ;\@@new_data ; 946F000A movh r15,[r3+0Ah]
254Axxxx sub   r10,xxxxh ;/           ; 3C080000 mov  r8,0h
3C09xxxx lui   r9,xxxxh ;\@@new_data_end ; 01E2C025 or   r24,r15,r2
2529xxxx sub   r9,xxxxh ;/           ; 37190012 or   r25,r24,12h
    @@copy_lop:           ;    A479000A movh [r3+0Ah],r25
8D480000 mov  r8,[r10]        ; 24080028 mov  r8,28h
00000000 nop              ;    @@wait_lop:
AC4809C8 mov  [r2+9C8h],r8 ;B(5Bh)+9C8h.. ; 2508FFFF sub  r8,1h
254A0004 add   r10,4h        ; 1500FFFE jnz  r8,@@wait_lop
1549FFFFB jne  r10,r9,@@copy_lop ; 00000000 +nop
24420004 +add  r2,4h        ; 03E00008 ret   ;above delay is
                           ... ; 00000000 +nop ;in UNCACHED RAM

```

Alternately, slightly different code used in elo2 at 800396D4h, and in Resident Evil 2 at 800910E4h:

```

240A00B0 mov r10,0B0h ;\ ; @swap_begin:
0140F809 call r10 ; B(57h) GetB0Table ; 3C088xxxx lui r8,8xxxxh
24090057 +mov r9,57h ;/ ; 2508xxxx sub r8,xxxxh
8C42016C mov r2,[r2+5Bh*4] ;B(5Bh) ; 0100F809 call r8 ;=8xxxxxxxxx
3C0Axxxx mov r10,xxxx0000h ; 00000000 +nop
3C09xxxx mov r9,xxxx0000h ; 00000000 nop
8C4309C8 mov r3,[r2+9C8h] ;blah ; @swap_end:
254Axxxx sub r10,xxxxh ;=@swap_begin ; - - -
2529xxxx sub r9,xxxxh ;=@swap_end ; 00000000 nop
    @@swap_lop: ; 240800C8 mov r8,0C8h
8C4309C8 mov r3,[r2+9C8h] ;B(5Bh)+9C8h.. ; @wait_lop:
8D480000 mov r8,[r10] ; 2508FFFF sub r8,1h
254A0004 add r10,4h ; 1500FFE jnz r8,@@wait_lop
AD43FFFC mov [r10-4h],r3 ; 00000000 +nop
24420004 add r2,4h ; 03E00008 ret ;above delay is
1549FFFA jne r10,r9,@@swap_lop ; 00000000 +nop ;in CACHED RAM
AC4809C4 +mov [r2+9C4h],r8 ;

```

patch_card_info_step4:

The "card_info" function sends an incomplete read command to the card; in order to receive status information. After receiving the last byte, the function does accidentally send a further byte to the card, so the card responds by another byte (and another IRQ7), which is not processed nor acknowledged by the BIOS. This patch kills the opcode that sends the extra byte.

Used in alone1 at 800AE214h:

```

24090057 mov r9,57h ;\
240A00B0 mov r10,0B0h ; B(57h) GetB0Table
0140F809 call r10 ;
00000000 +nop ;/
240A0009 mov r10,9h ;=blah
8C42016C mov r2,[r2+5Bh*4] ;B(5Bh)
00000000 nop
20431988 addt r3,r2,1988h ;=B(5Bh)+1988h ;\store a NOP,
0xxxxxxxx call xxxxxxxxxxx ; and call ...
AC600000 +mov [r3],0 ;=nop ;/

```

patch_pad_error_handling_and_get_pad_enable_functions:

If a transmission error occurs (or if there's no controller connected), then the Pad handler handler does usually issue a strange chip select signal to the OTHER controller slot, and does then execute the bizarre_pad_delay function. The patch below overwrites that

behaviour by NOPs. Purpose of the original (and patched) behaviour is unknown.

Used by Perfect Assassin at 800519D4h:

```

240A00B0 mov r10,0B0h ; \
0140F809 call r10 ; B(57h) GetB0Table
24090057 +mov r9,57h ;/
8C42016C mov r2,[r2+5Bh*4] ;=B(5Bh)
3C01xxxx mov r1,xxxx0000h
20430884 addt r3,r2,884h ;B(5Bh)+884h
AC23xxxx mov [r1+xxxxh],r3 ;<--- SetPadEnableFlag()
3C01xxxx mov r1,xxxx0000h
20430894 addt r3,r2,894h ;B(5Bh)+894h
2409000B mov r9,0Bh ;len
AC23xxxx mov [r1+xxxxh],r3 ;<--- ClearPadEnableFlag()
    @@fill_lop: ; \
2529FFFF sub r9,1h ;
AC400594 mov [r2+594h],0 ;B(5Bh)+594h.. ; erase error handling
1520FFFD jnz r9,@@fill_lop ;
24420004 +add r2,4h ;/

```

Alternately, same as above, but with inefficient nops, used by Sporting Clays at 8001B4B4h:

```

24090057 mov r9,57h ; \
240A00B0 mov r10,0B0h ; B(57h) GetB0Table
0140F809 call r10 ;
00000000 +nop ;/
8C42016C mov r2,[r2+5Bh*4]
2409000B mov r9,0Bh ;len
20430884 addt r3,r2,884h
3C01xxxx mov r1,xxxx0000h
AC23xxxx mov [r1+xxxxh],r3 ;<--- SetPadEnableFlag()
20430894 addt r3,r2,894h
3C01xxxx mov r1,xxxx0000h
AC23xxxx mov [r1+xxxxh],r3 ;<--- ClearPadEnableFlag()
    @@fill_lop: ; \
AC400594 mov [r2+594h],0 ;
24420004 add r2,4h ; erase error handling
2529FFFF sub r9,1h ;
1520FFFC jnz r9,@@fill_lop ;
00000000 +nop ;/

```

Alternately, same as above, but without getting PadEnable functions, used in Pandemonium II (at 80083C94h and at 8010B77Ch):

```

240A00B0 mov r10,0B0h ; \
0140F809 call r10 ; B(57h) GetB0Table
24090057 +mov r9,57h ;/
8C42016C mov r2,[r2+5Bh*4] ;=B(5Bh)
2409000B mov r9,0Bh ;len ; \

```

```

@@fill_lop:                                ;
2529FFFF sub  r9,1h                      ; erase error handling
AC400594 mov   [r2+594h],0    ;B(5Bh)+594h.. ;
1520FFFD jnz   r9,@@fill_lop           ;
24420004 +add  r2,4h                  ;/

```

patch_optional_pad_output:

The normal BIOS functions are only allowing to READ from the controllers, but not to SEND data to them (which would be required to control Rumble motors, and to auto-activate Analog mode without needing the user to press the Analog button). Internally, the BIOS does include some code for sending data to the controller, but it doesn't offer a function vector for setting up the data source address, and, even if that would be supported, it clips the data bytes to 00h or 01h. The patch below retrieves the required SetPadOutput function address (in which only the src1/src2 addresses are relevant, the blah1/blah2 values aren't used), and suppresses clipping (ie. allows to send any bytes in range 00h..FFh).

Used in Resident Evil 2 at 80091914h:

```

240A00B0 mov   r10,0B0h          ; \
0140F809 call  r10             ; B(57h) GetB0Table
24090057 +mov  r9,57h          ; /
8C42016C mov   r2,[r2+5Bh*4]  ;B(5Bh)
3C0Axxxx mov   r10,xxxx0000h
3C09xxxx mov   r9,xxxx0000h
3C01xxxx mov   r1,xxxx0000h
204307A0 addt  r3,r2,7A0h    ;B(5Bh)+7A0h
254Axxxx add   r10,xxxxh    ;=@@new_data
2529xxxx add   r9,xxxxh    ;=@@new_data_end
AC23xxxx mov   [r1-xxxxh],r3 ;<--- SetPadOutput(src1,blah1,src2,blah2)
    @@double_copy_lop:          ; \
8D430000 mov   r3,[r10]         ; @@@new_data:
254A0004 add   r10,4h          ; : 00551024 and      r2,r21
AC4303D8 mov   [r2+3D8h],r3  ;<--- here   ; : 00000000 nop
24420004 add   r2,4h          ; : 00000000 nop
1549FFFB jne   r10,r9,@@double_copy_lop ; : 00000000 nop
AC4304DC +mov  [r2+4DCh],r3  ;<--- here   ; / @@@new_data_end:

```

Alternately, more inefficient (with NOPs), used in Lemmings at 80036618h:

```

24090057 mov   r9,57h          ; \
240A00B0 mov   r10,0B0h          ; B(57h) GetB0Table
0140F809 call  r10             ;
00000000 +nop                 ; /
3C0Axxxx mov   r10,xxxx0000h
254Axxxx add   r10,xxxxh    ;=@@new_data
3C09xxxx movvp r9,xxxx0000h

```

```

2529xxxx add r9,xxxxh      ;=@@new_data_end
8C42016C mov r2,[r2+5Bh*4] ;B(5Bh)
00000000 nop
204307A0 addt r3,r2,7A0h   ;B(5Bh)+7A0h
3C01xxxx mov r1,xxxx0000h
AC23xxxx mov [r1+xxxxh],r3 ;<--- SetPadOutput(src1,blah1,src2,blah2)
    @@double_copy_lop:          ; \
8D430000 mov r3,[r10]        ;           @@new_data:
00000000 nop                ;           00551024 and r2,r21
AC4303D8 mov [r2+3D8h],r3   ;           00000000 nop
AC4304E0 mov [r2+4E0h],r3   ;           00000000 nop
24420004 add r2,4h          ;           00000000 nop
254A0004 add r10,4h         ;           @@new_data_end:
1549FFF9 jne r10,r9,@@double_copy_lop
00000000 +nop              ; /

```

patch_no_pad_card_auto_ack:

This patch suppresses automatic IRQ0 (vblank) acknowledging in the Pad/Card IRQ handler, that, even if auto-ack is enabled. Obviously, one could as well disable auto-ack via B(5Bh) ChangeClearPad(int), so this patch is total nonsense. Used in Resident Evil 2 at 800919ACh:

```

240A00B0 mov r10,0B0h          ; \
0140F809 call r10             ;   B(57h) GetB0Table
24090057 +mov r9,57h          ; /
8C42016C mov r2,[r2+5Bh*4] ;=B(5Bh)
240A0009 mov r10,9h           ;len   ; \
2043062C addt r3,r2,62Ch     ;=B(5Bh)+62Ch   ;
    @@fill_lop:                 ;
254AFFFF sub r10,1h           ; ;
AC600000 mov [r3],0            ; ;
1540FFFD jnz r10,@@fill_lop   ; ;
24630004 +add r3,4h          ; /

```

Alternately, same as above, but more inefficient, used in Sporting Clays at 8001B53Ch:

```

24090057 mov r9,57h          ; \
240A00B0 mov r10,0B0h          ;   B(57h) GetB0Table
0140F809 call r10             ; ;
00000000 +nop                ; /
240A0009 mov r10,9h           ;len
8C42016C mov r2,[r2+5Bh*4]
00000000 nop
2043062C addt r3,r2,62Ch
    @@fill_lop:                 ;
AC600000 mov [r3],0            ; ;
24630004 add r3,4h           ; ;
254AFFFF sub r10,1h           ; ;

```

```
1540FFFC jnz    r10,@@fill_lop          ;\n00000000 +nop           ;/
```

Either way, no matter if using the patch or if using ChangeClearPad(int), having auto-ack disabled allows to install a custom vblank IRQ0 handler, which is probably desired for most games, however, mind that the PSX BIOS doesn't actually support the same IRQ to be processed by two different IRQ handlers, eg. the custom handler may acknowledge the IRQ even when the Pad/Card handler didn't process it, so pad input may become bumpy.

patch_install_lightgun_irq_handler:

Used in Sporting Clays at 80027D68h (when Konami Lightgun connected):

```
240A00B0 mov   r10,0B0h      ;\\n\n0140F809 call  r10       ; B(56h) GetC0Table\n24090056 +mov  r9,56h      ;/\n3C0Axxxx mov   r10,xxxx0000h ;src\n3C09xxxx mov   r9,xxxx0000h ;src.end\n8C420018 mov   r2,[r2+06h*4] ;C(06h)\n254Axxxx add   r10,xxxxh     ;src\n2529xxxx add   r9,xxxxh     ;src.end (=src+10h)\n    @@copy_lop:             ;\\n    ; @@src:\n8D430000 mov   r3,[r10]      ; ;3C02xxxx mov   r2,xxxx0000h\n254A0004 add   r10,4h       ; ;2442xxxx add   r2,xxxxh\n24420004 add   r2,4h       ; ;0040F809 call  r2  ;lightgun_proc\n1549FFFC jne   r10,r9,@@copy_lop ; ;00000000 +nop\nAC43007C +mov  [r2+80h-4],r3   ;/          @@src_end:
```

Alternately, same as above, but more inefficient, used in DQM (Dragon Quest Monsters 1&2) at 80089390h (install) and 800893F8h (uninstall):

```
24090056 mov   r9,56h      ;\\n\n240A00B0 mov   r10,0B0h      ; B(56h) GetC0Table\n0140F809 call  r10       ;\n00000000 +nop           ;/\n8C420018 mov   r2,[r2+06h*4] ;=00000C80h = exception_handler = C(06h)\n3C0Axxxx mov   r10,xxxx0000h ;\\@new_data (3xNOP)\n254Axxxx add   r10,-xxxxh    ;/\n3C09xxxx mov   r9,xxxx0000h ;\\@new_data_end\n2529xxxx add   r9,-xxxxh    ;/\n    @@copy_lop:             ;\\n    ; @@new_data: ;for (un-)install...\n8D430000 mov   r3,[r10]      ; @@new_data: ;for (un-)install...\n00000000 nop           ; 00000000 nop / 3C02xxxx mov r2,xxxx0000h\nAC430080 mov   [r2+80h],r3   ; 00000000 nop / 2442xxxx add r2,-xxxxh\n254A0004 add   r10,4h       ; 00000000 nop / 0040F809 call r2  ;proc\n1549FFFB jne   r10,r9,@@copy_lop ; @@new_data_end:\n24420004 +add r2,4h       ;/
```

Some lightgun games (eg. Project Horned Owl) do (additionally to above stuff) hook the exception vector at 00000080h, the hook copies the horizontal coordinate (timer0) to a variable in RAM, thus getting the timer0 value "closest" to the actual IRQ execution. Doing that may eliminate some unpredictable timing offsets that could be caused by cache hits/misses during later IRQ handling (and may also eliminate a rather irrelevant 1-cycle inaccuracy depending on whether EPC was pointing to a GTE opcode, and also eliminates constant cycle offsets depending on whether early_card_irq_handler was installed and enabled, and might eliminate timing differences for different BIOS versions).

set_conf_without_realloc:

Used in Spec Ops Airborne Commando at 80070AE8h, and also in the homebrew game Roll Boss Rush at 80010B68h and 8001B85Ch. Purpose is unknown (maybe to override improperly defined .EXE headers).

```

8C030474 mov    r3,[200h+(9Dh*4)]      ;\get ptr to A(9Dh) GetConf (done so,
00000000 nop                           ;/as there's no "GetA0Table" funtion)
94620000 movh   r2,[r3+0h] ;lui msw    ;\
84630004 movhs  r3,[r3+4h] ;lw lsw+8   ; extract ptr to "boot_cnf_values"
00021400 shl    r2,10h    ;msw*10000h ; (from first 2 opcodes of GetConf)
2442FFF8 sub    r2,8h     ;undo +8    ;
00431021 add    r2,r3     ;lsw       ;/
AC450000 mov    [r2+0h],r5 ;num_TCB    ;\set num_EvCB,num_TCB,stacktop
AC440004 mov    [r2+4h],r4 ;num_EvCB    ; (unlike A(9Ch) SetConf, without
03E00008 ret                           ; actually reallocating anything)
AC460008 +mov   [r2+8h],r6 ;stacktop  ;/

```

Cheat Devices

CAETLA detects the PSX BIOS version by checksumming BFC06000h..BFC07FFFh and does then use some hardcoded BIOS addresses based on that checksum. The reason for doing that is probably that the Pre-Boot Expansion ROM vector is called with the normal A0h/B0h/C0h vectors being still uninitialized.

Problems are that the hardcoded addresses won't work with all BIOSes (eg. not with the no\$psx bios clone, probably also not with the newer PS2 BIOS), moreover, the checksumming can fail with patched original BIOSes (eg. no\$psx allows to enable TTY debug messages and to skip the BIOS intro).

The Cheat Firmwares are probably also hooking the Vblank handler, and maybe also some other functions.

ACTION REPLAY (at least later versions like 2.81) uses the Pre-Boot handler to set a COP0 hardware breakpoint at 80030000h and does then resume normal BIOS booting (which will then initialize important things like A0h/B0h/C0h tables, and will then break

when starting the GUI code at 80030000h).

XPLORER searches opcode 24040385h at BFC06000h and up, and does then place a COP0 opcode fetch breakpoint at the opcode address+10h (note: this is within a branch delay slot, which makes COP0 emulation twice as complicated). XPLORER does also require space in unused BIOS RAM addresses (eg. Xplorer v3.20: addr 7880h at 1F002280h, addr 017Fh at 1F006A58h).

Note

Most games include two or three patches. The only game that I've seen so far that does NOT use any patches is Wipeout 2097.

20. Arcade Cabinets

PSX-Based Arcade Boards

Namco System 11, System 12 (and System 10?)
 Capcom/Sony ZN-1, ZN-2
 Konami GV, Konami GQ
 Taito FX-1A, Taito FX-1B
 Atlus PSX, PS Arcade 95, Tecmo TPS

CPU

Same as in PSX. Except, one board is said to be having the CPU clocked at 48MHz, instead of 33MHz???

GPU

Same as in PSX. Except, most or all boards are said to have 2MB VRAM instead of 1MB. Unknown how the extra VRAM is accessed... maybe as Y=512..1023... (though the PSX VRAM transfer commands are limited to 9bit Ysiz values, but maybe Y coordinates can be 10bit wide).

ROM vs CDROM

Arcade games are stored on ROM (or FLASH) instead of using CDROM drives.

SPU

Most PSX-based arcade boards are having the PSX-SPU replaced by a different sound chip (with each arcade manufacturer using their own custom sound chip, often controlled by a separate sound CPU).

Controls

Arcade boards are typically having digital joysticks instead of joypads, with differently named buttons (instead of /\, [], (), > <), probably accessed via custom I/O ports (instead of serial transmission)? Plus additional coin inputs and DIP switches.

Note: There's no documentation for those arcade boards yet, however, it might be possible to extract that info from MAME source code.

21. Cheat Devices

Action Replay, GameShark, Gamebuster, GoldFinger, Equalizer (Datel/clones)

The Datel devices exist in various official/cloned hardware revisions, the DB25 connector requires a special Comms Link ISA card (or a "FiveWire" mod for making it compatible with normal PC parallel ports). Later "PAR3" models are said to not require Comms Link, and do thus probably work directly with normal parallel ports).

[Cheat Devices - Datel I/O](#)

[Cheat Devices - Datel DB25 Comms Link Protocol](#)

[Cheat Devices - Datel Chipset Pinouts](#)

[Cheat Devices - Datel Cheat Code Format](#)

Xplorer/Xploder/X-Terminator (FCD/Blaze)

The FCD/Blaze devices are all same hardware-wise (with some cosmetic PCB revisions, and with extra SRAM and bigger FLASH installed in some carts). The DB25 connector can be directly connected to a PC parallel port.

[Cheat Devices - Xplorer Memory and I/O Map](#)

[Cheat Devices - Xplorer DB25 Parallel Port Function Summary](#)

[Cheat Devices - Xplorer DB25 Parallel Port Command Handler](#)

[Cheat Devices - Xplorer DB25 Parallel Port Low Level Transfer Protocol](#)

[Cheat Devices - Xplorer Versions](#)

[Cheat Devices - Xplorer Chipset Pinouts](#)

[Cheat Devices - Xplorer Cheat Code Format](#)

[Cheat Devices - Xplorer Cheat Code and ROM-Image Decryption](#)

FLASH Chips (for both Xplorer and Datel)

[Cheat Devices - FLASH/EEPROMs](#)

<http://gamehacking.org/faqs/hackv500c.html> - cheat code formats

http://doc.kodewerx.org/hacking_psx.html - cheat code formats

<http://xianaix.net/museum.htm> - around 64 bios versions

<http://www.murraymoffatt.com/playstation-xplorer.html> - xplorer bioses

Separating between Gameshark and Xplorer Codes

First Digit	Usage
3,8	Same for Gameshark & Xplorer (for Xplorer: can be encrypted)
1,2,C,D,E	Gameshark
4,6,7,9,B,F	Xplorer
0,5	Meaning differs for Gameshark & Xplorer
A	Unused

Codebreaker

Megacom Power Replay III Game Enhancer

21.1 Cheat Devices - Datel I/O

Datel Memory and I/O Map (for PAR2 or so)

1F000000h-1F01FFFFh	R/W	Flash (first 128K)
1F020010h	R	Comms Link STB pin state (bit0)
1F020018h	R	Switch Setting (bit0: 0=Off, 1=On)
1F040000h-1F05FFFFh	R/W	Flash (second 128K) + feedback area (see below)
1F060000h	R	Comms Link data in (byte)
1F060008h	W	Comms Link data out (byte, pulses ACK to Comms Link)

Datel PAR1

Original PAR1 might have supported only 128K FLASH (?) if so, the I/O ports are probably same as above, but without the "second 128K" FLASH area.

Datel PAR3

The PAR3 version is said to work with parallel ports (not needing the Comms Link IDA card), and said to support more FLASH with bankswitching, so the I/O ports must work somehow entirely different as described above.

Some notes from a (poorly translated) japanese document:

PAR3 Memory:

```
1f000000-1f01ffff ROM. Change in bank switching.  
1f020000-1f03ffff ROM. Change in bank switching.  
1f040000-1f05ffff whopping RAM. It is able to use.  
1f060000-1f06003f I/O. Intently mirror to the subsequent 1f07ffff.
```

PAR3 I/O:

```

1f060000 for reception. (1f060000 use only.) All bytes same treatment like.
    It is 01h in the state that does not connect anything.
1f060008 for transmission. (1f060008 use only.) This is ffh in the state
    that does not connect anything.
1f060010 during data reception it will stand the least significant bit.
    Usually is fe.
1f060018 state of the push button. In not pressed and fefefefefefefefe,
    it will be 0st ffffffffffffff.
1f060020 I think 1f060020 unused. It is ffffffffffffff.
1f060028 I think 1f060028 unused. It is ffffffffffffff.
1f060030 bank switching. 1 put and run-time of the ROM, and changes to the
    3's and the start-up of the ROM.
1f060038 would be what? It is lbu. Like there is a meaning bits 0 and 1.
    It was fcfcfcfcfcfcfcfc. I think that it is bank cult.

```

21.2 Cheat Devices - Datel DB25 Comms Link Protocol

Boot Command Handler

The Boot Command Handler is executed once at Pre-Boot, and also (at least in some firmware versions) once before displaying the GUI. Following command(s) can be sent from PC side:

```

Repeatedly send 8bit "W", until receiving "R"
Repeatedly send 8bit "B", until receiving "W"
Send 8bit command "X" (upload/exec) or "U" (upload/flash), and receive ECHO
Send 32bit ADDRESS, and receive ECHO or "BX" (bad command)
Send 32bit LENGTH, and receive ECHO
Send DATA[LENGTH], and receive ECHO
Send 16bit CHECKSUM, and receive ECHO
(for upload/flash and if checksum was good, PSX will now BURN ADDR, LENGTH)
Send 16bit DUMMY, and receive "OK"/"BC"/"BF" (okay, bad checksum, bad flash)
(for upload/exec and if checksum was good, PSX will now CALL ADDR)
(thereafter, PAR2.0 and up will reboot via jmp BFC00000h)

```

Data is always transferred as byte-pair (send one byte, receive one byte), 16bit/32bit values are transferred MSB first (with ECHO after each byte).

The upload/exec command is supported by both Datel and Caetla, the upload/flash command is supported by Datel only (but it's totally bugged in PAR1.99, and might also have upwards compatibility issues in later versions, so it's better to upload a custom flash function via upload/exec instead of using upload/flash).

The 16bit checksum is all DATA[len] bytes added together, and then ANDed with 0FFFh (ie. actually only 12bit wide).

Menu/Game Command Handler

There must be some further command handler(s) after the Boot Command Handler, with support for additional cheat related commands, and (at least in Caetla) with support for uploading EXE files with Kernel functions installed (the Boot Command Handler at Pre-Boot time can also upload EXE code, but doesn't have Kernel installed).

Original Datel commands for Menu/Game mode are unknown. The Caetla commands are documented in japanese, and there are also two english translations:

<http://www.psxdev.net/forum/viewtopic.php?f=49&t=370> - good (though incomplete)
<http://www.psxdev.net/forum/viewtopic.php?f=53&t=462#p6849> - very bad (beware)

21.3 Cheat Devices - Datel Chipset Pinouts

There appear to be numerous Datel hardware revisions (and possibly numerous Datel clones). So this chapter is unlikely to cover all hardware revisions.

```
PSX Expansion cards:
PCB Controller FLASH DB25 spotted by
DATEL REF 1215 GAL + 74HC245 128K+128K yes Type79
DATEL REF 1288 DATEL ASIC1 256K yes nocash
DATEL xxx? GAL + PIC + HC245 128K yes CharlesMacD
noname? GAL + 74HC245 256K+0K yes Type79
DATEL REF 1324 lots of chips? lots? no CyrusDevX
DATEL REF 1326 lots of chips? lots? yes Type79
PS-121 ZISAN GAL + PIC? + HC245 128K yes Kryptonick
```

Comms Link ISA cards:

PCB	Chipset	spotted by
DATEL COMMS LINK, XXX?	blurry SMD chipset?	lowres photo
DATEL REF 1113, IBM SATURN LINK EMS, PCCOM	1x74HC74, 2x74HC373, 1xXXX? 1x74HC74, 2x74HC373, 1xXXX?	Type79 jokergameth

DIY Alternatives to Comms Link

FiveWire	;simple hardware mod for use with parallel ports, for SPP/EPP
FreeWing	;parallel port adaptor, lots of 74xxx TTL chips, for SPP/EPP
ExStand	;parallel port adaptor, lots of 74xxx TTL chips, for EPP
CommLinkUSB	;USB adaptor, Buy-and-Diy technology (adafruit/teensy based)

DATEL REF1288 board (with DATEL ASIC1 chip)

The ASIC1 chip is found in this hardware:

```

Label: "EQUALIZER, EVEN THE ODDS" (sticker on outside of case)
Case: "DATEL ENGLAND" (printed inside of case)
PCB: "DATEL REF1288 SONY SONYP SX2meg"
U: 44pin "DATEL, ASIC1, A8B1944A, 9832" ;custom logic chip
U: 32pin "SST, 29EE020, 150-4C-NH, 981918-D" ;256Kx8 EEPROM
U: 8pin "83BA, LM78L, 05ACM" ;5V voltage regulator
CN: 25pin DB25 connector (for Comms Link ISA card)
CN: 68pin PSX expansion port connector
SW: 3pin Switch

```

The ASIC1 is basically same as the PAL/GAL on other boards, with the 74HC245 transceiver intergrated; the ASIC1 is using a 44pin PLCC package, with pin1 being upper-middle, and pin7 being upper-left. Pinouts are:

7 D0	18 DB25.2.DATA0	29 D0 (same as pin7)	40 A3
8 D1	19 DB25.3.DATA1	30 EEPROM./WE	41 A4
9 D2	20 DB25.4.DATA2	31 /WR	42 /EXP
10 GND	21 GND	32 GND	43 GND
11 D3	22 DB25.5.DATA3	33 /RD	44 A17
12 D4	23 DB25.6.DATA4	34 /MODE ("jumper")	1 A18
13 D5	24 DB25.7.DATA5	35 VCC	2 GND
14 VCC	25 VCC	36 DB25.11.ACK	3 VCC
15 D6	26 DB25.8.DATA6	37 ?	4 EEPROM./OE
16 VCC	27 DB25.9.DATA7	38 VCC	5 DB25.10.STB
17 D7	28 EEPROM./CS	39 ?	6 SWITCH

D0 is wired to both pin7 and pin29. The /MODE pin is NC (but could be GNDed via the two solder points in middle of the PCB). The SWITCH has 10K pullup (can can get GNDed depending on switch setting).

PALCE20V8 Cuthbert Action Replay schematic (from hitmen webpage)

1-NC	8-NC	15-NC	22-NC
2-FBIN	9-CPU.A4	16-GNDed	23-FLASH./WE
3-CPU.A17	10-CPU./EXP	17-DB25.pin10 (PAR.STB)	24-FBOUT
4-CPU./WR	11-CPU.A3	18-FLASH./CS	25-FLASH./OE (and BUF.DIR)
5-CPU./RD	12-CPU.A5	19-DB25.pin11 (PAR.ACK)	26-BUF./EN
6-CPU.A18	13-SWITCH	20-CPU.D0	27-unused
7-CPU.A20	14-GND	21-FLASH.A17	28-VCC

Charles MacDonald Game Shark schematic

1-FBIN	7-CPU.A4.NC?	13-GNDed	19-FLASH./WE
2-PIC.RC1	8-CPU./EXP.NC?	14-PAR.STB	20-FBOUT
3-CPU./WR	9-CPU.A3	15-PIC.RA0	21-BUF.DIR
4-CPU./RD	10-CPU.A2	16-PAR.ACK	22-BUF./OE
5-CPU.A18	11-SWITCH	17-CPU.D0	23-PIC.RC0
6-CPU.A17	12-GND	18-FLASH./OE	24-VCC

Uhm, schematic shows "PAR.ACK" instead of "BUF.DIR" as transceiver direction?
The 24pin PAL in Charles schematic does actually seem to be a 28pin PLCC GAL in actual hardware (which has four NC pins, hence the 24pin notation in the schematic).
The three PIC pins connect to a 28pin PIC16C55 microprocessor (unknown purpose).
Most of the PIC pins are NC (apart from the above three signals, plus supply, plus OSC ... derived from some oscillator located "behind" the DB25 connector?).

Charles MacDonald Gold Finger schematic

1-FBIN	6-CPU.A17	11-CPU.A2	16-FBOUT
2-SWITCH	7-CPU.A4.NC?	12-PAR.ACK	17-CPU.A20
3-CPU./WR	8-CPU./EXP.NC?	13-CPU.D0	18-PAR.STB
4-CPU./RD	9-CPU.A3	14-FLASH./OE	19-BUF./OE
5-CPU.A18	10-GND	15-FLASH./WE	20-VCC

Note: This is a datel clone, without "BUF.DIR" signal (instead, the transceiver DIR pin is wired to "PAR.ACK"; it's probably functionally same as real datel hardware, assuming that "PAR.ACK" is only a short pulse during writing; then reading should be possible anytime else).

Charles MacDonald Comms Link schematic

PAL

1-/STATUS	7-ISA.A6	13-JP2	19-NC
2-ISA.A1	8-ISA.A7	14-ISA.A9	20-PCWR
3-ISA.A2	9-ISA.A8	15-NC	21-/PCRD
4-ISA.A3	10-ISA.AEN	16-ISA./IOW	22-NC
5-ISA.A4	11-JP1	17-/IRQ	23-ISA./IOR
6-ISA.A5	12-GND	18-ISA.D0	24-VCC

The JP1/JP2 pins allow to select Port 300h,310h,320h,330h via two jumpers. The /IRQ pin could be forward to ISA./IRQ2..7 via six jumpers (but the feature is unused and the six jumpers aren't installed at all).

DB25 Connector

Pin	Parallel Port	CommsLink (PC)	cable	PAR (PSX)
1	/STB	----->	"strobe" -----o-----o---	-- NC
2-9	DATA <-/->	DATA <-- --o-----o----->	-----o-----> DATA	
10	/ACK	<---- "strobe"	'-----o-----o----->	"strobe"
11	BUSY	<---- "ack"	<-----o-----o----->	"ack"
12	PE	<---- NC	-- --o-----o---	-- NC
13	SLCT	<---- NC	-- --o-----o---	-- NC
14	/AUTOLF	-----> NC	-- --o-----o--.	.--- GNDed
15	/ERROR	<---- NC	-- --o-----o--.	.--- GNDed
16	/INIT	-----> NC	-- --o-----o--.	.--- GNDed
17	/SELECT	-----> GNDed	-- . --o-----o--.	.--- GNDed
18-25	GND	----- GND	--'---'-----o---'---'	-- GND

nocash FiveWire mod (for connecting datel expansion cart to parallel port)

```

disconnect DB25.pin14,15,16,17 from GND (may require to desolder the DB25)
repair any GND connections that were "routed through" above pins
wire DB25.pin1./STB to DB25.pin10./ACK
wire DB25.pin16./INIT to PSX.EXPANSION.pin2./RESET
wire DB25.pin15./ERROR to PSX.EXPANSION.pin28.A20
wire DB25.pin13.SLCT to PSX.EXPANSION.pin62.A21
wire DB25.pin12.PE to PSX.EXPANSION.pin29.A22

```

21.4 Cheat Devices - Datel Cheat Code Format

PSX Gameshark Code Format

```

30aaaaaaaa 00dd ;-8bit Write [aaaaaaaa]=dd
80aaaaaaaa dddd ;-16bit Write [aaaaaaaa]=dddd

```

Below for v2.2 and up only

```

D0aaaaaaaa dddd ; -16bit/Equal      If dddd=[aaaaaaaa] then (exec next code)
D1aaaaaaaa dddd ; -16bit/NotEqual   If dddd<>[aaaaaaaa] then (exec next code)
D2aaaaaaaa dddd ; -16bit/Less       If dddd<[aaaaaaaa] then (exec next code)
D3aaaaaaaa dddd ; -16bit/Greater    If dddd>[aaaaaaaa] then (exec next code)
E0aaaaaaaa 00dd ; -8bit/Equal       If dd=[aaaaaaaa] then (exec next code)
E1aaaaaaaa 00dd ; -8bit/NotEqual   If dd<>[aaaaaaaa] then (exec next code)
E2aaaaaaaa 00dd ; -8bit/Less       If dd<[aaaaaaaa] then (exec next code)
E3aaaaaaaa 00dd ; -8bit/Greater    If dd>[aaaaaaaa] then (exec next code)
1aaaaaaaaa dddd ; -16bit Increment [aaaaaaaa]=[aaaaaaaa]+dd
11aaaaaaaa dddd ; -16bit Decrement [aaaaaaaa]=[aaaaaaaa]-dd
20aaaaaaaa 00dd ; -8bit Increment  [aaaaaaaa]=[aaaaaaaa]+dd
21aaaaaaaa 00dd ; -8bit Decrement  [aaaaaaaa]=[aaaaaaaa]-dd

```

Below for v2.41 and up only

```

D4000000 dddd ; -Buttons/If  If dddd=JoypadButtons then (exec next code)
D5000000 dddd ; -Buttons/On   If dddd=JoypadButtons then (turn on all codes)
D6000000 dddd ; -Buttons/Off  If dddd=JoypadButtons then (turn off all codes)
C0aaaaaaaa dddd ; -If/On      If dddd=[aaaaaaaa] (turn on all codes)

```

Below probably v2.41, too (though other doc claims for v2.2)

```

5000nnbb dddd ; \Slide Code aka Patch Code aka Serial Repeater
aaaaaaaa ??ee ; /for i=0 to nn-1, [aaaaaaaa+(i*bb)]=dd+(i*??ee), next i
00000000 0000 ; -Dummy (do nothing?) needed between slides (CD version only)

```

Below probably v2.41, too (though other doc claims for ALL versions)

```

C1000000 nnnn ; -Delays activation of codes by nnnn (4000-5000 = 20-30 sec)
C2ssssss nnnn ; \Copy ssss bytes from 80ssssss to 80tttttt
80tttttt 0000 ; /

```

Below from Caetla .341 release notes

These are probably caetla-specific, not official Datel-codes. In fact, Caetla .341 itself might be an unofficial hacked version of Caetla .34 (?) so below might be totally unofficial stuff:

```

C3aaaaaaaa 0000 ; \Indirect 8bit Write  [[aaaaaaaa]+bbbb]=dd
9100bbbb 000000dd ; /
C3aaaaaaaa 0001 ; \Indirect 16bit Write [[aaaaaaaa]+bbbb]=dd (Tomb Raider 2)
9100bbbb 0000dd ; /
C3aaaaaaaa 0002 ; \Indirect 32bit Write [[aaaaaaaa]+bbbb]=dddddd

```

```

9100bbbb dddddddd ;/
FFFFFFFFFF 0001 ; -Optional prefix for GameShark 2.2 codes (force non-caetla)
1aaaaaaaa dddddddd ; -32bit Increment [aaaaaaaa]=[aaaaaaaa]+ddddddddd
2aaaaaaaa dddddddd ; -32bit Decrement [aaaaaaaa]=[aaaaaaaa]-ddddddddd

```

Notes

- A maximum of 30 increment/decrement codes can be used at a time.
- A maximum of 60 conditionals can be used at a time (this includes Cx codes).
- Increment/decrement codes should (must?) be used with conditionals.
- Unknown if greater/less conditionals are signed or unsigned.
- Unclear if greater/less compare dddd by [aaaaaaaa], or vice-versa.
- Unknown if 16bit codes do require memory alignment.

21.5 Cheat Devices - Xplorer Memory and I/O Map

Xplorer Memory Map

```

1F000000h-1F03FFFFh.RW First 256K of FLASH (fixed mapping)
1F040000h-1F05FFFFh.RW Map-able: 2x128K FLASH or 4x128K SRAM (if any)
1F060000h-1F060007h.xx I/O Ports
1F060008h-1F06FFFFh Mirrors of I/O at 1F060000h..1F060007h
1F070000h-1F07FFFFh Unused (open bus)

```

FLASH can be 256Kbyte (normal), or 512Kbyte (in FX versions). When programming FLASH chips: Observe that the carts can be fitted with chips from different manufacturers, and, Xplorer carts can have either one or two 256K chips, or one 512K chip.

SRAM can be 0Kbyte (normal/none), or 128Kbyte (in FX versions). The PCB supports max 512K SRAM (but there aren't any carts having that much memory installed).

Xplorer I/O Map

```

1F005555h.W FLASH Cmd 1st/3rd byte ;\for first FLASH chip
1F002AAAh.W FLASH Cmd 2nd byte      ;/
1F045555h.W FLASH Cmd 1st/3rd byte ;\for 2nd FLASH chip (if any)
1F042AAAh.W FLASH Cmd 2nd byte      ;/
1F060000h.R I/O - Switch Setting (bit0: 0=Off, 1=On)
1F060001h.R I/O - 8bit Data from PC (bit0-7)
1F060001h.W I/O - 8bit Latch (Data to PC, and Memory Mapping)
    0 DB25.pin13.SLCT    ;\
    1 DB25.pin12.PE      ; used for data to PC
    2 DB25.pin11.BUSY    ;/

```

```

3  DB25.pin10./ACK    ;-used for handshake to PC
4  Memory Mapping (0=EEPROM, 1=SRAM)
5  Memory Mapping (EEPROM A17 when A18=1)
6  Memory Mapping (SRAM A17 or SRAM CE2)
7  Memory Mapping (SRAM A18 or NC)

1F060002h.R I/O - Handshake from PC (bit0)      (DB25.pin17./SEL)
1F060005h.W I/O - Unknown (used by Xplorer v4.52, set to 03h)
1F060006h.R I/O - Unknown (used by Xplorer v4.52, bit0 used)
1F060007h.R I/O - Unknown (used by Xplorer v4.52, bit0 used)

```

21.6 Cheat Devices - Xplorer DB25 Parallel Port Function Summary

Xplorer Parallel Port Commands (from PC side)

GetByteByAddr32	Tx(5702h, Addr32), Rx(Data8)
OldMenuBuReadFile	Tx(5703h), TxFilename, RxDataFFEEh
OldMenuBuDeleteFile	Tx(5704h), TxFilename
OldMenuBuWriteFile	Tx(5705h), TxFilename, TxFiledata
OldMenuBuGetFileHdr	Tx(5706h), TxFilename, Rx(00h,00h), RxTurbo, Rx(02h)
OldMenuBuOpenEvents	Tx(5707h)
SetCop0Breakpoint	Tx(5708h, Addr32, Mask32, Ctrl32) ;Menu: Dummy?
OldMenuBuCopyFile	Tx(5709h), TxFilename ;to other memcard
OldMenuBuFormat	Tx(570Ah, Port8)
OldMenuBuGetStatus2x	Tx(570Bh), Rx(Stat8, Stat8) ;\different in old/new
NewMenuBuGetStatus1x	Tx(570Bh, Port8), Rx(Stat8) ;/
MenuGetSetFlag	Tx(570Ch), Rx(Flag8) ;get old flg, then set flg=01h
NewMenuBuReadSector	Tx(570Dh, Port8, Sector16), Rx(Data[80h])
NewMenuBuWriteSector	Tx(570Eh, Port8, Sector16, Data[80h])
NewRawExecute	Tx(570Fh, Addr32) ;call Addr
MidMenuBuggedExecJump	Tx(5710h, ORra32, ORgp32, ORsp32, pc32) ;aka r31, r28, r29, pc
MidMenuSendComment	Tx(5711h, Len8, AsciiMessage[Len])
NewMenuFillVram	Tx(5712h, Xloc32, Yloc32, Xsiz32, Ysiz32, FillValue32)
NewGetVram	Tx(5713h, Xloc32, Yloc32), Rx(Data[800h]) ;32x32pix
NewGetSetIrqMask	Tx(5714h), Rx(OldMask16), Tx(NewMask16) ;Menu: Dummy
NewSetVram	Tx(5715h, Xloc8, Yloc8, Data[800h]) ;X/Y=div32 ;32x32pix
NewMenuGetFlgAndOrVal	Tx(5716h), Rx(00h, or 01h, Val32) ;\
NewMenuGetTwoValues	Tx(5717h), Rx(Val32, Val32) ;
NewMenu...	Tx(5718h), ... ;
NewMenuGet2kGarbage	Tx(5719h, Dummy32), Rx(Garbage[800h]) ; whatever
NewMenuGetSomeValue	Tx(571Ah), Rx(Val32) ;
NewMenu...	Tx(571Bh, Data[4]) ;similar to 5763h ;
NewMenuNoLongerSupp.	Tx(571Ch) ;probably WAS supported someday ;/
GameAddCheatCode	Tx(5741h, Addr32, Data16), Rx(Index8)
MenuReBootKernel	Tx(5742h) ;jumps to BFC00000h
GameDelCheatCode	Tx(5744h, Index8)
GetMem	Tx(5747h, Addr32, Len32), Rx(Data[Len]), TxRxChecksum
Lock/Freeze	Tx(574Ch)
OldMenuBuGetDirectory	Tx(574Dh), RxTurbo

```

MenuTestDB25Handshake Tx(574Eh), ...
MenuOptimalGetMem     Tx(574Fh,Addr32,Len32), RxFaster(Data[Len]), TxRxChksum
OldMenuGetWhatever   Tx(5750h), RxDataFFEEh ;whatever
Release/Unfreeze      Tx(5752h)
SetMem                Tx(5753h,Addr32,Len32,Data[Len]), TxRxChksum
TurboGetMem           Tx(5754h,Addr32,Len32), RxFast(Data[Len]), TxRxChksum
MenuSetMemAndBurnFirm Tx(5755h,Addr32,Len32,Data[Len]), TxRxChksum ;burnFlash
GetStateGameOrMenu    Tx(5757h), Rx(47h=Game, or 58h=Menu)
SetMemAndExecute      Tx(5758h,Addr32,Len32,Data[Len]), TxRxChksum ;call Addr
NewMenu...             Tx(5763h,Val32) ;similar to 571Bh ;whatever
GetByteByAddr24       Tx(5767h,Addr24), Rx(Data8)
NewMenuBuggedExecJump Tx(577Ah,ORra32,ORgp32,ORsp32,pc32) ;formerly 5710h
NewMenuFlashAndReboot Tx(57C7h,Dest32,Len32,DataXorD3h[Len])

```

Function names starting with "Game/Menu" and/or "New/Mid/Old" are working only in Game/Menu mode, or only in New/Old xplorer firmware versions (new commands exist in v4.52, old commands exist in v1.091, mid commands exist in v2.005, but neither in v1.091 nor v4.52, unknown when those new/mid/old commands have been added/removed exactly, in which specific versions).

The only useful command is SetMemAndExecute, which works in ALL versions, and which can be used to do whatever one wants to do (unfortunately, most of the official & inofficial tools are relying on other weird commands, which are working only with specific xplorer firmware versions).

21.7 Cheat Devices - Xplorer DB25 Parallel Port Command Handler

The command handler is called once and then during booting, during xplorer GUI, and during Game execution.

Each call to the command handler does allow to execute ONLY ONE command, however, the "Freeze" command can be used to force the xplorer to stay in the command handler, so one can send MORE commands, until leaving the command handler by sending the "Unfreeze" command.

The command handling can vary depending on current boot phase (see below cautions on Pre-Boot, Mid-Boot, and In-Game phases).

Pre-Boot Handler

This is called shortly after the kernel has done some basic initialization, and after the Xplorer has relocated its EEPROM content to RAM (which means it may be called about a second after reset when using official PSX kernel and Xplorer Firmware).

```
OLD Explorer Firmware: Call command handler ONCE (in MENU mode)
NEW Explorer Firmware: Call command handler TWICE (in MENU mode)
if SWITCH=ON or [800000030h]="WHB." then
    NEW Explorer Firmware: Call command handler ONCE AGAIN (in MENU mode)
    Install Mid-Boot hook
endif
```

Observe that the Kernel function vectors at A0h, B0h, and C0h aren't installed at this point. If you want to upload an EXE with Kernel vectors installed: send THREE dummy commands (eg. Unfreeze) to skip the above early command handling. On the other hand, the ReBootKernel command can be used if you WANT to upload something during Pre-Boot (the ReBootKernel command works only in MENU mode though, ie. during Xplorer GUI, but not during Game).

Mid-Boot Handler (Xplorer GUI)

The Xplorer GUI is called only if the Pre-Boot handler has installed it (eg. if the SWITCH was ON). The handler is called alongside with joypad reading (which does NOT take place during the Xplorer intro, so there will be a long dead spot between Pre-Boot and Mid-Boot command handling).

```
Call command handler ONCE (in MENU mode) alongside with each joypad read
```

Observe that the GUI may have smashed various parts of the Kernel initialization, so you can upload EXE files, and can use Kernel functions, but the EXE won't get booted in same state as when booting from CDROM. The boot state can also vary dramatically depending on the Xplorer Firmware version.

Post-Boot Handler (at start of CDROM booting)

This is called when starting CDROM booting.

```
Install GAME mode hook for the B(17h) ReturnFromException() handler
OLD Explorer Firmware: Call command handler ONCE (still in MENU mode)
NEW Explorer Firmware: Call command handler ONCE (already in GAME mode)
```

In-Game Handler (after CDROM booting) (...probably also DURING booting?)

This is called via the hooked B(17h) ReturnFromException() handler.

```
if SWITCH=ON
    Call command handler ONCE (in GAME mode) upon each B(17h)
    And, process game cheat codes (if any) upon each B(17h)
endif
```

Observe that GAME mode doesn't support all commands. And, above will work only if the game does use B(17h), eg. when using non-kernel exception handling, or if it has crashed, or disabled exceptions. Some internal kernel functions are using ReturnFromException() directly (without going through the indirect B(17h) function table entry; so the hook cannot trap such direct returns).

21.8 Cheat Devices - Xplorer DB25 Parallel Port Low Level Transfer Protocol

All 16bit/24bit/32bit parameters are transferred MSB first.

Tx(Data) - transmit data byte(s)

Output 8bit data to DATA0-7	(DB25.pin2-9)	; -Send Data (D0-D7)
Output /SEL=HIGH	(DB25.pin17)	; \Handshake High
Wait until /ACK=HIGH	(DB25.pin10)	; /
Output /SEL=LOW	(DB25.pin17)	; \Handshake Low
Wait until /ACK=LOW	(DB25.pin10)	; /

Rx(Data) - receive data byte(s)

Wait until /ACK=HIGH	(DB25.pin10)	; \
Get 3bit from SLCT,PE,BUSY	(DB25.pin13,12,11)	; 1st Part (D6,D7,HIGH)
Output /SEL=HIGH	(DB25.pin17)	; /
Wait until /ACK=LOW	(DB25.pin10)	; \
Get 3bit from SLCT,PE,BUSY	(DB25.pin13,12,11)	; 2nd Part (D3,D4,D5)
Output /SEL=LOW	(DB25.pin17)	; /
Wait until /ACK=HIGH	(DB25.pin10)	; \
Get 3bit from SLCT,PE,BUSY	(DB25.pin13,12,11)	; 3rd Part (D0,D1,D2)
Output /SEL=HIGH	(DB25.pin17)	; /
Wait until /ACK=LOW	(DB25.pin10)	; \4th Part (ver,LOW,LOW)
Get 3bit from SLCT,PE,BUSY	(DB25.pin13,12,11)	; (ver=LOW for v1.091)
Output /SEL=LOW	(DB25.pin17)	; / (ver=HIGH for v4.52)
Wait until all 4bits LOW	(DB25.pin13,12,11,10)	; -xlink95 fails if not

RxFast(Data) for TurboGetMem - slightly faster than normal Rx(Data)

First, for invoking the Turbo transfer:

```
Wait for BUSY=LOW          (DB25.pin11)
Output DATA = 00h           (DB25.pin2-9)
Wait for BUSY=HIGH          (DB25.pin11)
Output DATA = ECh            (DB25.pin2-9)
```

Thereafter, receive the actual Data byte(s) as so:

```
Wait for /ACK transition    (DB25.pin10)      ; \
Get 3bit from SLCT,PE,BUSY   (DB25.pin13,12,11) ; 1st Part (D6,D7,LOW)
Output DATA = 02h             (DB25.pin2-9)      ;/
Wait for /ACK transition    (DB25.pin10)      ; \
Get 3bit from SLCT,PE,BUSY   (DB25.pin13,12,11) ; 2nd Part (D3,D4,D5)
Output DATA = 04h             (DB25.pin2-9)      ;/
Wait for /ACK transition    (DB25.pin10)      ; \
Get 3bit from SLCT,PE,BUSY   (DB25.pin13,12,11) ; 3rd Part (D0,D1,D2)
Output DATA = 01h             (DB25.pin2-9)      ;/
```

The /ACK transitions can be sensed by polling the parallel port IRQ flag on PC side.

RxFaster(Data) for OptimalGetMem - much faster than normal Rx(Data)

First, for invoking the Turbo transfer:

```
Output DATA = 00h ;<-- crap      (DB25.pin2-9) ; -BUGGY, but REQUIRED
```

Thereafter, receive the actual Data byte(s) as so:

```
Get 4bit from SLCT,PE,BUSY,/ACK (DB25.pin13,12,11,10); \1st Part (D4,D5,D6,D7)
Output DATA = 00h                 (DB25.pin2-9)      ;/
Get 4bit from SLCT,PE,BUSY,/ACK (DB25.pin13,12,11,10); \2nd Part (D0,D1,D2,D3)
Output DATA = 01h                 (DB25.pin2-9)      ;/
```

BUG: The first received byte will be garbage with upper and lower 4bit both containing the lower 4bits (the bugged firmware does explicitly want DATA=00h before transfer, although DATA=00h is also 'confirming' that the upper 4bit can be 'safely' replaced by lower 4bit).

TxRxChecksum for SetMem/GetMem functions

```
Tx(chkMsb), Rx(chkMsb), Tx(chkLsb), Rx(chkLsb), Rx("OK" or "CF" or "BG")
```

The 16bit checksum is all bytes in Data[Len] added together. The two final response bytes should be "OK"=Okay, or, if the transmitted chksum didn't match, either "CF"=ChecksumFail (for SetMem functions) or "BG"=BadGetChecksum (for GetMem functions). MenuSetMemAndBurnFirm is a special case with three response codes: "OF"=FlashOkay, "CF"=ChecksumFail, "FF"=FlashWriteFail.

TxFilename for Memcard (bu) functions

```
Rx(Addr32), Tx(Addr32, Len32, Data[Len]), TxRxChksum
```

This is internally using the standard "SetMem" function; preceeded by Rx(Addr32). Whereas Addr is the target address for the filename (just pass the Rx'ed address to the Tx part), Len should be max 38h, Data should be the filename with ending zero (eg. "bu10:name",00h).

TxFiledata for Memcard (bu) WriteFile

```
Rx(Filename[26h]) ;-name from TxFilename, echo'ed back
Rx(Addr32) ;-buffer address for fragments
Tx(NumFragments8) ;-number of fragments
Tx(Addr32, Len32, Data[Len]), TxRxChksum ;<-- repeat this for each fragment
Rx(FileHandle8) ;-ending dummy byte (filehandle)
```

This is also using the standard "SetMem" function, plus some obscure extra's. The filedata is split into fragments, Len should be max 2000h per fragment.

RxDATAFFEEh for Memcard (bu) ReadFile and GetWhatever

```
Rx(FFEEh, "W", Len32, Data[Len]) ;<-- can be repeated for several fragments
Rx(FFEEh, "CA") ;<-- End Code (after last fragment)
```

Memcard ReadFile does transfer N fragments of Len=2000h (depending on filesize). The GetWhatever function transfers one fragment with Len=80h, followed by N*6 fragments with Len=40Ah.

RXTurbo for Memcard (bu) GetDirectory/GetFileHeader functions

```
Rx(Addr32), Tx(Addr32, Len32), RxFast(Data[Len]), TxRxChksum
```

This is internally using the standard "TurboGetMem" function; preceeded by Rx(Addr32). Whereas Addr is the source address of the actual data (just pass the Rx'ed address to the

Tx part).

For GetDirectoy, Len should be max 800h (actual/data data is only 4B0h bytes, ie. 258h bytes per memcard, aka 28h bytes per directory entry). For GetFileHeader, Len should be max 80h.

21.9 Cheat Devices - Xplorer Versions

Xplorer names

```
Xploder (Germany/USA)
Xplorer (England/Spain/Netherlands)
X-Terminator (Japan)
```

Xplorer suffices

```
V1/V2/V3    normal boards    (256K EEPROM, no SRAM, no DB25 resistor)
FX/DX      extended boards (512K EEPROM, 128K SRAM, with DB25 resistor)
PRO        meaningless suffix
```

The V1/V2/V3 suffix does just indicate the pre-installed firmware version (so that suffices become meaningless after software upgrades).

The FX suffix (or DX in japan) indicates that the PCB contains more memory and an extra resistor (the memory/resistor are intended for use with the "X-Assist" add-on device).

Xplorer PCB types

- 1) PXT6 ;original board
- 2) Nameless ;with alternate solder pads for smaller SRAM/GAL
- 3) PXT6-3 ;with alternate solder pads for smaller SRAM/GAL and 2nd EEPROM

Xplorer Compatibility Issues

The three PCB versions are functionally identical, and do differ only by cosmetic changes for alternate/smaller chip packages.

However, some things that can make difference in functionality are the installed components and installed firmware version:

- FX carts have some extra components & more memory installed.
(needed for "bigger" firmwares, mainly needed for the X-Assist add-on)
- FLASH chips from different manufacturers can occassionally cause problems
(eg. older software not knowing how to program newer FLASH chips).

- DB25 transfer protocol has some changed commands in each firmware version (and most transfer tools tend to rely on such commands, so most tools will fail unless the cart is flashed with a certain firmware version).

X-Assist add-on for Xplorer carts

The X-Assist is a quity huge clumsy controller with DPAD, plus 4 buttons, plus small LCD screen. The thing connects to the Xplorer's DB25 connector, allowing to enter/search cheat codes without using a PC.

The device works only with "FX" Xplorer boards (which contain an extra resistor for outputting supply power on the DB25 connector, plus more memory which is somewhat intended for use by the X-Assist thing).

21.10 Cheat Devices - Xplorer Chipset Pinouts

Xplorer Pinout GAL20V8 (generic array logic)

```

1 IN0  (DB25.pin17./SEL)
2 IN1  (PSX.pin14.A0)
3 IN2  (PSX.pin48.A1)
4 IN3  (PSX.pin15.A2)
5 IN4  (74373.pin15.Q5)
6 IN5  (PSX.pin4./EXP)
7 IN6  (74373.pin12.Q4)
8 IN7  (PSX.pin26.A16) (EEPROM.pin2.A16) (SRAM.pin2.A16) (10000h)
9 IN8  (PSX.pin60.A17)                               (20000h)
10 IN9  (PSX.pin27.A18) (EEPROM.pin1.A18 or NC)      (40000h)
11 IN10 (PSX.pin30./RD)
12 GND
---
13 IN11 (GND)
14 IN12 (/SWITCH_ON)
15 IO   (74373.pin11.LE)
16 IO   (PSX.pin6.D0)
17 IO   (SRAM./CE.pin22)
18 IO   (EEPROM2./CE.pin22) (for 2nd EEPROM chip, if any)
19 IO   (EEPROM1./CE.pin22) (for 1st EEPROM chip)
20 IO   (NC)           (reportedly has wire?)
21 IO   (EEPROM.pin30.A17) (reportedly A14 ?)
22 IO   (74245.pin19./E)
23 IN13 (PSX.pin64./WR) (SRAM.29, EEPROM.31)
24 VCC

```

The GALs are programmed nearly identical for all Xplorer versions, some small differences are: One or two EEPROM chip selects (depending on EEPROM chipset), and extra ports at

1F060005h, 1F060006h, 1F060007h (used in v4.52).

Note: The 28pin PLCC GAL has same pinout as the 24pin chip, but with four NC pins inserted (at pin 1,8,15,22, whereof, there is a wire routed "through" pin 8, so that pin isn't literally NC).

Xplorer Pinout 74373 (8bit tristate latch)

```
1  /OE  (GND)
2  Q0  (DB25.pin13.SLCT)
3  D0  (PSX)
4  D1  (PSX)
5  Q1  (DB25.pin12.PE)
6  Q2  (DB25.pin11.BUSY)
7  D2  (PSX)
8  D3  (PSX)
9  Q3  (DB25.pin10./ACK)
10 GND
11 LE  (GAL.pin15.LatchEnable)
12 Q4  (GAL.pin7)          (0=EEPROM, 1=SRAM)
13 D4  (PSX)
14 D5  (PSX)
15 Q5  (GAL.pin5)          (EEPROM bank 2/3)
16 Q6  (SRAM.pin30.A17 or CE2)
17 D6  (PSX)
18 D7  (PSX)
19 Q7  (SRAM.pin1.A18 or NC)
20 VCC
```

Xplorer Pinout 74245 (8bit bus transceiver)

```

1  DIR  (GNDed)
2  D7   (PSX)
3  D6   (PSX)
4  D5   (PSX)
5  D4   (PSX)
6  D3   (PSX)
7  D2   (PSX)
8  D1   (PSX)
9  D0   (PSX)
10 GND
11 D0  (DB25.pin2)
12 D1  (DB25.pin3)
13 D2  (DB25.pin4)
14 D3  (DB25.pin5)
15 D4  (DB25.pin6)
16 D5  (DB25.pin7)
17 D6  (DB25.pin8)
18 D7  (DB25.pin9)
19 /E   (GAL.pin22)
20 VCC

```

Xplorer Pinout 7805 (voltage regulator)

```

1  5V    (VCC)
2  GND   (GND)
3  7.5V  (PSX.pin18,52)

```

Xplorer Pinout SWITCH (on/off)

```

OFF  NC
COM  PAL.pin14 (with 10K pull-up to VCC)
ON   GND

```

Xplorer Pinout DB25 (parallel/printer port)

```

1  In   /STB   (NC)
2  In   DATA0  (74245.pin11)
3  In   DATA1  (74245.pin12)
4  In   DATA2  (74245.pin13)
5  In   DATA3  (74245.pin14)
6  In   DATA4  (74245.pin15)
7  In   DATA5  (74245.pin16)
8  In   DATA6  (74245.pin17)
9  In   DATA7  (74245.pin18)
10 Out  /ACK   (74373.Q3)
11 Out  BUSY   (74373.Q2)

```

```

12 Out PE      (74373.Q1)
13 Out SLCT   (74373.Q0)
---
14 In  /LF     (NC)
15 Out /ERR    (VCC via 0.47ohm) (installed only on carts with SRAM)
16 In  /INIT   (NC)
17 In  /SEL    (GAL.IN0.pin1)
18..25 GND   (Ground)

```

EEPROM.pin1 is NC on 256Kx8 chip (however it is wired to A18 for use with 512Kx8 chips).

EEPROM.pin30 is A17 from GAL.pin21 (not from PSX.A17), accordingly GAL.pin21 is EEPROM.A17 (not A14).

Boards with solder pads for TWO EEPROMs are leaving A18 not connected on the 2nd EEPROM (but do connect A18 to the first EEPROM, so one could either use one 512K chip or two 256K chips).

DB25.pin15./ERR is VCC via 0.47ohm (installed only on carts with SRAM, intended as supply for the X-ASSIST thing).

SRAM (if any) is wired to GAL.pin17 (/CE), 74373.Q6 (A17 or CE2), 74373.Q7 (A18 or NC), other SRAM pins are wired straight to D0-D7, A0-A16, /RD, /WR.

VCC is 5V, derived from a 7805 voltage converter (with 7.5V used as input).

Existing boards seem to have 128K SRAM (if any), so SRAM A17/A18 aren't actually used (unless a board would have 512K SRAM), however, for 128K SRAMs one should switch SRAM CE2 (aka A17) high.

21.11 Cheat Devices - Xplorer Cheat Code Format

PSX Xplorer/Xploder Code Format

```

3aaaaaaaaa 00dd ; -8bit write [aaaaaaaa]=dd
8aaaaaaaaa dddd ; -16bit write [aaaaaaaa]=dddd
0aaaaaaaaa dddd ; -32bit write [aaaaaaaa]=0000dddd <-- not "0aaaaaaaaa dddd" ?
4t0000000 000x ; -Slow Motion (delay "x" whatever/ns,us,ms,frames?)
7aaaaaaaaa dddd ; -IF [aaaaaaaa]=dddd then <execute following code>
9aaaaaaaaa dddd ; -IF [aaaaaaaa]<>dddd then <execute following code>
Faaaaaaaaa dddd ; -IF [aaaaaaaa]=dddd then activate "other selected" codes (uh?)
5aaaaaaaaa ?nnn ; \
d0d1d2d3 d4d5 ; write "?nnn" bytes to [aaaaaaaa] ; ordered d0,d1,d2... ?
d6d7d8... .... ; /
6t000000 nnnn ; \COP0 hardware breakpoint
aaaaaaaaaa cccc ; aaaaaaaaaa=break_address, mmmmmmmmm=break_mask
mmmmmmmmmm d0d1 ; nnnn=num_bytes (d0,d1,d2,etc.), cccc=break_type (see below)
d2d3d4... .... ; /
B?nnbbbb eeee ; \Slide/Patch Code, with unclear end: "end=?nn+/-1" ?

```

```
10aaaaaaaa dddd ;/for i=0 to end, [aaaaaaaa+(i*bbbb)]=dddd+(i*eeee), next i
C0aaaaaaaa dddd ;-garbage/mirror of 70aaaaaaaa dddd ? ;\or maybe meant to be
D0aaaaaaaa dddd ;-garbage/mirror of 70aaaaaaaa dddd ? ;/same as on GameShark?
```

The second code digit (t) contains encryption type (bit0-2), and a "default on/off" flag (bit3: 0=on, 1=off; whatever that means, it does probably require WHATEVER actions to enable codes that are "off"; maybe via the Faaaaaaaa dddd code).

break_type (cccc) (aka MSBs of cop0r7 DCIC register)

```
E180 (instruction gotten by CPU but not yet implemented) (uh, gotten what?)
EE80 (data to be read or written) ;<--looks okay
E680 (data to be read) ;<--looks okay
EA80 (data to be wrtten) ;<--looks okay
EF80 (instruction) ;<-- looks crap, should be probably E180
```

The CPU supports one data breakpoint and one instruction breakpoint (though unknown if the Xplorer does support to use both simultaneously, or if it does allow only one of them to be used).

If the break_type/address/mask to match up with CPU's memory access actions... then "something" does probably happen (maybe executing a sub-function that consists of the d0,d1,d2,etc-bytes, if so, maybe at a fixed/unknown memory address, or maybe at some random address; which would require relocatable code).

Notes

The "Slide" code shall be used only with even addresses, unknown if other 16bit/32bit codes do also require aligned addresses.

21.12 Cheat Devices - Xplorer Cheat Code and ROM-Image Decryption

decrypt_xplorer_cheat_code:

```
key = x[0] and 07h ;'----- AABCCDD EEFF -----';
x[0] = x[0] xor key ;           / / / \ \ \ ;
if key=0             ; x[0] --' / / \ \ '-- x[5];
;unencrypted (keep as is) ; x[1] ---' / \ '--- x[4];
elseif key=4        ; x[2] ----' '---- x[3];
x[1] = x[1] xor (025h) ;.....
x[2] = x[2] xor (0FAh + (x[1] and 11h))
x[3] = x[3] xor (0C0h + (x[2] and 11h) + (x[1] xor 12h))
```

```

x[4] = x[4] xor (07Eh + (x[3] and 11h) + (x[2] xor 12h) + x[1])
x[5] = x[5] xor (026h + (x[4] and 11h) + (x[3] xor 12h) + x[2] + x[1])
elseif key=5
    x[1] = (x[1] + 057h) ; "W"ayne
    x[2] = (x[2] + 042h) ; "B"eckett
    x[3] = (x[3] + 031h) ; "1"
    x[4] = (x[4] + 032h) ; "2"
    x[5] = (x[5] + 033h) ; "3"
elseif key=6
    x[1] = (x[1] + 0ABh) xor 01h
    x[2] = (x[2] + 0ABh) xor 02h
    x[3] = (x[3] + 0ABh) xor 03h
    x[4] = (x[4] + 0ABh) xor 04h
    x[5] = (x[5] + 0ABh) xor 05h
elseif key=7
    x[5] = x[5] + 0CBh
    x[4] = x[4] + 0CBh + (x[5] and 73h)
    x[3] = x[3] + 05Ah + (x[4] and 73h) - (x[5] xor 90h)
    x[2] = x[2] + 016h + (x[3] and 73h) - (x[4] xor 90h) + x[5]
    x[1] = x[1] + 0F5h + (x[2] and 73h) - (x[3] xor 90h) + x[4] + x[5]
else
    error ;(key=1,2,3)
endif

```

decrypt_xplorer_fcd_rom_image:

```

for i=0 to romsize-1
    x=45h
    y=(i and 37h) xor 2Ch
    if (i and 001h)=001h then x=x xor 01h
    if (i and 002h)=002h then x=x xor 01h
    if (i and 004h)=004h then x=x xor 06h
    if (i and 008h)=008h then x=x xor 04h
    if (i and 010h)=010h then x=x xor 18h
    if (i and 020h)=020h then x=x xor 30h
    if (i and 040h)=040h then x=x xor 60h
    if (i and 080h)=080h then x=x xor 40h
    if (i and 100h)=100h then x=x xor 80h
    if (i and 006h)=006h then x=x xor 0ch
    if (i and 00Eh)=00Eh then x=x xor 08h
    if (i and 01Fh)>=016h then x=x-10h
    rom[i]=(rom[i] XOR x)+y
next i

```

21.13 Cheat Devices - FLASH/EEPROMs

FLASH/EEPROM Commands

Below commands should work on all chips (for write: page size may vary, eg. 1 byte, 128 bytes, or 256 bytes). Some chips do have some extra commands (eg. an alternate older get id command, or sector erase commands, or config commands), but those extras aren't needed for basic erase/write operations.

```
[5555h]=AAh, [2AAAh]=55h, [5555h]=A0h, [addr...]=byte(s) ;write page
[5555h]=AAh, [2AAAh]=55h, [5555h]=90h, id=[0000h..0001h] ;enter id mode
[5555h]=AAh, [2AAAh]=55h, [5555h]=F0h ;exit id mode
[5555h]=AAh, [2AAAh]=55h, [5555h]=80h ;erase chip, step 1
[5555h]=AAh, [2AAAh]=55h, [5555h]=10h ;erase chip, step 2
```

Above addresses are meant to be relative to the chip's base address (ie. "5555h" would be 1F005555h in PSX expansion ROM area, or, if there are two flash chips, then it would be 1F045555h for the 2nd chip in xplorer and datel carts; whereas, that region is using bank switching in xplorer carts, so one must output some FLASH address bits I/O ports, and the others via normal CPU address bus; whilst datel carts have noncontinuous FLASH areas at 1F000000h and 1F040000h, with a gap at 1F020000h).

Observe that the chips will output status info (instead of FLASH data) during write/erase/id mode (so program code using those commands must execute in RAM, not in FLASH memory).

FLASH/EEPROM Wait Busy

Waiting is required after chip erase and page write (after writing the last byte at page end), and on some chips it's also required after enter/exit id mode. Some chips indicate busy state via a toggle bit (bit6 getting inverted on each 2nd read), and/or by outputting a value different than the written data, and/or do require hardcoded delays (eg. AM29F040). Using the following 3-step wait mechanism should work with all chips:

```
Wait 10us (around 340 cpu cycles on PSX)    ;-step 1, hardcoded delay
Wait until [addr]=[addr]                      ;-step 2, check toggle bit
Wait until [addr]=data                         ;-step 3, check data
```

Whereas, "addr" should be the last written address (or 0000h for erase and enter/exit id mode). And "data" should be the last written data (or FFh for erase, or "don't care" for enter/exit id mode).

Board and Chip Detection

First of, one should detect the expansion board type, this can be done as so:

```
Enter Chip ID mode (at 1F000000h)
Compare 400h bytes at 1F000000h vs 1F020000h
If different --> assume Datel PAR1/PAR2 hardware
If same --> assume Xplorer hardware (or Datel PAR3, whatever that is)
Exit Chip ID mode (at 1F000000h)
```

Next, detect the Chip ID for the (first) FLASH chip:

```
Enter Chip ID mode (at 1F000000h)
Read the two ID bytes (at 1F000000h)
Exit Chip ID mode (at 1F000000h)
```

Finally, one needs to check if there's a second FLASH chip, there are two such cases:

```
If cart=xplorer AND 1st_chip=256K --> might have a 2nd 256K chip
If cart=datel AND 1st_chip=128K --> might have a 2nd 128K chip
```

In both cases, the 2nd chip would be mapped at 1F400000h, and one can test the following four combinations:

```
Enter Chip ID (at 1F000000h) and Enter Chip ID (at 1F400000h) ;id1+id2
Exit Chip ID (at 1F000000h) and Enter Chip ID (at 1F400000h) ;id2
Exit Chip ID (at 1F400000h) and Enter Chip ID (at 1F000000h) ;id1
Exit Chip ID (at 1F400000h) and Exit Chip ID (at 1F000000h) ;none
```

For each combination compare 400h bytes at 1F000000h vs 1F400000h.

```
If they are all same --> there is only one chip (mirrored to both areas)
If different --> 1F400000h is either garbage, or a 2nd chip
```

In the latter case, do Chip ID detection at 1F400000h to see if there's really another chip there, and which type it is (if present, then it should be usually the same type as the 1st chip; and if it's not present, then there might be just open bus garbage instead of valid ID values).

FLASH/EEPROM Chip IDs

ChipID	Kbyte	Page	Maker/Name	;notes
1Fh,D5h	128	128	ATMEL AT29C010A	;xplorer/prototypes?
1Fh,35h	128	128	ATMEL AT29LV010A	;-

```

1Fh,DAh 256K 256 ATMEL AT29C020 ;xplorer
1Fh,BAh 256K 256 ATMEL AT29BV020 ;xplorer
1Fh,A4h 512K 256 ATMEL AT29C040A ;xplorer
1Fh,C4h 512K 256 ATMEL AT29xV040A ;-*
BFh,07h 128K 128 SST SST29EE010 ;-*
BFh,08h 128K 128 SST SST29xE010 ;-*
BFh,22h 128K 128 SST SST29EE010A ;-*
BFh,23h 128K 128 SST SST29xE010A ;-*
BFh,10h 256K 128 SST SST29EE020 ;xplorer
BFh,12h 256K 128 SST SST29xE020 ;xplorer
BFh,24h 256K 128 SST SST29EE020A ;-*
BFh,25h 256K 128 SST SST29xE020A ;-*
BFh,04h 512K 256 SST SST28SF040 ;said to be used in "AR/GS Pro"
DAh,C1h 128K 128 WINBOND W29EE01x ;-*
DAh,45h 256K 128 WINBOND W29C020 ;-*
DAh,46h 512K 256 WINBOND W29C040 ;xplorer
01h,A4h 512K 1 AMD AM29F040 ;nocash psone bios (intact console)
20h,20h 128K 1 ST M29F010B ;nocash psone bios (broken console)
31h,B4h 128K ?? CATALYST CAT28F010 ;NEEDS VPP=12V !!! ("PS-121 ZISAN")

```

The above Atmel/SST/Winbond chips are commonly used in Datel or Xplorer carts (or both). The CATALYST chip is used in some Datel clones (but seems to require 12 volts, meaning that it can't be properly programmed on PSX, nevertheless, it's reportedly working "well enough" to encounter flash corruption upon programming attempts). The two ST/AMD chips aren't really common in PSX world (except that I've personally used them in my PSones).

22. PSX Dev-Board Chipsets

Sony DTL-H2000 CPU Board

```

CL825 20pin pin test points (2x10 pins)
CL827 20pin pin test points (2x10 pins)
U83   64pin SEC KM4216V256G-60 (DRAM 256Kx16) ;dual-ported VRAM
U84   64pin SEC KM4216V256G-60 (DRAM 256Kx16) ;dual-ported VRAM
CL828 20pin pin test points (2x10 pins)
CL826 20pin pin test points (2x10 pins)
X10    4pin JC53.20      (PAL, 53.203425MHz)
X2     4pin 53.69317MHz (NTSC, 53.693175MHz)
U62   20pin LVT244 (dual 4-bit 3-state noninverting buffer/line driver)
U27   64pin Sony CXD2923AR      ;GPU'b
CL813 20pin pin test points (2x10 pins)
CL814 20pin pin test points (2x10 pins) (with one resistor or so installed)
U16   160pin Sony CXD8514Q      ;GPU'a
X7    4pin 67.73760 MHz
CL807 20pin pin test points (2x10 pins)
CL809 20pin pin test points (2x10 pins)
CL811 20pin pin test points (2x10 pins)
U801  208pin Sony CXD8530BQ      ;CPU
U11   28pin SEC KM48V2104AJ-6 (DRAM 2Mx8) ;Main RAM
U10   28pin SEC KM48V2104AJ-6 (DRAM 2Mx8) ;Main RAM
U9    28pin SEC KM48V2104AJ-6 (DRAM 2Mx8) ;Main RAM
U8    28pin SEC KM48V2104AJ-6 (DRAM 2Mx8) ;Main RAM
CN801 100pin Blue connector (to other ISA board)
U66   48pin LVT16244? (quad 4-bit 3-state noninverting buffer/line driver)
U65   48pin LVT16244? (quad 4-bit 3-state noninverting buffer/line driver)
U64   48pin LVT16245? (dual 8-bit 3-state noninverting bus transceiver)
U34   100pin Sony CXD2922Q      ;SPU
U63   14pin 74F74N (dual flipflop)
U32   44pin SEC KM416V256B1-8 (DRAM 256Kx16) ;SoundRAM
CL801 20pin pin test points (2x10 pins)
CL802 20pin pin test points (2x10 pins)
Q881  3pin voltage stuff?
U31   20pin 74ACT244P (dual 4-bit 3-state noninverting buffer/line driver)
U35   18pin Sony CXD2554P or OKI M6538-01 (aka MSM6538-01?) (audio related?)
U36   20pin Sanyo LC78815 ;16bit D/A Converter
U37   8pin NEC ...? C4558C? D426N0B or 9426HOB or so?
J806  8pin solder pads...
J805  9pin solder pads...
J804  10pin solder pads... (11pins, with only 10 contacts?)
-    48pin solder pads (12x4pin config jumpers or so)
U26   20pin SN74ALSxxx logic?
U71   24pin Sony CXA1xxxx? ;RGB?
JPxx  9pin PAL/NTSC Jumpers (three 3pin jumpers)
J801  24pin solder pads...
J803  9pin rear connector: Serial Port (3.3V) (aka "J308") (DB9) (5+4pin)

```

J802	15pin rear connector: AV Multi-out (5+5+5pin)
CN881	98pin ISA Bus Cart-edge (2x31 basic pins, plus 2x18 extended pins)

Sony DTL-H2000 PIO Board

JP72x 68pin Black connector (maybe equivalent to 68pin PSX expansion port?)
 SWI 5pin solder pads...
 U371 40pin HN27C4000G-12 (512Kx8 / 256Kx16 EPROM) (sticker: "94/7/27")
 U370 84pin Altera EPM7160ELC84-12 (sticker: "U730, cntl 1")
 U3 14pin SN74ALS1004N (hex inverters)
 U43 44pin Altera EPM7032LC44-10 (sticker: "U43, add 1")
 U716 28pin Sharp LH5498D-35 (FIFO 2Kx9)
 U717 28pin Sharp LH5498D-35 (FIFO 2Kx9)
 U719 28pin Sharp LH5498D-35 (FIFO 2Kx9)
 U720 28pin Sharp LH5498D-35 (FIFO 2Kx9)
 U724 20pin SN74ALS688N (8bit inverting identity comparator with enable)
 U722 20pin SN74ALS245AN (8bit tristate noninverting bus transceiver)
 U47 20pin 74FCT244ATP (dual 4-bit 3-state noninverting buffer/line driver)
 U732 48pin LVT16245? (dual 8-bit 3-state noninverting bus transceiver)
 U711 20pin SN74ALS244BN (dual 4-bit 3-state noninverting buffer/line driver)
 U712 20pin SN74ALS244BN (dual 4-bit 3-state noninverting buffer/line driver)
 U713 20pin 74HC244AP (dual 4-bit 3-state noninverting buffer/line driver)
 U714 20pin 74HC244AP (dual 4-bit 3-state noninverting buffer/line driver)
 U721 20pin SN74ALS244BN (dual 4-bit 3-state noninverting buffer/line driver)
 U55 14pin SN74ALS08N (quad 2-input AND gates)
 U726 20pin SN74ALS245AN (8bit tristate noninverting bus transceiver)
 U715 20pin 74HC244AP (dual 4-bit 3-state noninverting buffer/line driver)
 JPxx 100pin Blue connector (to other ISA board)
 U738 20pin LVT244 (SMD) (dual 4-bit 3-state noninverting buffer/line driver)
 U734 32pin KM684000G-7 (SRAM 512Kx8) ;\maybe 1Mbyte EXP3 RAM ?
 U733 32pin KM684000G-7 (SRAM 512Kx8) ;/
 U725 20pin SN74ALS688N (8bit inverting identity comparator with enable)
 S700 24pin 12bit DIP switch (select I/O Address bits A15..A4)
 JP700 8pin Jumper (4x2 pins) (select IRQ15/IRQ12/IRQ11/IRQ10)
 JP7xx 12pin Jumper (3x4 pins) (select DMA7/DMA6/DMA5)
 U64 48pin LVT16245? (dual 8-bit 3-state noninverting bus transceiver)
 U65 48pin LVT16244? (quad 4-bit 3-state noninverting buffer/line driver)
 U66 48pin LVT16244? (quad 4-bit 3-state noninverting buffer/line driver)
 U737 48pin LVT16244? (quad 4-bit 3-state noninverting buffer/line driver)
 U710 20pin SN74ALS244BN (dual 4-bit 3-state noninverting buffer/line driver)
 U709 20pin HD74HC245P (8bit tristate noninverting bus transceiver)
 U723 14pin SN74ALS38AN (quad open-collector NAND gates with buffered output)
 U2 14pin SN74LS19AN (hex inverters with schmitt-trigger)
 U1 8pin Dallas DS1232 (MicroMonitor Chip) ;power-good-detect ?
 U708 20pin HD74HC245P (8bit tristate noninverting bus transceiver)
 X3 2pin 4.1900 (4.19MHz for SPC700 CPU)
 U42 80pin P823, U01Q (Sony CXP82300 SPC700 CPU with piggyback EPROM socket)
 U42' 32pin 27C256A-15 (EPROM 32Kx8) (sticker: "94/11/28")
 U706 10pin some slim chip with 1x10 pins
 BT700 2pin battery (or super-cap?) for DS1302S (?) (not installed)
 U729? 5pin voltage stuff?
 U40 8pin Dallas DS1302S (real time clock)
 X4 2pin small crystal (32.768kHz for DS1302S)

```

JP702 34pin Black connector (maybe for internal CDROM Emulator ISA cart?)
U736 28pin Sony CXK58257ASP-70L (SRAM 32Kx8) ;CDROM Sector Buffer?
U735 100pin Sony CXD1199BQ ;CDROM Decoder/FIFO
JP715 40pin Blue connector... to external DTL-H2010 CDROM drive?
JP721 9pin rear connector: Joypad/Memcard 2 (DB9)
JP719 9pin rear connector: Joypad/Memcard 1 (DB9)
? - rear hole for cdrom-cable to Blue 40pin connector?
J70x 98pin ISA Bus Cart-edge (2x31 basic pins, plus 2x18 extended pins)

```

JP715 must be either connected to an external CDROM drive, or to some of "terminator" plug (which shortcuts Pin23 and Pin26 with each other; software may hang upon certain I/O operations without that terminator).

Sony DTL-H2500 Dev board (PCI bus)

Newer revision of the DTL-H2000 board. Consists of a single PCI card (plus tiny daughterboard with Controller ports).

```

Mainboard      "PI-27 1-589-867-11, DTL-H2500, MAIN BOARD 1575E01A0, SONY"
Daughterboard "SONY,CN-102 1-589-865-11,CONNECTOR BOARD,DTL-H2500,1575E02A0"
CJ1      9pin rear connector: DB9
CJ2?    15pin rear connector: AV Multi-out (5+5+5pin)
CJ3      10pin gray connector (to controller daughterboard with two DB9's)
CJ4      34pin black connector (maybe for internal CDROM Emulator ISA cart?)
CJ5      50pin black connector (to DTL-H2510, Gray Internal CDROM Drive?)
CJ6      68pin black connector (maybe equivalent to 68pin PSX expansion port?)
-       124pin PCI bus cart edge connector
CJ1'    9pin rear connector: DB9 (CTR1, joypad 1) ;\
CJ2'    9pin rear connector: DB9 (CTR2, joypad 2) ; on daughterboard
CJ3'    10pin gray ribbon cable (to CJ3 on main board) ;/
IC103   208pin Sony CXD8530CQ (CPU)
IC106   28pin SEC KM48V2104AT-6 (DRAM 2Mx8)
IC107   28pin SEC KM48V2104AT-6 (DRAM 2Mx8)
IC108   28pin SEC KM48V2104AT-6 (DRAM 2Mx8)
IC109   28pin SEC KM48V2104AT-6 (DRAM 2Mx8)
IC201   64pin SEC KM4216V256G-60 (DRAM 256Kx16) ;dual-ported VRAM
IC202   64pin SEC KM4216V256G-60 (DRAM 256Kx16) ;dual-ported VRAM
IC203   160pin Sony CXD8514Q ;GPU'a
IC207   64pin Sony CXD2923AR ;GPU'b
IC303   28pin HM62W256LFP-7T (CDROM SRAM 32Kx8) ;on back side
IC304   52pin "D 2021, SC430920PB, G64C 185, JSAA9618A" (Sub-CPU) ;on back
IC305   100pin Sony CXD1199BQ (CDROM Decoder/FIFO) ;on back side
IC308   100pin Sony CXD2922BQ (SPU) ;on back side
IC310   44pin SEC KM416V256BLT-7 (DRAM 256Kx16) ;SoundRAM ;on back side
IC402   24pin something bigger
IC404   8pin something small
IC405   8pin something small
IC501   24pin Sony CXA1645M (Analog RGB to Composite) ;on back side
IC701   4pin "RD, 5B" or so ;on back side
IC801   +++pin "ALTERA, FLEX, EPF8820ARC208-3, A9607" ;on back side
IC802   20pin LVT245A <-- ;on back side

```

```

IC803  52pin "IDT71321, LA35J, S9704P" (2Kx8 dual port SRAM)
IC804  20pin LVT244A
IC805  8pin something with socket (sticker: "PD3")
IC807-2 32pin MX 27C1000MC-90 (PROM) ;\on back side
IC808  32pin F 29F040A-90 (FLASH) ;/BIOS on these chip(s) or so?
IC901  4pin 37, 69 ;\on back side
IC902  4pin 37, 69 ;/
ICxxx? 28pin "DALLAS, DS1230Y-100, NONVOLATILE SRAM"
U28   20pin LVT244A
Z1    20pin LVT244A ;\on back side
Z2    20pin LVT245A <-- ;/
Z3    20pin LVT244A
Z4    20pin LVT244A ;\
Z5    20pin LVT245A <-- ; on back side
Z6    20pin LVT244A ;/
Z7    20pin LVT244A
Z8    20pin LVT244A
Z9    20pin LVT244A
X101   4pin RC67.73, JVC 5L (67.7376MHz oscillator for main cpu)
X201   4pin JC53.20, JVC 6A (for GPU, PAL)
X202   4pin JC53.69, JVC 6A (for GPU, NTSC)
X302   3pin 4.000MHz (for sub-cpu)

```

Sony DTL-H2700 Dev board (ISA bus) (CPU, ANALYZER ...?)

Another revision of the DTL-H2000/DTL-H2500 boards. Consists of a single ISA card stacked together with two huge daughterboards, and probably additionally having a small connector daughterboard. Exact chipset is unknown (there might be components on both sides of the PCBs, most of them not visible due to the PCB stacking, so taking photos/scans of the PCBs would require advanced techniques with screwdrivers).

Currently the only known chip name is an EPROM (MX 27C1000DC-90, with sticker "Title=DTL-H2700, Ver=1.00, Date=96.12.4, Sum=046B No."). The ISA card is having markings: "SONY HCD MWB-7? MADE IN JAPAN, PA47 1-589-003-01 1642E03A0". One uncommon feature is an extra connector for a "trigger switch" (foot pedal), which is reportedly used for activating performance analyzer logging.

Sony DTL-H201A / DT-HV - Graphic Artist Board (IBM PC/ATs to NTSC video)

```

X2      xpin TXC-2 OSC 66.000MHz
X1      xpin TXC-2AOSC 53.693MHz
U16    14pin 74F74 (dual flipflop)
U29    14pin 74AS04 (hex inverters)
U14    20pin LVT244 (dual 4-bit 3-state noninverting buffer/line driver)
U18    20pin LVT244 (dual 4-bit 3-state noninverting buffer/line driver)
U15    20pin ACT244 (dual 4-bit 3-state noninverting buffer/line driver)
U11    84pin Altera EPM7096LC84-12 (sticker: "artpc13" or "ARTPC13")
U13    160pin Sony CXD8514Q ;GPU'a
U5     14pin ALS38A ? (quad open-collector NAND gates with buffered output)

```

```

U27 20pin ALS244AJ ? (dual 4bit tristate noninverting buffer/line driver)
Q1   3pin T B596
U23 64pin KM4216V256G-60 (DRAM 256Kx16) ;dual-ported VRAM
U22 64pin KM4216V256G-60 (DRAM 256Kx16) ;dual-ported VRAM
U28 64pin Sony CXD2923AR ;GPU'b
S1   16pin 8bit DIP switch (select I/O address A15..A8)
S2   8pin 4bit DIP switch (select I/O address A7..A4)
U1   20pin SN74ALS688N (8bit inverting identity comparator with enable)
U2   20pin SN74ALS688N (8bit inverting identity comparator with enable)
U3   20pin ALS245A (8bit tristate noninverting bus transceiver)
JP9  12pin Jumper (6x2 pins) (select IRQ15/IRQ11/IRQ10/IRQ9/IRQ5/IRQ3)
U26  24pin Sony CXA1145M ? ;RGB?
JP10 3pin Jumper ;\
JP12 3pin Jumper ; select "S" or "O" (?)
JP11 3pin Jumper ;/
J3   2pin? Yellow connector (composite video out?)
J2?  pin? Mini DIN? connector (maybe S-video out?)
J1   15pin High Density SubD (maybe video multi out?)
CJx  98pin ISA Bus Cart-edge (2x31 basic pins, plus 2x18 extended pins)

```

DTL-S2020 aka Psy-Q CD Emu

```

Yellow PCB "CD Emulator System, (C) Cirtech & SN Systems Ltd, 1994 v1.2"
IC   24pin GAL20V8B
IC   68pin Analog Devices ADSP-2101 (16bit DSP Microprocessor)
IC   20pin HD74HC244P
IC15 20pin HD74HC244P
IC14 20pin CD74HCT245E
IC7  28pin 27C512-10 (EPROM 64Kx8) (yellow sticker, without text)
IC   28pin HY62256ALP-70 (SRAM 32Kx8)
IC12 28pin HY62256ALP-70 (SRAM 32Kx8)
IC   28pin HY62256ALP-70 (SRAM 32Kx8)
IC13 84pin Emulex/QLogic FAS216 (Fast Architecture SCSI Processor)
IC5  84pin Emulex/QLogic FAS216 (Fast Architecture SCSI Processor)
IC4  24pin GAL20V8B (near IO Addr jumpers)
IC   20pin 74LS244B1 (near lower 8bit of ISA databus)
IC   20pin SN74LS245N? (near lower 8bit of ISA databus)
IC   20pin SN74LS245N (near upper 8bit of ISA databus)
DMA  12pin Jumpers (select DMA7/6/5)
IRQ  12pin Jumpers (select IRQ15/12/11/10/7/5)
IO   16pin Jumpers (select IO Addr 300/308/310/318/380/388/390/398)
SCSI 6pin Jumpers (select SCSI ID 4/2/1) (aka 3bit 0..7 ?)
PL3  34pin Connector to DTL-H2000 ?
PL1  50pin Connector to INTERNAL SCSI hardware ?
PL2  50pin? Connector to EXTERNAL SCSI hardware ? (25pin plug/50pin cable?)
Jx   98pin ISA Bus Cart-edge (2x31 basic pins, plus 2x18 extended pins)

```

Note: There's also a similar ISA cart (DTL-S510B) with less chips and less connectors.

Note: The SN Systems carts seem to have been distributed by Sony (with "DTL-Sxxxx")

numbers), and also distributed by Psygnosis. The external SCSI connectors can be possibly also used with Psy-Q Development Systems for SNES and Sega Saturn?

PSY-Q Development System (Psygnosis 1994)

```

32pin GM76C8128ALLFW85 (SRAM 128Kx8)
44pin ALTERA EPM7032LC44-15T
34pin EMULEX FAS101 (SCSI Interface Processor)
28pin 27C64 (EPROM 8Kx8) (green sticker, without text)
20pin LCX245 (=74245?)
8pin 2112, CPA, H9527 (?)
3pin transistor? voltage regulator?
20pin DIP socket (containing two 10pin resistor networks)
20pin DIP socket (containing two 10pin resistor networks)
2pin CR2032 Battery 3V
68pin Connector to PSX "Parallel I/O" expansion port
25pin Connector to SCSI hardware (to DTL-S510B or DTL-S2020 ISA cart or so?)

```

Sony DTL-H800 Sound Artist Board (with optical fibre audio out)

```

U15 24pin ?
U5  28pin 27C256 (EPROM 32Kx8) (not installed)
U7  4pin 67.7376MHz oscillator
U8  14pin ?
U11 44pin SEC KM416V256B1-8 (DRAM 256Kx16) ;SoundRAM
      (44pin package with middle 4pin missing, 40pins used)
U10 100pin Sony CXD2925Q ;SPU
U4  160pin Lattice IspLSI 3256 (sticker: "VER3")
U6  128pin Lattice IspLSI xxxx ?
U12 48pin ?
U13 48pin ?
U3  20pin 74ACT244
U14 5pin "LM25755, -3.3 P+" ?
U2  54pin ?
U1  54pin ?
U9  ?pin GP1F31T (light transmitting unit for optical fibre cable)
?  124pin PCI bus cart edge connector
?  8pin internal jumper/connector? (7pin installed, 1pin empty)

```

Note: There's also a similar board (DTL-H700) for MAC/NuBus instead of PCI bus.

Sony COH-2000 (unknown purpose)

```

U1 14pin SN74ALS388N ?
U2 20pin SN74ALS688N (8bit inverting identity comparator with enable)
U3 20pin SN74ALS688N (8bit inverting identity comparator with enable)
U4 24pin PALxxx ?
U5 20pin SN74ALS245AN

```

```

U6 20pin SN74ALS245AN
U7 20pin SN74ALS244N
U8 20pin SN74ALS244N
U9 20pin SN74ALS245AN
U10 20pin SN74ALS245AN
U11 20pin SN74ALS244N
S2 16pin 8bit DIP switch (ISA 15/14/13/12/11/10/9/8) ;I/O address bit15-8
S1 8pin 4bit DIP switch (ISA 7/6/5/4) ;I/O address bit7-4
S3 8pin 4bit DIP switch (BISO? 3/2/1/0) ;BISO? or BISD? or 8150?
JPxx .... several jumpers (unknown purpose)
Jx 98pin ISA Bus Cart-edge (2x31 basic pins, plus 2x18 extended pins)
J5 68pin Connector on rear side (unknown purpose)

```

Unknown what COH-2000 was used for. One theory was that it's related to PSX-based arcade cabinets. The 68pin connector might be also related to the 68pin PSX "Parallel I/O" expansion port.

Sony DTL-H2010 (Black External CDROM Drive for DTL-H2000, CD-R compatible)

External front loading CDROM drive with Eject button. Connects to the blue 40pin connector on DTL-H2000 boards.

```

IC101 100pin SONY CXD2515Q (Signal Processor + Servo Amp) ; \
IC102 28pin BA6297AFP ; on mainboard
ICxx 20pin SONY CXA1571N (RF Amp) (on tiny daughterboard) ; (HCMK-81X)
CN101 21pin connector to DEX2010.SCH board ;
CN10x 12pin connector to KSS-240A (laser pickup) ;
S101 2pin pos0 switch or so? ;
M101 2pin spindle motor ;/
U1 20pin 74ALS244BN ;\
U2 20pin 74ALS244BN ;
U3 20pin 74ALS244BN ; on DEX2010.SCH board
J1 2pin connector to EJECT BUTTON ;
J2 5pin connector to LOADING MOTOR ;
J3 21pin connector to mainboard ;
JP1 40pin external connector to DTL-H2000 ;/
CN151 5pin connector to DEX2010.SCH board ;\
M151 2pin loading motor (eject motor) ; on CDM 14, CMK PSX board
S151 2pin OUT SW ;\switches, probably to ;
S152 2pin IN SW ;\sense load/eject status ;/
CN1 2pin connector to DEX2010.SCH board ;\on DTL-H2010(1) board
SW1 2pin eject button ;/

```

The required cable consists of a Yamaichi NFS-40a female connector (blue connector on DTL-H2000 side), 0.635mm pitch ribbon cable, and 3M Sub-D MDR40 connector (silver connector on DTL-H2010 side). But caution: the odd/even pins on the cable are somewhat swapped, on DTL-H2000 side the wires should be ordered 1,2,3,4,..,39,40, but on DTL-H2010 side they should be ordered 2,1,4,3,..,40,39.

Sony DTL-H2510 (Gray Internal CDROM Drive)

This is some sort of a mimicked front loading PC CDROM drive (consisting of a tray that contains a normal (top-loading) PSX cdrom drive unit).

```
IC309 80pin Sony CXD2510Q (CDROM Signal Processor)
ICxx   ?pin Unknown if there are further ICs (eg. CXA1782BR should exist?)
CN1   10pin Connector to daughterboard (with drive unit)
CN2   4pin Connector to PC power supply (12V/5V and 2xGND)
CN3   50pin Connector to DTL-H2500 or so? (need "PCS-E50FC" plug?)
```

There is no eject button, unknown if there's some eject motor, or if one does need to push/pull drive tray manually.

Sony SCPH-9903 (Gray SCEx-free Playstation)

A rare SCEx-free Playstation that can boot from CDR's without SCEx strings; maybe intended for beta-testers. Marked "Property of Sony Computer Entertainment", "U/C".

23. Hardware Numbers

Sony's own hardware (for PSX) (can be also used with PSone)

SCPH-1000 PlayStation (1994) (NTSC-J) (with S-Video)
 SCPH-1001 PlayStation (1995) (NTSC-U/C) (without S-Video)
 SCPH-1002 PlayStation (199x) (PAL) (without S-Video)
 SCPH-1010 Digital joypad (with short cable) (1994)
 SCPH-1020 Memory Card 1Mbits (1994)
 SCPH-1030 2-button Mouse (with short cable) (1994)
 SCPH-1040 Serial Link Cable
 SCPH-1050 RGB Cable (21-pin RGB Connector)
 SCPH-1060 RFU Cable/Adaptor (antennae connector) (NTSC-JP?) (1995)
 SCPH-1061 RFU Cable/Adaptor (antennae connector) (NTSC-US?)
 SCPH-1062 RFU Cable/Adaptor (antennae connector) (PAL)
 SCPH-1070 Multitap adaptor (four controllers/memory cards on one slot) (1995)
 SCPH-1080 Digital joypad (with longer cable) (1996)
 SCPH-1090 2-button Mouse (with longer cable) (1998)
 SCPH-1100 S Video Cable (1995)
 SCPH-1110 Analog Joystick (1996)
 SCPH-1120 RFU Adaptor (antennae connector) (NTSC-JP?) (1996)
 SCPH-1121 RFU Adaptor (antennae connector) (NTSC-US?)
 SCPH-1122 RFU Adaptor (antennae connector) (PAL)
 SCPH-1130 AC Power Cord (1996)
 SCPH-1140 AV Cable (1997)
 SCPH-1150 Analog Joypad (with one vibration motor, with red/green led) (1997)
 SCPH-1160 AV Adaptor (1997)
 SCPH-1170 Memory Card Triple Pack (three Memory Cards) (1996)
 SCPH-1180 Analog Joypad (without vibration motors, with red/green led)
 SCPH-119X Memory Card (X=different colors) (1997)
 SCPH-1200 Analog Joypad (with two vibration motors) (dualshock) (1997)
 SCPH-1210 Memory Card Case (1998)
 SCPH-2000 Keyboard/Mouse adapter (PS/2 to PSX controller port; for Lightspan)
 SCPH-3000 PlayStation (1995) (NTSC-J) (with the S-video output removed)
 SCPH-3500 PlayStation Fighting Box (console bundled with 2 controllers) (1996)
 SCPH-4000 PocketStation (Memory Card with LCD-screen) (1999)
 SCPH-4010 VPick (guitar-pick controller) (for Quest for Fame, Stolen Song)
 SCPH-4020 Long Strap for PocketStation (1999)
 SCPH-4030 Wrist Strap for PocketStation (1999)
 SCPH-5000 PlayStation (cost reduced) (Japan) (1996) ;\exists in these three
 SCPH-5001 PlayStation (cost reduced) (North America) ; regions only (not
 SCPH-5003 PlayStation (Asia) ;/in Europe)
 SCPH-5500 PlayStation without Cinch sockets (ie. AV Multi Out only) (1996) (J)
 SCPH-5501 "" North American version of the 5500
 SCPH-5502 "" European version of the 5500 (shipped with 1 digital joypad)
 SCPH-5552 Same as SCPH-5502 (but shipped with memcard and 2 digital joypads)
 SCPH-5903 PlayStation with built-in MPEG Video-CD decoder (Asia-only)
 SCPH-7000 PlayStation with Dualshock (1997) (Japan)
 SCPH-7001 PlayStation with Dualshock (199x) (North America)
 SCPH-7002 PlayStation with Dualshock (199x) (Europe)

SCPH-7003 PlayStation with Dualshock (199x) (Asia)
 SCPH-7000W PlayStation (10 million model, not for sale, blue, region free)
 SCPH-7500 PlayStation with Dualshock, cost reduced (1999) (Japan)
 SCPH-7501 PlayStation with Dualshock, cost reduced (199x) (North America)
 SCPH-7502 PlayStation with Dualshock, cost reduced (199x) (Europe)
 SCPH-7503 PlayStation with Dualshock, cost reduced (199x) (Asia)
 SCPH-9000 PlayStation without Parallel I/O port (1999) (Japan)
 SCPH-9001 PlayStation without Parallel I/O port (199x) (North America)
 SCPH-9002 PlayStation without Parallel I/O port (199x) (Europe)
 SCPH-9003 PlayStation without Parallel I/O port (199x) (Asia)
 SCPH-9903 Rare SCEEx-free PSX (Property of Sony Computer Entertainment, U/C)
 SFX-100 PlayStation Super Disc Prototype (with SNES chipset, no PSX chips)

Sony's own hardware (for PSone)

SCPH-100 PSone (miniaturized PlayStation) (2000) (Japan)
 SCPH-101 PSone (miniaturized PlayStation) (200x) (North America)
 SCPH-102 PSone (miniaturized PlayStation) (200x) (Europe)
 SCPH-103 PSone (miniaturized PlayStation) (200x) (Asia)
 SCPH-102A PSone Europe (UK/AU, with A/V cable) ; \revision of "SCPH-102"
 SCPH-102B PSone Europe (UK, with RFU adaptor) ; with PM-41(2) board ?
 SCPH-102C PSone Europe (Continent, with A/V cable) ;/
 SCPH-110 Dual Analog Pad (for PSone) (Dualshock) (2000)
 SCPH-111 Multitap for PSone (seems to be quite rare, except in brazil)
 SCPH-112 AC adapter for PSone (In: 110-220VAC, Out: 7.5VDC, 2.0A, Japan)
 SCPH-113 AC adapter for PSone (In: 120VAC/60Hz, Out: 7.5VDC, 2.0A, USA)
 SCPH-114 AC adapter for PSone (In: 220-240VAC, Out: 7.5VDC, 2.0A, Europe)
 SCPH-115 AC adapter for PSone (In: 220-240VAC, Out: 7.5VDC, 2.0A, UK)
 SCPH-116 AC adapter for PSone (In: 220-240VAC, Out: 7.5VDC, 2.0A, Australia)
 SCPH-117 AC adapter for PSone (In: 110VAC, Out: 7.5VDC, 2.0A, Asia?)
 SCPH-120 AC adapter for PSone with LCD Screen (In: 100VAC, Out: 7.5VDC, 3.0A)
 SCPH-130 LCD Screen for PSone (to be attached to the console) (2001)
 SCPH-140 PSone and LCD screen combo (2001)
 SCPH-152 LCD screen for PSone (PAL SCPH-152C)
 SCPH-162 PSone and LCD screen (PAL SCPH-162C)
 SCPH-170 Car Adapter for PSone from car cigarette lighter (2001)
 SCPH-180 AV Connection Cable for LCD-screen's AV IN
 SCPH-10180K DoCoMo I-Mode Adaptor Cable (for internet via mobile phones)

Sony's own devkits

DTL-H201A Graphic Artist Board (ISA bus) (with NTSC video out)
 DTL-H240 PS-X RGB Cable
 DTL-H500C Digital joypad prototype (SNES-style design, with DB9 connector)
 DTL-H505 PS-X (Code Name) Target Box ? (PSX prototype, SCSI instead CDROM?)
 DTL-H700 Sound Artist Board (NuBus for Mac)
 DTL-H800 Sound Artist Board (PCI Bus for IBM) (with optical fibre sound out)
 DTL-H1000 Debugging Station (CD-R compatible PSX console) (Japan)
 DTL-H1001 Debugging Station (CD-R compatible PSX console) (North America)
 DTL-H1002 Debugging Station (CD-R compatible PSX console) (Europe)
 DTL-H1030 Mouse ?

DTL-H1040 Link Cable ?
 DTL-H1050 RGB Cable ?
 DTL-H110x Debugging Station revision? (DC-powered)
 DTL-H120x Debugging Station revision? (AC-powered)
 DTL-H1500 Stand-Alone Box ? With ethernet, for SGI Workstation ?
 DTL-H2000 Dev board v1 (PSX on two ISA carts) (old pre-retail)
 DTL-H2010 Black External CDROM Drive for DTL-H2000 (CD-R compatible)
 DTL-H2040 Memory Box ?
 DTL-H2050 Adaptor for Controller port ?
 DTL-H2060 Serial Link cable
 DTL-H2070 RGB Cable ?
 DTL-H2080 Controller Box (joypad/memcard adaptor for DTL-H2000/DTL-xxxx?)
 DTL-H2500 Dev board (PCI bus)
 DTL-H2510 Gray Internal CDROM Drive for DTL-H2500/DTL-H2700 (CD-R compatible)
 DTL-H2700 Dev board (ISA bus) (CPU, ANALYZER ...?)
 DTL-H3000 Net Yaroze (hobby programmer dev kit) (Japan)
 DTL-H3001 Net Yaroze (hobby programmer dev kit) (North America)
 DTL-H3002 Net Yaroze (hobby programmer dev kit) (Europe)
 DTL-H3020 Access Card (for yaroze)
 DTL-H3050 Communication Cable (link port to rs232, for yaroze)
 DTL-D2020 Documentation: BUILD CD (Manual of Programmer's Tool)
 DTL-D2120 Documentation: (Manual of Programmer's Tool)
 DTL-D2130 Documentation: PsyQ (Manual of Programmer's Tool)
 DTL-D2130 Documentation: SdevTC (Manual of Programmer's Tool)
 DTL-D2140A Documentation: Ver.1.0 (Manual of Programmer's Tool)
 DTL-D2150A Documentation: Ver.2.0 (Manual of Programmer's Tool)

SN System / Psy-Q devkit add-ons / SCSI cards

DTL-S510B Unknown (another CDROM emulator version?)
 DTL-S2020 CD-ROM EMULATOR for DTL-H2000/DTL-H2500/DTL-H2700

Sony Licensed Hardware (Japan)

SLPH-00001 Namco neGcon (white) (NPC-101), Twist controller (SLEH-0003)
 SLPH-00002 Hori Fighting stick, digital stick with autofire/slowmotion/rumble
 SLPH-00003 ASCII Fighter stick V, psx-shaped digital stick (SLEH-0002)
 SLPH-00004 Sunsoft Sunstation pad, digital pad with autofire/slowmotion
 SLPH-00005 ASCII ASCIIPAD V, digital pad with autofire/slowmotion
 SLPH-00006 Imagineer Sandapaddo ThunderPad
 SLPH-00007 SANKYO N.ASUKA aka Nasca Pachinco Handle, bizarre paddle
 SLPH-00008 Spital SANGYO Programmable joystick
 SLPH-00009 Hori Fighting commander 2way controller
 SLPH-00010 Optec Super Pro Commander
 SLPH-00011 Super Pro Commander Accessory / Extended memo repack memory
 SLPH-00012 Hori Fighting Commander 10B Pad (gray), digital pad with extras
 SLPH-00013 Konami Hyper Blaster (green) ;\IRQ10-based Lightgun
 SLPH-00014 Konami Hyper Blaster (black) ;/(SLEH-0005/SLUH-00017)
 SLPH-00015 Namco Volume controller, paddle with 2 buttons
 SLPH-00016 Waka Up Scan Converter "[chiyo] clean! peripheral equipment?"
 SLPH-00017 Hori Fighting Commander 10B Pad (black), digital pad with extras

SLPH-00018 Hori Real Arcade Stick, digital stick, small L1/L2 (HPS-10)
SLPH-00019 Konami Hyperstick
SLPH-00020 Imagineer Thunder Pad Transparent
SLPH-00021 Imagineer Imagegun
SLPH-00022 Optec AI Commander Pro, digital pad with extras / lcd display
SLPH-00023 Namco Joystick (SLEH-00004)
SLPH-00024 Optec Cockpit Wheel, analog joystick/analog pedals or so
SLPH-00025 Optec AI Commander Accessory (extended memo repack ZERO2 version)
SLPH-00026 Hori Command Stick PS (SLPH-00026 aka HPS11)
SLPH-00027 ASCII Grip, single-handed digital pad (SLEH-00008)
SLPH-00028 Hori Grip (gray) (see also: SLPH-00040, and 00086..00088)
SLPH-00029 Hori Horipad (clear), digital pad
SLPH-00030 Hori Horipad (black), digital pad
SLPH-00031 Hori Horipad (gray), digital pad
SLPH-00032 Hori Horipad (white), digital pad
SLPH-00033 Hori Horipad (blue), digital pad
SLPH-00034 Namco G-CON 45, Cinch-based Lightgun (SLEH-0007/SLUH-00035)
SLPH-00035 ASCII Fighter stick V Jr. (SLEH-00009)
SLPH-00036 Optec Wireless Dual Shot, digital pad with turbo button
SLPH-00037 ?
SLPH-00038 ASCII Pad V Jr., digital pad without any extras
SLPH-00039 ASCII Pad V2 (gray), digital pad with turbo switches (SLEH-00010)
SLPH-00040 Hori Grip (black)
SLPH-00041 ASCII Grip V
SLPH-00042 ASCII Grip V plus (Derby Stallion'99 supplement set), single-hand
SLPH-00043 ASCII Pad V2 (clear pink)
SLPH-00044 ASCII Pad V2 (clear white)
SLPH-00045 ASCII Pad V2 (clear blue)
SLPH-00046 ASCII Pad V2 (clear green)
SLPH-00047 ASCII Pad V2 (clear black)
SLPH-00048 ASCII Pad V2 (clear red/lead?)
SLPH-00049 ASCII Pad V2 (clear yellow)
SLPH-00050 ASCII Pad V2 (clear orange)
SLPH-00051 Taito Streetcar GO! Controller 2 steering "wheel?" tie toe strange
SLPH-00052 Koei Video Capture, Ergosoft EGWord, and Lexmark Printer bundle
SLPH-00053 Koei Word Processor Ergosoft September EGWORD Ver.2.00
SLPH-00054 Hori Zerotech Steering Controller (black)
SLPH-00055 Hori Grip (clear blue)
SLPH-00056 Hori Grip (clear pink)
SLPH-00057 Hori Grip (clear yellow)
SLPH-00058 ASCII Pad V2 (gold)
SLPH-00059 ASCII Pad V2 (silver)
SLPH-00060 ASCII Biohazard, digital pad with re-arranged buttons (SLEH-0011)
SLPH-00061 ASCII Pad V2 (pearl white)
SLPH-00062 ASCII Pad V2 (pearl blue)
SLPH-00063 ASCII Pad V2 (pearl pink)
SLPH-00064 ASCII Pad V2 (pearl green)
SLPH-00065 ASCII Pad V Pro, with lcd for button-combinations (ASC-0508GX)
SLPH-00066 ASCII Arcade Stick 3 "Ultimate"
SLPH-00067 ASCII Pad V2 (purple metallic)
SLPH-00068 ASCII Pad V2 (lead metallic)
SLPH-00069 Namco neGcon (black) (NPC-104), Twist controller (SLEH-0003)
SLPH-00070 Sankyo Pachinko FF Controller (alternate to SLPH-00007)
SLPH-00071 Hori Command Stick PS Custom

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SLPH-00072 ASCII Command Pack (memory card add-on or so)
SLPH-00073 Optec Wireless digital set (gray)           ; \
SLPH-00074 Optec Wireless digital set (black)          ; pad with receiver
SLPH-00075 Optec Wireless digital set (clear)          ;
SLPH-00076 Optec Wireless digital set (clear blue)     ;
SLPH-00077 Optec Wireless digital set (clear black)    ;/
SLPH-00078 Optec Wireless digital shot (gray)          ; \
SLPH-00079 Optec Wireless digital shot (black)          ; extra pad for
SLPH-00080 Optec Wireless digital shot (clear)          ; second player
SLPH-00081 Optec Wireless digital shot (clear blue)    ; (without receiver)
SLPH-00082 Optec Wireless digital shot (clear black)   ;/
SLPH-00083 ASCII Stick Justice controller
SLPH-00084 Hori ZeroTech Steering Controller (clear)
SLPH-00085 Hori Compact joystick (black)
SLPH-00086 Hori Compact joystick (clear)
SLPH-00087 Hori Compact joystick (clear blue)
SLPH-00088 Hori Multi Analog Pad (clear) or Hori Grip (pink?)
SLPH-00089 Hori AV Cable with selector
SLPH-00090 Hori Multi Analogue Pad (clear black)
SLPH-00091 Hori AV Multi-Out Converter
SLPH-00092 ASCII Pad V2 (margin green)
SLPH-00093 ASCII Pad V2 (margin blue)
SLPH-00094 ASCII Pad V2 (margin pink)
SLPH-00095 ASCII Pad V2 (margin orange)
SLPH-00096 ASCII Hyper Steering V ("high pass tear ring V controller?")
SLPH-00097 Hori S Cable with selector (uh, maybe S-video or so?) (HPS-36)
SLPH-00098 NSYS COM Pachinko slot controller (NSC-1)
SLPH-00099 ASCII Pad V2 (rainbow)
SLPH-00100 ASCII 'Hanging' Fishing Controller, controller for fishing games
SLPH-00101 Optec Cockpit big shock
SLPH-00102 ASCII Grip V (set for mars story)
SLPH-00103 Hori Pad V2 (clear)
SLPH-00104 Hori Pad V2 (clear blue)
SLPH-00105 Hori Pad V2 (clear pink)
SLPH-00106 Hori Pad V2 (black)
SLPH-00107 Hori Compact Joystick (camouflage)
SLPH-00108 Hori Rumble Digital Pad (clear blue)
SLPH-00109 Hori Monoaural AV Cable
SLPH-00110 ASCII Pad V2 (marble)
SLPH-00111 ASCII Pad V2 (camouflage)
SLPH-00112 ASCII Pad V3
SLPH-00113 ASCII Pad V3 with cable reel
SLPH-00114 ASCII Pad V3 with V2 (pearl white) bundle
SLPH-00115 ASCII Pad V3 with V2 (pearl pink) bundle
SLPH-00116 ASCII Pad V3 with V2 (pearl blue) bundle
SLPH-00117 ASCII Pad V3 (blue) with V2 (pearl green) bundle
SLPH-00118 Hori Pad V3
SLPH-00119 Hori Pad V3 (white)
SLPH-00120 Hori Analog Rumble Pad (clear pink)
SLPH-00121 Hori Analog Rumble Pad (clear)
SLPH-00122 Hori Analog Rumble Pad (clear blue)
SLPH-00123 Hori Analog Rumble Pad (clear red)
SLPH-00124 Hori Analog Rumble Pad (clear black)
SLPH-00125 Hori Analog Rumble Pad (clear yellow)

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SLPH-00126 Namco Jogcon, digital pad, steering dial (SLEH-0020/SLUH-00059)
 SLPH-00127 ?
 SLPH-00128 ASCII stick ZERO3
 SLPH-00129 ASCII Pad V2 (wood grain pitch)
 SLPH-00130 Hori Real Arcade (camouflage)
 SLPH-00131 Hori Ehrgeiz Stick
 SLPH-00132 ASCII Pad V3 (blue)
 SLPH-00133 ASCII Fighter Stick V Jr. (limited edition)
 SLPH-00134 ASCII Pad V3 (blue) with cable reel
 SLPH-00135 ASCII Pad V3 (blue) with V2 (silver)
 SLPH-00136 ASCII Pad V3 with V2 (purple metallic)
 SLPH-00137 ASCII Pad V3 with V2 (gold)
 SLPH-00138 ASCII Pad V3 with "VPRO. aka Ascii Fighter Stick V"
 SLPH-00139 Hori Analog Rumble Pad (gray)
 SLPH-00140 Hori Analog Rumble Pad (black)
 SLPH-00141 Hori Analog Rumble Pad (blue)

And, maybe unlicensed (they don't have official SLPH numbers, still they are listed as official controllers on PSX CDROM back covers):

ASC-05158B ASCII Beatmania Junk (similar to SLEH-0021)
 ASC-0528T Sammy Shakkato Tambourine
 BANC-0001 Bandai Fishing Controller
 BANC-0002 Bandai Kids Station
 RU017 Konami Dance Dance Revolution Controller (Dance Mat)
 GAE001 G.A.E. Baton stick with 2 buttons (for The Maestromusic)

And whatever:

RU029 Konami Beatmania IIDX
 RU014 Konami Pop'n Music (buttons A,B,C,D,E,F,G,H,I, and Select/Start)
 RU014-J2 Konami Pop'n Controller 2
 RU036 Konami Pop'n Controller (Arcade Style)
 ? Produce! Paca Paca Passion
 ? Sega/Ascii Minimoni Shakatto Tambourine

Sony Licensed Hardware (Europe)

SLEH-00001 Ascii Specialized Pad (similar to SLPH-00005: ASCII ASCIIPAD V)
 SLEH-00002 Ascii Arcade Stick, psx-shaped digital stick (SLPH-00003)
 SLEH-00003 Namco Negcon, Twist controller (SLPH-00001)
 SLEH-00004 Namco Arcade Stick (SLPH-00023)
 SLEH-00005 Konami Hyper Blaster, IRQ10-based Lightgun (SLPH-00014/SLUH-00017)
 SLEH-00006 Mad Catz Steering Wheel (SLPH-?)
 SLEH-00007 Namco G-Con 45, Cinch-based Lightgun (SLPH-00034/SLUH-00035)
 SLEH-00008 Ascii Grip, single-handed digital pad (SLPH-00027/SLUH-00038)
 SLEH-00009 Ascii Arcade Stick v2 (SLPH-00035)
 SLEH-00010 Ascii Enhanced Control Pad (similar as SLEH-00001) (SLPH-00039)
 SLEH-00011 Resident Evil Pad (aka SLPH-00060 ASCII Biohazard)
 SLEH-00012 Reality-Quest The Glove (right-handed only) (SLUH-00045/SLPH-?)

SLEH-00013 CD Case (small nylon bag for fourteen CDs) (SLPH-?)
 SLEH-00014 ?
 SLEH-00015 PlayStation Case (bigger bag for the console) (SLPH-?)
 SLEH-00016 PlayStation Case + Digital Joypad + Memory Card
 SLEH-00017 ?
 SLEH-00018 Ascii Sphere 360 (SLUH-00028/SLPH-?)
 SLEH-00019 Interact V3 Racing Wheel (SLPH-?)
 SLEH-00020 Namco JogCon, digital pad, steering dial (SLPH-00126/SLUH-00059)
 SLEH-00021 Konami Beatmania Controller (SLPH-?)
 SLEH-00022 ?
 SLEH-00023 Official Dance Mat (RU017/SLUH-00071) (for PSone and PS2)
 SLEH-00024 Fanatec Speedster 2 (wheel with pedals) (for PSone and PS2)
 SLEH-00025 Mad Catz 8MB Memory Card (for PS2)
 SLEH-00026 Olympus Eye-Trek FMD-20P Game/DVD glasses (for PS2)
 SLEH-00027 Logitech Cordless Controller... or Eye-Trek FMD-20P, too? (PSx?)
 SLEH-00028 ?
 SLEH-00029 Fanatec Speedster 3 (for PS2)
 SLEH-00030 Logitech Eye Toy (camera?) (for PS2)

And, maybe unlicensed:

Mad Catz Wrist Rumbler (rumble add-on for pre-dualshock controllers)

Sony Licensed Hardware (USA)

SLUH-00001 Specialized Joystick (single-axis, digital?)
 SLUH-00002 Control Pad (redesigned joypad)
 SLUH-00003 InterAct Piranha Pad, digital pad, autofire/slowmotion
 SLUH-00017 Konami Justifier, IRQ10-based Lightgun (Hyperblaster/SLPH-00014)
 SLUH-00018 Enhanced Pad (joypad with whatever extra functions)
 SLUH-00022 Analog and Digital Steering Wheel with pedals (for testdrive 4?)
 SLUH-00026 Optec Mach 1 (gray steering/flight controller with pedals)
 SLUH-00028 Ascii Sphere 360 (SLEH-00018)
 SLUH-00029 Namco NPC-102 Joystick (single-axis, digital?)
 SLUH-00031 Interact Program Pad
 SLUH-00033 Piranha Pad (redesigned joypad)
 SLUH-00034 NUBY Manufacturing The Heater, white lightgun (irq10 or cinch?)
 SLUH-00035 Namco G-CON 45, Cinch-based Lightgun (SLEH-0007/SLPH-00034)
 SLUH-00037 Arcade Stick (single-axis, digital?)
 SLUH-00038 ASCII Grip V, single-handed digital pad (SLPH-00027/SLEH-00008)
 SLUH-00040 System Organizer (huh? looks like... a black storage box?)
 SLUH-00041 V3 Racing Wheel with pedals
 SLUH-00043 GunCon (bundled with Time Crisis 1)
 SLUH-00044 Remote Wizard (looks like wireless joypad or so)
 SLUH-00045 Reality-Quest The Glove (right-handed only) (SLEH-00012/SLPH-?)
 SLUH-00046 GunCon (bundled with Point Blank)
 SLUH-00055 Aftershock Wheel with pedals
 SLUH-00056 UltraRacer Steering Controller (grip-style)
 SLUH-00057 EA Sports Game Pad (redesigned joypad)
 SLUH-00058 something for point blank 2 (?) (maybe a lightgun)
 SLUH-00059 Namco Jogcon, digital pad, steering dial (SLEH-0020/SLPH-00126)

SLUH-00061 MadCatz MC2 Racing Wheel (black/gray)
 SLUH-00063 Bass Landing Fishing Reel controller
 SLUH-00066 Sportster racing wheel
 SLUH-00068 Jungle Book Rhythm N Groove Dance Pack
 SLUH-00071 Konami Dance Pad (DDR Dance Pad) (RU017)
 SLUH-00072 GunCon (bundled with Point Blank 3)
 SLUH-00073 GunCon (bundled with Time Crisis 2 - Project Titan)
 SLUH-00077 Logitech Cordless Controller, analog pad (ps1/ps2)
 SLUH-00081 Logitech NetPlay Controller, pad with keyboard (usb/ps2)
 SLUH-00083 Konami Dance Dance Revolution Controller (for PS1 and PS2)
 SLUH-00084 NYKO iType2, pad with keyboard (usb/ps2)
 SLUH-00085 Logitech Cordless Action Controller (for PS2)
 SLUH-00086 Namco/Taiko Drum Master (Taiko Controller Pack) (for PS2)
 SLUH-00088 RedOctane In the Groove Dance Pad Controller ?
 SLUH-00090 Dance Pad (bundled with Pump It Up) (for PS2)

Sony Licensed Hardware (Asia)

Unknown (if any)

Newer hardware add-ons?

SCEH-0001 SingStar (USB to Microfon) (for PS2)

Note

Early SLEH/SLUH devices used 4-digit numbers (eg. the "official" name for SLEH-00003 is SLEH-0003; unlike as shown in the above list).

Software (CDROM Game Codes)

SCES-NNNNN Sony Computer Europe Software
 SCED-NNNNN Sony Computer Europe Demo
 SLES-NNNNN Sony Licensed Europe Software
 SLED-NNNNN Sony Licensed Europe Demo
 SCPS-NNNNN Sony Computer Japan Software
 SLPS-NNNNN Sony Licensed Japan Software
 SLPN-NNNNN Sony Licensed Japan ... ?
 SCUS-NNNNN Sony Computer USA Software
 SLUS-NNNNN Sony Licensed USA Software
 PAPX-NNNNN Demo ...?
 LSPN-NNNNNN Lightspan series (non-retail educational games)

Note: Multi-disc games have more than one game code. The game code for Disc 1 is also printed on the CD cover, and used in memory card filenames. The per-disk game codes are printed on the discs, and are used as boot-executable name in SYSTEM.CNF file.

There is no fixed rule for the multi-disc numbering; some games are using increasing numbers of XNNNN or NNNNX (with X increasing from 0 upwards), and some are randomly using values like NNNXX and NNNYY for different discs.

24. Pinouts

External Connectors

[Pinouts - Controller Ports and Memory-Card Ports](#)

[Pinouts - Audio, Video, Power, Expansion Ports](#)

[Pinouts - SIO Pinouts](#)

Internal Pinouts

[Pinouts - Chipset Summary](#)

[Pinouts - CPU Pinouts](#)

[Pinouts - GPU Pinouts \(for old 160-pin GPU\)](#)

[Pinouts - GPU Pinouts \(for new 208-pin GPU\)](#)

[Pinouts - SPU Pinouts](#)

[Pinouts - DRV Pinouts](#)

[Pinouts - VCD Pinouts](#)

[Pinouts - HC05 Pinouts](#)

[Pinouts - MEM Pinouts](#)

[Pinouts - CLK Pinouts](#)

[Pinouts - PWR Pinouts](#)

[Pinouts - Component List and Chipset Pin-Outs for Digital Joypad, SCPH-1080](#)

[Pinouts - Component List and Chipset Pin-Outs for Analog Joypad, SCPH-1150](#)

[Pinouts - Component List and Chipset Pin-Outs for Analog Joypad, SCPH-1200](#)

[Pinouts - Component List and Chipset Pin-Outs for Analog Joypad, SCPH-110](#)

[Pinouts - Component List and Chipset Pin-Outs for Namco Lightgun, NPC-103](#)

[Pinouts - Component List and Chipset Pin-Outs for Multitap, SCPH-1070](#)

[Pinouts - Memory Cards](#)

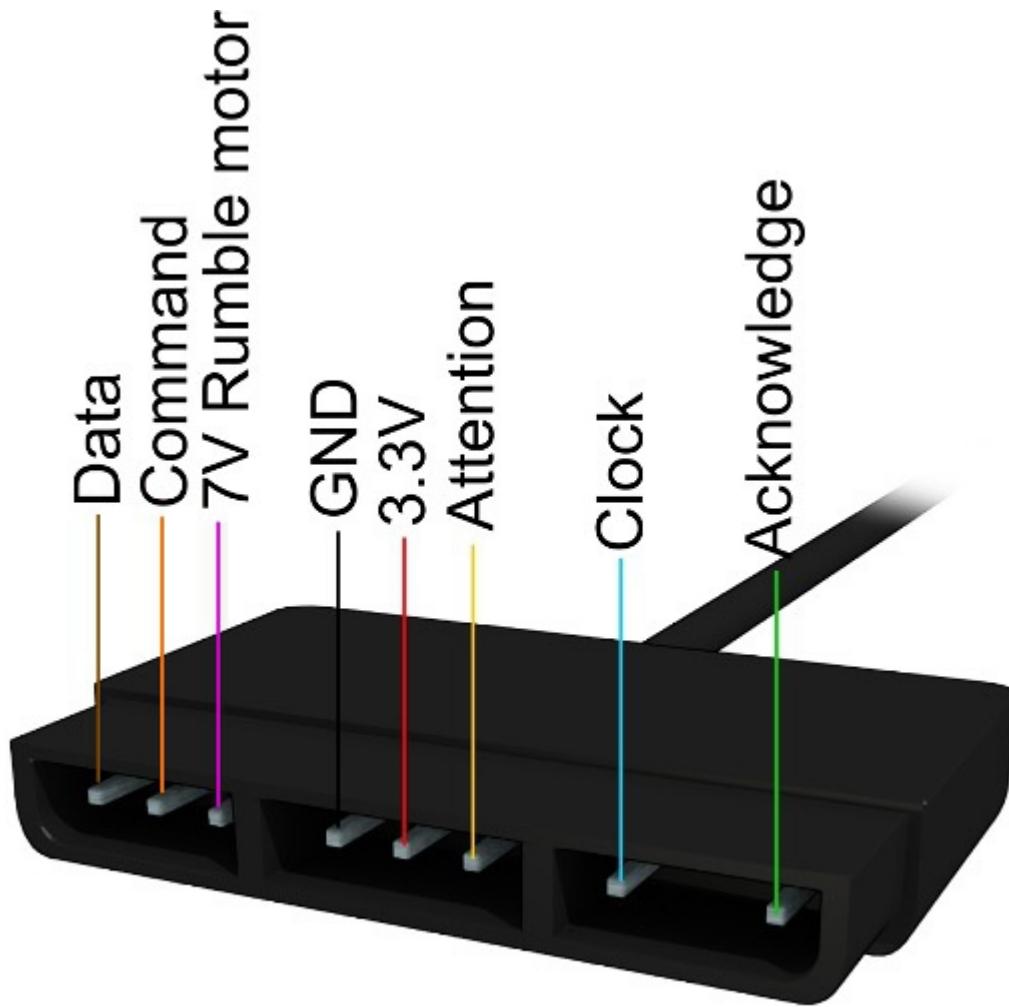
Mods/Upgrades

[Mods - Nocash PSX-XBOO Upload](#)

[Mods - PAL/NTSC Color Mods](#)

24.1 Pinouts - Controller Ports and Memory-Card Ports

Controller Ports and Memory-Card Ports



`/JOYn` are two separate signals (`/JOY1` for left card/pad, `/JOY2` for right card/pad) (whether it is an card or pad access depends on the first CMD bit). All other signals are exactly the same on all four connectors (except that pin8 and shield are missing on the card slots).

Pin8 (/IRQ10)

Most or all controllers leave pin8 unused, the pin can be used as lightpen input (not sure if the CPU is automatically latching a timer somewhere?), if there's no auto-latched timer, then the interrupt would be required to be handled as soon as possible; ie. don't disable interrupts, and don't "halt" the CPU for longer periods (as far as I understood, the GTE can halt the CPU when trying to read results of incomplete operations; to avoid that, one could wait by software, eg. inserting NOPs, before reading GTE results...?)
 (Some (or maybe all?) existing psx lightguns are reportedly connected to the Video output on the Multiout port for determining the current cathode ray position though).

24.2 Pinouts - Audio, Video, Power, Expansion Ports

AV Multi Out (Audio/Video Port)

1	RGB-Video Green	
2	RGB-Video Red	
3	Supply +5.0V (eg. supply for external RF adaptor)	
4	RGB-Video Blue	
5	Supply Ground	
6	S-Video C (chrominance)	
7	Composite Video (yellow cinch)	
8	S-Video Y (luminance)	
9	Audio Left (white cinch)	_____
10	Audio Left Ground	12 11 10 9 8 7 6 5 4 3 2 1
11	Audio Right (red cinch)	_____
12	Audio Right Ground	
	Shield Video Ground	

The standard AV-cable connects only to Pins 7,9,10,11,12,Shield (with pin 1 and 3 and Shield shortcut with each other, used for both audio and video ground).

The plug on that cable does have additional sparsings for pin 1,3,5 (though without any metal-contacts installed in there) (pin 3,5 would be used as supply for external RF modulators) (no idea what pin 1 could be used for though?).

RGB displays may (or may not) be able to extract /SYNC from the Composite signal, if that doesn't work, note that /SYNC (and separate /VSYNC, /HSYNC signals) are found on the GPU pinouts, moreover, the GPU outputs 24bit digital RGB.

Not sure if a VGA monitor can be connected? The SYNC signals are there (see GPU pininputs), but the vertical resolution is only 200/240 lines... standard VGA displays probably support only 400/480 lines (or higher resolutions for newer multisync SVGA

displays) (as far as I know, the classic 200 lines VGA mode is actually outputting 400 lines, with each line repeated twice).

Parallel Port (PIO) (Expansion Port) (CN103)

This port exists only on older PSX boards (not on newer PSX boards, and not on PSone boards).

The parallel port is used by Gameshark, Game Enhancer II, and Gold Finger cheat devices (not used by the Code Breaker CDROM cheat software).

			Console Rear View
GND	== 1	35 == GND	.
/RESET	= 2	36 = DACK5	1 2 3 32 33 34
DREQ5	= 3	37 = /IRQ10	35 36 37 66 67 68
/EXP?	= 4	38 = /WR1? (CPU99)	_____.-----. _
NC?GND?	= 5	39 = GND?NC?	
D0	= 6	40 = D1	
D2	= 7	41 = D3	
D4	= 8	42 = D5	
D6	= 9	43 = D7	
D8	= 10	44 = D9	
D10	= 11	45 = D11	
D12	= 12	46 = D13	
D14	= 13	47 = D15	
A0	= 14	48 = A1	
A2	= 15	49 = A3	
NC?GND?	= 16	50 = GND?NC?	
+3.5V	== 17	51 == +3.5V	
+7.5V	== 18	52 == +7.5V	
GND?	= 19	53 = GND?NC?	
A4	= 20	54 = A5	
A6	= 21	55 = A7	
A8	= 22	56 = A9	
A10	= 23	57 = A11	
A12	= 24	58 = A13	
A14	= 25	59 = A15	
A16	= 26	60 = A17	
A18	= 27	61 = A19	
A20	= 28	62 = A21	
A22	= 29	63 = A23	
/RD	= 30	64 = /WR0	
NC!X?	= 31	65 = X?NC!	
SYSCK?	= 32	66 = LRCK (44.1kHz)	
SCLK?	= 33	67 = SDATA?	
GND	== 34	68 == GND	

Lots of pins are still unknown?

EDIT: see <http://cgfm2.emuvies.com/new/psx-pio.png>
 apparently, many of the "unknown" pins are just GROUND, is that possible?

Internal Power Supply (PSX)

The PSX contains an internal power supply, however, like the PSone, it's only having a "Standby" button, which merely disconnects 3.5V and 7.9V from the mainboard. The actual power supply remains powered, and wastes energy day and night, thanks Sony!

External Power Supply (PSone)

Inner +7.5V DC 2.0A (inside diameter 0.8mm)
 Outer GND (outside diameter 5.0mm)

24.3 Pinouts - SIO Pinouts

Serial Port

That port exists only on original Playstation (not on the PSone). The shape of the Serial Port is identical to the 12pin Multiout (audio/video) port, but with only 8pins.

1 SIO1 In	RXD receive data	(from remote TXD)									
2 SIO2 -	VCC +3.5VDC	(supply, eg. for voltage conversion)									
3 SIO3 In	DSR	(from remote CTS)									
4 SIO4 Out	TXD transmit data	(to remote RXD)									
5 SIO5 In	CTS clear to send	(from remote RTS)		8	7	6	5	4	3	2	1
6 SIO6 Out	DTR	(to remote DSR)									
7 SIO7 -	GND Ground	(supply, eg. for voltage conversion)									
8 SIO8 Out	RTS request to send	(to remote CTS)									
Shield	GND Ground	(to/from remote GND)									

Can be used to communicate with another PSX via simple cable connection. With an external RS232 adaptor (for voltage conversion) it could be also used to communicate with a PC, a mouse, a modem, etc.

PSone Serial Port

The PSone doesn't have an external serial connector, however, easy to use soldering points for serial port signals are found as cluster of 5 soldering points (below CPU pin52),

and a single soldering point (below CPU pin100), arranged like so (on PM-41 boards) (might be different on PM-41(2) boards):

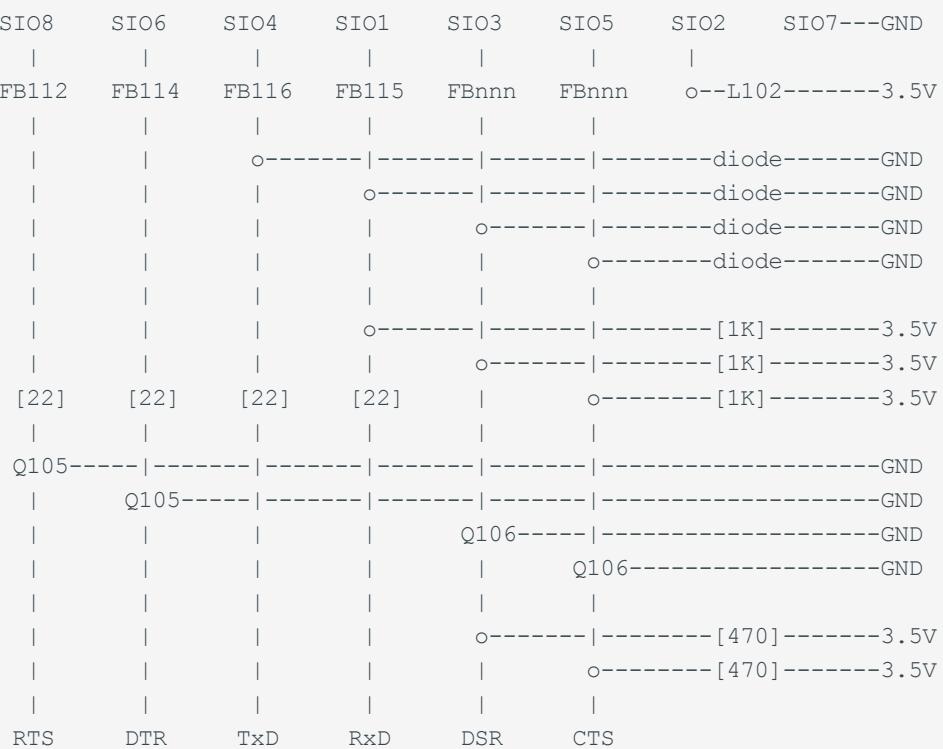
CPU70.RTS						
CPU71.CTS	CPU74.TxD					
CPU72.DTR	CPU75.RxD					
						CPU73.DSR

The three outputs (RTS,DTR,TXD) are left floating, the RXD input is wired via a 1K ohm pull-up resistor to 3.5V, the other two inputs (CTS,DSR) are wired via 1K ohm pull-down resistors to GND.

If you want to upgrade the PSone, remove that resistors, and then install the PSX-style serial circuit (as shown below), or, think of a more simplified circuit without (dis-)inverted signals.

PSX Serial Port Connection (PU-23 board) (missing on PM-41 board)

The PSX serial circuit basically consists of a few transistors, diodes, and resistors. The relevant part is that most of the signals are inverted - compared with RS232 signals, the CPU uses normal high/low levels (of course with 0V and 3.5V levels, not -12V and +12V), and the signals at the serial port socket are inverted. Ie. if you want to built a RS232 adaptor, you must either externally undo the inversion, or, disconnect the transistors, and wire your circuit directly to the CPU signals.



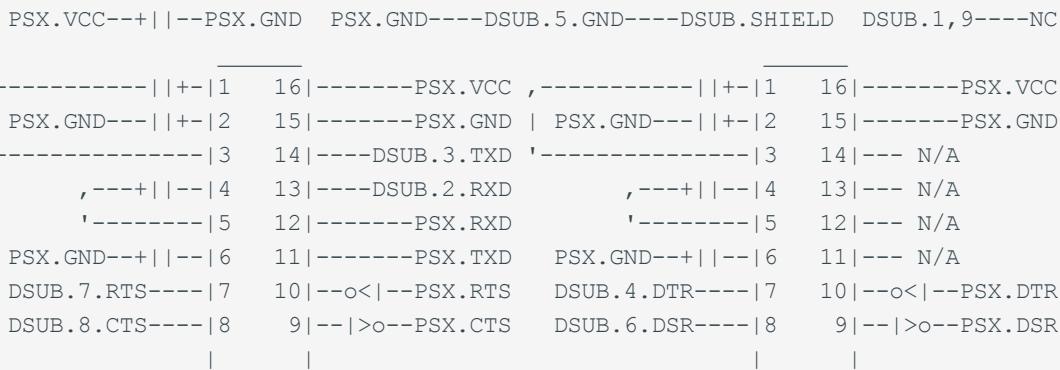
CPU70	CPU72	CPU74	CPU75	CPU73	CPU71	<-- CPU Pin Numbers
out	out	out	in	in	in	

All six signals are passed through fuses (or loops or so). The three inputs have 1K ohm pull-ups, and diodes as protection against negative voltages, two of the inputs are inverted via transistors, with 470 ohm pull-ups at the CPU side, the other input is passed through 22 ohm to the CPU. The three outputs are also passed through 22 ohm, one of them having a diode as negative voltage protection, the other two are inverted via transistors (which may also serve as negative voltage protection).

Note that there is no positive voltage protection (ie. +12V inputs would do no good, also strong -12V inputs might overheat the diodes/fuses, so if you want to use RS232 voltages, better use a circuit for voltage conversion).

Serial RS232 Adaptor

The PSX serial port uses 0V/3.5V logic, whilst RS232 uses -5V/+5V...-15V/+15V logic. An example circuit for converting the logic levels would be:



Parts List: 1 or 2 MAX232 chips (voltage conversion), 0 or 1 7400 (NAND, used as inverter), 4 or 8 1uF/16V capacitors, 1x 10uF/16V capacitor, 1x 9pin male SubD plug. The four inverters are needed only for external adapters (which need to undo the transistor inversion on the PSX mainboard) (ie. the inverters are not needed when connecting the circuit directly to the PSX CPU).

The second MAX232 chip is needed only if DTR/DSR "not ready" conditions are required (for an "always ready" condition: DSUB.4.DTR can be wired to -8.5V, which is available at Pin6 of the first MAX232 chip, and PSX.DSR can be wired to +3.5V).

With the above DSUB pin numbers, peripherals like mice or modems can be connected directly to the circuit. For connection to another computer, use a "null modem" cable (with crossed RXD/TXD, RTS/CTS, DTR/DSR wires).

The circuit works with both VCC=5V (default for MAX232) and with VCC=3.5V (resulting

in slightly weaker signals, but still strong enough even for serial mice; which are misusing the RS232 signals as power supply).

24.4 Pinouts - Chipset Summary

PSX/PSone Mainboards

Board	Expl.
PU-7	PSX, with AV multiout+cinch+svideo, GPU in two chips (160+64pins)
PU-8	PSX, with AV multiout+cinch, four 8bit Main RAM chips EARLY-PU-8: "PU-8 1-658-467-11, N4" --> old chipset, resembles PU-7 LATE-PU-8: "PU-8 1-658-467-22, N6" --> new chipset, other as PU-7
PU-9	PSX, without SCPH-number (just sticker saying "NOT FOR SALE, SONY")
PU-16	PSX, with extra Video CD daughterboard (for SCPH-5903)
PU-18	PSX, with AV multiout only, single 32bit Main RAM (instead 4x8bit)
PU-20	PSX, unknown if/how it differs from PU-18
PU-22	PSX, unknown if/how it differs from PU-18
PU-23	PSX, with serial port, but without expansion port
PM-41	PSone, older PSone, for GPU/SPU with RAM on-board (see revisions)
PM-41(2)	PSone, newer PSone, for GPU/SPU with RAM on-chip

There are at least two revisions of the "PM-41" board:

PM-41, 1-679-335-21	PSone with incomplete RGB signals on multiout port
PM-41, 1-679-335-51	PSone with complete RGB signals on multiout port

The "incomplete" board reportedly requires to solder one wire to the multiout port to make it fully functional... though no idea which wire... looks like the +5V supply? Also, the capacitors near multiout are arranged slightly differently.

CPU chips

IC103 - 208pin - "SONY CXD8530BQ"	; seen on PU-7 board
IC103 - 208pin - "SONY CXD8530CQ"	; seen on PU-7 and PU-8 boards
IC103 - 208pin - "SONY CXD8606Q"	; seen in PU-18 schematic
IC103 - 208pin - "SONY CXD8606AQ"	; seen on PU-xx? board
IC103 - 208pin - "SONY CXD8606BQ"	; seen on PM-41, PU-23, PU-20 boards
IC103 - 208pin - "SONY CXD8606CQ"	; seen on PM-41 board, too

These chips contain the MIPS CPU, COP0, and COP2 (aka GTE), MDEC and DMA.

GPU chips - Graphics Processing Unit

```

IC203 - 160pin - "SONY CXD8514Q" ;seen on PU-7 and EARLY-PU-8 boards
IC203 - 208pin - "SONY CXD8561Q" ;seen on LATE-PU-8 board
IC203 - 208pin - "SONY CXD8561BQ" ;seen on PU-18, PU-20 boards
IC203 - 208pin - "SONY CXD8561CQ" ;seen on PM-41 board
IC203 - 208pin - "SONY CXD9500Q" ;with on-chip RAM ;for PM-41(2) board
IC21 - 208pin - "SONY CXD8538Q" ;seen on GP-11 (namco System 11) boards
IC103 - 208pin - "SONY CXD8654Q" ;seen on GP-15 (namco System 12) boards

```

SPU chips - Sound Processing Unit

```

IC308 - 100pin - "SONY CXD2922Q" (SPU) ;PU-7 and EARLY-PU-8
IC308 - 100pin - "SONY CXD2922BQ" (SPU) ;EARLY-PU-8
IC308 - 100pin - "SONY CXD2925Q" (SPU) ;LATE-PU-8, PU-18, PU-20
IC732 - 208pin - "SONY CXD2938Q" (SPU+CDROM) ;PSone/PM-41 Board
IC732 - 176pin - "SONY CXD2941R" (SPU+CDROM+SPU_RAM) ;PSone/PM-41(2) Board
IC402 - 24pin - "AKM AK4309VM" (Serial 2x16bit DAC);older boards only
IC405 - 8pin - "NJM2100E (TE2)" Audio Amplifier ;PU-8 and PU-22 boards
IC405 - 14pin - "NJM2174" Audio Amplifier with Mute ;later boards

```

IC106 CPU-RAM / Main RAM chips

```

IC106/IC107/IC108/IC109 - NEC 424805AL-A60 (28pin, 512Kx8) (PU-8 board)
IC106 - "Samsung K4Q153212M-JC60" (70pin, 512Kx32) (newer boards)
IC106 - "Toshiba T7X16 (70pin, 512Kx32) (newer boards, too)

```

GPU-RAM / Video RAM chips

```

IC201 - 64pin NEC uPD482445LGW-A70-S ;VRAM ;\on PU-7 and EARLY-PU-8 board
IC202 - 64pin NEC uPD482445LGW-A70-S ;VRAM ;/split into 2 chips !
IC201 - 64pin SEC KM4216Y256G-60 ;VRAM ;\on other PU-7 board
IC202 - 64pin SEC KM4216Y256G-60 ;VRAM ;/split into 2 chips !
IC201 - 100pin - Samsung KM4132G271BQ-10 (128Kx32x2) ;-on later boards
IC201 - 100pin - Samsung K4G163222A-PC70 (256Kx32x2) ;on PM-41

```

Note: The older 64pin VRAM chips are special dual-ported DRAM, the newer 100pin VRAM chips are just regular DRAM.

Note: The PM-41 board uses a 2MB VRAM chip (but allows to access only 1MB)

Note: The PM-41(2) board has on-chip RAM in the GPU (no external memory chip)

IC310 - SPU-RAM - Sound RAM chips

```
IC310 - 40pin - "TOSHIBA TC51V4260DJ-70" ;seen on PU-8 board
IC310 - 40pin - EliteMT M11B416256A-35J (256K x 16bit)
```

Note: The PM-41(2) board has on-chip RAM in the SPU (no external memory chip)

BIOS ROM

```
IC102 - 40pin - "SONY ..." ;seen on PU-7 & early-PU-8 board (40pin!)
IC102 - 44pin - "SONY M538032E-02" ;seen on PU-16 (video CD, 1Mbyte BIOS)
IC102 - 32pin - "SONY M534031C-25" ;seen on later-PU-8 board
IC102 - 32pin - "SONY 2030" ;seen on PU-18 board
IC102 - 32pin - "SONY M534031E-47" ;seen on PM-41 board and PM-41(2)
IC102 - 32pin - "SONY M27V401D-41" ;seen on PM-41 board, too
```

Oscillators and Clock Multiplier/Divider

```
X101 - 4pin - "67.737" (NTSC, presumably) ;PU-7 .. PU-20
X201 - 2pin - "17.734" (PAL) or "14.318" (NTSC) ;PU-22 .. PM-41(2)
IC204 - 8pin - "2294A" (PAL) or <unknown?> (NTSC) ;PU-22 .. PM-41(2)
```

Voltage Converter (for +7.5V to +5.0V conversion)

```
IC601 - 3pin - "78M05" or "78005" ;used in PSone
```

Pulse-Width-Modulation Power-Control Chip

```
IC606 16pin/10mm "TL594CD" (alternately to IC607) ;seen on PM-41 board
IC607 16pin/5mm "T594" (alternately to IC606) ;seen on PM-41 board, too
```

The PM-41 board has locations for both IC606 and IC607, some boards have the bigger IC606 (10mm) installed, others the smaller IC607 (5mm), both chips have exactly the same pinouts, the only difference is the size.

Reset Generator

```
IC002 - 8pin - <not installed> (would be alternately to IC003) ;\on PSone
IC003 - 5pin - <usually installed> ;/
IC101 - 5pin - M51957B (Reset Generator) (on PSX-power supply boards)
```

CDROM Chips

```

U42    80pin   SUB-CPU (CXP82300) with piggyback EPROM ;DTL-H2000
IC304  80pin   SUB-CPU (MC68HC05L16) 80pin package      ;PU-7 and EARLY-PU-8
IC304  52pin   SUB-CPU (MC68HC05G6) 52pin package      ;LATE-PU-8 and up
IC305 - 100pin SONY CXD1199BQ (Decoder/FIFO)        ;PU-7
IC305 - 100pin SONY CXD1815Q (Decoder/FIFO)        ;PU-8, PU-18
IC309 - 100pin SONY CXD2516Q (Signal Processor)     ;PU-7 (100pin!)
IC309 - 80pin  SONY CXD2510Q (Signal Processor)     ;PU-8 and DTL-H2510
IC702 - 48pin  SONY CXA1782BR (Servo Amplifier)     ;PU-7, PU-8
IC101 - 100pin SONY CXD2515Q (=CXD2510Q+CXA1782BR) ;DTL-H2010
IC701 - 100pin SONY CXD2545Q (=CXD2510Q+CXA1782BR) ;PU-18
IC720 - 144pin SONY CXD1817R (=CXD2545Q+CXD1815Q)   ;PU-20
IC102 - 28pin  "BA6297AFP"                         ;seen on DTL-H2010 drives
IC704 - 28pin  "BA6398FP"                           ;seen on PU-7
IC722 - 28pin  "BA6397FP"                           ;seen on late PU-8
IC722 - 28pin  "BA5947FP"                           ;seen on PM-41 and various boards
IC722 - 28pin  "Panasonic AN8732SB"               ;seen on PM-41 board
ICxxx - 20pin  SONY CXA1571N (RF Amplifier) (on DTL-H2010 drives)
IC703 - 20pin  SONY CXA1791N (RF Amplifier) (on PU-18 boards)
IC723 - 20pin  SONY CXA2575N-T4 (RF Matrix Amplifier) (on PU-22 .. PM-41(2))

```

Note: The SUB-CPU contains an on-chip BIOS (which does exist in at least seven versions, plus US/JP/PAL-region variants, plus region-free debug variants).

RGB Chips

```

IC207 64pin "SONY CXD2923AR" VRAM Data to Analog RGB      ;\oldest
IC501 24pin "SONY CXA1645M" Analog RGB to Composite       ;/
IC202 44pin "Philips TDA8771H" Digital RGB to Analog RGB  ;\old boards
IC202 44pin "Motorola MC141685FT" Digital RGB to Analog RGB ;/
IC?   48pin "H7240AKV" 24bit RGB to Analog+Composite      ;-SCPH-7001?
IC502 48pin "SONY CXA2106R-T4" 24bit RGB to Analog+Composite ;-newer boards

```

MISC

```

CDROM Drive: "KSM-440BAM" ;seen used with PM-41 board
IC602 5pin          "L/\1B" or "<symbol> 3DR"

```

Controller/Memory Card Chips

```

U? 24pin "9625H, CFS8121"      ;SCPH-1080, digital pad (alternate?)
U? ?pin "SC438001"            ;SCPH-1080, digital pad (alternate?)
U? 32pin "(M), SC401800"      ;SCPH-1080, digital pad
U? 32pin "(M), SC442116"      ;SCPH-xxxx, mouse
IC? 64pin "SONY CXD103, -166Q" ;SCPH-1070, multitap
U1 42pin "SD657, 9702K3006"   ;SCPH-1150, analog pad, single motor

```

U1	42pin "SD657, 9726K3002"	;SCPH-1180, analog pad, without motor
U1	44pin "SONY CXD8771Q"	;SCPH-1200, analog pad, two motors (PSX)
U1	44pin "SD707, 039 107"	;SCPH-110, analog pad, two motors (PSone)
U1	44pin "SD787A"	;SCPH-xxx, analog pad, two motors (PS2?)
U?	64pin "SONY CXD8732AQ"	;SCPH-1020, memory card, on-chip FLASH
U?	XXpin other chips	;SCPH-xxxx, memory card, external FLASH
U1	44pin "NAMCO103P"	;NPC-103, namco lightgun

24.5 Pinouts - CPU Pinouts

CPU Pinouts (IC103)

1-3.5V	27-GND	53-3.5V	79-3.5V	105-3.5V	131-3.5V	157-3.5V	183-3.5V
2-3.5V	28-DQ12	54-3.5V	80-/JOY1	106-3.5V	132-A5	158-3.5V	184-GD19
3-67/NC	29-DQ11	55-A11:A8	81-JOYCLK	107-D0	133-A6	159-HBLANK	185-GD20
4-67MHz	30-DQ10	56-A10:NC	82-/IRQ7	108-D1	134-A7	160-DOTCLK	186-GD21
5-DQ31	31-DQ9	57-A9	83-JOYCMD	109-D2	135-A8	161-GD0	187-GD22
6-DQ30	32-DQ8	58-A8:NC	84-JOYDAT	110-D3	136-A9	162-GD1	188-GD23
7-DQ29	33-DQ7	59-A7	85-DACK5	111-D4	137-A10	163-GD2	189-GD24
8-DQ28	34-DQ6	60-A6	86-DREQ5	112-D5	138-A11	164-GD3	190-GD25
9-DQ27	35-DQ5	61-A5	87-DMA4	113-D6	139-A12	165-GD4	191-GD26
10-DQ26	36-DQ4	62-A4	88-/SPUW	114-D7	140-A13	166-GD5	192-GD27
11-DQ25	37-DQ3	63-A3	89-/IRQ10	115-D8	141-A14	167-GD6	193-GD28
12-DQ24	38-3.5V	64-A2	90-/IRQ9	116-D9	142-A15	168-GD7	194-GD29
13-DQ23	39-GND	65-GND	91-GND	117-GND	143-GND	169-GD8	195-GND
14-3.5V	40-DQ2	66-3.5V	92-3.5V	118-3.5V	144-3.5V	170-GND	196-3.5V
15-GND	41-DQ1	67-A1	93-GND	119-D10	145-A16	171-3.5V	197-GD30
16-DQ22	42-DQ0	68-A0	94-/IRQ2	120-D11	146-A17	172-GD9	198-GD31
17-DQ21	43-/W	69-3.5V	95-/CD	121-D12	147-A18	173-GD10	199-VBLANK
18-DQ20	44-/RAS1	70-RTS	96-/SPU	122-D13	148-A19	174-GD11	200-GPU12
19-DQ19	45-/RAS	71-CTS	97-/BIOS	123-D14	149-A20	175-GD12	201-33MHzG
20-DQ18	46-/CAS3	72-DTR	98-/EXP	124-D15	150-A21	176-GD13	202-GPU5
21-DQ17	47-/CAS2	73-DSR	99-CPU99	125-A0	151-A22	177-GD14	203-/GWR
22-DQ16	48-/CAS1	74-TxD	100-/WR	126-A1	152-A23	178-GD15	204-/GRD
23-DQ15	49-/CAS0	75-RxD	101-/RD	127-A2	153-GPU.A2	179-GD16	205-/GPU
24-DQ14	50-3.5V	76-/RES	102-/IRQ1	128-A3	154-33MHzS	180-GD17	206-67MHzG
25-DQ13	51-GND	77-/JOY2	103-GND	129-A4	155-GND	181-GD18	207-GND
26-3.5V	52-GND	78-GND	104-GND	130-GND	156-GND	182-GND	208-GND

Pin5-68 = Main RAM bus. Pin 95-152 = System bus. Pin 102,153,159-206 = Video bus.

85=DACK5	93=GND=/CSHTST	199=/INT0	44=/RAS1:NC
86=DREQ5	99=/SWR1=NC	200=DREQ2	45=/RAS0
87=DACK4	100=/SWR0	201=SYSCLK0	
88=DREQ4	154=SYSCLK1	202=DACK2	

CPU Pinout Notes

Pin 3,4: 67MHz is Pin3/old or Pin4/new (with Pin3=NC/new or Pin4=GND/old)

Pin 43,45..49,100,101,125(A0!),201,203..206 are connected via 22 ohm.

Pin 77,80,81,83 are connected via 470 ohm.

Pin 82,84,89 are connected via 47 ohm.

Pin 95,96,97 are connected via 100 ohm.

Pin 44: goes LOW for a short time once every N us (guessed: maybe /REFRESH ?)

Pin 4: 67MHz (from IC204.pin5)

Pin 87/88: SPU-DMA related (/SPUW also permanent LOW for Manual SPU-RAM Write)

Pin 154: 33MHzS (via 22ohm and FB102 to SPU) (and TESTPOINT near MainRAM pin70)

Pin 160: DOTCLK (via 22ohm), and IC502.Pin41 (without 22ohm)

Pin 56,58 are maybe additional address lines for the addressable 8MB RAM.

The System Bus address lines are latched outputs (containing the most recently used / BIOS /EXP /SPU /CD address) (not affected by Main RAM and GPU addressing).

24.6 Pinouts - GPU Pinouts (for old 160-pin GPU)

Old 160-pin GPU is used on PU-7 boards and EARLY-PU-8 boards.

IC203 - Sony CXD8514Q - Old 160pin GPU for use with Dual-ported VRAM

Unlike the later 208pin GPU's, the old 160pin GPU has less supply pins, and, it doesn't have a 24bit RGB output (nor any other video output at all), instead, it's used with a RGB D/A converter that reads the video data directly from the Dual-ported VRAM chips (ie. from special RAM chips with two data busses, one bus for GPU read/write access, and one for the RGB video output).

1-VCC	21-GND	41-D16	61-D2	81-D12'a	101-GND	121-D7'b	141-GND
2-GND	22-D31	42-D15	62-D1	82-D11'a	102-DT/OE'b	122-D6'b	142-53MHz
3-/GPU	23-D30	43-VCC	63-D0	83-D10'a	103-DT/OE'a	123-D5'b	143-VCC
4-GPU.A2	24-D29	44-GND	64-GND	84-D9'a	104-/RAS	124-D4'b	144-GND
5-/GRD	25-D28	45-D14	65-VCC	85-D8'a	105-/WE'a	125-D3'b	145-FSC
6-/GWR	26-D27	46-D13	66-A8'a	86-VCC	106-/WE'b	126-D2'b	146-VCC
7-DACK2	27-D26	47-D12	67-A7'a	87-GND	107-/SE	127-D1'b	147-GND
8-/RES	28-VCC	48-D11	68-A6'a	88-D7'a	108-SC	128-D0'b	148-DOTCLK
9-VCC	29-GND	49-D10	69-A5'a	89-D6'a	109-VCC	129-VCC	149-VCC
10-GND	30-D25	50-GND	70-GND	90-D5'a	110-GND	130-GND	150-GND
11-33MHzG	31-D24	51-VCC	71-A4'a	91-D4'a	111-D15'b	131-A8'b	151-MEMCK1
12-VCC	32-D23	52-D9	72-A3'a	92-D3'a	112-D14'b	132-A7'b	152-MEMCK2
13-GND	33-D22	53-D8	73-A2'a	93-D2'a	113-D13'b	133-A6'b	153-BLANK
14-DREQ2	34-D21	54-D7	74-A1'a	94-D1'a	114-D12'b	134-A5'b	154-/24BPP
15-/IRQ1	35-D20	55-D6	75-A0'a	95-D0'a	115-D11'b	135-A4'b	155-/SYNC

16-HBLANK	36-VCC	56-D5	76-GND	96-VCC	116-D10'b	136-A3'b	156-/HSYNC
17-VBLANK	37-GND	57-D4	77-VCC	97-DSF	117-D9'b	137-A2'b	157-/VSYNC
18-high?	38-D19	58-D3	78-D15'a	98-/CAS'b	118-D8'b	138-A1'b	158-VCC
19-high?	39-D18	59-GND	79-D14'a	99-/CAS'a	119-VCC	139-A0'b	159-GND
20-VCC	40-D17	60-VCC	80-D13'a	100-VCC	120-GND	140-VCC	160-67MHzG

Pin 1-63,148,160 = CPU Bus, Pin 66-139 = VRAM Bus (two chips, A and B), Pin 142-155 = Misc (CXA and RGB chips), Pin 18-19,156-157 = Test points.

Pin 3,5,6,11,98,99,102,103,108,148,160 via 22 ohm. Pin 104,105,106 via 100 ohm.

Pin 107 via 220 ohm. Pin 155 via 2200 ohm. Pin 145 via 220+2200 ohm.

151-?	---	(mem clock?)
152-?		(mem clock?)
153-BLANK		(high in HBLANK & VBLANK)
154-/24BPP		(high=15bpp, low=24bpp)
156-/HSYNC		rate:65us=15KHz, low:3.5us
157-/VSYNC		rate:20ms=50Hz, low:130us=TwoLines

IC207 - SONY CXD2923AR - Digital VRAM to Analog RGB Converter (for old GPU)

This chip is used with the old 160pin GPU and two Dual-ported VRAM chips. The 2x16bit databus is capable of reading up to 32bits of VRAM data, and the chip does then extract the 15bit or 24bit RGB values from that data (depending on the GPU's current color depth).

The RGB outputs (pin 5,7,9) seem to be passed through transistors and capacitors... not sure how the capacitors could output constant voltage levels... unless the RGB signals are actually some kind of edge-triggering PWM pulses rather than real analog levels(?)

1-test?	9-BLUE	17-GND	25-D0'a	33-D8'a	41-D15'a	49-D7'b	57-D13'b
2-test?	10-Vxx	18-MEMCK1	26-D1'a	34-D9'a	42-D0'b	50-D8'b	58-D14'b
3-Vxx	11-test?	19-/24BPP	27-D2'a	35-D10'a	43-D1'b	51-D9'b	59-D15'b
4-Vxx	12-test?	20-MEMCK2	28-D3'a	36-D11'a	44-D2'b	52-D10'b	60-GND
5-RED	13-test?	21-BLANK	29-D4'a	37-D12'a	45-D3'b	53-D11'b	61-GND
6-Vxx	14-aGND?	22-DOTCLK	30-D5'a	38-D13'a	46-D4'b	54-D12'b	62-GND
7-GREEN	15-aGND?	23-GND	31-D6'a	39-D14'a	47-D5'b	55-GND	63-test?
8-GND	16-aGND?	24-Vxx	32-D7'a	40-GND	48-D6'b	56-Vxx	64-GND

Pin 5,7,9 = RGB outputs (via transistors and capacitors?), Pin 18-22 = GPU, Pin 25-59 = VRAM (chip A and B), Pin 1-2,11-13,63 = Test points.

IC201 - 64pin NEC uPD482445LGW-A70-S or SEC KM4216Y256G-60 (VRAM 256Kx16)**IC202 - 64pin NEC uPD482445LGW-A70-S or SEC KM4216Y256G-60 (VRAM 256Kx16)**

These are special Dual-ported VRAM chips (with two data busses), the D0-D15 pins are wired to the GPU (for read/write access), the Q0-Q15 pins are wired to the RGB D/A converter (for sequential video output).

1-VCC	9-Q2	17-D5	25-/UWE	33-GND	41-DSF	49-Q10	57-VCC
2-/DT/OE	10-D2	18-VCC	26-/RAS	34-A3	42-GND	50-D11	58-D14
3-GND	11-Q3	19-Q6	27-A8	35-A2	43-D8	51-Q11	59-Q14
4-Q0	12-D3	20-D6	28-A7	36-A1	44-Q8	52-GND	60-D15
5-D0	13-GND	21-Q7	29-A6	37-A0	45-D9	53-D12	61-Q15
6-Q1	14-Q4	22-D7	30-A5	38-QSF	46-Q9	54-Q12	62-GND
7-D1	15-D4	23-GND	31-A4	39-/CAS	47-VCC	55-D13	63-/SE
8-VCC	16-Q5	24-/LWE	32-VCC	40-NC	48-D10	56-Q13	64-SC

The 8bit /LWE and /UWE write signals are shortcut with each other and wired to the GPU's 16bit /WE write signal.

IC501 24pin "SONY CXA1645M" Analog RGB to Composite (older boards only)

1-GND1	4-BIN	7-NPIN	10-SYNCIN	13-IREF	16-YOUT	19-VCC2	22-GOUT
2-RIN	5-NC	8-BFOUT	11-BC	14-VREF	17-YTRAP	20-CVOUT	23-ROUT
3-GIN	6-SCIN	9-YCLPC	12-VCC1	15-COUT	18-FO	21-BOUT	24-GND2

Used only on older boards (eg. PU-7, PU-8, PU-16), newer boards generate composite signal via 48pin IC502.

Pin7 (NPIN): NTSC=VCC, PAL=GND. Pin6 (SCIN aka FSC): Sub Carrier aka PAL/NTSC color clock, which can be derived from three different sources:

GPU pin 145 (old 160-pin GPU)
 GPU pin 154 (new 208-pin GPU)
 IC204 (on later boards, eg. PSone)

for the color clocks from GPU pins, the GPU does try to automatically generate PAL or NTSC clock depending on current frame rate, which is resulting in "wrong" color clock when chaning between 50Hz/60Hz mode).

24.7 Pinouts - GPU Pinouts (for new 208-pin GPU)

New 206-pin GPU is used LATE-PU-8 boards and up.

GPU Pinouts (IC203)

1-/GPU	27-GD28	53-GD10	79-D29	105-GND	131-CLK	157-/PAL	183-R3
2-GPU.A2	28-GD27	54-GD9	80-3.5V	106-3.5V	132-GND	158-/VSYNC	184-GND
3-/GRD	29-3.5V	55-GD8	81-GND	107-D17	133-3.5V	159-/HSYNC	185-3.5V
4-/GWR	30-GND	56-GD7	82-D28	108-D16	134-CLK	160-B0	186-R4
5-CPU202	31-GD26	57-GD6	83-D27	109-D7	135-GND	161-B1	187-R5
6-/RES	32-GD25	58-GD5	84-D26	110-D6	136-3.5V	162-B2	188-R6
7-3.5V	33-GD24	59-GD4	85-D25	111-D5	137-(A10)	163-B3	189-R7
8-GND	34-GD23	60-GND	86-D24	112-D4	138-A9/AP	164-GND	190-GND
9-33MHzG	35-GD22	61-3.5V	87-3.5V	113-GND	139-A7	165-3.5V	191-3.5V
10-3.5V	36-GD21	62-GD3	88-GND	114-3.5V	140-A6	166-B4	192-53MHzP
11-GND	37-3.5V	63-GD2	89-D15	115-D3	141-3.5V	167-B5	193-3.5V
12-CPU200	38-GND	64-GD1	90-D14	116-D0	142-GND	168-B6	194-GND
13-/IRQ1	39-GD20	65-GD0	91-D13	117-D1	143-A5	169-B7	195-3.5V
14-HBLANK	40-GD19	66-GND	92-D12	118-D2	144-A4	170-G0	196-53MHzN
15-GND	41-GD18	67-3.5V	93-D11	119-GND	145-A3	171-G1	197-3.5V
16-3.5V	42-GD17	68-(high)	94-D10	120-3.5V	146-GND	172-G2	198-GND
17-VBLANK	43-3.5V	69-(high)	95-D9	121-NC	147-3.5V	173-G3	199-DOTCLK
18-(pull)	44-GND	70-(high)	96-GND	122-/CS	148-A2	174-GND	200-GND
19-(low)	45-GD16	71-3.5V	97-3.5V	123-DSF	149-A1	175-3.5V	201-3.5V
20-GND	46-GD15	72-3.5V	98-D8	124-/RAS	150-A0	176-G4	202-BLANK
21-(low)	47-GD14	73-3.5V	99-D18	125-/CAS	151-3.5V	177-G5	203-(low)
22-3.5V	48-GD13	74-3.5V	100-D19	126-/WE	152-GND	178-G6	204-GND
23-3.5V	49-GD12	75-3.5V	101-D20	127-DQM1	153-FSC	179-G7	205-3.5V
24-GD31	50-GD11	76-GND	102-D21	128-DQM0	154-3.5V	180-R0	206-67MHzG
25-GD30	51-3.5V	77-D31	103-D22	129-GND	155-GND	181-R1	207-GND
26-GD29	52-GND	78-D30	104-D23	130-3.5V	156-/SYNC	182-R2	208-3.5V

Pin 77..150 = Video RAM Bus. Pin 156..189 = Video Out Bus. Other = CPU Bus. Pin 153: Sub Carrier (NC on newer boards which pick color clock from IC204).

GPU Pinout Notes

Pin 1,3,4,9,122..128,199,206 are connected via 22 ohm.

Pin 18 has a 4K7 ohm pullup to 3.5V

Pin 77..118 data lines (DQ0..DQ31) are connected via 82 ohm.

Pin 192/196: via 220 ohm to IC204.pin1 (53MHz)

At RAM Side: CKE via 4K7 to 3.5V, and, A8 is GROUNDED!

DQM0 is wired to both DQM0 and DQM2, DQM1 is wired to both DQM1 and DQM3.

CLK is wired to both GPU pin 131 and 134.

RGBnn = IC502 pin nn

/VSYNC, /HSYNC, (and BLANK?) are test points (not connected to any components).

/SYNC = (/VSYNC AND /HSYNC). BLANK = (VBLANK OR HBLANK).

IC202 44pin "Philips TDA8771H" Digital to Analog RGB (older boards only)

Region Japan+Europe: TDA8771AN

Region America+Asia: MC151854FLTEG or so?

1-IREF	6-GNDd1	11-R1	16-G4	21-B7	26-B2	31-CLK	36-OUTB	41-NC
2-GNDa1	7-VDDd1	12-R0	17-G3	22-B6	27-VDDd2	32-VDDa1	37-NC	42-GNDa2
3-R7	8-R4	13-G7	18-G2	23-B5	28-GNDd2	33-VREF	38-NC	43-VDDa4
4-R6	9-R3	14-G6	19-G1	24-B4	29-B1	34-NC	39-VDDa3	44-OUTR
5-R5	10-R2	15-G5	20-G0	25-B3	30-B0	35-VDDa2	40-OUTG	

Used only LATE-PU-8 boards (and PU-16, which does even have two TDA8771AH chips: one on the mainboard, and one on the VCD daughterboard).

Earlier boards are generating analog RGB via 64pin IC207, and later boards RGB via 48pin IC502.

IC502 48pin "SONY CXA2106R-T4" - 24bit RGB video D/A converter

1-(cap)	7-Comp.	13-/PAL	19-R4	25-G7	31-G1	37-B3	43-NC
2-GND	8-Chro.	14-/SYNC	20-5.0V	26-G6	32-G0	38-B2	44-(cap)
3-Red	9-5.0V	15-4.4MHz	21-R3	27-G5	33-B7	39-B1	45-GND
4-Green	10-YTRAP	16-R7	22-R2	28-G4	34-B6	40-B0	46-(cap)
5-Blue	11-NC	17-R6	23-R1	29-G3	35-B5	41-DOTCLK	47-5.0V
6-Lum.	12-NC	18-R5	24-R0	30-G2	36-B4	42-GND	48-(cap)

Pin 3..8 (analogue outputs) are passed via external 75 ohm resistors.

Pin 6,7 additionally via 220uF. Pin 8 additionally via smaller capacitor.

Pin 10 (YTRAP) wired via 2K7 to 5.0V.

Pin 1,44,46,48 (can) connect via capacitors to ground (only installed for 44).

The 4.4MHz clock is obtained via 2K2 from IC204.Pin6.

The /PAL pin can be reportedly GROUNDED to force PAL colors in NTSC mode, when doing that, you may first want to disconnect the pin from the GPU.

Note: Rohm BH7240AKV has same pinout (XXX but with pin7/pin8 swapped?)

Beware

Measuring in the region near GPU Pin10 is the nocash number one source for blowing up components on the mainboard. If you want to measure that signals while power is on, better measure them at the CPU side.

24.8 Pinouts - SPU Pinouts

IC308 - SONY CXD2922Q (SPU) (on PU-7, EARLY-PU-8 boards)

IC308 - SONY CXD2925Q (SPU) (on LATE-PU-8, PU-16, PU-18, PU-20 boards)

1-D0	14-D11	27-A8	40-GND	53-3.5V	66-A15	79-5V	92-LRIA
2-D1	15-GND	28-3.5V	41-SYSCK	54-GND	67-A14	80-A3	93-DTIA
3-3.5V	16-D12	29-GND	42-GND	55-D7	68-A13	81-A2	94-BCIB
4-GND	17-D13	30-A9	43-TEST	56-D6	69-A12	82-A1	95-LRIB
5-D2	18-D14	31-/SPU	44-TES2	57-D5	70-A11	83-A0	96-DTIB
6-D3	19-D15	32-/RD	45-D15	58-D4	71-A10	84-/WE0	97-BCKO
7-D4	20-A1	33-/WR	46-D14	59-D3	72-A9	85-/OE0	98-LRCO
8-D5	21-A2	34-DACK	47-D13	60-D2	73-A8	86-/WE1	99-DATO
9-D6	22-A3	35-/IRQ	48-D12	61-D1	74-A7	87-/OE1	100-WCKO
10-D7	23-A4	36-DREQ	49-D11	62-D0	75-A6	88-GND	
11-D8	24-A5	37-MUTE	50-D10	63-/RAS	76-A5	89-XCK	
12-D9	25-A6	38-/RST	51-D9	64-/CAS	77-A4	90-GND	
13-D10	26-A7	39-NC	52-D8	65-GND	78-GND	91-BCIA	

Pin 1..36 = MIPS-CPU bus. Pin 45..87 = SPU-RAM bus (A0,A10-A15,/WE1,OE1=NC). Pin 91..99 = Digital serial audio in/out (A=CDROM, B=EXP, O=OUT).

IC732 - SONY CXD2941R (SPU+CDROM+SPU_RAM) (on PM-41(2) boards)

1-DA16	23-FILO	45-LOCK	67-FSTO	89-SCSY	111-XCS	133-HD9	155-VSS5
2-DA15	24-FILI	46-SSTP	68-COUT	90-SCLK	112-XRD	134-HD8	156-HA1
3-DA14	25-PCO	47-SFDR	69-XDRST	91-SQSO	113-XWR	135-HD7	157-HA0
4-VDDM0	26-CLTV	48-SRDR	70-DA11	92-SENS	114-HINT	136-HD6	158-VDDM3
5-DA13	27-AVSS0	49-TFDR	71-DA10	93-DATA	115-XIRQ	137-VDD4	159-XCK
6-DA12	28-RFAC	50-TRDR	72-DA09	94-XLAT	116-VDDM2	138-HD5	160-DTIB
7-LRCK	29-BIAS	51-VSSM1	73-DA08	95-CLOK	117-XSCS	139-HD4	161-BCKO
8-WDCK	30-ASYI	52-FFDA	74-AVSMO	96-XINT	118-XHCS	140-HD3	162-LRCO
9-VDD0	31-AVDD0	53-FRDA	75-AVDM0	97-A4	119-XHRD	141-HD2	163-DAVDD0
10-VSS0	32-ASYO	54-MDP	76-DA07	98-A3	120-XHWR	142-VSS4	164-DAREFL
11-PSSL	33-VC	55-MDS	77-DA06	99-A2	121-DACK	143-HD1	165-AOUTL
12-ASYE	34-CE	56-VDD2	78-VDDM1	100-A1	122-DREQ	144-HD0	166-DAVSS0
13-GND	35-CEO	57-VSS2	79-DA05	101-A0	123-XRST	145-VSSM3	167-DAVSS1
14-C4M	36-CEI	58-MIRR	80-DA04	102-D7	124-VDD3	146-HA9	168-AOUTR
15-C16M	37-RFDC	59-DFCT	81-DA03	103-D6	125-SYSCK	147-HA8	169-DAREFR
16-FSOF	38-ADIO	60-AVSM1	82-DA02	104-D5	126-VSS3	148-HA7	170-DAVDD1
17-XTSL	39-AVDD1	61-AVDM1	83-DA01	105-D4	127-HD15	149-HA6	171-MUTO
18-VDD1	40-IGEN	62-FOK	84-WFCK	106-VSSM2	128-HD14	150-HA5	172-DATO
19-GND	41-AVSS1	63-PWMI	85-SCOR	107-D3	129-HD13	151-HA4	173-MTS3
20-VPCO1	42-TE	64-FSW	86-SBSO	108-D2	130-HD12	152-VDD5	174-MTS2
21-VPCO2	43-SE	65-MON	87-EXCK	109-D1	131-HD11	153-HA3	175-MTS1
22-VCTL	44-FE	66-ATSK	88-SQCK	110-D0	132-HD10	154-HA2	176-MTS0

IC732 - SONY CXD2938Q (SPU+CDROM) (on newer boards) (PM-41 boards)

1-SCLK	27-RFAC	53-TrckR	79-/XINT	105-A0	131-3.5V	157-(tst)	183-A8
2-GNDed	28-GNDed	54-TrckF	80-SQCK	106-3.5V	132-D9	158-(tst)	184-A7
3-GNDed	29-CLTV	55-FocuR	81-SQSO	107-A1	133-D8	159-GND	185-A6
4-SBSO	30-PCO	56-3.5V	82-SENSE	108-A2	134-D7	160-D15	186-A5
5-WFCK	31-FILI	57-FocuF	83-GND	109-A3	135-D6	161-D0	187-GND
6-GNDed	32-FILO	58-SledR	84-GND	110-A4	136-D5	162-D14	188-A4
7-C16M	33-VCTL	59-SledF	85-CD.D7	111-A5	137-3.5V	163-D1	189-A3
8-3.5V	34-VPC02	60-NC	86-CD.D6	112-3.5V	138-D4	164-D13	190-A2
9-C4M	35-VPC01	61-GND	87-CD.D5	113-A6	139-D3	165-3.5V	191-A1
10-GNDed	36-VC	62-NC	88-CD.D4	114-A7	140-D2	166-D2	192-A0
11-4.3MHz	37-FE	63-GND	89-CD.D3	115-A8	141-D1	167-D12	193-3.5V
12-12MHz	38-SE	64-(tst)	90-CD.D2	116-A9	142-D0	168-D3	194-NC
13-V16M	39-TE	65-(tst)	91-CD.D1	117-/IRQ2	143-GND	169-D11	195-(tst)
14-DOUT	40-CE	66-note	92-CD.D0	118-/IRQ9	144-33MHzS	170-D10	196-GND
15-LACK	41-CEO	67-note	93-3.5V	119-/RD	145-	171-D4	197-(tst)
16-WDCK	42-CEI	68-(tst)	94-CD/CS	120-/WR	146-3.48V	172-D9	198-NC
17-3.5Ved	43-RFDC	69-3.5V	95-CD/WR	121-DMA4	147-ZZ11	173-GND	199-NC
18-LOCK	44-ADIO	70-(tst)	96-CD/RD	122-GND	148-GND	174-D5	200-NC
19-GND	45-GND	71-(tst)	97-CD.A0	123-GND	149-GND	175-D8	201-3.5V
20-MDS	46-IGEN	72-(tst)	98-CD.A1	124-/SPUW	150-ZZ7	176-D6	202-NC
21-MDP	47-AVD1	73-(tst)	99-CD.A2	125-D15	151-3.48V	177-D7	203-NC
22-3.5Ved	48-GNDed	74-DATA	100-GND	126-D14	152-/RES	178-/CAS	204-NC
23-AVDO	49-GNDed	75-XLAT	101-CDA3	127-D13	153-3.5V	179-/WE	205-GND
24-ASYO	50-GND	76-CLOK	102-CDA4	128-D12	154-ZZ5	180-3.5V	206-(tst)
25-ASYI	51-GNDed	77-SCOR	103-/CD	129-D11	155-(tst)	181-/OE	207-(tst)
26-BIAS	52-GNDed	78-GND	104-/SPU	130-D10	156-(tst)	182-/RAS	208-GND

Pin 74..102 = SubCPU. Pin 103..144 = MainCPU. Pin 160..192 = Sound RAM Bus.

Pin 21 and 53..59 = Drive Motor Control (IC722).

Pin 1..47 are probably mainly CDROM related.

Pin 39 "TE9" = IC723.Pin16 - CL709, and via 15K to SPU.39

Pin 66 connects via 4K7 to IC723.Pin19.

Pin 67 not connected (but there's room for an optional capacitor or resistor)

The (tst) pins are wired to test points (but not connected to any components)

CXD2938Q SPU Pinout Notes

Pin 74,75,76,119,120 are connected via 22 ohm.

Pin 103,104 are connected via 100 ohm.

ZZnn = IC405 Pin nn (analog audio related, L/R/MUTE).

Pin 103..142 = System Bus (BIOS,CPU). Pin 160..192 = Sound RAM Bus.

Pin 178 used for both /CASL and /CASH (which are shortcut with each other).

Pin 146 and 151 are 3.48V (another supply, not 3.5V).

Pin 147 and 150 are connected via capacitors.

Pin 195 and 197 testpoints are found below of the pin 206/207 testpoints.

```
SPU155 (tst) always low      ;=maybe external audio (serial) this?
SPU156 (tst) 45kHz   (22us)    ;=probably 44.1kHz (ext audio sample-rate)
SPU157 (tst) 2777kHz  (0.36us)  ;=probably 64*44.1kHz (ext audio bit-rate)
SPU158 (tst) always high     ;=maybe external audio (serial) or this?
```

SPU.Pin5 connects to MANY modchips

SPU.Pin42 connects to ALL modchips

SPU.Pin42 via capacitor to SPU.Pin41, and via resistor?/diode? to IC723.10

CXD2938Q CDROM clocks

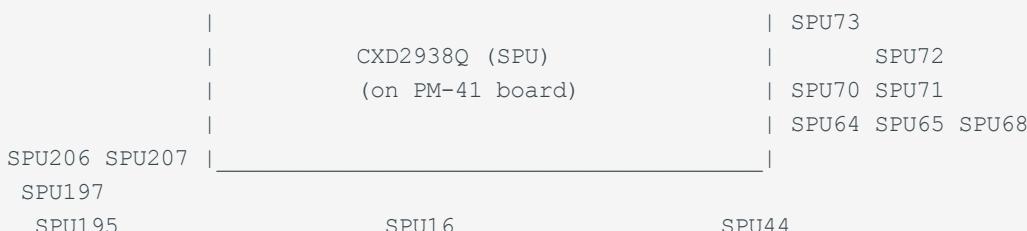
```
SPU197 (*) 7.35kHz (44.1kHz/6) (stable clock, maybe DESIRED drive speed)
SPU5      (*) 7.35kHz (44.1kHz/6) (unstable clock, maybe ACTUAL drive speed)
SPU15     (*) 44.1kHz (44.1kHz*1)
SPU16     (*) 88.2kHz (44.1kHz*2)
SPU206    (*) circa 2.27MHz
SPU70     (*) whatever clock (with SHORT low pulses)
```

(*) these frequencies are twice as fast in double speed mode.

CXD2938Q CDROM signals

```
SPU207  fastsignal?
SPU195  slowsignal?
SPU18   usually high, low during seek or spinup or so
SPU44   superslow hi/lo with superfast noise on it
SPU73   mainly LOW with occasional HIGH levels...
SPU71   LOW=SPIN_OK, PULSE=SPIN_UP/DOWN_OR_STOPPED
SPU72   similar as SPU71
SPU64   LOW=STOP, HI=SPIN
SPU68   always low...?
SPU65   whatever?
SPU75   mainly HIGH, short LOW pulses when changing speed up/down/break
```

CXD2938Q CDROM/SPU Testpoints (on PM-41 board)



```
SPU18 SPU5 SPU15
      SPU12
```

IC402 - 24pin AKM AK4309VM (or AK4309AVM/AK4310VM) - Serial 2x16bit DAC

1-TST?	4-/PD	7-CKS	10-LRCK	13-NC?	16-AOUTL	19-GNDa	22-VREFH
2-VCCd	5-/RST	8-BICK	11-NC?	14-NC?	17-VCOM	20-NC?	23-VREFL
3-GNDd	6-MCLK	9-SDATA	12-NC?	15-AOUTR	18-VCCA	21-NC?	24-DZF?

Used only on older boards (eg. PU-8), newer boards seem to have the DAC in the 208pin SPU.

No 24pin AK4309VM datasheet exists (however it seems to be same as 20pin AK4309B's, with four extra NC pins at pin10-14).

IC405 - "2174, 1047C, JRC" or "3527, 0A68" (on newer boards)

Called "NJM2174" in service manual. Audio Amplifier with Mute.

```
1 GND
2 NC      ? via 100ohm to multiout pin 9      ;Audio Left (white cinch)
3 OUT-R  ?
4 MUTE1    ;specified as LOW = Mute
5 MUTE2    ;specified as HIGH = Mute
6 MUTEC    ;unspecified, maybe capacitor, or output based on MUTE1+MUTE2?
7 IN-R     via capacitor to SPU.150
8 BIAS
9 NC
10 NC
11 IN-L    via capacitor to SPU.147
12 OUT-L  ?
13 NC      ? via 100ohm to multiout pin 11      ;Audio Right (red cinch)
14 VCC    +5.0V (via L401)
```

Audio amplifier, for raising the signals to 5V levels.

IC405 - "NJM2100E (TE2)" Audio Amplifier (on older PU-8 and PU-22 boards)

```
1-ROUT
2-RIN- IC732.SPU.150
3-RIN+
4-GND
5-LIN+
6-LIN- IC732.SPU.147
7-LOUT
8-VCC 4.9V (+5.0V via L401)
```

24.9 Pinouts - DRV Pinouts

IC304 - 52pin/80pin - Motorola HC05 8bit CPU

Pinouts - HC05 Pinouts

IC305 - SONY CXD1815Q - CDROM Decoder/FIFO (used on PU-8, PU-16, PU-18)

1-D0	14-/XINT	27-/HRD	40-GND	53-VDD	66-/MWR	79-GND	92-LRCO
2-D1	15-GND	28-VDD	41-HDRQ	54-GND	67-MDB0	80-CLK	93-WCKO
3-VDD	16-A0	29-GND	42-/HAC	55-MA8	68-MDB1	81-HCLK	94-BCKO
4-GND	17-A1	30-/HWR	43-MA0	56-MA9	69-MDB2	82-CKSL	95-MUTE
5-D2	18-A2	31-HD0	44-MA1	57-MA10	70-MDB3	83-RMCK	96-TD7
6-D3	19-A3	32-HD1	45-MA2	58-MA11	71-MDB4	84-LRCK	97-TD6
7-D4	20-A4	33-HD2	46-T01	59-MA12	72-MDB5	85-DATA	98-TD5
8-D5	21-TD0	34-HD3	47-T02	60-MA13	73-MDB6	86-BCLK	99-TD4
9-D6	22-/HRS	35-HD4	48-MA3	61-MA14	74-MDB7	87-C2PO	100-TD3
10-D7	23-/HCS	36-HD5	49-MA4	62-MA15	75-MDBP	88-EMP	
11-/CS	24-HA0	37-HD6	50-MA5	63-MA16	76-XTL2	89-/RST	
12-/RD	25-HA1	38-HD7	51-MA6	64-/MOE	77-XTL1	90-GND	
13-/WR	26-HINT	39-HDP	52-MA7	65-GND	78-VDD	91-DATO	

Pin 1..20 to HC05 CPU, pin 22..42 to MIPS cpu, pin 43..75 to SRAM cd-buffer.

The pinouts/registers in CXD1199AQ datasheet are about 99% same as CXD1815Q.

Note: Parity on the 8bit data busses is NC. SRAM is 32Kx8 (A15+A16 are NC). Later boards have this integrated in the SPU.

ICss - SONY CXA1782BR - CDROM Servo Amplifier (used on PU-8 boards)

1-FEO	7-FE_M	13-RA_O	19-CLK	25-FOK	31-RF_O	37-FE_BIAS	43-LPFI
2-FEI	8-SRCH	14-SL_P	20-XLT	26-CC2	32-RF_M	38-F	44-TEI
3-FDFCT	9-TGU	15-SL_M	21-DATA	27-CC1	33-LD	39-E	45-ATSC
4-FGD	10-TG2	16-SL_O	22-XRST	28-CB	34-PD	40-EI	46-TZC
5-FLB	11-FSET	17-ISET	23-C.OUT	29-CP	35-PD1	41-GND	47-TDFCT
6-FE_O	12-TA_M	18-VCC	24-SENS	30-RF_I	36-PD2	42-TEO	48-VC

Datasheet exists. Later boards have CXA1782BR+CXD2510Q integrated in CXD2545Q, and even later boards have it integrated in the SPU.

IC309 - SONY CXD2510Q - CDROM Signal Processor (used on PU-8, PU-16 boards)

1-FOK	11-PDO	21-GNDa	31-WDCK	41-DA09-XPLCK	51-APTL	61-EMPH	71-DATA
2-FSW	12-GND	22-VLTV	32-LRCK	42-DA08-GFS	52-GND	62-WFCK	72-XLAT
3-MON	13-TEST0	23-VDDa	33-VDD 5V	43-DA07-RFCK	53-XTAI	63-SCOR	73-VDD
4-MDP	14-NC	24-RF	34-DA16-SDTA48	44-DA06-C2PO	54-XTAO	64-SBSO	74-CLOK

5-MDS	15-NC	25-BIAS	35-DA15-SCLK48	45-DA05-XRAOF	55-XTSL	65-EXCK	75-SEIN
6-LOCK	16-VPCO	26-ASYI	36-DA14-SDTA64	46-DA04-MNT3	56-FSTT	66-SQSO	76-CNIN
7-NC	17-VCKI	27-ASYO	37-DA13-SCLK64	47-DA03-MNT2	57-FSOF	67-SQCK	77-DATO
8-VCOO	18-FILO	28-ASYE	38-DA12-LRCK64	48-DA02-MNT1	58-C16M	68-MUTE	78-XLTO
9-VCOI	19-FILI	29-NC	39-DA11-GTOP	49-DA01-MNT0	59-MD2	69-SENS	79-CLKO
10-TEST	20-PCO	30-PSSL	40-DA10-XUGF	50-APTR	60-DOUT	70-XRST	80-MIRR

Datasheet exists. Later boards have CXA1782BR+CXD2510Q integrated in CXD2545Q, and even later boards have it integrated in the SPU.

IC701 - SONY CXD2545Q - Signal Processor + Servo Amp (used on PU-18 boards)

1-SRON	14-TEST	27-TE	40-VDDa	53-DA09-XPLCK	66-FSTI	79-MUTE	92-DFCT
2-SRDR	15-GND	28-SE	41-VDD	54-DA08-GFS	67-FSTO	80-SENS	93-FOK
3-SFON	16-TES2	29-FE	42-ASYE	55-DA07-RFCK	68-FSOF	81-XRST	94-FSW
4-TFDR	17-TES3	30-VC	43-PSSL	56-DA06-C2PO	69-C16M	82-DIRC	95-MON
5-TRON	18-PDO	31-FILO	44-WDCK	57-DA05-XRAOF	70-MD2	83-SCLK	96-MDP
6-TRDR	19-VPCO	32-FILI	45-LRCK	58-DA04-MNT3	71-DOUT	84-DFSW	97-MDS
7-TFON	20-VCKI	33-PCO	46-DA16-SDTA48	59-DA03-MNT2	72-EMPH	85-ATSK	98-LOCK
8-FFDR	21-VDDa	34-CLTV	47-DA15-SCLK48	60-DA02-MNT1	73-WFCK	86-DATA	99-SSTP
9-FRON	22-IGEN	35-GNDa	48-DA14-SDTA64	61-DA01-MNT0	74-SCOR	87-XLAT	100-SFDR
10-FRDR	23-GNDa	36-RFAC	49-DA13-SCLK64	62-XTAI	75-SBSO	88-CLOK	
11-FFON	24-ADIO	37-BIAS	50-DA12-LRCK64	63-XTAO	76-EXCK	89-COUT	
12-VCOO	25-RFC	38-ASYI	51-DA11-GTOP	64-XTSL/GNDed	77-SQSO	90-VDD	
13-VCOI	26-RFDC	39-ASYO	52-DA10-XUGF	65-GND	78-SQCK	91-MIRR	

Datasheet exists. The CXD2545Q combines the functionality of CXA1782BR+CXD2510Q from older boards (later boards have it integrated in the SPU). XTAI/XTAO input is 16.9344MHz (44.1kHz*180h), with XTSL=GND. Clock outputs are FSTO=16.9344MHz/3, FSOF=16.9344MHz/4, C16M=16.9344MHz/1.

IC101 - SONY CXD2515Q - Signal Processor + Servo Amp (used on DTL-H2010)

Pinouts are same as CXD2545Q, except, three pins are different: Pin24=ADII (instead of ADIO), Pin25=ADIO (instead of RFC), Pin68=C4M (instead of FSOF).

IC720 - 144pin SONY CXD1817R (=CXD2545Q+CXD1815Q) ;PU-20

1..48	- unknown
49	- SCOR
50..144	- unknown

IC701 - 8pin chip (on bottom side, but NOT installed) (PU-7 and EARLY-PU-8)

1-8 Unknown (maybe CDROM related, at least it's near other CDROM chips)

IC722 "BA5947FP" or "Panasonic AN8732SB" - IC for Compact Disc Players

Drive Motor related.

```

1 to pin24,27
2 SPINDLE           - via 15K to SPU21
3 SW (ON/OFF)      - IC304.27
4 TRACKING FORWARD
5 TRACKING REVERSE
6 FOCUS FORWARD
7 FOCUS REVERSE
8 GND               - CN702 pin 11
9 NC (INTERNAL)    - via C731 (10uF) to GND
10 +7.5V (Pow VCC ch1,2)
11 FOCUS COIL (1)   - CN702 pin 15
12 FOCUS COIL (2)   - CN702 pin 14
13 TRACKING COIL (1) - CN702 pin 16
14 TRACKING COIL (2) - CN702 pin 13
15 SPINDLE MOTOR (1) - CN701 pin 4
16 SPINDLE MOTOR (2) - CN701 pin 3
17 SLED MOTOR (1)   - CN701 pin 1
18 SLED MOTOR (2)   - CN701 pin 2
19 +7.5V (Pow VCC ch3,4)
20 MUTE              - /RES (via 5K6)
21 GND
22 SLED REVERSE
23 SLED FORWARD
24 to pin1
25 via capacitors to pin1
26 BIAS 1.75V
27 to pin1
28 +7.5V (Pre VCC)

```

Additionally to the above 28pins, the chip has two large grounded pins (between pin 7/8 and 21/22) for shielding or cooling purposes.

IC703 - 20pin - "SONY CXA1791N" (RF Amplifier) (on PU-18 boards)

```

1 LD      O APC amplifier output
2 PD      I APC amplifier input
3 PD1     I Input 1 for RF I-V amplifiers
4 PD2     I Input 2 for RF I-V amplifiers
5 GND/VEE - Supply Ground
6 F       I Input F for I-V amplifier
7 E       I Input E for I-V amplifier
8 VR      O DC Voltage Output (VCC+VEE) /2
9 VC      I Center Voltage Input
10 NC     - NC
11 NC     - NC
12 EO      O Monitoring Output for I-V amplifier E
13 EI      - Gain Adjust for I-V amplifier E

```

```

14 TE      O Tracking Error Amplifier Output
15 FE_BIAS I BIAS Adjustment for Focus Error
16 FE      O Focus Error Amplifier Output
17 RFO     O RF Amplifier Output
18 RFI     I RF Amplifier Input
19 /LD_ON  I APC amplifier ON=GND, OFF=VCC
20 VCC    - Supply

```

Datasheet for CXA1791N does exist. Later boards have IC703 replaced by IC723. Older PU-7/PU-8 boards appear to have used a bunch of smaller components (8pin chips and/or transistors) instead of 20pin RF amplifiers.

IC723 - 20pin - "SONY CXA2575N-T4" (RF (Matrix?) Amplifier) (PU-22..PM-41(2))

```

1-TEIM
2-TEIG
3-VEE      GND
4-E        via 33K to CN702 pin 4
5-F        via 33K to CN702 pin 8
6-PD2     via 36K to CN702 pin 6
7-PD1     via 36K to CN702 pin 7
8-PD      to CN702 pin 9
9-LD
10-VC     CL710, and CN702.Pin3, and via resistor?/diode? to SPU42
11-LD_ON   IC304.Pin49 "LDON" ..... XXX or is that Pin 20 "LD_ON" ?
12-G_CONT          ;or AL/TE?
13-RF0     CL704, and...
14-RFM
15-FE      CL708, and...           (maybe focus error?)
16-TE      CL709, and via 15K to SPU.39 (maybe tracking error?)
17-TE0
18-COMP+
19-MIRR    via 4K7 to SPU66
20-VCC    3.48V (not 3.5V)

```

Used only on PU-22 .. PM-41(2) boards (PU-18 boards used IC703 "CXA1791N", and even older boards... maybe had this in CXA1782BR... or maybe had it in a bunch of 8pin NJMxxxx chips?).

There is no CXA2575N datasheet (but maybe some signals do resemble CXA2570N/ CXA2571N/CXA1791N datasheets).

CN702 CDROM Data Signal socket (PU-23 and PM-41 board)

```

1-LD      to Q701
2-VCC    to Q701
3-VC      to IC723.Pin10 (and CL710)
4-F-      to IC723.Pin4 (via 33K ohm)
5-NC      to CL776

```

```

6-PD2      to IC723.Pin6 (via 33K ohm)
7-PD1      to IC723.Pin7 (via 33K ohm)
8-E-       to IC723.Pin5 (via 33K ohm)
9-M1       to IC723.Pin8
10-VR      via 91 ohm to GND
11-GND     GND
12-LS      /POS0 (switch, GNDed when at head is at inner-most position)
13-FCS+    TRACKING COIL (2) ;\
14-TRK+    FOCUS COIL (2)   ; or swapped?
15-TRK     FOCUS COIL (1)   ;
16-FCS    TRACKING COIL (1) ;/

```

PU-23 and PM-41 board seem to be using exactly the same Drive, the only difference is the length (and folding) of the attached cable.

CN701 CDROM Motor socket (PU-8, PU-18, PU-23, PM-41 boards)

```

1-SL-      SLED MOTOR (1)
2-SL+      SLED MOTOR (2)
3-SP+      SPINDLE MOTOR (2)
4-SP-      SPINDLE MOTOR (1)

```

CLnnn - Calibration Points (PU-23 and PM-41 boards)

```

CL616 +7.5V (PM-41 only, not PM-23) (before power switch)
CL617 GND (PM-41 only, not PM-23)
CL316 to IC304 pin 21
CL704 to IC723.Pin13
CL706 GND
CL708 to IC723.Pin15
CL709 to IC723.Pin16
CL710 to IC723.Pin10, and CN702.Pin3
CL711 via 1K to IC723.Pin15
CL776 to CN702.Pin5

```

Probably test points for drive calibration or so.

24.10 Pinouts - VCD Pinouts

SCPH-5903 Video CD PlayStation

VCD Mainboard "PU-16, 1-655-191-11" Component List

The overall design is very close to LATE-PU-8 boards (1-658-467-2x). Changed components are IC102/IC304 (different kernel and cdrom firmware), C318/C325/C327

(height reduced capacitors for mounting the daughterboard above of them). Plus some extra components: Three triple multiplexors (for switching between PSX and VCD audio/video), and the daughterboard connector.

IC102	44pin SONY, M538032E-02, JAPAN 6465401	(uncommonly big BIOS, 1Mx8)
IC304	52pin C 4021 SC430924PB (HC05 sub-cpu, with extra Video CD command 1Fh)	
C318	2pin S5	; tantalum capacitors with lower height (instead
C325	2pin CA7	of the electrolytic capacitors on PU-8 boards)
C327	2pin CA7	;/
ICnnn	16pin 4053C (Triple multiplexor, for Audio LRCK,BCLK,DATA)	(PCB top)
ICnnn	16pin 4053C (Triple multiplexor, for Video FSC,CSYNC)	(PCB bottom)
ICnnn	16pin 2283 (Triple multiplexor, for Video R,G,B)	(PCB bottom)
CNnnn	30pin Connector to daughterboard	(PCB top)

VCD Daughterboard "MP-45, 1-665-192-11" Component List

IC102	3pin TA78M05F voltage regulator (7.5V to 5V)	(Toshiba)
IC104	120pin CXD1852AQ Video CD decoder (Sony)	
IC106	40pin MB814260-70 (256Kx16 DRAM) (Fujitsu) ;see also: IC114	
IC107	20pin 6230FV 649 115 (OSD, similar to BU6257AFV-E2)	(PCB back)
IC109	14pin Y2932 (TLC2932 PLL) (TI) (for RGB.DAC.CLK)	
IC110	44pin TDA8771AH Triple Video DAC for RGB (Philips)	(PCB back)
IC111	64pin CXP10224-603R 732A02E (MCU) (Sony)	
IC112	14pin HCT32A (74HCT32 Quad OR gate) (TI)	(PCB back) (for RGB.DAC.CLK)
IC113	8pin H74 7H (single D-type flip-flop; OSD clock divider)	(PCB back)
IC114	40pin MB814260-70 (256Kx16 DRAM) (Fujitsu) ;see also: IC106	
CN101	30pin Male Connector (to female 30pin socket on PU-16 mainboard)	
X103	2pin 45.00MHz (for VCD decoder chip)	
X104	4pin 12.000MHz (for MCU chip)	
X105	2pin 28.636MHz (for VCD decoder chip) (8*3.579545 NTSC clock)	

VCD Daughterboard Connector

.---.----.					
	GND	/	1	2	GND
(CXD1815Q.86)	CD.BCLK		3	4	CD.LRCK (CXD1815Q.84)
(CXD1815Q.87)	CD.C2PO		5	6	CD.DATA (CXD1815Q.85)
	GND		7	8	CD.SQCK (CXD2510Q.67) CXP.31
(TDA.44)	VIDEO.OUTR		9	10	CD.SQSO (CXD2510Q.66) CXP.29
	GND		11	12	SIO.OUT (HC05.51.PORTF1 to CXP.47)
(TDA.40)	VIDEO.OUTG		13	14	SIO.IN (HC05.50.PORTF0 from CXP.48)
	GND		15	16	SIO.CLK (HC05.52.PORTF2 to CXP.49)
(TDA.36)	VIDEO.OUTB		17	18	VIDEO.FSC (CXD1852AQ.95)
	GND		19	20	VIDEO.CSYNC (CXD1852AQ.96)
(PSU.3)	3.5V		21	22	3.5V (PSU.3)
(PSU.1)	7.5V		23	24	AUDIO.FSXI (CXD1852AQ.103 to VCD)
(PSU.7)	/RES		25	26	AUDIO.DATA (CXD1852AQ.100)
(CXD1852AQ.102)	AUDIO.BCLK		27	28	AUDIO.LRCK (CXD1852AQ.101)

GND		29	30	GND
		'-----'		

IC104 "Sony CXD1852AQ" (MPEG-1 Decoder for Video CD) (120 pin)

1-GND	16-HD7	31-GND	46-MD4	61-GND	76-G/Y3	91-GND	106-XTL2O
2-XTL0O	17-MA3	32-MA7	47-MD11	62-/VOE	77-G/Y4	92-HSYNC	107-XTL2I
3-XTL0I	18-MA4	33-MA8	48-MD3	63-R/Cr0	78-G/Y5	93-VSYNC	108-VDD
4-VDD	19-MA2	34-/RAS	49-MD12	64-R/Cr1	79-G/Y6	94-FID/FHREF	109-C2PO
5-HA2	20-MA5	35-/MWE	50-MD2	65-R/Cr2	80-G/Y7	95-CBLNK/FSC	110-LRCI
6-HA3	21-MA1	36-/CAS2	51-MD13	66-R/Cr3	81-B/Cb0	96-CSYNC	111-DATI
7-HD0	22-GND	37-/CAS0	52-MD1	67-R/Cr4	82-B/Cb1	97-/SGRST	112-BCKI
8-HD1	23-MA6	38-MD7	53-MD14	68-R/Cr5	83-B/Cb2	98-CLK0O	113-DOIN
9-HD2	24-MA0	39-MD8	54-MD0	69-R/Cr6	84-B/Cb3	99-DOUT	114-/HCS
10-HD3	25-BC	40-MD6	55-MD15	70-R/Cr7	85-B/Cb4	100-DATO	115-/HDT
11-HD4	26-TCKI	41-MD9	56-OSDEN	71-G/Y0	86-B/Cb5	101-LRCO	116-HRW
12-HD5	27-TDI	42-MD5	57-OSDB	72-G/Y1	87-B/Cb6	102-BCKO	117-/HIRQ
13-HD6	28-TENA1	43-MD10	58-OSDG	73-G/Y2	88-B/Cb7	103-FSXI	118-/RST
14-VDD	29-TDO	44-VDD	59-OSDR	74-VDD	89-DCLK	104-VDD	119-HA0
15-GND	30-VST	45-GND	60-VDD	75-GND	90-VDD	105-GND	120-HA1

The Hxxx pins are for the Host (the 8bit CXP CPU), the Mxxx for the RAM chips, the R/G/B pins are 24bit RGB video. Pin36 can be /CAS2 or MA9 (and, the VCD daughterboard has alternate solderpads for one large RAM instead of two small RAMs).

IC107 "6230FV" (OSD chip, similar to BU6257AFV-E2) (20 pin)

1-SIO.CLK	5-VDD	9-TEST	13-BLK2	17-OSDG
2-SIO./CS	6-/CKOUT	10-GND	14-VC2	18-OSDB
3-SIO.DTA	7-OSCOUT	11-BLK1	15-OSDEN	19-/VSYNC
4-/RESET	8-OSCIN	12-VC1	16-OSDR	20-/HSYNC

SIO pin1/2/3 are wired to CXP pin38/37/36. OSCIN is the RGB DAC CLK divided by two (from H74 chip pin5). OSD/SYNC on pin15-20 connect to the MPEG1 decoder chip. No datasheet (but pinouts are same/similar as for BU6257AFV, documented in several service manuals for tape decks with vcd player: HCD-V5500, HCD-V8900/V8900AV, HCD-V909AV).

IC111 "Sony CXP10224-603R" (8bit SPC700 CPU) (64pin LQFP)

1-PB5=TP	17-PD5=/HCS	33-AVREF=VDD	49-PG5/SCK1=HC05.PF2
2-PB4=TP	18-PD4=TP	34-AVDD=VDD	50-PG4=/RST.OUT
3-PB3=HA3	19-PD3=TP	35-PF7/AN7=TP	51-PG3/TO=TP
4-PB2=HA2	20-PD2=TP	36-PF6/AN6=OSD.DTA	52-PA7=TP
5-PB1=HA1	21-PD1=TP	37-PF5/AN5=OSD./CS	53-PA6=TP
6-PB0=HA0	22-PD0=TP	38-PF4/AN4=OSD.CLK	54-PA5=TP

7-PC7=HD7	23-MP/TEST=GND	39-PF3/AN3=GND	55-PA4=TP
8-PC6=HD6	24-XTAL=12MHZ	40-PF2/AN2=GND	56-VPP=VDD
9-PC5=HD5	25-EXTAL=12MHZ	41-PE1/AN1=GND	57-VDD=VDD
10-PC4=HD4	26-VSS=GND	42-PF0/AN0=10KtoGND	58-VSS=GND
11-PC3=HD3	27-/RST=/RES	43-PE3/PWM1=TP	59-PA3=TP
12-PC2=HD2	28-/CS0=VDD	44-PE2/PWM0=TP	60-PA2=TP
13-PC1=HD1	29-SI0=CD.SQSO	45-PE1/INT2/EC=/VSYNC	61-PA1=TP
14-PC0=HD0	30-SO0=TP	46-PE0/INT0=/HIRQ	62-PA0=TP
15-PD7=HRW	31-/SCK0=CD.SQCK	47-PG7/SI1/INT1=HC05.PF1	63-PB7=TP
16-PD6=/HDT	32-AVSS=GND	48-PG6/SO1=HC05.PFO	64-PB6=TP

Pin 3-15,45,46,50 connect to MPEG1 decoder. Pin 36-38 to OSD. Pin 47-49 to HC05.PortF. Pin 27 is /RESET from PSU. Pin 29,31 are SUBQ from CXD2510Q. The "TP" pins connect to test points (but seem to be NC otherwise).
 Pinouts are same as in CXP811P24 datasheet (which uses SPC700 instruction set; that instruction set is also used by SNES sound CPU).

IC109 "TLC2932" (PLL) (14pin)

1-LOGIC_VDD=5V	5-FIN-B=HSYNC.PLL	9-PFD_INHIBIT=GND	13-BIAS
2-SELECT=5V	6-PFD_OUT	10-VCO_INHIBIT=GND	14-VCO_VDD=5V
3-VCO_OUT=RGB.DAC.CLK.PLL	7-LOGIC_GND=GND	11-VCO_GND=GND	
4-FIN-A=FID/FHREF.PLL	8-NC	12-VCO_IN	

Used to generate the CLK for the TDA chip (that is, the dotclk, paused during VSYNC, or so?). The same CLK, divided by two, is also used as OSD.OSCIN.

IC112 "74HCT32" (Quad OR gate) (14pin)

1-FID/FHREF.MPEG	4-HSYNC.MPEG	8-(low)	11-RGB.DAC.CLK.TDA	7-GND
2-FID/FHREF.MPEG	5-HSYNC.MPEG	9-GNDed	12-RGB.DAC.CLK.PLL	14-VCC/5V
3-FID/FHREF.PLL	6-HSYNC.PLL	10-GNDed	13-RGB.DAC.CLK.PLL	

Used to sharpen the output from the PLL chip, and to level-shift signals for the two PLL inputs from 3.5V to 5V. The input-pairs for the OR gates are shortcut with each other, so the chip isn't actually ORing anything.

IC113 "H74 7H" (single D-type flip-flop; OSD clock divider) (8 pin)

1-CLK	2-D	3-/Q	4-GND	5-Q	6-/RES	7-/SET	8-VCC
-------	-----	------	-------	-----	--------	--------	-------

Used to divide the RGB DAC CLK by two. CLK comes from TDA.pin31, D and /Q are shortcut with each other, /RES and /SET are wired to VDD, and Q goes to OSD.OSCIN.

ICnnn "4053C" (Triple multiplexor, for Audio LRCK,BCLK,DATA) (16pin)

1-IN2B=DATA.VCD	5-IN3A=LRCK.SPU	9-SEL3=LRCK.SEL	13-IN1B=BCLK.VCD
2-IN2A=DATA.SPU	6-/OE=GNDed	10-SEL2=DATA.SEL	14-OUT1=BCLK.OUT
3-IN3B=LRCK.VCD	7-VEE=GNDed	11-SEL1=BCLK.SEL	15-OUT2=DATA.OUT
4-OUT3=LRCK.OUT	8-GND=GND	12-IN1A=BCLK.SPU	16-VDD=VDD/3.5V

The three SEL pins are wired to HC05.PortF3, the three SPU pins are wired via 10Kohm.

ICnnn "4053C" (Triple multiplexor, for Video FSC,CSYNC) (16pin)

1-IN2B=FSC.VCD	5-IN3A=CSYNC.PSX	9-SEL3=CSYNC.SEL	13-IN1B=GNDed
2-IN2A=FSC.PSX	6-/OE=GNDed	10-SEL2=FSC.SEL	14-OUT1=NCed
3-IN3B=CSYNC.VCD	7-VEE=GNDed	11-SEL1=DUMMY.SEL	15-OUT2=FSC.OUT
4-OUT3=CSYNC.OUT	8-GND=GND	12-IN1A=GNDed	16-VDD=VCC/5V

The three SEL pins are wired to HC05.PortF3, the two OUTx pins are wired via 2.2Kohm.

ICnnn "NJM2283" (Triple multiplexor, for Video R,G,B) (16pin)

1-IN1B=R.VCD	5-OUT2=G.OUT	9-IN3B=B.VCD	13-V=VCC/5V
2-SEL1=R.SEL	6-OUT3=B.OUT	10-GND3=81ohm/GND	14-IN2B=G.VCD
3-OUT1=R.OUT	7-SEL3=B.SEL	11-IN2A=G.PSX	15-GND1=GND
4-GND2=GND	8-IN3A=B.PSX	12-SEL2=G.SEL	16-IN1A=R.PSX

The three SEL pins are wired to HC05.PortF3, the six INxx pins wired through resistors and capacitors, the three OUTx pins are wired through capacitors.

24.11 Pinouts - HC05 Pinouts

Motorola HC05 chip versions for PSX cdrom control

80pin "4246xx" - MC68HC05L16, on-chip ROM (DTL-H120x & old retail consoles)
80pin "MC68HC705L16CFU" - MC68HC705L16, on-chip ROM (DTL-H100x, and PU-9)
52pin "SC4309xx" - MC68HC05G6, on-chip ROM (newer retail consoles)

The early DTL-H2000 devboard is also using a 80pin CPU (with piggyback EPROM socket), but that CPU is a Sony CXP82300 SPC700 CPU, not a Motorola HC05 CPU.

IC304 - "C 3060, SC430943PB, G63C 185" (PAL/PSone) - CDROM Controller

Called "MC68HC05G6PB" in service manual (=8bit CPU).

```

1 NC      NC (TEST:DTR/out) (VCD:AVSEL/out)    ;-Port F           ;PortF.Bit3
2 VDD     3.5V
3 NC      NC          ;\                                ;maybe PortE.Bit7?
4 NC      NC          ; maybe MSBs of Port E       ;maybe PortE.Bit6?
5 NC      NC          ;/                                ;maybe PortE.Bit5?
6 DECA4   SPU102      ;\                                ;PortE.Bit4
7 DECA3   SPU101      ; Port E [04h], aka Address/Index ;PortE.Bit3
8 DECA2   SPU99        ;                                ;PortE.Bit2
9 DECA1   SPU98        ;                                ;PortE.Bit1
10 DECA0  SPU97       ;/                                ;PortE.Bit0
11 VSS    GND
12 NDLY   GND         reserved for factory test, should be wired to VDD, not GND?
13 /RES   /RES (via 5K6)
14 OSC1   4.3MHz (SPU11) (used as external clock for some modchips) (low volts)
15 OSC2   NC
16 F-BIAS  aka FOK=NC (in SCPH-5500)           ;PortB.Bit0
17 CG      NC          aka CG=CG (in SCPH-5500)      ;this IS portb.1! ;PortB.Bit1
18 LMTSW  /POS0 (switch, GNDed when head at inner-most position) ;PortB.Bit2
19 DOOR   SHELL_OPEN                         ;PortB.Bit3
20 TEST2  NC
21 TEST1  to CL316                           ;PortB.Bit4
22 COUT   NC
23 SENSE  SPU82  ;CXD2510Q.69                ;PortB.Bit5
24 SUBQ   SPU81  ;CXD2510Q.66                ;PortB.Bit6
25 NC      NC          ;NC                  ;PortB.Bit7
26 SQCK   SPU80  ;CXD2510Q.67                ;PortC.Bit0
27 SPEED   IC722.Pin3 (SW)                   ;PortC.Bit1
28 AL/TE   ;transistor aka MIRROR=.. (in SCPH-5500);ISN'T PortB.Bit1 !
29 ROMSEL  ;NC          aka ROMSEL=SCLK (in SCPH-5500) ;PortC.Bit2
30 /XINT   SPU79  ;CXD1815Q.14                ;PortC.Bit3
31 SCOR   SPU77  ;CXD2510Q.63                ;PortC.Bit4
32 VDD    3.5V
33 DECD0  CD.D0      ;\                                ;PortA.Bit0
34 DECD1  CD.D1      ;                                ;PortA.Bit1
35 DECD2  CD.D2      ;                                ;PortA.Bit2
36 DECD3  CD.D3      ; Port A [00h], aka Data ;PortA.Bit3
37 DECD4  CD.D4      ;                                ;PortA.Bit4
38 DECD5  CD.D5      ;                                ;PortA.Bit5
39 VSS    GND
40 DECD6  CD.D6      ;                                ;PortA.Bit6
41 DECD7  CD.D7      ;/                                ;PortA.Bit7
42 NC      NC
43 DATA   SPU74 (via 22 ohm)                 ;maybe PortD.Bit0?
44 XLAT   SPU75 (via 22 ohm)                 ;PortD.Bit1
45 CLOK   SPU76 (via 22 ohm)                 ;PortD.Bit2
46 DECCS  SPU94
47 DECWR  SPU95
48 DECRD  SPU96
49 LDON   IC723.Pin11                         ;PortD.Bit3

```

```

50 NC      NC (TEST:TX/out)  (VCD:SIO.IN/in) ;\PortF (used by ;PortF.Bit0
51 NC      NC (TEST:RX/in)   (VCD:SIO.OUT/out) ; Motorola Testmode;PortF.Bit1
52 NC      NC (TEST:RTS/out) (VCD:SIO.CLK/out) ;/and VCD version) ;PortF.Bit2

```

This chip isn't connected directly to the CPU, but rather to a Fifo Interface, which is then forwarding data to/from the CPU. On older PSX boards, that Fifo Interface has been located in a separate chip, on newer PSX boards and PSone boards, the Fifo stuff is contained in the SPU chip. The CDROM has a 32K buffer, which is also implemented at the Fifo Interface side.

OSC input (internally HC05 is running at OSC/2, ie. around 2MHz):

```

PU-8      4.0000MHz from separate 4.000MHz oscillator (X302)
PU-16     4.0000MHz from separate 4.000MHz oscillator (X302)
DTL-H2000 4.1900MHz from separate 4.1900MHz oscillator (SPC700, not HC05)
PU-18     4.2336MHz from CXD2545Q.pin68 (Servo+Signal) (FSOF=16.9344MHz/4)
PU-20     4.2xxxMHz from CXD1817R.pin? (Servo+Signal+Decoder)
PM-41     4.2xxxMHz from CXD2938Q.pin11 (Servo+Signal+Decoder+SPU)

```

HC05 - 80pin version (pinout from MC68HC05L16 datasheet)

```

1 VDD
2 FP28/PE6    ;\
3 FP29/PE5    ;
4 FP30/PE4    ;
5 FP31/PE3    ; Port E LSBs
6 FP32/PE2    ;
7 FP33/PE1    ;
8 FP34/PE0    ;/
9 FP35/PD7    ;\
10 FP36/PD6   ; Port D MSBs
11 FP37/PD5   ;
12 FP38/PD4   ;/
13 VLCD3
14 VLCD2
15 VLCD1
16 VSS
17 NDLY
18 XOSC1
19 XOSC2
20 /RESET
---
21 OSC1
22 OSC2
23 PA0        ;\
24 PA1        ;
25 PA2        ;
26 PA3        ; Port A
27 PA4        ;
28 PA5        ;

```

```
29 PA6      ;
30 PA7      ;/
31 PB0/KWI0 ;\
32 PB1/KWI1 ;
33 PB2/KWI2 ;
34 PB3/KWI3 ; Port B
35 PB4/KWI4 ;
36 PB5/KWI5 ;
37 PB6/KWI6 ;
38 PB7/KWI7 ;/
39 PC0/SDI  ;\
40 PC1/SDO  ;
---
41 PC2/SCK  ; Port C
42 PC3/TCAP ;
43 PC4/EVI  ;
44 PC5/EVO  ;
45 PC6/IRQ2 ;
46 PC7/IRQ1 ;/
47 VDD
48 BP3/PD3  ;\
49 BP2/PD2  ; Port D LSBs
50 BP1/PD1  ;
51 BP0 (no "PD0") ;/
52 FP0
53 FP1
54 FP2
55 FP3
56 FP4
57 FP5
58 FP6
59 FP7
60 VSS
---
61 FP8
62 FP9
63 FP10
64 FP11
65 FP12
66 FP13
67 FP14
68 FP15
69 FP16
70 FP17
71 FP18
72 FP19
73 FP20
74 FP21
75 FP22
76 FP23
77 FP24
78 FP25
79 FP26
80 FP27/PE7 ;- Port E MSB
```

HC05 - 32pin/64pin Versions

Sony's Digital Joypad and Mouse contain 32pin CPUs, which are probably also HC05's:

[Pinouts - Component List and Chipset Pin-Outs for Digital Joypad, SCPH-1080](#)

Moreover, some old memory cards contain a 64pin Motorola SC419510FU (probably also a HC05) with separate Atmel AT29LV010A (128Kx8 FLASH).

24.12 Pinouts - MEM Pinouts

IC102 - BIOS ROM (32pin, 512Kx8, used on LATE-PU-8 boards, and newer boards)

1-A19	5-A7	9-A3	13-D0	17-D3	21-D7	25-A11	29-A14	
2-A16	6-A6	10-A2	14-D1	18-D4	22-/CE	26-A9	30-A17	; /CE=/BIOS
3-A15	7-A5	11-A1	15-D2	19-D5	23-A10	27-A8	31-A18	
4-A12	8-A4	12-A0	16-GND	20-D6	24-/OE	28-A13	32-3.5V	; /OE=/RD

Uses standard EPROM pinouts, VCC is 3.5V though, when replacing the ROM by an EPROM, it may be required to replace the supply by 5V. Note that, on PM-41 boards at least, Pin 1 is connected to A19 (allowing to install a 1MB BIOS chip on that board, however, normally, a 512KB BIOS chip is installed, and, the CPU is generating an exception when trying to access more than 512KB, but that 512K limit can be disabled via memory control registers).

Datasheet for (MS-)M534031E does exist.

IC102 - BIOS ROM (40pin, 512Kx8, used on PU-7 boards, and EARLY-PU-8 boards)

1-A18	6-A4	11-GND	16-D9	21-VCC	26-D6	31-GND (/BYTE)	36-A13
2-A8	7-A3	12-/OE	17-D2	22-D4	27-D14	32-A17	37-A12
3-A7	8-A2	13-D0	18-D10	23-D12	28-D7	33-A16	38-A11
4-A6	9-A1	14-D8	19-D3	24-D5	29-A0 (D15)	34-A15	39-A10
5-A5	10-/CS	15-D1	20-D11	25-D13	30-GND	35-A14	40-A9

The chip supports 8bit/16bit mode, on the PSX D0-D14 are actually wired, but A0/D15 is wired to A0, and /BYTE is wired to GND, so 16bit mode doesn't work.

Datasheet for MX23L4100 does exist.

IC102 - BIOS ROM (44pin, 1Mx8, used on P16-boards, ie. VCD console)

1-NC	5-A7	9-A3	13-GND	17-D1	21-D3	25-D12	29-D14	33-/BYT	37-A14	41-A10
2-A19	6-A6	10-A2	14-/OE	18-D9	22-D11	26-D5	30-D7	34-A17	38-A13	42-A9

3-A18	7-A5	11-A1	15-D0	19-D2	23-VCC	27-D13	31-D15/A0	35-A16	39-A12	43-NC
4-A8	8-A4	12-/CE	16-D8	20-D10	24-D4	28-D6	32-GND	36-A15	40-A11	44-NC

Pinouts are from OKI MSM538032E datasheet.

CPU-RAM (four 28pin chips) (older boards)

Unknown.

Note: The newer 70pin RAM comes up without external /REFRESH signal, but maybe the 28pin RAMs required refresh (the CPU has some odd delays once and when).

IC106 - CPU-RAM (single 70pin chip, on newer boards)

"Samsung K4Q153212M-JC60" (70pin, 512Kx32) (newer boards)

"Toshiba T7X16" (70pin, 512Kx32) (newer boards, too)

1-VCC	11-N.C	21-DQ15	31-A3	41-N.C	51-DQ17	61-DQ24
2-DQ0	12-VCC	22-N.C	32-A4	42-N.C	52-DQ18	62-DQ25
3-DQ1	13-DQ8	23-N.C!	33-A5	43-/OE	53-DQ19	63-DQ26
4-DQ2	14-DQ9	24-N.C	34-A6	44-/W	54-VSS	64-DQ27
5-DQ3	15-DQ10	25-N.C	35-VCC	45-/CAS3	55-DQ20	65-VSS
6-VCC	16-DQ11	26-N.C	36-VSS	46-/CAS2	56-DQ21	66-DQ28
7-DQ4	17-VCC	27-/RAS	37-A7	47-/CAS1	57-DQ22	67-DQ29
8-DQ5	18-DQ12	28-A0	38-A8	48-/CAS0	58-DQ23	68-DQ30
9-DQ6	19-DQ13	29-A1	39-A9	49-N.C	59-VSS	69-DQ31
10-DQ7	20-DQ14	30-A2	40-N.C	50-DQ16	60-N.C	70-VSS

Notes: Pin23 must NC or VSS. In the PSone, /OE is wired to GND.

Datasheet for K4Q153212M-JC60 does exist (the chip supports 27ns Hyper Page mode access, which seems to be used for DMA).

IC106/IC107/IC108/IC109 - CPU-RAM (four 28pin chips, on PU-8, PU-18 boards)

SEC KM48V514BJ-6 (DRAM 512Kx8) (four pieces = 512Kx32 = 2Mbyte)

1-VCC	5-DQ3	9-A9	13-A3	17-A5	21-NC	25-DQ5
2-DQ0	6-NC	10-A0	14-VCC	18-A6	22-/OE	26-DQ6
3-DQ1	7-/W	11-A1	15-GND	19-A7	23-/CAS	27-DQ7
4-DQ2	8-/RAS	12-A2	16-A4	20-A8	24-DQ4	28-GND

Datasheet for KM48V514B-6 and BL-6 exist (though none for BJ-6). The chips support 25ns Hyper Page mode access.

IC310 - SPU-RAM (512Kbyte)

EliteMT M11B416256A-35J (256K x 16bit) (40pin SOJ, PM-41 boards)

Nippon Steel NN514256ALTT-50 (256K x 16bit) (40pin TSOP-II, PU-23 boards)

Toshiba TC51V4260DJ-70 (40pin, PU-8 board) (PseudoSRAM)

1-5.0V	6-5.0V	11-NC	16-A0	21-VSS	26-A8	31-I/O8	36-I/O12
2-I/O0	7-I/O4	12-NC	17-A1	22-A4	27-/OE	32-I/O9	37-I/O13
3-I/O1	8-I/O5	13-/WE	18-A2	23-A5	28-/CASH	33-I/O10	38-I/O14
4-I/O2	9-I/O6	14-/RAS	19-A3	24-A6	29-/CASL	34-I/O11	39-I/O15
5-I/O3	10-I/O7	15-NC	20-5.0V	25-A7	30-NC	35-VSS	40-VSS

Note: SPU-RAM supply can be 3.5V (PU-8), or 5.0V (PU-22 and PM-41).

Note: The /CASL and /CASH pins are shortcut with each other on the mainboard, both wired to the /CAS pin of the SPU (ie. always accessing 16bit data at once).

Note: The TSOP-II package (18mm length, super-flat and with spacing between pin 10/11 and 30/31) is used on PU-23 boards. The pinouts and connections are identical for SOJ and TSOP-II.

Note: Nippon Steels NN514256-series is normally 256Kx4bit, nevertheless, for some bizarre reason, their 256Kx16bit chip is marked "NN514256ALTT"... maybe that happened accidentally in the manufacturing process.

Note: The PM-41(2) board has on-chip RAM in the SPU (no external memory chip).

IC303 - CDROM Buffer (32Kbyte)

"HM62W256LFP-7T" (SRAM 32Kx8) (PCB bottom side) (PU-8)

"SONY CXK5V8257BTM" 32Kx8 SRAM (PU-18)

1-A14	4-A6	7-A3	10-A0	13-D2	16-D4	19-D7	22-/OE	25-A8	28-VCC
2-A12	5-A5	8-A2	11-D0	14-GND	17-D5	20-/CS	23-A11	26-A13	
3-A7	6-A4	9-A1	12-D1	15-D3	18-D6	21-A10	24-A9	27-/WE	

Used only on older boards (eg. PU-8, PU-18), newer boards seem to have that RAM included in the 208pin SPU chip.

IC201 - GPU-RAM (1MByte) (or 2MByte, of which, only 1MByte is used though)

Samsung KM4132G271BQ-10 (128K x 32bit x 2 Banks, Synchronous Graphic RAM) 1MB

Samsung K4G163222A-PC70 (256K x 32bit x 2 Banks, Synchronous Graphic RAM) 2MB

1-DQ3	13-DQ19	25-/WE	37-N.C	49-A6	61-DQ9	73-VDDQ	85-VSS	97-DQ0
2-VDDQ	14-VDDQ	26-/CAS	38-N.C	50-A7	62-VSSQ	74-DQ24	86-N.C	98-DQ1

3-DQ4	15-VDD	27-/RAS	39-N.C	51-A8	63-DQ10	75-DQ25	87-N.C	99-VSSQ
4-DQ5	16-VSS	28-/CS	40-N.C	52-N.C	64-DQ11	76-VSSQ	88-N.C	100-DQ2
5-VSSQ	17-DQ20	29-A9 (BA)	41-N.C	53-DSF	65-VDD	77-DQ26	89-N.C	
6-DQ6	18-DQ21	30-NC (GND)	42-N.C	54-CKE	66-VSS	78-DQ27	90-N.C	
7-DQ7	19-VSSQ	31-A0	43-N.C	55-CLK	67-VDDQ	79-VDDQ	91-N.C	
8-VDDQ	20-DQ22	32-A1	44-N.C	56-DQM1	68-DQ12	80-DQ28	92-N.C	
9-DQ16	21-DQ23	33-A2	45-N.C	57-DQM3	69-DQ13	81-DQ29	93-N.C	
10-DQ17	22-VDDQ	34-A3	46-VSS	58-NC	70-VSSQ	82-VSSQ	94-N.C	
11-VSSQ	23-DQM0	35-VDD	47-A4	59-VDDQ	71-DQ14	83-DQ30	95-N.C	
12-DQ18	24-DQM2	36-N.C	48-A5	60-DQ8	72-DQ15	84-DQ31	96-VDD	

Newer boards often have 2MB VRAM installed (of which only 1MB is used, apparently the 2MB chips became cheaper than the 1MB chips). At the chip side, the only difference is that Pin30 became an additional address line (that, called A8, and, accordingly, the old A8,A9 pins were renamed to A9,A10). At the mainboard side, the connection is exactly the same for both 1MB and 2MB chips; Pin30 is grounded on both PU-23 boards (which typically have 1MB) and PM-41 boards (which typically have 2MB).

Note: The PM-41(2) board has on-chip RAM in the GPU (no external memory chip).

24.13 Pinouts - CLK Pinouts

The "should-be" CPU clock is 33.868800 Hz (ie. the 44100Hz CDROM/Audio clock, multiplied by 300h). However, the different PSX/PSone boards are using different oscillators, multipliers and dividers, which aren't exactly reaching that "should-be" value. The PSone are using a single oscillator for producing CPU/GPU clocks, and for producing the TV/color signal:

```
For PAL, Fsc=4.43361875MHz (5^6*283.75Hz+25Hz) --> 4*Fsc=17.734MHz
For NTSC, Fsc=3.579545MHz (4.5*455/572 MHz) --> 4*Fsc=14.318MHz
```

PSone/PAL - IC204 8pin - "CY2081, SL-509" or "2294A, 1913"

Clock Multiplier/Divider

```
1 53MHz ;17.734MHz*3 = 53.202 MHz (?)
2 GND
3 X1 17.734MHz
4 X2 17.734MHz
5 67MHz ;17.734MHz*3*2*7/11 = 67.711636 MHz (?)
6 4.4Mhz ;17.734MHz/4 = 4.4335MHz (?) ;via 2K2 to IC502.pin15
7 3.5V
8 3.5V
```

PSone/NTSC - IC204 8pin "CY2081 SL-500" (PSone, and PSX/PU-20 and up)

Unknown. Uses a 14.318MHz oscillator, so multiply/divide factors must be somehow different.

```
3*3*7*5/2/11 = 14.3181818
3*3*7*7*100 = 44100
```

The "optimal" conversion would be (hardware is barely able to do that):

```
14.3181818 * 3*7*11*64 / (5*5*5*5*5) = 67.737600
```

So, maybe it's doing

```
14.3181818 * 2*2*13/11 ... or so?
```

PSX/PAL

PU-7 and PU-8 boards are using three separate oscillators:

```
X101: 67.737MHz (div2 = CPU Clock = 33.8685MHz) (div600h = 44.1kHz audio)
X201: 53.20MHz (GPU Clock) (div12 = PAL color clock)
X302: 4.000MHz (for CDROM SUB CPU)
```

PU-18 does have same X101/X201 as above, but doesn't seem to have X302.

PSX/NTSC

PU-7 and PU-8 boards are using three separate oscillators:

```
X101: 67.737MHz (div2 = CPU Clock = 33.8685MHz) (div600h = 44.1kHz audio)
X201: 53.69MHz (GPU Clock) (div15 = NTSC color clock)
X302: 4.000MHz (for CDROM SUB CPU)
```

PU-20 works more like PSone (a single oscillator, and CY2081 SL-500 divider)

24.14 Pinouts - PWR Pinouts

Voltage Summary

```
+7.5V Used to generate other voltages and CDROM/Joypad/MemoryCard/Expansion
+5.0V Used for Multiout, IC405, and IC502, and IC602
+3.5V Used for most ICs, and for Joypad/MemoryCard/Expansion
+3.48V Used for SPU and CDROM
GND     Ground, shared for all voltages
```

Fuses

There are a lot of SMD elements marked FBnnn, these are NOT fuses (at least they don't seem to blow-up whatever you do). The actual fuses are marked PSnnn, found near the power switch and near the power socket.

IC601 3pin +5.0V "78M05, RZ125, (ON)"

```
1 +7.5V
2 GND
3 +5.0V (used for Multiout, IC405, and IC502)
```

IC602 - Audio/CDROM Supply

Called "LP29851MX-3.5" in service manual.

```
1 VIN      5.0V (in)
2 GND      GND
3 ON/OFF   5.0V (in)
4 NOISE    ?
5 VOUT     3.48V (out)
```

IC002/IC003 - Reset Generator (PM-41 board)

```
IC002  IC003  Expl.
2      2      connected to Q002 (reset input?)
5      5      connected via capacitor to GND
6      1      reset-output (IC002=wired to /RES, IC003: via Q004 to /RES)
7      -      7.5V
4      3      GND
1,3,8 4      NC
```

/RES is connected via 330 ohm to GPU/CPU, and via 5K6 SPU/IC722/IC304.

Note: Either IC002 or IC003/Q004 can be installed on PM-41 boards. Most or all boards seem to contain IC003/Q004.

Note: PSX consoles have something similar on the Power Supply boards (IC101: M51957B).

IC606/IC607 - TL594CD - Pulse-Width-Modulation Power-Control Chip

```

1 1IN+
2 1IN-
3 FEEDBACK
4 DTC
5 CT
6 RT
7 GND
8 C1
9 E1
10 E2
11 C2
12 VCC
13 OUTPUT CTRL
14 REF
15 2IN-
16 2IN+

```

Q602

```

x +7.5V
y +3.5V
z REG

```

CN602 - PU-8, PU-9 board Power Socket (to internal power supply board)

```

1 Brown 7.5V (actually 7.69V)
2 Red GND Ground
3 Orange 3.5V (actually 3.48V)
4 Yellow GND Ground
5 White STAND-BY (3.54V, always ON, even if power switch is off)
6 Blue GND Ground
7 Magenta /RES Reset input (from power-on logic and reset button)

```

Purpose of the standy-by voltage is unknown... maybe to expansion port?

CN602 - PU-18, PU-23 board Power Socket (to internal power supply board)

```

1 Brown 7.5V (actually 7.92V or so) (ie. higher than in PSone)
2 Red GND Ground
3 Orange 3.5V (actually 3.53V or so) (ie. quite same as PSone)
4 Yellow GND Ground
5 White /RES Reset input (from power-on logic and reset button)

```

CN102 - Controller/memory card daughter-board connector (PU-23 board)

```

1 /IRQ10 (/IRQ10)
2 /ACK (/IRQ7)
3 /JOY2
4 7.5V (or actually 7.92V)
5 /JOY1
6 DAT
7 GND
8 CMD
9 3.5V
10 CLK

```

24.15 Pinouts - Component List and Chipset Pin-Outs for Digital Joypad, SCPH-1080

Digital Joypad Component List (SCPH-1080)

Case: "SONY, CONTROLLER, Sony Computer Entertainment Inc. H"
 Case: "SCPH-1080 Made in China"
 PCB: "CMK-PIHB \, CFS8121-200010-01"
 U?: 32pin "(M), SC401800, FB C37B, JSJD520C" (Motorola) (TQFP-32 package)
 U?: 14pin "BA10339F, 528 293" (Quad Comparator) (/ACK, JOYDAT, and reset or so)
 X?: 3pin "4.00G1f" (on PCB bottom side)
 Z1: 2pin z-diode or so (on PCB bottom side) (+1.7V VREF for BA10339F)
 CN?: 7pin cable to controller port (plus shield; but not connected to PCB)
 C1 2pin to GND and R5
 C2 2pin capacitor for power supply input (between +3.5V and GND)
 C3 2pin between BA.pin8 and (via R6) BA.pin15
 R1 2pin 1M ohm (for X1)
 R2 2pin 2.7K
 R3 2pin 8xK ohm?
 R4 2pin 100K
 R5 2pin 22K ohm
 R6 2pin 56K ohm
 RN1 8pin 4x200 ohm (/JOYn, JOYCMD, JOYCLK)
 RN2 8pin 4x22K ohm (pull-ups for button bit0..3)
 RN3 8pin 4x22K ohm (pull-ups for button bit12..15)

```
RN4 8pin 4x22K ohm (pull-ups for button bit8..11)
RN5 8pin 4x22K ohm (pull-ups for button bit4..7)
```

Digital Joypad Connection Cable:

```
PSX.1 -----brown---- PAD.2 JOYDAT
PSX.2 -----orange--- PAD.6 JOYCMD
PSX.3 --- NC +7.5V
PSX.4 -----black---- PAD.3 GND
PSX.5 -----red----- PAD.4 +3.5V
PSX.6 -----yellow--- PAD.5 /JOYn
PSX.7 -----blue----- PAD.7 JOYCLK
PSX.8 --- NC /IRQ10
PSX.9 -----green---- PAD.1 /ACK
PSX.Shield --shield--- NC (cable is shielded but isn't connected in joypad)
```

Digital Joypad 32pin SC401800 Chip Pin-Outs

```
1 Bit14 SW-X
2 Bit13 SW-O
3 Bit12 SW-/\'
4 Bit11 SW-R1 (via cable pin1, white wire)
5 Bit10 SW-L1 (via cable pin1, white wire)
6 Bit9 SW-R2 (via cable pin3, black wire)
7 Bit8 SW-L2 (via cable pin3, black wire)
8 via BA10339F.pin7 to cn.2 JOYDAT (PSX.1)
---
9 via RN1 (200 ohm) to cn.5 /JOYn (PSX.6)
10 via RN1 (200 ohm) to cn.6 JOYCMD (PSX.2)
11 via RN1 (200 ohm) to cn.7 JOYCLK (PSX.7)
12 GND to cn.3 (PSX.4)
13 Bit7 SW-LEFT
14 Bit6 SW-DOWN
15 Bit5 SW-RIGHT
16 via BA10339F.pin5 to cn.1 /ACK (PSX.9)
---
17 Bit4 SW-UP
18 Bit3 SW-START
19 Bit2 (HI) (would be R3 on Analog Pads) ;\unused, but working button inputs
20 Bit1 (HI) (would be L3 on Analog Pads) ;/(each fitted with a RN2 pullup)
21 Bit0 SW-SELECT
22
23
24 wired to SC401800.pin25
---
25 wired to SC401800.pin24
26 4.00MHz'a
27 4.00MHz'b
28 +3.5V to cn.4 (PSX.5)
29 wired to SC401800.pin32, and via 22K ohm to +3.5V, and to BA.14
30
```

```

31 Bit15 SW-[]
32 wired to SC401800.pin29

```

Digital Joypad 14pin BA10339F Chip Pin-Outs

```

1 OUT2 CN.2 JOYDAT (PSX.1)
2 OUT1 CN.1 /ACK (PSX.9)
3 VCC +3.5V
4 -IN1 +1.7V VREF via Z1 to GND
5 +IN1 CXD.16 /ACK
6 -IN2 +1.7V VREF via Z1 to GND
7 +IN2 CXD.8 JOYDAT
---
8 -IN3 +1.7V VREF via Z1 to GND
9 +IN3 C3,R3,R4
10 -IN4 C1 to +3.5V
11 +IN4 GND
12 GND GND
13 OUT4 NC ?
14 OUT3 CXD.29/32

```

24.16 Pinouts - Component List and Chipset Pin-Outs for Analog Joypad, SCPH-1150

This applies for two controller versions:

```

SCPH-1150 Analog Pad with Single Rumble Motor (japan only)
SCPH-1180 Analog Pad without Rumble Motor

```

Both are using the same PCB, and the same SD657 chip. The difference is that the motor, transistors, and some resistors aren't installed in SCPH-1180.

Analog Joypad Component List (SCPH-1150, single motor)

```

Case "SONY, ANALOG, CONTROLLER, SonyCompEntInc. A, SCPH-1150 MADE IN CHINA"
PCB1 "DD1P09A" (mainboard with digital buttons)
PCB2 "DD1Q14A" (daughterboard with analog joysticks)
PCB3 "DD1Q15A-R" (daughterboard with R-1, R-2 buttons) (J3)
PCB4 "DD1Q15A-L" (daughterboard with L-1, L-2 buttons) (J2)
U1 42pin "SD657, 9702K3006" (2x21pins, L=17.8mm, W=7mm, W+Pins=11mm)
U2 3pin "DR, 4.Z"
Q1 3pin "BQ03" or so (motor post-amp)
Q2 3pin "S6","SG","9S" or so (motor pre-amp)
Y1 3pin "400CMA"
CN1 8pin cable to PSX controller port
CN2 8pin ribbon cable to analog-joystick daughterboard (not so robust cable)

```

```

J1  2pin wires to rumble motor (in left handle) (digital, on/off)
J2  3pin ribbon cable to L-1, L-2 button daughterboard
J3  3pin ribbon cable to R-1, R-2 button daughterboard
LED1 4pin red/green LED (optics without mirror)
D1,D2 diodes
plus resistors/capacitors

```

Analog Joypad Connection Cables (SCPH-1150)

CN1 (cable to PSX controller port) (same for SCPH-1150 and SCPH-1200)

```

PSX.1 -----brown---- PAD.2 JOYDAT
PSX.2 -----orange--- PAD.6 JOYCMD
PSX.3 -----magenta-- PAD.8 +7.5V
PSX.4 -----black---- PAD.3 GND
PSX.5 -----red----- PAD.4 +3.5V
PSX.6 -----yellow--- PAD.5 /JOYn
PSX.7 -----blue----- PAD.7 JOYCLK
PSX.8 --- NC /IRQ10
PSX.9 -----green---- PAD.1 /ACK
PSX.Shield --shield--- NC (cable is shielded but isn't connected in joypad)

```

CN2 (ribbon cable to analog-joystick daughterboard) (SCPH-1150)

```

8 +3.5V to POT pins
7 Button L3 pins A,C
6 GND to POT pins and Button L3/R3 pins B,D
5 Button R3 pins A,C
4 Axis R_Y middle POT pin (SD657.18)
3 Axis R_X middle POT pin (SD657.17)
2 Axis L_Y middle POT pin (SD657.16)
1 Axis L_X middle POT pin (SD657.15)

```

J3 (ribbon cable to R-1, R-2 button daughterboard) (SCPH-1150)

```

1 (red) R1
2 (gray) GND
3 (gray) R2

```

J2 (ribbon cable to L-1, L-2 button daughterboard) (SCPH-1150)

```

1 (red) L1
2 (gray) GND
3 (gray) L2

```

J1 wires to small rumble motor (SCPH-1150)

```
1 (red) +7.5V
2 (black) Q1
```

Analog Joypad Chipset Pin-Outs (SCPH-1150)

U1 42pin "SD657, 9702K3006"

```

1 NC?
2 NC?
3 /RESET? (U2.3)
4 OSC
5 OSC
6 BUTTON Bit3 START SW1
7 BUTTON Bit2 R3 (via CN2.5)
8 BUTTON Bit1 L3 (via CN2.7)
9 BUTTON Bit0 SELECT SW3
10 GND
11 BUTTON Bit7 LEFT SW4
12 BUTTON Bit6 DOWN SW5
13 BUTTON Bit5 RIGHT SW6
14 BUTTON Bit4 UP SW7
15 Analog Axis L_X (via CN2.1)
16 Analog Axis L_Y (via CN2.2)
17 Analog Axis R_X (via CN2.3)
18 Analog Axis R_Y (via CN2.4)
19 NC?
20 3.5V
21 3.5V
---
22 BUTTON Bit15 [] SW11
23 BUTTON Bit14 >< SW10
24 BUTTON Bit13 () SW9
25 BUTTON Bit11 R1 (via J3.1)
26 BUTTON Bit12 /\ SW8
27 BUTTON Bit10 L1 (via J3.1)
28 BUTTON Bit9 R2 (via J3.3)
29 BUTTON Bit8 L2 (via J3.3)
30 PSX.2/CN1.6 JOYCMD orange (via 220 ohm R14)
31 PSX.1/CN1.2.JOYDAT brown (via 22 ohm R13 and diode D2)
32 PSX.7/CN1.7 JOYCLK blue (via 220 ohm R12)
33 PSX.6/CN1.5./JOYn yellow (via 220 ohm R11)
34 LED.GREEN (LED.4)
35 LED.RED (LED.3)
36 MOTOR (via 4.7Kohm R8 to Q2, then via Q1 to motor)
37 NC?
38 NC?
39 PSX.9/CN1.1./ACK green (via 22 ohm R10)
40 NC?
```

```
41 MODE SW2 (analog button)
42 GND
```

U2 (probably reset signal related)

```
1 from 3.5V (via R1,D1,R2)
2 to U1.3 (/RESET?) (U2.rear contact = same as U2.pin2)
3 GND
```

Q1 "BQ03" or so (motor post-amp)

```
1 Q2.2 (via 1Kohm R7)
2 to Motor (-)
3 GND
```

Q2 "S6","SG","9S" or so (motor pre-amp)

```
1 SD657.36 (via 4.7Kohm R8)
2 Q1.1 (via 1Kohm R7) (and via 100Kohm R13 to GND)
3 3.5V
```

Motor

Left/Single Motor (SCPH-1150)

27.5mm Total Length (18.5mm Motor, 2mm Axis, 7mm Weight/block)
12.0mm Width/Diameter (of Weight, and of Motor at flat side)

24.17 Pinouts - Component List and Chipset Pin-Outs for Analog Joypad, SCPH-1200

Analog Joypad Component List (SCPH-1200, two motors)

Case "SONY, ANALOG, CONTROLLER, SonyCompEntInc. H, SCPH-1200 MADE IN CHINA"
 PCB1 "01, /\YG-H2, (r)RU" (mainboard with digital buttons)
 PCB2 "M-29-01, YG-H3, (r)RU" (daughterboard with analog joysticks)
 PCB3 "E, /\YG-H2, (r)RU, 01" (daughterboard with R-1, R-2 buttons) (J1)
 PCB4 "01, W, /\YG-H2, (r)RU" (daughterboard with L-1, L-2 buttons) (J2)
 U1 44pin "SONY, CXD8771Q 4A03, JAPAN 9840 HAL, 148896"
 U2 4pin ",\ 29" (PST9329) (System Reset with 2.9V detection voltage)
 U3 8pin "2904, 8346G, JRC" (NJM2904) (Dual Operational Amplifier)
 Q1 3pin ".Y S'" (big transistor for big M1 rumble motor)
 Q2 3pin "Z" (small transistor for small M2 rumble motor)

```

Y1 3pin "800CMLX" or so (hides underneath of the CN2 ribbon cable)
CN1 8pin cable to PSX controller port
CN2 8pin ribbon cable to analog-joystick daughterboard
J1 3pin ribbon cable to R-1, R-2 button daughterboard
J2 3pin ribbon cable to L-1, L-2 button daughterboard
M1 2pin wires to left/big rumble motor (analog, slow/fast)
M2 2pin wires to right/small rumble motor (digital, on/off)
ZD1,ZD2 some Z-diodes
D1,D2 diodes near M1,M2 motors (these diodes aren't installed)
LED1 red analog mode LED (with transparent optics/light direction mirror)
plus resistors/capacitors

```

Note: There's also a different SCPH-1200 revision, which having a smaller mainboard with analog joysticks on board, plus a single sided PCB for the digital buttons (that is, similar to SCPH-110, but with the single sided PCB instead of membrane foil).

Analog Joypad Connection Cables (SCPH-1200)

CN1 (cable to PSX controller port) (same for SCPH-1150 and SCPH-1200)

```

PSX.1 -----brown---- PAD.2 JOYDAT
PSX.2 -----orange--- PAD.6 JOYCMD
PSX.3 -----magenta-- PAD.8 +7.5V
PSX.4 -----black---- PAD.3 GND
PSX.5 -----red----- PAD.4 +3.5V
PSX.6 -----yellow--- PAD.5 /JOYn
PSX.7 -----blue----- PAD.7 JOYCLK
PSX.8 --- NC /IRQ10
PSX.9 -----green---- PAD.1 /ACK
PSX.Shield --shield--- NC (cable is shielded but isn't connected in joypad)

```

CN2 (ribbon cable to analog-joystick daughterboard) (SCPH-1200)

- 1 +3.5V to POT pins
- 2 Button L3 pins C,D
- 3 GND to POT pins and Button L3/R3 pins A,B
- 4 Button R3 pins C,D
- 5 Axis R_Y middle POT pin (CXD.20)
- 6 Axis R_X middle POT pin (CXD.19)
- 7 Axis L_X middle POT pin (CXD.21)
- 8 Axis L_Y middle POT pin (CXD.22)

J1 (ribbon cable to R-1, R-2 button daughterboard) (SCPH-1200)

```

1 (red) R1
2 (gray) GND
3 (gray) R2

```

J2 (ribbon cable to L-1, L-2 button daughterboard) (SCPH-1200)

```

1 (red) L1
2 (gray) GND
3 (gray) L2

```

M1 wires to big rumble motor (SCPH-1200)

```

+ (red) Q1.E
- (black) GND

```

M2 wires to small rumble motor (SCPH-1200)

```

+ (red) +7.5V
- (black) Q2.C

```

Analog Joypad Chipset Pin-Outs (SCPH-1200)**U1 SONY CXD8771Q**

```

1 PSX.7/CN1.7 JOYCLK (via 220 ohm R2)
2 via R10 to U3.3 (for big M1 motor)
3 via R15 to Q2.B (for small M2 motor)
4 GND
5 BUTTON Bit15 []
6 BUTTON Bit14 ><
7 BUTTON Bit13 ()
8 BUTTON Bit12 /\
9 BUTTON Bit11 R1 (via J1.1)
10 BUTTON Bit10 L1 (via J2.1)
11 BUTTON Bit9 R2 (via J1.3)
---
12 BUTTON Bit8 L2 (via J2.3)
13 GND
14 U2.Pin3 (reset)
15 Y1'a
16 Y1'b
17 GND
18 +3.5V
19 Analog Axis R_X via CN2.6
20 Analog Axis R_Y via CN2.5
21 Analog Axis L_X via CN2.7
22 Analog Axis L_Y via CN2.8
---
23 GND
24 GND
25 GND
26 GND
27 GND

```

```

28 +3.5V
29 BUTTON Bit0 SELECT
30 BUTTON Bit1 L3 (via CN2.2)
31 BUTTON Bit2 R3 (via CN2.4)
32 BUTTON Bit3 START
33 BUTTON Bit4 UP
---
34 BUTTON Bit5 RIGHT (aka spelled RIHGT on the PCB)
35 BUTTON Bit6 DOWN
36 BUTTON Bit7 LEFT
37 PSX.6/CN1.5./JOYn (via 220 ohm R1)
38 ANALOG BUTTON
39 GND
40 +3.5V
41 /LED (to LED1, and from there via 300 ohm R6 to +3.5V)
42 PSX.9/CN1.1./ACK (via 22 ohm R5)
43 PSX.1/CN1.2.JOYDAT (via 22 ohm R3)
44 PSX.2/CN1.6 JOYCMD (via 220 ohm R4)

```

U2 PST9329 (System Reset with 2.9V detection voltage)

```

1 NC     GND
2 GND    GND
3 Vout   U1.14
4 VCC    +3.5V

```

U3 NJM2904 (Dual Operational Amplifier)

```

1 A.OUTPUT Q1.B (big motor M1 transistor)
2 A.INPUT- to R11/R12
3 A.INPUT+ to R10/R17
4 GND      PSX.4/CN1.3 GND
5 B.INPUT+ GND
6 B.INPUT- NC?
7 B.OUTPUT NC?
8 VCC      PSX.3/CN1.8 +7.5V

```

Q1 (transistor for big M1 motor)

```

E M1+
B U3.1 (NJM2904)
C +7.5V

```

Q2 (transistor for small M2 motor)

```

E GND
B via 1K ohm R15 to U1.3 (CXD), and via 100K ohm R16 to GND
C M2-

```

Motors

Left/Large Motor (SCPH-1200)

24.0mm Total Length (12.0mm Motor, 2.5mm Axis, 9.5mm Weight/plates)

24.0mm Diameter (Motor), 20.0mm Diameter (Weight/plates)

Right/Small Motor (SCPH-1200)

25.4mm Total Length (18.7mm Motor, 2mm Axis, 4.7mm Weight/plates)

12.0mm Width/Diameter (of Weight, and of Motor at flat side)

24.18 Pinouts - Component List and Chipset Pin-Outs for Analog Joypad, SCPH-110

Analog Joypad Component List (SCPH-110, two motors, PSone-design)

Case "SONY, ANALOG CONTROLLER, SonyCompEntInc. A, SCPH-110 MADE IN CHINA"

PCB1 "SA1Q22A, <PF-LP>, KPC, 7694V-0" (mainboard with joysticks onboard)

PCB2 "..." (membrane/foil with digital buttons)

U1 44pin "SD707, 039 107"" (4x11pin)

Q1 3pin "KA" (big transistor for left/big M1 rumble motor)

Q2 3pin "LG" (small transistor for right/small M2 rumble motor)

D1 2pin diode (for large motor, reference Z-diode with pull-up?)

D2 3pin dual-diode (R5/IRQ7 to GND and R3/DAT to GND)

CN1 9pin cable to PSX controller port

J1 16pin ribbon cable from membrane/foil

M1 2pin wires to left/big rumble motor (analog, slow/fast)

M2 2pin wires to right/small rumble motor (digital, on/off)

LED1 2pin red analog mode LED (with long legs, without mirror/optics)

plus resistors/capacitors

Analog Joypad Connection Cables (SCPH-110)

CN1 (cable to PSX controller port)

1 +3.5V (logic supply)

2 GND3 (logic supply)

3 /IRQ7

4 /SEL

5 CMD

6 DAT

7 CLK

8 GND7 (motor supply)

9 +7.5V (motor supply)

J1 (ribbon cable with membrane/foil with digital buttons)

```

1 BUTTON Bit8 L2
2 BUTTON Bit10 L1
3 BUTTON Bit4 UP
4 BUTTON Bit5 RIGHT
5 BUTTON Bit6 DOWN
6 BUTTON Bit7 LEFT
7 GND3
8 ANALOG BUTTON
9 BUTTON Bit0 SELECT
10 BUTTON Bit3 START
11 BUTTON Bit15 SQUARE      []
12 BUTTON Bit14 CROSS      ><
13 BUTTON Bit13 CIRCLE      ()
14 BUTTON Bit12 TRIANGLE   /\_
15 BUTTON Bit11 R1
16 BUTTON Bit9 R2

```

M1 wires to left/big rumble motor (SCPH-110)

```

1 (red)    Q1
2 (black)  GND (via some ohm)

```

M2 wires to right/small rumble motor (SCPH-110)

```

1 (red)    +7.5V
2 (black)  Q2

```

U1 ("SD707, 039 107")

```

1 via R9/Q2 to M2 (right/small)      (digital 0V=off, 3V=on)
2 via "JP1" to LED (330 ohm)
3 +3.5V
4 BUTTON Bit2 R3
5 vr2 RX (lt/rt)
6 vr1 RY (up/dn)
7 vr4 LX (lt/rt)
8 vr3 LY (up/dn)
9 BUTTON Bit1 L3
10 GND3
11 GND7
---
12 via Q1 to M1 (left/large)        (1V=off, 6V=fast)
13 via D1/R7 to M1 (left/large)     (6.7V)
14 +7.5V
15 +7.5V
16 BUTTON Bit8 L2
17 BUTTON Bit10 L1

```

```

18 BUTTON Bit4 UP
19 BUTTON Bit5 RIGHT
20 BUTTON Bit6 DOWN
21 BUTTON Bit7 LEFT
22 GND3
---
23 BUTTON Bit9 R2
24 BUTTON Bit11 R1
25 BUTTON Bit12 TRIANGLE /\_
26 BUTTON Bit13 CIRCLE   ()
27 BUTTON Bit14 CROSS   ><
28 BUTTON Bit15 SQUARE  []
29 BUTTON Bit3 START
30 BUTTON Bit0 SELECT
31 ANALOG BUTTON
32 NC
33 +3.5V
---
34 GND3
35 NC
36 via R5 to /IRQ7
37 via R1 to /SEL
38 via R4 to CMD
39 via R3 to DAT
40 via R2 to CLK
41 +7.5V
42 +7.5V
43 GND7
44 GND7

```

Misc

VR1..VR4 -- analog inputs

R1..R5 -- signals to/from psx

R6 ?

R7 M1

R8

R9

R10

JP1

C1 3.5V to GND3 (22uF)

C2 3.5V to GND3 (U1)

C3 VR1 to GND3

C4 VR2 to GND3

C5 VR3 to GND3

C6 VR4 to GND3

C7 M2+ to M2-

C8 M1+ to M1-

C9 M1 related

S5

S6

Motors

Left/Large Motor (SCPH-110)

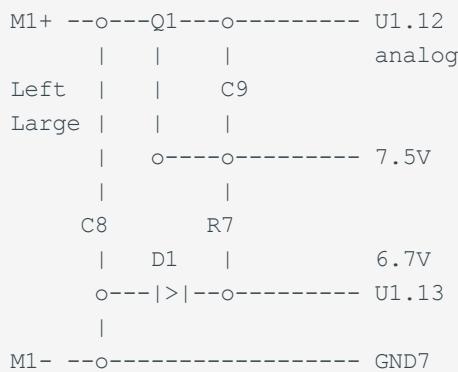
23.0mm Total Length (12.0mm Motor, 3mm Axis, 8.0mm Weight/plates)

24.0mm Diameter (Motor), 20.0mm Diameter (Weight/plates)

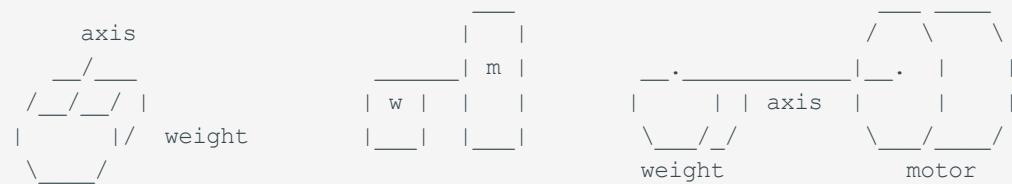
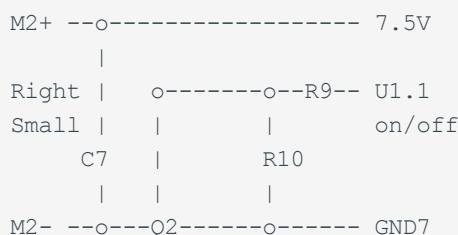
Right/Small Motor (SCPH-110)

25.4mm Total Length (18.7mm Motor, 2mm Axis, 4.7mm Weight/plates)

12.0mm Width/Diameter (of Weight, and of Motor at flat side)



D1 is probably a Z-diode with R7 as pull-up, creating a reference/source voltage at U1.13 for the analog output at U1.12.



24.19 Pinouts - Component List and Chipset Pin-Outs for Namco Lightgun, NPC-103

Schematic

<http://www.nicolaselectronics.be/reverse-engineering-the-playstation-g-con45/>

Namco Lightgun "NPC-103, (C) 1996 NAMCO LTD." Component List

PCB "DNP-0500A, NPC10300, namco, CMK-P3X"

```

U1 44pin "NAMCO103P, 1611U1263, JAPAN 9847EAI, D0489AAF"
U2 8pin "7071, 8C19" (=BA7071F, Sync Separator IC with AFC)
XTAL 2pin "CSA 8.00WT"
PS1 3pin Light sensor with metal shielding
J1 9pin Connector for 9pin cable to PSX controller and GunCon plugs
plus resistors and capacitors, and A1,A2,B1,B2,T1,T2 wires to buttons

```

PCB "DN-P-0501"

```
DIP Button (with black T1,T2 wires) (trigger)
```

PCB "DN-P-0502"

```

Button A (with red A1,A2 wires) (left side)
Button B (with white B1,B2 wires) (right side)

```

Other Components

```
Lens (20mm)
```

Cable Pinouts

```

J1.Pin1 green PSX.Controller.Pin5 +3.5V
J1.Pin2 brown PSX.Controller.Pin4 GND
J1.Pin3 black PSX.Controller.Pin9 /ACK/IRQ7
J1.Pin4 red PSX.Controller.Pin6 /JOYn
J1.Pin5 yellow PSX.Controller.Pin1 JOYDAT
J1.Pin6 orange PSX.Controller.Pin2 JOYCMD
J1.Pin7 blue PSX.Controller.Pin7 JOYCLK
J1.Pin8 gray GunCon shield (GND)
J1.Pin9 white GunCon composite video
N/A PSX.Controller.Pin3 +7.5V

```

N/A	PSX.Controller.Pin8 /IRQ10
N/A	PSX.Controller Shield

U1 "NAMCO103P" Pinouts (44pin, arranged as 4x11pin)

1 GND	12 SYNC (from U2)	23 3.5V	34 SW1 (A)
2 GND	13 3.5V	24 3.5V	35 3.5V
3 GND	14 3.5V	25 3.5V	36 3.5V
4 GND	15 SW3 (TRIGGER)	26 GND	37 SW2 (B)
5 GND	16 JOYCLK (J1.Pin7 via 220 ohm R7)	27 GND	38 3.5V
6 GND	17 3.5V	28 GND	39 3.5V
7 GND	18 JOYCMD (J1.Pin6 via 220 ohm R8)	29 GND	40 LIGHT (from PS1)
8 GND	19 JOYDAT (J1.Pin5 via 0 ohm R10)	30 -	41 GND
9 -	20 /JOYn (J1.Pin4 via 220 ohm R9)	31 GND	42 GND
10 GND	21 /ACK/IRQ7 (J1.Pin3 via 0 ohm R11)	32 GND	43 OSC 8MHz
11 GND	22 GND	33 GND	44 OSC 8MHz

U2 "7071" Pinouts (=BA7071F, Sync Separator IC with AFC) (2x4pin)

1 VIN	= SYNC.IN from J1.Pin9 Composite Video (via C5/C6/C7/R6)
2 HD_OUT	= NC
3 GND	= GND
4 PD_OUT	= NC
5 HOSC_R	= via 100K to GND
6 VCC	= 3.5V
7 VD_OUT	= NC
8 SYNC_OUT	= SYNC.OUT to U1.pin12 (with R4 pull-up)

24.20 Pinouts - Component List and Chipset Pin-Outs for Multitap, SCPH-1070

Multitap Component List

Case "SONY, MULTITAP, SonyComputerEntertainmentInc, SCPH-1070 MADE IN CHINA"
 PCB1 "SONY 1-659-343-11" (mainboard with Slot A,B, ICs, X1, PSX-cable)
 PCB2 "SONY 1-711-414-11" (daughterboard with Slot C,D)
 IC? 64pin "SONY JAPAN, CXD103, -166Q, 550D66E" (smd/back side)
 IC02 8pin "7W14, 5K" some tiny SMD chip (for JOYCLK) (smd/back side)
 X1 2pin "4.00G CMj" oscillator (front side)
 J34 2pin fuse or 1 ohm resistor or so (for +3.5V input) (front side)
 Jxx 2pin normal wire bridges (except: J34 is NOT a wire) (front side)

Cables from Multitap PCB1 to PCB2:

```
1pin black wire Shield/GND (lower edge)
1pin black wire Shield/GND (upper edge)
2x8pin red/gray ribbon cable (side edge)
2x2pin red/gray ribbon cable (lower edge)
2pin red/gray ribbon cable (upper middle) (gray=+3.3V, red=+7.5V)
```

plus a bunch of SMD capacitors and around 70 SMD resistors.

Multitap PSX Controller Port Cable

```
PSX.1 -----brown----- TAP.1 JOYDAT ;via 47 ohm (R57) to CXD.35
PSX.2 -----orange----- TAP.2 JOYCMD ;via 220 ohm (R58) to CXD.37
PSX.3 -----magenta---- TAP.3 +7.5V ;directly to +7.5V on JOY/CARD's
PSX.4 -----black----- TAP.4 GND ;directly to GND
PSX.5 -----red----- TAP.5 +3.3V ;via 1 ohm or so (J34) to +3.3V
PSX.6 -----yellow----- TAP.6 /JOYn ;via 220 ohm (R59) to CXD.46
PSX.7 -----blue----- TAP.7 JOYCLK ;via 220 ohm (R60) to IC02.pin6
PSX.8 -----gray----- TAP.8 /IRQ10 ;via 47 ohm (R02/R16/R30/R44) to JOY's
PSX.9 -----green----- TAP.9 /ACK ;via 47 ohm (R61) to CXD.51
PSX.Shield --shield---- TAP.shielding.plate (GND)
```

Multitap CARD A/B/C/D Slots

```
1 JOYDAT Via 47 ohm (R11/R25/R38/R5x) to CXD.18/29/60/5 (and to JOY slot)
2 JOYCMD Via 220 ohm (R10/R24/R39/R52) to CXD.19/30/62/6
3 +7.5V Directly to PSX.3
4 GND Directly to PSX.4
5 +3.3V Via J34 to PSX.5 (+3.3V)
6 /JOYn Via 220 ohm (R09/R2x/Rxx/R51) to CXD.11/22/52/61
7 JOYCLK Via 220 ohm (R08/R2x/Rxx/R50) to CXD.33/33/47/47
9 /ACK Via 47 ohm (R07/R2x/Rxx/R49) to CXD.12/21/45/64
```

Multitap JOY A/B/C/D Slots

```
1 JOYDAT Via 47 ohm (R06/Rxx/R34/R5x) to CXD.18/29/60/5 (and to CARD slot)
2 JOYCMD Via 220 ohm (R05/R19/R35/R5x) to CXD.17/28/59/4
3 +7.5V Directly to PSX.3
4 GND Directly to PSX.4
5 +3.3V Via 1 ohm or so (J34) to PSX.5 (+3.3V)
6 /JOYn Via 220 ohm (R04/R18/R32/R4x) to CXD.16/20/55/63
7 JOYCLK Via 220 ohm (R03/R17/R31/R45) to CXD.15/23/56/2
8 /IRQ10 Via 47 ohm (R02/R16/R30/R44) to PSX.8
9 /ACK Via 47 ohm (R01/R15/R29/R43) to CXD.13/27/54/7
Shield Directly to Shield/GND
```

Multitap IC02 8pin "7W14, 5K" some tiny SMD chip

```

1
2
3
4 GND
5
6 via 220 ohm (R60) to PSX.7 (JOYCLK)
7 to CXD.Pin48
8 +3.3V, aka via 1 ohm (J34) to PSX.5 (+3.5V)

```

Multitap "SONY CXD103-166Q" Chip Pin-Outs (Multitap CPU)

```

1 via to 10K (R63) to +3.3V, and via C13 to GND (probably power-on reset)
2 JOY.D.7.JOYCLK
3
4 JOY.D.2.JOYCMD
5 JOY/CARD.D.1.JOYDAT
6 CARD.D.2.JOYCMD
7 JOY.D.9./ACK
8 4MHz X1/C12
9 4MHz X1/C11
10 GND
11 CARD.A.6./JOYn
12 CARD.A.9./ACK
13 JOY.A.9./ACK
14
15 JOY.A.7.JOYCLK
16 JOY.A.6./JOYn
17 JOY.A.2.JOYCMD
18 JOY/CARD.A.1.JOYDAT
19 CARD.A.2.JOYCMD
---
20 JOY.B.6./JOYn
21 CARD.B.9./ACK
22 CARD.B.6./JOYn
23 JOY.B.7.JOYCLK
24
25 GND
26 +3.3V
27 JOY.B.9./ACK
28 JOY.B.2.JOYCMD
29 JOY/CARD.B.1.JOYDAT
30 CARD.B.2.JOYCMD
31 GND
32
---
33 CARD.A/B.7.JOYCLK
34
35 PSX.1.JOYDAT
36
37 PSX.2.JOYCMD

```

```

38
39
40
41
42 GND
43
44 GND
45 CARD.C.9./ACK
46 PSX.6./JOYn
47 CARD.C/D.7.JOYCLK
48 IC02.Pin7.PSX.JOYCLK
49
50
51 PSX.9./ACK
---
52 CARD.C.6./JOYn
53
54 JOY.C.9./ACK
55 JOY.C.6./JOYn
56 JOY.C.7.JOYCLK
57 GND
58 +3.3V
59 JOY.C.2.JOYCMD
60 JOY/CARD.C.1.JOYDAT
61 CARD.D.6./JOYn
62 CARD.C.2.JOYCMD
63 JOY.D.6./JOYn
64 CARD.D.9./ACK

```

24.21 Pinouts - Memory Cards

Sony Playstation Memory Card (SCPH-1020)

The "SONY CXD8732AQ" chip is installed on memory cards with "SPC02K1020B" boards, however, the text layer on the board says that it's an "LC86F8604A" chip. So, the CXD8732AQ is most probably a standard LC86F8604A chip (more on that below) with a Sony Memory Card BIOS ROM on it.

The "SONY CXD8732AQ" comes in a huge 64pin package, but it connects only to:

5 = /IRQ7 (via 22 ohm)	2 = /RESET (from U2)
6 = JOYCLK (via 220 ohm)	30,31 = CF1,CF2 (12 clock pulses per 2us)
7 = /JOYn (via 220 ohm)	14,16,25,32,38,39,61 = 3.5V (via 3.3 ohm)
12 = JOYCMD (via 220 ohm)	8,15,28,29 = GND
13 = JOYDAT (via 22 ohm)	All other pins = Not connected

Aside from that chip, the board additionally contains some resistors, capacitors, z-diodes (for protection against too high voltages), a 6MHz oscillator (for the CPU), and a 5pin

reset generator (on the cart edge connector, the supply pins are slightly longer than the data signal pins, so when inserting the cartridge, power/reset gets triggered first; the 7.5V supply pin is left unconnected, only 3.5V are used).

Caution: The "diagonal edge" at the upper-left of the CXD8732AQ chip is Pin 49 (not pin 1), following the pin numbers on the board (and the Sanyo datasheet pinouts), pin 1 is at the lower-left.

Sanyo LC86F8604A

8bit CPU with 132Kbyte EEPROM, 4Kbyte ROM, 256 bytes RAM, 2 timers, serial port, and general purpose parallel ports. The 132K EEPROM is broken into 128K plus 4K, the 4K might be internally used by the CPU, presumably containing the BIOS (not too sure if it's really containing 4K EEPROM plus 4K ROM, or if it's meant to be only either one).

1=P40/A0	9=P13	17=TP0	25=VDD	33=A11	41=NC	49=A7	57=NC
2=/RES	10=P14	18=TP1	26=NC	34=A9	42=NC	50=A6	58=NC
3=TEST2	11=P15	19=TP2	27=NC	35=A8	43=NC	51=A5	59=NC
4=TEST1	12=P16	20=TP3	28=NC	36=A13	44=NC	52=A4	60=NC
5=P10	13=P17	21=TP4	29=VSS	37=A14	45=A17	53=NC	61=NC61
6=P11	14=/CE	22=TP5	30=CF1	38=/WE	46=A16	54=NC	62=P43/A3
7=P12	15=A10	23=TP6	31=CF2	39=VDD	47=A15	55=NC	63=P42/A2
8=VSS	16=/OE	24=TP7	32=VDD	40=EP	48=A12	56=NC	64=P41/A1

Ports P10..P17 have multiple functions (I/O port, data bus, serial, etc):

P10/DQ0/SEPMOD	P12/DQ2/FSI0	P14/DQ4	P16/DQ6/SI0/FSTART
P11/DQ1/SCLK0/FCLK	P13/DQ3	P15/DQ5	P17/DQ7/SO0/FRW

In March 1998, Sanyo has originally announced the LC86F8604A as an 8bit CPU with "2.8V FLASH, achieved for the first time in the industry", however, according to their datasheet, what they have finally produced is an 8bit CPU with "3.5V EEPROM". Although, maybe the 3.5V EEPROM version came first, and the 2.8V FLASH was announced to be a later low-power version of the old chip; namely, otherwise, it'd be everyone's guess what kind of memory Sony used in memory cards before 1998?

Note

For the actual pin-outs of the cart-edge connector, see
[Pinouts - Controller Ports and Memory-Card Ports](#)

24.22 Mods - Nocash PSX-XBOO Upload

Nocash PSX-XBOO Connection (required)

```

GND (BOARD) ----- GND (SUBD.18-25, CNTR.19-30)
A16 (ROM.2) ----- SLCT (SUBD.13, CNTR.13) ; \
A17 (ROM.30) ----- PE (SUBD.12, CNTR.12) ; 4bit.dta.out
A18 (ROM.31) ----- /ACK (SUBD.10, CNTR.10) ;
A19 (ROM.1) ----- BUSY (SUBD.11, CNTR.11) ;/
/RESET ----- |>| /INIT (SUBD.16, CNTR.31) ;-reset.in
D0..D7 (74HC541) ----- DATA (SUBD.2-9, CNTR.2-9) ; \
Y0..Y7 (74HC541) ----- D0..D7 (ROM.13-15,17-21) ; 7bit.dta.in, and
/OE1 (74HC541.1) ----- /EXP (CPU.98) ; 1bit.dta.clk.in
/OE2 (74HC541.19) ----- /OE (ROM.24) ;
GND (74HC541.10) ----- GND (BOARD) ;
VCC (74HC541.20) ----- +5V (BOARD) ;/

```

Nocash PSX-BIOS Connection (required)

```

A0..A19 (ROM) ----- A0..A19 (EPROM)
D0..D7 (ROM) ----- D0..D7 (EPROM)
/BIOS (CPU.97) ----- /CS (EPROM.22)
/OE (ROM.24) ----- /OE (EPROM.24)
+5V (BOARD) ----- VCC (EPROM.32)
GND (BOARD) ----- GND (EPROM.16)
/CS (ROM.22) --/cut-- /BIOS (CPU.97)
/CS (ROM.22) ----- +5V (BOARD) (direct, or via 100k ohm)

```

Nocash BIOS "Modchip" Feature (optional)

```

SPU.Pin42 "data" -----|>|----- CPU.Pin149 (A20)
SPU.Pin5 "sync" ----- IC723.Pin17

```

The nocash PSX bios outputs the "data" signal on the A20 address line, so (aside from the BIOS chip) one only needs to install a 1N4148 diode and two wires to unlock the CDROM. For more variants, see:

[CDROM Protection - Chipless Modchips](#)

Composite NTSC/PAL Mod (optional)

[Mods - PAL/NTSC Color Mods](#)

Component List

32pin socket for EPROM
 EPROM (or FLASH)
 74HC541 (8-bit 3-state noninverting buffer/line driver)
 1N4148 diode (for reset signal)
 1N4148 diode (for optional "modchip" feature)
 36pin Centronics socket for printer cable (or 25pin dsub)

PSX-XBOO Upload BIOS

The required BIOS is contained in no\$psx (built-in in the no\$psx.exe file), the Utility menu contains a function for creating a standalone ROM-image (file PSX-XBOO.ROM in no\$psx folder; which can be then burned to FLASH or EPROM).

Pinouts

A19,VPP12		1	32		VCC6	/OE1		1	20		VCC
A16		2	31		A18,/PGM	D0		2	19		/OE2
A15		3	30		A17	D1		3	18		Y0
A12		4	29		A14	D2		4	17		Y1
A7		5	28		A13	D3		5	74541		16 Y2
A6		6	27		A8	D4		6	15		Y3
A5		7	26		A9,IDENT12	D5		7	14		Y4
A4		8	25		A11	D6		8	13		Y5
A3		9	24		/OE,VPP12	D7		9	12		Y6
A2		10	23		A10	GND		10	11		Y7
A1		11	22		/CE, (/PGM)		_____				
A0		12	21		D7						
D0		13	20		D6						
D1		14	19		D5						
D2		15	18		D4						
GND		16	17		D3						

Note

Instead of the above internal mod, the nocash kernel clone can be also installed on cheat devices, which do also include DB25 connectors for parallel port uploads, too.

For DB25 parallel port uploads, do the following mods to the cheat device:

- Datel: use the FiveWire mod to get it parallel port compatible
- Xplorer: simply wire DB25./INIT to EXP./RESET (with diode, if needed)

24.23 Mods - PAL/NTSC Color Mods

The PSX hardware is more or less capable of generating both PAL and NTSC signals. However, it's having the bad habit to do this automatically depending on the game's frame rate. And worse, it's doing it regardless of whether the board is having matching oscillators installed (eg. a PAL board in 60Hz mode will produce NTSC encoding with faulty NTSC color clock).

color encoding	PAL	NTSC
color clock	4.43361875MHz	3.579545MHz
frame rate	50Hz	60Hz

RGB Cables

RGB cables don't rely on composite PAL/NTSC color encoding, and thus don't need any color mods (except, see the caution on GNDed pins for missing 53.20MHz/53.69MHz oscillators below).

Newer Consoles (PU-22, PU-23, PM-41, PM-41(2))

These consoles have 17.734MHz (PAL) or 14.318MHz (NTSC) oscillators with constant dividers, so the color clock will be always constant, and one does only need to change the color encoding:

```
/PAL (IC502.pin13) ---/cut/--- /PAL (GPU.pin157)
/PAL (IC502.pin13) ----- GND (PAL) or VCC (NTSC)
```

This forces the console to be always producing the desired composite color format (regardless of whether the GPU is in 50Hz or 60Hz mode).

That works for NTSC games on PAL consoles (and vice-versa). However, it won't work for NTSC consoles with PAL TV Sets (for that case it'd be easiest to install an extra oscillator, as done on older consoles).

Older Consoles (PU-7, PU-8, PU-16, PU-18, PU-20)

These consoles have 53.20MHz (PAL) or 53.69MHz (NTSC) oscillators and the GPU does try to change the clock divider depending on the frame rate (thereby producing a nonsense clock signal that's neither PAL nor NTSC). Best workaround is to install an extra

4.43361875MHz (PAL) or 3.579545MHz (NTSC) oscillator (with internal amplifier, ie. in 4pin package, which resembles DIP14, hence the pin 1,7,8,14 numbering):

```

GPU -----/cut/--- CXA1645M.pin6 SCIN
GPU -----/cut/--- CXA1645M.pin7 /PAL
Osc.pin14 VCC ----- CXA1645M.pin12 VCC (5V)
Osc.pin7 GND ----- CXA1645M.pin1 GND
Osc.pin8 OUT ----- CXA1645M.pin6 SCIN
Osc.pin1 NC --
GND (PAL) or VCC (NTSC) ----- CXA1645M.pin7 /PAL

```

Caution: Many mainboards have solder pads for both 53.20MHz and 53.69MHz oscillators, the missing oscillator is either GNDed or shortcut with the installed oscillator (varies from board to board, usually via 0 ohm resistors on PCB bottom side). If it's GNDed, remove that connection, and instead have it shortcut with the installed oscillator. Alternately, instead of the above mods, one could also install the missing oscillator (and remove its 0 ohm resistor), so the board will have both 53.20MHz and 53.69MHz installed; that will produce perfect PAL and NTSC signals in 50Hz and 60Hz mode accordingly, but works only if the TV Set recognizes both PAL and NTSC signals.

Notes

External 4.433MHz/3.579MHz osciallors won't be synchronized with the GPU frame rate (normally you don't want them to be synchronized, but there's some small risk that they might get close to running in sync, which could result in static or crawling color artifacts). For the CXA1645 chip modded to a different console region, one should also change one of the resistors (see datasheet), there's no noticeable difference on the TV picture though.

Region Checks

Some kernel versions contain regions checks (additionally to the SCEx check), particulary for preventing NTSC games to run on PAL consoles, or non-japanese games on japanese consoles. Some PAL modchips can bypass that check (by patching the region byte in BIOS). Expansions ROMs or nocash kernel clone could be also used to avoid such checks.

25. About & Credits

Credits

GPU.TXT by doomed/padua; based on info from K-communications & Nagra/Blackbag
GTE.TXT by doomed@c64.org / psx.rules.org
SPU.TXT by doomed@c64.org / psx.rules.org
CDINFO.TXT by doomed with big thanks to Barubary, who rewrote a large part
SYSTEM.TXT by doomed with thanx to Herozero for breakpoint info
PS_ENG.TXT PlayStation PAD/Memory Interface Protocol by HFB03536
IDT79R3041 Hardware User's Manual by Integrated Device Technology, Inc.
IDTR3051, R3052 RISController User's Manual by Integrated Device Technology
PSX.* by Joshua Walker (additional details in various distorted file formats)
LIBMIRAGE by Rok; info/source code for various cdrom-image formats
psxdev.ru; cdrom sub-cpu decapping

PSXSPX homepage

<http://problemkaputt.de/psx.htm> no\$psx emulator/debugger
<http://problemkaputt.de/psx-spx.htm> psx specs in html formal
<http://problemkaputt.de/psx-spx.txt> psx specs in text formal

Contact

[\(spam-shielded\)](http://problemkaputt.de/email.htm)

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Cheat Devices - Datel DB25 Comms Link Protocol
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[Pinouts - Audio, Video, Power, Expansion Ports](#)

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[Pinouts - Chipset Summary](#)

[Pinouts - CPU Pinouts](#)

[Pinouts - GPU Pinouts \(for old 160-pin GPU\)](#)

[Pinouts - GPU Pinouts \(for new 208-pin GPU\)](#)

[Pinouts - SPU Pinouts](#)

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[Pinouts - VCD Pinouts](#)

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[Pinouts - MEM Pinouts](#)

[Pinouts - CLK Pinouts](#)

[Pinouts - PWR Pinouts](#)

[Pinouts - Component List and Chipset Pin-Outs for Digital Joypad, SCPH-1080](#)

[Pinouts - Component List and Chipset Pin-Outs for Analog Joypad, SCPH-1150](#)

[Pinouts - Component List and Chipset Pin-Outs for Analog Joypad, SCPH-1200](#)

[Pinouts - Component List and Chipset Pin-Outs for Analog Joypad, SCPH-110](#)

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[extracted from no\$psx v2.0 documentation]

26. CDROM Video CDs (VCD)

VCDs are Video CDs with MPEG compression, yielding a playtime of 72 minutes per disc (whole movies usually being stored on two CDs). VCDs are popular in asia (as opposed to VHS tapes used in western world).

VCDs on Playstation

For the Playstation, the asian SCPH-5903 model includes a special daughterboard with MPEG decoding hardware for playing VCDs.

[CDROM - Video CD Commands](#)

[Pinouts - VCD Pinouts](#)

Without that hardware it has been widely believed to be impossible to play VCDs on Playstations, although, as of 2017, it turned out that the Playstation's CPU and MDEC decoder are fast enough for that purpose (when skipping B-frames, rendering the movie in monochrome without colors, and reducing audio output to 11kHz/mono).

ISO Filesystem (Track 1)

[VCD ISO Basic Files \(INFO, ENTRIES, AVSEQnn, ISO Filesystem\)](#)

[VCD ISO Playback Control PBC Files \(PSD, LOT, ITEMnnnn\)](#)

[VCD ISO Search Files \(SCANDATA, SEARCH, TRACKS, SPICONTX\)](#)

[VCD ISO Misc files \(CAPTnn, AUDIONn, KARINFO, PICTURES, CDI\)](#)

MPEG Streams (Track 2 and up)

[VCD MPEG-1 Multiplex Stream](#)

[VCD MPEG-1 Video Stream](#)

[XXX MPEG-1 Macroblocks](#)

[VCD MP2 Audio Stream](#)

VCD Versions & Variants

[XXX](#)

26.1 VCD ISO Basic Files (INFO, ENTRIES, AVSEQnn, ISO Filesystem)

Primary Volume Descriptor (00:02:16)

VCDs are having a standard ISO Primary Volume Descriptor, with some VCD specific entries:

```
008h 32 System Identifier (always "CD-RTOS CD-BRIDGE" for VCDs)
028h 32 Volume Identifier (often nonsense, eg. "" or "__" or "VolumeLabel")
23Eh 128 Application Identifier ("CDI/CDI_APPL.VCD;1" or "CDI/CDI_VCD.APP;1")
400h 8 CD-XA Identifying Signature ("CD-XA001" for PSX and VCD)
```

There are some more differences to normal CDROMs:

```
VCDs are using MODE2 (with 800h-byte and 914h-byte sectors)
MPEG videos are on extra data tracks (outside of the ISO area on Track 1)
Files in VCD or SVCD folders use fixed sectors numbers (00:04:00 and up)
All 16bit/32bit values in files in VCD, SVCD, EXT, etc are BIG-ENDIAN
```

Due to the fixed sector numbers, VCDs players can completely ignore the ISO filesystem with filenames and folders, and just address everything via sector numbers (though accessing files in EXT and CDI folders seem to require using the filesystem).

VCD\INFO.VCD or SVCD\INFO.SVD (00:04:00) (800h bytes, one sector)

```
000h 8 ID "VIDEO_CD" for VCD (or "SUPERVCD"/"HQ-VCD" for SVCD)
008h 1 Version ;Version Major (01h) (or 02h for VCD 2.0)
009h 1 System Profile Tag ;Version Minor (00h) (or 01h for VCD 1.1 or HQ)
00Ah 16 Album ID/Desc (name in ASCII, padded with SPC) (usually empty)
01Ah 2 Total Number of CDs in Album (1..N) ;\usually always 1,1 (even
01Ch 2 Number of this CD in Album (1..N) ;/for movies with 2 discs)
01Eh 13 PAL Flags, 98x1bit, for each Track? (0=NTSC, 1=PAL)
02Bh 1 InfoStatusFlags (see below)
Below is usually zero-filled when not using PBC
02Ch 4 Size of PSD.VCD file (or PSD.SVD?) (0=None)
030h 3 First segment addr MM:SS:00 in BCD (00:02:00 ???)
033h 1 Offset Multiplier for "PsdOffset" values in PSD.VCD (must be 8)
034h 2 Number of ListIDs in LOT.VCD file (1..7FFFh, plus 1 in some discs)
036h 2 Number of ITEMnnnn.DAT files (plus nonsense in some discs?)
Below is usually zero-filled (maybe exists on SVCD only?)
038h 1980 SegmentContent[1..1980] (b0-1=Audio, b2-4=Video, b5=Cont, b6-7=OGT)
7F4h 5*2 volume start time[0]: 5x16bit ;aka playing_time[5] in seconds (?)
7FEh 2 Reserved (0)
```

InfoStatusFlags at [02Bh] describes certain characteristics of the disc:

```

bit0 Reserved, must be zero
bit1-2 Restriction (0=No, 1..3=Restricted category 1..3) (eg. "not for kids")
bit3 Special Information is encoded in the pictures, uh?
bit4 MPEG User Data is used for Closed Caption (user_data_cc) (0=No, 1=Yes)
bit5 Next Disc with PBC (0=Start at ListID#1, 1=Start at ListID#2)
bit6 Next Disc without PBC (0=Start at Track #2, 1=Start at Track #3)
bit7 Extended PBC available (0=No, 1=Yes... aka EXT\PSD_X exists?)

```

Note: Bit5/6 are used only if the next disc has the same Album ID (eg. the feature allows to skip copyright messages if the same message was already shown on another disc).

First_segment_addr: The location of the first sector of the Segment Play Item Area [that is... the first ITEMnnnn.DAT file?], in the form mm:ss:00. Must be 00:00:00 if PSD size is zero. If PSD size is nonzero, but no segments used: Usually set to 00:02:00.

VCD\ENTRIES.VCD or SVCD\ENTRIES.SVD (00:04:01) (800h bytes, one sector)

```

000h 8      ID "ENTRYVCD" for VCD and SVCD (or "ENTRYSVD" for VCD30)
008h 1      Version           ;\same as in INFO.VCD/SVD
009h 1      System Profile Tag    ;/
00Ah 2      Number of Entries/Chapters (1..500)
00Ch 4*500 Entry[N] (Track 02h..99h, and MM:SS:FF) (all 4 bytes in BCD)
7DCh 36     Reserved (0)

```

Version;

```

0x02 --- VCD2.0
0x01 --- SVCD, should be same as version in INFO.SVD

```

Sys_prof_tag;

```

0x01 if VCD1.1
0x00 else

```

MPEGAV\AVSEQnn.DAT (pointers to max 98 MPEG-1 Tracks, nn=01..98) (for VCDs)

MPEG2\AVSEQnn.MPG (pointers to max 98 MPEG-2 Tracks, nn=01..98) (for SVCDs)

MPEGAV\AVSEQnn.MPG (pointers to WHATEVER) (as so on some SVCDs or VCD30?)

These filesystem entries contain pointers to the video tracks (that is, outside of the ISO area on Track 1).

Commercially made SVCDs can reportedly contain 7 folders: Autorun, Data, Ext, Mpegav, Segment, Svcd and Vmp (ie. there's no MPEG2 folder on all SVCDs? though that MPEGAV folder is said to contain a .MPG file instead of .DAT file).

26.2 VCD ISO Playback Control PBC Files (PSD, LOT, ITEMnnnn)

Playback Control (PBC) is an optional feature that allows to define menus, pictures or text pages (whereas all those are internally just consisting of MPEG compressed bitmaps; rather than of text characters).

Presence of the PBC feature is indicated by PSD.VCD filesize entry (in INFO.VCD) being nonzero. PBC seems to be supported by most VCDs (except older discs from around 1997), however, many VCDs are merely including a single PlayList entry for the movie track, without any further menus/extras.

VCD\PSD.VCD or SVCD\PSD.SVD (00:04:34 and up) (max 256 sectors)

The Descriptors in this file can be considered as being "program code". The program is usually stuck on "executing" the current descriptor (eg. playing a movie, or showing a selection menu) without automatically increasing the program counter. Actual program flow occurs only if the user presses a button (or upon selection timeouts), causing the program to "goto" to a new PsdOffset. And, something does probably happen upon end-of-track/item... maybe that does automatically trigger the Next button handler?

```

<B> PsdPlayListDescriptor (14+2*N bytes) :</B>
 00h 1  Type (10h=PlayList)
 01h 1  Number of Items (noi)      ;for Start-of-Movie and Numeric-Input?
 02h 2  ListID for this Descriptor (1..7FFFh)
 04h 2  PsdOffset for Prev button          (FFFFh=Disable)
 06h 2  PsdOffset for Next button          (FFFFh=Disable)
 08h 2  PsdOffset for Return/back button (FFFFh=Disable)
 0Ah 2  Play time in 1/15s (=max 72.8 minutes) (or 0000h=full item)
 0Ch 1  Delay time in "1s/10s" units after ;<-- uh, after? after what?
 0Dh 1  Auto pause time in "1s/10s" units (used for each item in list if
        the auto pause flag in a sector is true) [WHAT is that? Trigger bit?]
 0Eh 2*N ItemID[N] ;item number (0..599 or 1000..2979)
    Entry 0 is for "start of movie" (usually 0002h=Track 2)
    Entry 1..N-1 is for numeric input ?
<B> PsdSelectionListDescriptor (20+2*N bytes, or 36+6*N bytes) :</B>
 00h      1  Type (18h=SELECTION_LIST, or 1Ah=EXT_SELECTION_LIST)
 01h      1  Flags (bit0=SelectionArea, bit1=CommandList, bit2-7=Reserved)
 02h      1  nos     <-- aka Number of Numeric-input selections ?
 03h      1  bsn     <-- ?
 04h      2  ListID for this Descriptor (1..7FFFh)
 06h      2  PsdOffset for Prev button

```

```

08h      2    PsdOffset for Next button
0Ah      2    PsdOffset for Return/back button
0Ch      2    PsdOffset for Default button (uh, what is that?)
0Eh      2    PsdOffset for Timeout
10h      1    totime <-- aka Timeout Time maybe? in WHAT units?
11h      1    loop  <-- aka ?
12h      2    itemid <-- aka Item to be displayed during the selection?
14h      2*N PsdOffset[N] for Numeric-input ?

Below only for SVCDs (with Type=18h), or for Extended VCDs (with Type=1Ah):
(14h+2*N) 4    Area for Prev   (x1,y1,x2,y2) ;\these extra entries exist for
(18h+2*N) 4    Area for Next  (x1,y1,x2,y2) ; SVCDs with Type=18h, and
(1Ch+2*N) 4    Area for Return (x1,y1,x2,y2) ; Extended VCDs with Type=1Ah
(20h+2*N) 4    Area for Default (x1,y1,x2,y2) ; (but do NOT exist for
(24h+2*N) 4*N Area[N]        (x1,y1,x2,y2) ;\older VCDs with Type=18h)

<B> PsdEndListDescriptor (8 bytes)</B>
00h 1    Type (1Fh=EndList)
01h 1    Next_disc ;00h to stop PBC or NNh to switch to disc no NN (BCD!?)
02h 2    Item (0 or 1000..2979, should be still image, eg. Change Disc pic)
04h 4    Reserved (0)
N/A -    This descriptor doesn't have a ListID (unlike as other descriptors)

<B> PsdCommandListDescriptor (5+2*N bytes)</B>
00h 1    Type (20h=CommandList)
01h 2    Command_count
03h 2    ListID for this Descriptor (1..7FFFh)
05h 2*N  command[EMPTY_ARRAY_SIZE] ;uh, WHAT is a command?

<B> PsdAlignmentPadding (after each list entry)</B>
00h 0..7  Padding to next 8-byte PsdOffset boundary (00h-filled)

```

Delay values in "1s/10s" units (for Playlist[0Ch,0Dh]):

```

1..60   --> wait "N" seconds
61..254 --> wait "(N-60)*10+60" seconds
255     --> wait infinite

```

Item numbers (0..599 or 1000..2979) can be:

```

0..1      - Play nothing
2..99     - Play Track 2..99 (TOC tracks, for AVSEQnn.DAT and AUDIOnn.DAT?)
100..599   - Play Entry 1..500 from table in ENTRIES file up to end of track
600..999   - Reserved
1000..2979 - Play SPI Segment Play Item 1..1980 (ITEMnnnn.DAT file)
2980..65535 - Reserved

```

PsdOffset values can be:

```

0..N    Offset within PSD.VCD file, in 8-byte units
FFF Dh  PSD_OFS_MULTI_DEF_NO_NUM ;\uh, what is that?
FFFEh  PSD_OFS_MULTI_DEF      ;/
FFFFh  PSD_OFS_DISABLED       ;-no function assigned to the button

```

For whatever reason, some PsdOffsets are specified as ListID (lid), these ListID values must be translated to actual PsdOffset via the ListID Offset Table (aka LOT.VCD/LOT.SVD file).

VCD\LOT.VCD or SVCD\LOT.SVD (00:04:02..33) (64Kbyte, 32 sectors)

The ListID Offset Table (LOT) allows to translate ListIDs to PsdOffsets. The file is always 64Kbyte in size (unused entries should be set to FFFFh).

The PSD.VCD file does also assign ListIDs to each descriptor (ie. instead of using the LOT.VCD file, one could also scan all descriptors in PSD.VCD when searching a specific ListID).

```
0000h 2      Reserved (0)
0002h 2*7FFFh PsdOffset[1..7FFFh] ;for ListID 1..7FFFh
```

Note: ListID#1 is used as entrypoint to PSD.VCD when inserting a new disc (or when inserting another disc of the SAME movie, the entrypoint can be ListID#2, depending on the Next Disc flag in INFO.VCD).

SEGMENT\ITEMnnnn.DAT (Pictures, Menu screens) (nnnn=0001..1980)

These files contain Pictures/Menu screens referenced from PSD.VCD. The files seem to be stored in FORM2 sectors (not FORM1). Unknown if the files are located on Track 1.

The content of the files seems to resemble short MPEG video clips (with only one picture frame, or eventually with a few frames for short animations, including audio in some cases). Still images are said to be allowed to use twice the resolution of MPEG videos.

EXT\PSD_X.VCD or EXT\PSD_X.SVD (extended version of PSD.VCD)

EXT\LOT_X.VCD or EXT\LOT_X.SVD (extended version of LOT.VCD)

The "extended" files are often identical to the normal PSD/LOT files. The difference is that, if disc uses SelectionLists, then PSD should use the normal descriptor (18h), and PSD_X should use the extended descriptor (1Ah), the latter one seems to be intended to allow to highlight the current menu selection (particulary useful when using +/- buttons instead of Numeric Keypad input). Note: Nevertheless, Muppets from Space uses descriptor 18h in PSD_X.

Unknown if SVCDs do really have "extended" files, too (theoretically the VCD extension should be a default feature for SVCDs).

Playback Control Issues

Although PBC was intended as "nice extra feature", many VCDs are containing faulty PSD files. In general, VCD players should either leave PBC unsupported (or provide an option for disabling it).

Red Dragon from 2003 uses extended selection lists, but crops PSD_X.VCD to the same filesize as PSD.VCD.

Muppets from Space from 1999 assigns weird functions to Prev/Next buttons (Next wraps from Last Track to First Track, but Prev doesn't wrap from First to Last; default Non-PBC Prev/Next functions are more user friendly).

Sony's SCPH-5903 console refuses to display the HH:MM:SS playback time when using PBC (instead it does only display a "PBC" logo).

26.3 VCD ISO Search Files (SCANDATA, SEARCH, TRACKS, SPICONTX)

Below files can help searching I-frames, and provide some info about the content of Tracks and Segments.

Essentially, searching I-frames is possible without these files - however, if present, then the files may be useful in two cases: For discs with variable bitrates (which isn't allowed on VCDs though), and, for CDROM firmwares that don't support "inaccurate" seeking (like telling it to start reading anywhere NEAR some MM:SS:FF value, so one could skip sectors till reaching an I-frame) (ie. if the firmware insists on a "accurate" seek position, then it's best to give it a known I-frame address).

Caution: Overlapping Sectors (!?!)

Reportedly the new SVCD files TRACKS.SVD and SEARCH.DAT are on these sectors:

```
TRACKS_SVD_SECTOR = (PSD_VCD_SECTOR+1)      ;aka 2nd sector in PSD.SVD?
SEARCH_DAT_SECTOR = (TRACKS_SVD_SECTOR+1) ;aka 3rd..Nth sector in PSD.SVD?
```

If that's correct, then the files would overlap with PSD.SVD (when PSD.SVD is bigger than one sector), that would be weird, but possible (ie. the "PsdOffset" in PSD.SVD would need to "skip" the region used by those two files).

EXT\SCANDATA.DAT (12+3*N bytes for VCD 2.0) (or 16+3*N+2*X+3*Y+3*Z for SVCD)

This file fulfills much the same purpose of the SEARCH.DAT file except that this file is mandatory only if the System Profile Tag of the INFO.SVD file is 0x01 (HQ-VCD) and also that it contains sector addresses also for each video Segment Play Items in addition to the regular MPEG tracks.

```
SCANDATA.DAT Format for VCD 2.0 (12+3*N bytes):
000h 8    ID "SCAN_VCD"
008h 1    Version (02h for VCD 2.0)
009h 1    Reserved (0)
00Ah 2    Number of scan points (in 0.5s units) (max FFFFh = ca. 9.1 hours)
00Ch 3*N  Scan Point[0..N-1] ;MM:SS:FF of closest I-frame

SCANDATA.DAT Format for SVCD (16+3*N+2*X+3*Y+3*Z bytes):
000h 8    ID "SCAN_VCD"
008h 1    Version (01h for SVCD)
009h 1    Reserved (0)
00Ah 2    scandata_count ;number of 3-byte entries in the table
00Ch 2    track_count    ;number of MPEG tracks on disc
00Eh 2    spi_count      ;number of consecutively recorded play item segments
                           ; (as opposed to the number of segment play items).
010h 3*N  msf_t cum_playtimes[N] ;cumulative playing time up to track N.
                           ; (track time just wraps at 99:59:74)
xxxh 2*X   spi_indexes[X]       ;Indexes into the following scandata table
xxxh 2    mpegtrack_start_index ;Index into the following scandata table
                           ; (where the MPEG track scan points start)
xxxh 3*Y   The scandata table... [Y] ;8bit Track Number and 16bit Index
          uint8_t track_num; /* Track number as in TOC
          uint16_t table_offset; /* Index into scandata table
xxxh 3*Z   msf_t scandata_table[Z] ;MM:SS:FF
```

SVCD\SEARCH.DAT (13+3*N bytes)

This file defines where the scan points are. It covers all mpeg tracks together. A scan point at time T is the nearest I-picture in the MPEG stream to the given time T. Scan points are given at every half-second for the entire duration of the disc.

```
000h 8    ID "SEARCHHSV"
008h 1    Version (01h)
009h 1    Reserved (0)
00Ah 2    Number of scan points
00Ch 1    Time_interval (in units of 0.5 seconds) (must be 01h)
00Dh 3*N  Scan Point[0..N-1] ;MM:SS:FF of closest I-frame
```

Note: This SVCD file is about same as the old EXT\SCANDATA.DAT file on VCDs (with one extra entry for Time Interval). Whilst, SVCDs are storing some different stuff in EXT\SCANDATA.DAT (despite of the identical filename).

SVCD\TRACKS.SVD (11+4*N bytes) (or rarely:11+5*N bytes)

The TRACKS.SVD file contains a series of structures, one for each track, which indicates the track's playing time (in sectors, not actually real time) and contents.

SVCD\TRACKS.SVD is a mandatory file which describes the numbers and types of MPEG tracks on the disc.

```
SVCD\TRACKS.SVD Format for SVCD (11+4*N bytes) :
000h 8    ID "TRACKSVD"
008h 1    Version (01h)
009h 1    Reserved (0)
00Ah 1    Number of MPEG tracks (N)
00Bh 3*N Track playing_time[N] (MM:SS:FF, in BCD) (in sectors, not real time)
0xxh 1*N TrackContent[N] ;bit0-1=Audio,bit2-4=Video,bit5=Reserved,bit6-7=OGT
SVCD\TRACKS.SVD Format for VCD30 (11+5*N bytes) (some sort of SVCD-prototype) :
000h 8    ID "TRACKSVD"
008h 1    Version (01h)
009h 1    Reserved (0)
00Ah 1    Number of MPEG tracks (N)
00Bh 5*N Cum_Playing_time and Content (MM:SS:FF in BCD, and OGT, Audio)
```

SVCD\SPICONTX.SVD (1000h bytes, two sectors)

Unknown if/when/where/why this file exists, possibly only on VCD30?

Note: The same info can be stored in INFO.SVD at offsets [038h..7F3h].

```
0000h 8      ID "SPICONSV"
0008h 1      Version (01h)
0009h 1      Reserved (0)
000Ah 2*1980 Segment Content[1..1980] (1st byte=OGT, 2nd byte=Audio)
0F82h 126    Reserved (0)
```

Content Flags for Segments and Tracks

For SVCD\INFO.SVD and SVCD\TRACKS.SVD (on SVCD) these are encoded in 1 byte:

```
bit0-1  Audio characteristics:
        0 = No MPEG audio stream
        1 = One MPEG1 or MPEG2 audio stream without extension
        2 = Two MPEG1 or MPEG2 audio streams without extension
        3 = One MPEG2 multi-channel audio stream with extension
bit2-4  Video characteristics:
        In TRACKS.SVD this must be 0,3,7 (no still pictures)
        0 = No MPEG video data
        1 = NTSC still picture
        2 = NTSC Reserved (NTSC still pic hires?)
        3 = NTSC motion picture
```

```

4 = Reserved
5 = PAL still picture
6 = PAL Reserved (PAL still pic hires?)
7 = PAL motion picture
bit5 Indicates segment is continuation of an item
      In TRACKS.SVD this must be 0 (reserved)
      0 = First or only segment of item
      1 = Second or later segment of item
bit6-7 Overlay Graphics/Text (OGT):
      0 = No OGT substream
      1 = Sub-stream 0 available
      2 = Sub-stream 0 & 1 available
      3 = All OGT sub-substreams available

```

For SPICONTX.SVD and SVCD\TRACKS.SVD (on VCD30) these are encoded in 2 bytes:

```

1st byte = Audio characteristics ;\probably same values as
2nd byte = Overlay Graphics/Text (OGT) ;/in above bitfields?

```

26.4 VCD ISO Misc files (CAPTnn, AUDIOnn, KARINFO, PICTURES, CDI)

EXT\CAPTnn.DAT (Closed Caption data, aka subtitles) (SVCD only?)

VCDs with subtitles are usually/always having the subtitles encoded directly in the picture frames (ie. in the MPEG macroblocks, rather than using the Closed Caption feature).

These CAPTnn.DAT files are intended for Closed Captions (eg. subtitles in different languages and/or for deaf people).

Alternately, the "user_data_cc" flag in INFO.VCD?/INFO.SVD can indicate to store Closed Captions in MPEG User Data (with START_CODE=000001B2h=User Data) instead of in EXT\CAPTnn.DAT. Either way, the format of those Closed Captions is unknown.

Moreover, Content can be flagged to have Overlay Graphics/Text (OGT), whatever that is: it might be related to Closed Captions.

Note: Reportedly CAPTnn.DAT can exist on VCDs and SVCDs (although the same person reported that VCDs do not support subtitles, so that info sounds wrong).

CDDA\AUDIOnn.DAT (pointers to uncompressed CD Audio Tracks)

These filesystem entries contain pointers to uncompressed audio tracks (that is, outside of the ISO area on Track 1).

Most VCDs don't have audio tracks (though some VCDs do contain empty CDDA folders).

Maybe the feature is occassionally used the other way around: Music discs containing VCD clips as bonus feature?

KARAOKE\KARINFO.xxx (whatever)

The KARAOKE folder exists on many VCDs (about 50%), but it's usually/always empty on all discs.

Reportedly the folder can contain "KARINFO.xxx" files, but the purpose/format of that files is unknown.

Reportedly there are Midi VCDs (MVCDs) for karaoke, maybe those discs have "KARINFO.xxx" files(?)

PICTURES*.* (whatever)

Unknown purpose. The PICTURES folder has been spotted on one VCD (Wallace and Gromit), but the folder was just empty.

CDI*.* (some kind of GUI/driver for Philips CDI Players)

The CDI folder is some relict for Philips CDI Players, it isn't used by normal VCD players, however, the CDI folder & files are included on most or all VCDs.

The path/name for the CDI executable is stored at offset 23Eh in the ISO Primary Volume Descriptor (usually "CDI/CDI_APPL.VCD;1" or "CDI/CDI_VCD.APP;1") (or accidentally "CDI_CDI_VCD.APP;1" on homebrew Nero discs).

The files in the CDI folder are usually just some standard files (without any customizations), however, there are some different revisions of these files:

```
<B> Revision A (spotted on two discs from 1997 and 1999) :</B>
CDI_APPL.VCD    80702 bytes, 04-Mar-1996, CRC32=AE8FC5D0h ;executable
VCD_BACK.DYV    92572 bytes, 18-Jul-1995, CRC32=00693E5Eh ;whatever?
VCD_BTN.C8     93719 bytes, 18-Jul-1995, CRC32=FF0A636Ah ;whatever?

<B> Revision B (spotted on a disc from 2003) :</B>
CDI_VCD.APP    20648 bytes, 00-Nul-0000  CRC32=DC885F70h ;executable
CDI_FONT.FNT   145388 bytes, 00-Nul-0000  CRC32=FB4D63F4h ;font?
CDI_ALL.RTF      ? bytes,                 CRC32=?          ;realtimefile?
CDI_BUM.RTF      ? bytes,                 CRC32=?          ;realtimefile?

<B> Revision C (spotted on a disc from 2006, and homebrews from 2001 and 2017) :</B>
CDI_VCD.APP   102400 bytes, 00-Nul-0000  CRC32=E91E128Dh ;executable
CDI_VCD.CFG     193 bytes, 00-Nul-0000  CRC32=D1C6F7ADh ;config/ascii
CDI_TEXT.FNT   13616 bytes, 00-Nul-0000  CRC32=BDC55E86h ;font?
CDI_IMAG.RTF  1510028 bytes, 00-Nul-0000  CRC32=(RIFF)       ;realtimefile?
```

CDI_VCD.CFG is some ASCII text file (with uncommon 0Dh,0Dh,0Ah line breaks), the file could be customized to change things like GUI colors, but most or all discs seem to contain the same file with CRC32=D1C6F7ADh. Note: The CFG file is missing on the homebrew DemoVCD.

CDI_IMAG.RTF is seen as 1510028 byte file under windows (that is, with a windows RIFF header, and with data area containing the whole 930h bytes from each sector; this includes the MM:SS:FF values from the sector header, so the RTF file may look slightly different depending on which sectors it has been stored on, although the files are usually exactly same apart from those MM:SS:FF values). Note: The RTF file is cropped to 1324220 bytes (instead of 1510028) on the homebrew DemoVCD (apart from that, the file is same as normal).

CDI_ALL.RTF and CDI_BUM.RTF cannot be read/copied under Windows 7 (which is weirdly reporting them to use an "invalid MS-DOS function"; some people also reported having CDI_IMAG.RTF files with similar problems). The reason is unknown, maybe windows doesn't fully support the CD filesystem, or some VCDs are violating the filesystem specs, or whatever... maybe windows is mis-identifying certain RTF files as Rich Text Format files and tries to prevent virus-infections by throwing a faked "MS-DOS" error message.

26.5 VCD MPEG-1 Multiplex Stream

Multiplex Stream & Sector Boundaries

The Multiplex stream is some higher level stream, intended to help to distinguish between Audio- and Video-streams (which are enclosed in the Multiplex stream). MPEG's are somewhat organized in "sectors", with sector size varying for normal .mpg files and VCDs:

```
VCD discs    --> Sector Size = 914h bytes (the discs MODE2/FORM2 sector size)
.mpg files   --> Sector Size = 800h bytes (regardless of physical sector size)
```

Sectors are always beginning with a Multiplex Packet (and Multiplex Packets are never crossing sector boundaries). If the amount of video data exceeds the sector size, then it's split into several Multiplex packets, whereas, that may happen anywhere in the video stream (ie. there can be Multiplex Headers occurring even in the middle of Video packet).

MPEG-1 Multiplex Pack (sector header) (12 bytes)

The Pack Header is found at the begin of the stream (on VCDs, it's also found at the begin of each sector). The SCR values might help on identifying the current playback position, and, with the bitrate value, this could be also used to compute the distance to another position (though there are other ways to determine the position/bitrate, so the Pack is kinda useless).

```

32bit PACK_START_CODE (000001BAh) ;-4byte
2bit Fixed (00b for MPEG-1) (would be 01b for MPEG-2) ;\
2bit Fixed (10b) ;
3bit System Clock Reference, bit32-30 ;\ ;
1bit Marker (1) ; System Clock Reference (SCR) ;
15bit System Clock Reference, bit29-15 ; (intended Time, ; 5byte
1bit Marker (1) ; in 90kHz clock cycles) ;
15bit System Clock Reference, bit14-0 ;/ ;
1bit Marker (1) ;/
1bit Marker (1) ;\
22bit Multiplex Rate (total bitrate of the stream, in 400bit/s units) ; 3byte
1bit Marker (1) ;/

```

MPEG-1 Multiplex System Header (12+N*3 bytes)(optionally)(at start of stream)

The System Header is usually found after the first Pack at the begin of the stream.

```

32bit SYSTEM_HEADER_START_CODE (000001BBh) ;\6byte
16bit Header Length minus 6 (in bytes) (0006h+N*3) ;/
1bit Marker (1) ;\
22bit Rate bound (max multiplex rate of all packs in the stream, ; 3byte
1bit Marker (1) ; in 400bit/s units) ;/
6bit Audio Bound (max number of audio streams in this ISO stream) ;\
1bit Fixed Flag (1=Fixed bitrate) ; 1byte
1bit CSPS Flag (1=Constrained) ;/
1bit System Audio Lock Flag XXX ;\
1bit System Video Lock Flag XXX ; 1byte
1bit Marker (1) ;/
5bit Video Bound (max number of video streams in this ISO stream) ;/
8bit Reserved (FFh) ;-1byte

```

Followed by N*3 bytes for the streams (each with first bit=set):

```

8bit Stream ID (C0h..DFh=Audio, E0h..EFh=Video) ;\
2bit Fixed (11b) ; 3byte
1bit STD buffer scale (0=Mul128/audio, 1=Mul1024/video) ;
13bit STD buffer size (largest required buffer over all packets) ;/

```

Terminated by a value with first bit=cleared (eg. next 000001xxh value).

MPEG-1 Multiplex Video/Audio/Special Packets (7..24 bytes, plus data)

These packets are encapsulating the lower-level Video/Audio streams.

```
32bit START (000001xxh BDh-BFh=Special, C0h-DFh=Audio, E0h-EFh=Video); \6byte
16bit Packet Length minus 6 (in bytes) (1..18, plus data) ;/
```

If (and while) next two bits are 11b (0..16 padding bytes):

```
(2bit) Fixed (11b, indicates presence of stuffing) ;\optional 0..16byte
(6bit) Fixed (111111b) ;/
```

If next two bits are 01b (buffer size info):

```
(2bit) Fixed (01b, indicates presence of buffer size) ;\
(1bit) STD Buffer Scale (0=Mul128/audio, 1=Mul1024/video) ; optional 2byte
(13bit) STD Buffer Size (for decoding, in above scale units) ;/
```

Always:

```
2bit Fixed (00b, indicates no further stuffing/buffer info); \
1bit PTS Flag (Presentation Time Stamp) ; 0.5 bytes
1bit DTS Flag (Decoding Time Stamp) ;/
```

If PTS Flag set:

```
(3bit) Presentation Time Stamp, bit32-30 ;\
(1bit) Marker (1) ; optional 4.5 bytes
(15bit) Presentation Time Stamp, bit29-15 ; (time when to output the
(1bit) Marker (1) ; the packet to audio/video
(15bit) Presentation Time Stamp, bit14-0 ; hardware, in 90kHz cycles)
(1bit) Marker (1) ;/
```

If DTS Flag set (in this case PTS Flag must be also set):

```
(4bit) Fixed (0001b) ;\
(3bit) Decoding Time Stamp, bit32-30 ; optional 5 bytes
(1bit) Marker (1) ; (recommended time when
(15bit) Decoding Time Stamp, bit29-15 ; to decode the block,
(1bit) Marker (1) ; in 90kHz cycles)
(15bit) Decoding Time Stamp, bit14-0 ;
(1bit) Marker (1) ;/
```

If PTS and DTS Flags are both zero:

```
(4bit) Fixed (1111b) ;-optional 0.5 bytes
```

Always:

```
... packet data bytes ;-data... (not crossing sector)
```

Note: The first Multiplex Video Packet would usually start with a Sequence Header Code (000001B3h), and the first Multiplex Audio Packet should always start with an Audio Sync Word (FFFh).

However, the size of the Multiplex packets does usually differ from the size of the packets in the audio/video stream, so new Multiplex Packets may occur anywhere in the middle of those streams (eg. in the middle of a video slice, the next Multiplex Video packet would then begin with the remaining slice bytes, rather than with a 000001xxh code; it's also possible that a Multiplex Audio packet gets inserted in the middle of the video slice).

The best (or easiest) way to get continuous data for the lower level streams might be to memcopy the data from Multiplex packets to separate Audio & Video buffers.

MPEG-1 Multiplex End Code (4 bytes)

```
32bit END_CODE (000001B9h) ;-4byte
```

This should occur at the end of the video. On a VCD it does also occur at the end of each video track.

26.6 VCD MPEG-1 Video Stream

The Video stream is part of the Multiplex stream, meaning that the Video packets preceded (and interrupted) by Multiplex headers. Ie. before processing the Video packets, one must first extract the video snippets from the Multiplex stream (see previous chapter).

MPEG-1 Video Sequence Header (12, 76, or 140 bytes, ie. 12+N*64)

```
32bit SEQUENCE_HEADER_CODE (000001B3h) ;-4byte
12bit Width in pixels (1..4095) ;\3byte
12bit Height in pixels (1..2800, for max AFh slices) ;/
4bit Aspect Ratio (01h..0Eh, see below) ;\1byte
4bit Framerate (01h..08h, see below) ;/
```

```

18bit Bitrate (in 400bit/s units, 3FFFFh=variable rate)      ; \
1bit Marker (1)                                              ; 3byte
10bit VBV (required decoding memory size, in "16 kB" units) ; +6bit
1bit Constrained Parameter Flag                            ;/
1bit Load Intra Q Matrix      (0=No, use Standard Matrix, 1=Yes, Custom)

```

Next 64byte only when above bit was set:

```

(64byte) Intra Quantizer Matrix (64 x 8bit, unsigned) (in zigzag order)
1bit Load Non-Intra Q Matrix (0=No, use Standard Matrix, 1=Yes, Custom)

```

Next 64byte only when above bit was set:

```
(64byte) Non-Intra Quantizer Matrix (64 x 8bit, unsigned) (in zigzag order)
```

Aspect Ratio values:

```

0      -      ;forbidden
1      1.0      ;square pixels
2      0.6735   ;0.6735
3      0.7031   ;16:9, 625 line, PAL
4      0.7615   ;0.7615
5      0.8055   ;0.8055
6      0.8437   ;16:9, 525 line, NTSC
7      0.8935   ;0.8935
8      0.9157   ;4:3, 625 line, PAL, CCIR601
9      0.9815   ;0.9815
10     1.0255   ;1.0255
11     1.0695   ;1.0695
12     1.0950   ;4:3, 525 line, NTSC, CCIR601
13     1.1575   ;1.1575
14     1.2015   ;1.2015
15     -        ;reserved

```

Frame Rate values:

```

0      -      ;forbidden
1      23.976  (24000/1001) ;NTSC encapsulated film rate
2      24.0      ;Standard international cinema film rate
3      25.0      ;PAL video frame rate (625/50)
4      29.97    (30000/1001) ;NTSC video frame rate
5      30.0      ;NTSC video frame rate drop-frame (525/60)
6      50.0      ;PAL double frame rate/progressive
7      59.94   (60000/1001) ;NTSC double frame rate
8      60.0      ;NTSC double frame rate drop-frame
9-15   -        ;reserved

```

MPEG-1 Video Group of Pictures (GOP) (8 bytes) XXX...

```

32bit GROUP_START_CODE (000001B8h)
1bit Drop Frame (1=drop this frame; for reducing 30 fps to 29.97 fps)
5bit Time Code Hours (0..23)
6bit Time Code Minutes (0..59)
1bit Marker (1)
6bit Time Code Seconds (0..59)
6bit Time Code Picture (0..59)
1bit Closed GOP
1bit Broken Link

```

MPEG-1 Video Picture Header XXX...

```

32bit PICTURE_START_CODE (00000100h) ; \
10bit Temporal Reference (display order, 0..3FFh) ; 61bit
3bit Coding Type (0=Invalid, 1=I, 2=P, 3=B, 4=D, 5-7=Reserved); /
16bit VBV Delay (in 90kHz cycles, FFFFh=variable bitrate) ; /

```

If Coding Type is 2 or 3 (P-Frame or B-Frame):

```

(1bit) full fel forward vector (0=half pix, 1=full pix) ;\optional 4bit
(3bit) forward f code (0=invalid, 1..7=0..6bits) ;/

```

If Coding Type is 3 (B-Frame):

```

(1bit) full backward vector ;\optional 4bit
(3bit) backward f code ;/

```

If (and while) next bit is set:

```

(1bit) Fixed (1, indicates presence of Extra Info) ;\opt. N*9bit
(8bit) Extra Information ;/

```

End of Extra:

```

1bit Fixed (0, indicates no further Extra Info) ;-1bit
0-7bit Padding to byte boundary (0) ;-0..7bit

```

Coding Type values:

0	Forbidden	
1	I - Intra Coded	(full image)
2	P - Predictive Coded	(based on prev I or P frame)
3	B - Bidirectionally Predictive Coded	(based on prev+next I or P frame)

```

4 D - DC Intra Coded          (don't care, lowres thumbnail)
5 Reserved
6 Reserved
7 Reserved

```

Frame Order

DISPLAY ORDER:

I	B	B	B	P	B	B	B	P	B	B	B	I	B	B	B	P	B	B	B	P	B	B	B	...
																								...
I-Frame	P-frames				I-Frame	P-frames																		

The B-frames require to know the next P- (or I-) frame in advance, for that reason, the frames are stored as "PBBB" (although being played as "BBBB"):

STORAGE ORDER:

I	P	B	B	B	P	B	B	B	P	B	B	B	I	B	B	B	P	B	B	B	P	B	B	B	...
																									...
I-Frame	P-frames				I-Frame	P-frames																			

MPEG-1 Video Slice

Slices are containing the actual 16x16 pixel Macro Blocks. Usually a Slice contains one horizontal line - although, theoretically, it could be longer or shorter, ie. a slice could wrap to next line, or a line could be split into several slices (with the leading "MBA Increment" value greater than 1 to define the horizontal start offset).

```

32bit  PACK_START_CODE (000001xxh; xx=01h..AFh; vertical index) ;-4byte
      Quantizer Scale (1..31) (may be later changed by blocks) ;5bit

```

If (and while) next bit is set:

```

(1bit) Fixed (1, indicates presence of Extra Info) ;\opt. N*9bit
(8bit) Extra Information ;/

```

End of Extra:

```

1bit Fixed (0, indicates no further Extra Info) ;-1bit

```

If (and while) next 23bit are nonzero (ie. until next 000001xxh):

```
... Macroblock (within horizontal line) ;...
```

Final padding:

```
0-7bit Padding to byte boundary (0) ; -0..7bit
```

MPEG-1 Video Group/Sequence Extension Data (reserved)

MPEG-1 Video User Data (optional)

```
32bit START_CODE (000001B2h=User Data, 000001B5h=Extension Data) ; -4byte
... data (end is signaled by presence of next 000001xxh code) ; -data
```

User Data can contain Closed Captions (see flag in VCD\INFO.VCD or SVCD\INFO.SVD).
User Data contains 11h-byte "Created with Nero" in some homebrew discs.

MPEG-1 Video Sequence End Code (4 bytes)

```
32bit SEQUENCE_END_CODE (000001B7h) ; -4byte
```

MPEG-1 Video 4:2:0 Macroblock

```
N*11bit Macroblock_address_increase escape/stuffing codes (if any)
1..11bit Macroblock_address_increase
1-6bit Macroblock_type
5bit Quantizer_scale
... Motion_vector
3-9bit Coded_block_pattern
... Block(i)
```

Aka...

```
Addr Incr
Type
Motion Vector
QScale
CBP
Block b0 (Y1)
Block b1 (Y2)
Block b2 (Y3)
Block b3 (Y4)
```

```
Block b4 (Cb)
Block b5 (Cr)
```

26.7 VCD MP2 Audio Stream

VCD video discs and .mpg movie files are having the MP2 Audio Stream enclosed in the Multiplex stream (whilst .mp2 audio files may contain raw MP2 data without Multiplex stream).

Each MP2 frame is starting with a FFFh syncword (which is always located on a byte boundary). Unfortunately, the value FFFh can also occur anywhere in the audio data (eg. a 16bit sample with value 3FFCh).

So, when starting mid-stream, one will need some guessing when searching a valid syncword. The best method is to compute the frame size (based on the supposed frame header), and then to check if supposed frame begins AND ends with a sync word. Moreover, one could check for invalid sample rate values in the frame header, or invalid "groupings" in the frame's data part.

VCDs are conventionally having three audio frames encoded in one CDROM sector, so the first syncword can be simply found right after the multiplex packet header (though that might differ in some cases: VCD2.0 allows different audio bitrates, and a CDROM sector could be theoretically shared for Audio and Video data).

Overall MP2 Frame Format

```
Header (32bit)
Optional CRC (16bit) (or 0bit if none)
Allocation Information
Scale Factor Selector Information
Scale Factors
Data
```

MP2 Header

```
12bit Syncword (FFFh) ; \
1bit Revision (0=MPEG-2, 1=MPEG-1) ; 2 bytes
2bit Layer (2=Audio LayerII) ;
    (3=LayerI, 1=LayerIII, r3=reserved) ;
1bit Protection_bit (1=no crc) ; /
4bit Bitrate_index (1..14) ; \
    (0=free format, 15=reserved) ;
2bit Sampling_frequency ; 1 byte
1bit Padding_bit ;
```

```

1bit Private_bit           ;/
2bit Mode                 ;\
2bit Mode_extension (aka bound) ;
1bit Copyright            ; 1 byte
1bit Original/home        ;
2bit Emphasis             ;/

```

MP2 Checksum (optional)

16bit CRC

Allocation Information

Scale Factor Selector Information

Scale Factors

Data

XXX...

26.8 Inflate

Inflate/Deflate is a common (de-)compression algorithm. In the PSX world, it's used by the .CDZ cdrom-image format.

[Inflate - Core Functions](#)

[Inflate - Initialization & Tree Creation](#)

[Inflate - Headers and Checksums](#)

26.9 Inflate - Core Functions

tinf_uncompress(dst,src)

```

tinf_init()                  ;init constants (needed to be done only once)
tinf_align_src_to_byte_boundary()
repeat
  bfinal=tinf_getbit()       ;read final block flag (1 bit)
  btype=tinf_read_bits(2)    ;read block type (2 bits)
  if btype=0 then tinf_inflate_uncompressed_block()

```

```

if btype=1 then tinf_build_fixed_trees(), tinf_inflate_compressed_block()
if btype=2 then tinf_decode_dynamic_trees(), tinf_inflate_compressed_block()
if btype=3 then ERROR           ;reserved
until bfinal=1
tinf_align_src_to_byte_boundary()
ret

```

tinf_inflate_uncompressed_block()

```

tinf_align_src_to_byte_boundary()
len=LittleEndian16bit[src+0]                      ;get len
if LittleEndian16bit[src+2]<>(len XOR FFFFh) then ERROR ;verify inverse len
src=src+4                                         ;skip len values
for i=0 to len-1, [dst]=[src], dst=dst+1, src=src+1, next i ;copy block
ret

```

tinf_inflate_compressed_block()

```

repeat
sym1=tinf_decode_symbol(tinf_len_tree)
if sym1<256
[dst]=sym1, dst=dst+1
if sym1>256
len = tinf_read_bits(length_bits[sym1-257])+length_base[sym1-257]
sym2 = tinf_decode_symbol(tinf_dist_tree)
dist = tinf_read_bits(dist_bits[sym2])+dist_base[sym2]
for i=0 to len-1, [dst]=[dst-dist], dst=dst+1, next i
until sym1=256
ret

```

tinf_decode_symbol(tree)

```

sum=0, cur=0, len=0
repeat                               ;get more bits while code value is above sum
cur=cur*2 + tinf_getbit()
len=len+1
sum=sum+tree.table[len]
cur=cur-tree.table[len]
until cur<0
return tree.trans[sum+cur]

```

tinf_read_bits(num) ;get N bits from source stream

```

val=0
for i=0 to num-1, val=val+(tinf_getbit() shl i), next i
return val

```

tinf_getbit() ;get one bit from source stream

```
bit=tag AND 01h, tag=tag/2
if tag=00h then tag=[src], src=src+1, bit=tag AND 01h, tag=tag/2+80h
return bit
```

tinf_align_src_to_byte_boundary()

```
tag=01h ;empty/end-bit (discard any bits, align src to byte-boundary)
ret
```

26.10 Inflate - Initialization & Tree Creation

tinf_init()

```
tinf_build_bits_base(length_bits, length_base, 4, 3)
length_bits[28]=0, length_base[28]=258
tinf_build_bits_base(dist_bits, dist_base, 2, 1)
ret
```

tinf_build_bits_base(bits,base,delta,base_val)

```
for i=0 to 29
  bits[i]=min(0,i-delta)/delta
  base[i]=base_val
  base_val=base_val+(1 shl bits[i])
ret
```

tinf_build_fixed_trees()

```
for i=0 to 6, tinf_len_tree.table[i]=0, next i      ;[0..6]=0    ;len tree...
tinf_len_tree.table[7,8,9]=24,152,112           ;[7..9]=24,152,112
for i=0 to 23, tinf_len_tree.trans[i+0] =i+256, next i ;[0..23]   =256..279
for i=0 to 143, tinf_len_tree.trans[i+24] =i+0,   next i ;[24..167] =0..143
for i=0 to 7,   tinf_len_tree.trans[i+168]=i+280, next i ;[168..175]=280..287
for i=0 to 111, tinf_len_tree.trans[i+176]=i+144, next i ;[176..287]=144..255
for i=0 to 4, tinf_dist_tree.table[i]=0, next i ;[0..4]=0,0,0,0,0 ;\dist
tinf_dist_tree.table[5]=32                      ;[5]=32          ; tree
for i=0 to 31, tinf_dist_tree.trans[i]=i, next i ;[0..31]=0..31    ;/
ret
```

tinf_decode_dynamic_trees()

```

hlit  = tinf_read_bits(5)+257          ;get 5 bits HLIT (257-286)
hdist = tinf_read_bits(5)+1           ;get 5 bits HDIST (1-32)
hclen = tinf_read_bits(4)+4           ;get 4 bits HCLEN (4-19)
for i=0 to 18, lengths[i]=0, next i
for i=0 to hclen-1                  ;read lengths for code length alphabet
  lengths[clcidx[i]]=tinf_read_bits(3) ;get 3 bits code length (0-7)
tinf_build_tree(code_tree, lengths, 19);build code length tree
for num=0 to hlit+hdist-1           ;decode code lengths for dynamic trees
  sym = tinf_decode_symbol(code_tree)
  len=1, val=sym                   ;default (for sym=0..15)
  if sym=16 then len=tinf_read_bits(2)+3, val=lengths[num-1] ;3..6 previous
  if sym=17 then len=tinf_read_bits(3)+3, val=0             ;3..10 zeroes
  if sym=18 then len=tinf_read_bits(7)+11, val=0            ;11..138 zeroes
  for i=1 to len, lengths[num]=val, num=num+1, next i
tinf_build_tree(tinf_len_tree, 0,     hlit)    ;\build trees
tinf_build_tree(tinf_dist_tree, 0+hlit, hdist) ;/
ret

```

tinf_build_tree(tree, first, num)

```

for i=0 to 15, tree.table[i]=0, next i      ;clear code length count table
;scan symbol lengths, and sum code length counts...
for i=0 to num-1, x=lengths[i+first], tree.table[x]=tree.table[x]+1, next i
tree.table[0]=0
sum=0           ;compute offset table for distribution sort
for i=0 to 15, offs[i]=sum, sum=sum+tree.table[i], next i
for i=0 to num-1 ;create code to symbol xlat table (symbols sorted by code)
  x=lengths[i+first], if x<>0 then tree.trans[offs[x]]=i, offs[x]=offs[x]+1
next i
ret

```

tinf_data

```
clcidx[0..18] = 16,17,18,0,8,7,9,6,10,5,11,4,12,3,13,2,14,1,15 ;constants
```

```
typedef struct TINF_TREE:
  unsigned short table[16]      ;table of code length counts
  unsigned short trans[288]      ;code to symbol translation table
```

```
TINF_TREE tinf_len_tree ;length/symbol tree
TINF_TREE tinf_dist_tree ;distance tree
TINF_TREE code_tree      ;temporary tree (for generating the dynamic trees)
```

```
unsigned char lengths[288+32] ;temporary 288+32 x 8bit ;\for dynamic tree
unsigned short offs[16] ;temporary 16 x 16bit ;/creation
```

```
unsigned char length_bits[30]
unsigned short length_base[30]
unsigned char dist_bits[30]
unsigned short dist_base[30]
```

26.11 Inflate - Headers and Checksums

tinf_gzip_uncompress(void *dest, *destLen, *source, sourceLen)

```
src_start=src, dst_start=dst ;memorize start addresses
if (src[0]<>1fh or src[1]<>8Bh) then ERROR ;check id bytes
if (src[2]<>08h) then ERROR ;check method is deflate
flg=src[3] ;get flag byte
if (flg AND 0E0h) then ERROR ;verify reserved bits
src=src+10 ;skip base header
if (flg AND 04h) then src=src+2+LittleEndian16bit[src] ;skip extra data
if (flg AND 08h) then repeat, src=src+1, until [src-1]=00h ;skip file name
if (flg AND 10h) then repeat, src=src+1, until [src-1]=00h ;skip file comment
hcrc=(tinf_crc32(src_start, src-src_start) & 0000ffffh)) ;calc header crc
if (flg AND 02h) then x=LittleEndian16bit[src], src=src+2 ;get header crc
if (flg AND 02h) then if x<>hcrc then ERROR ;verify header
tinf_uncompress(dst, destLen, src, src_start+sourceLen-src-8) ;----> inflate
crc32=LittleEndian32bit[src], src=src+4 ;get crc32 of decompressed data
dlen=LittleEndian32bit[src], src=src+4 ;get decompressed length
if (dlen<>destLen) then ERROR ;verify dest len
if (crc32<>tinf_crc32(dst_start,dlen)) then ERROR ;verify crc32
ret
```

tinf_zlib_uncompress(dst, destLen, src, sourceLen)

```
src_start=src, dst_start=dst ;memorize start addresses
hdr=BigEndian16bit[src], src=src+2 ;get header
if (hdr MOD 31)<>0 then ERROR ;check header checksum (modulo)
if (hdr AND 20h)>0 then ERROR ;check there is no preset dictionary
if (hdr AND 0F00h)<>0800h then ERROR ;check method is deflate
if (had AND 0F000h)>7000h then ERROR ;check window size is valid
tinf_uncompress(dst, destLen, src, sourceLen-6) ;-----> inflate
chk=BigEndian32bit[src], src=src+4 ;get data checksum
if src-src_start<>sourceLen then ERROR ;verify src len
if dst-dst_start<>destLen then ERROR ;verify dst len
if a32<>tinf_adler32(dst_start,destLen)) then ERROR ;verify data checksum
ret
```

tinf_adler32(src, length)

```
s1=1, s2=0
while (length>0)
    k=max(length,5552)
    for i=0 to k-1, s1=s1+[src], s2=s2+s1, src=src+1, next i
    s1=s1 mod 65521, s2=s2 mod 65521, length=length-k
return (s2*10000h+s1)
```

27. CDROM Internal Info on PSX CDROM Controller

PSX software can access the CDROM via Port 1F801800h..1F801803h (as described in the previous chapters). The following chapters describe the inner workings of the PSX CDROM controller - this information is here for curiosity only - normally PSX software cannot gain control of those lower-level stuff (although some low level registers can be manipulated via Test commands, but that will usually conflict with normal operation).

Motorola MC68HC05 (8bit single-chip CPU)

The Playstation CDROM drive is controlled by a MC68HC05 8bit CPU with on-chip I/O ports and on-chip BIOS ROM. There is no way to reprogram that BIOS, nor to tweak it to execute custom code in RAM.

[CDROM Internal HC05 Instruction Set](#)

[CDROM Internal HC05 On-Chip I/O Ports](#)

[CDROM Internal HC05 I/O Port Usage in PSX](#)

[CDROM Internal HC05 Motorola Selftest Mode](#)

The PSX can read HC05 I/O Ports and RAM via Test Commands:

[CDROM - Test Commands - Read HC05 SUB-CPU RAM and I/O Ports](#)

Decoder/FIFO (CXD1199BQ or CXD1815Q)

This chip handles error correction and ADPCM decoding, and acts as some sort of FIFO interface between main/sub CPUs and incoming cdrom sector data. On the MIPS Main CPU it is controlled via Port 1F801800h..1F801803h.

[CDROM Controller I/O Ports](#)

On the HC05 Sub CPU it is controlled via Port A (data in/out), Port E (address/index), and Port D (read/write/select signals); the HC05 doesn't have external address/data bus, so one must manually access the CXD1815Q via those ports.

[CDROM Internal CXD1815Q Sub-CPU Configuration Registers](#)

[CDROM Internal CXD1815Q Sub-CPU Sector Status Registers](#)

[CDROM Internal CXD1815Q Sub-CPU Address Registers](#)

[CDROM Internal CXD1815Q Sub-CPU Misc Registers](#)

The PSX can read/write the Decoder I/O Ports and SRAM via Test commands:

[CDROM - Test Commands - Read/Write Decoder RAM and I/O Ports](#)

The sector buffer used in the PSX is 32Kx8 SRAM. Old PU-7 boards are using CXD1199BQ chips, later boards are using CXD1815Q, and even later boards have the stuff intergrated in the SPU. Note: The CXD1199BQ/CXD1815Q are about 99% same as described in CXD1199AQ datasheet.

Signal Processor and Servo Amplifier

Older PSX mainboards are using two separate chips:

[CDROM Internal Commands CX\(0x..3x\) - CXA1782BR Servo Amplifier](#)

[CDROM Internal Commands CX\(4x..Ex\) - CXD2510Q Signal Processor](#)

Later PSX mainboards have the above intergrated in a single chip, with some extended features:

[CDROM Internal Commands CX\(0x..Ex\) - CXD2545Q Servo/Signal Combo](#)

Later version is CXD1817R (Servo/Signal/Decoder Combo).

Even later PSX mainboards have it integrated in the Sound Chip: CXD2938Q (SPU+CDROM) with some changed bits and New SCEx transfer:

[CDROM Internal Commands CX\(0x..Ex\) - CXD2938Q Servo/Signal/SPU Combo](#)

Finally, PM-41(2) boards are using a CXD2941R chip (SPU+CDROM+SPU_RAM), unknown if/how far the CDROM part of that chip differs from CXD2938Q.

Some general notes:

[CDROM Internal Commands CX\(xx\) - Notes](#)

[CDROM Internal Commands CX\(xx\) - Summary of Used CX\(xx\) Commands](#)

The PSX can manipulate the CX(..) registers via some test commands:

[CDROM - Test Commands - Test Drive Mechanics](#)

Note: Datasheets for CXD2510Q/CXA1782BR/CXD2545Q do exist.

CDROM Pinouts

[Pinouts - DRV Pinouts](#)

[Pinouts - HC05 Pinouts](#)

27.1 CDROM Internal HC05 Instruction Set

ALU, Load/Store, Jump/Call

Opcode	Clk	HINZC	Name	Syntax	
x6 ...	2-5	--NZ-	LDA	MOV A,<op>	; A=op
xE ...	2-5	--NZ-	LDX	MOV X,<op>	; X=op
x7 ...	4-6	--NZ-	STA	MOV <op>,A	; op=A

xF ...	4-6 --NZ- STX	MOV <op>,X	; op=X
xC ...	2-4 ----- JMP	JMP <op>	; PC=op
xD ...	5-7 ----- JSR	CALL <op>	; [SP]=PC, PC=op
xB ...	2-5 H-NZC ADD	ADD A,<op>	; A=A+op
x9 ...	2-5 H-NZC ADC	ADC A,<op>	; A=A+op+C
x0 ...	2-5 --NZC SUB	SUB A,<op>	; A=A-op
x2 ...	2-5 --NZC SBC	SBC A,<op>	; A=A-op-C
x4 ...	2-5 --NZ- AND	AND A,<op>	; A=A AND op
xA ...	2-5 --NZ- ORA	OR A,<op>	; A=A OR op
x8 ...	2-5 --NZ- EOR	XOR A,<op>	; A=A XOR op
x1 ...	2-5 --NZC CMP	CMP A,<op>	; A-op
x3 ...	2-5 --NZC CPX	CMP X,<op>	; X-op
x5 ...	2-5 --NZ- BIT	TEST A,<op>	; A AND op

A7,AF,AC = Reserved (no STA/STX/JMP with immediate operand)

Operands can be...

Opcode	Clk ALU/LDA/LDX	Clk STA/STX	Clk JMP/CALL
Ax nn	2 cmd r,nn	- N/A	-/6 call relative (BSR)
Bx nn	3 cmd r,[nn]	4 mov [nn],r	2/5 cmd nn
Cx nn mm	4 cmd r,[nnmm]	5 mov [nnmm],r	3/6 cmd nnmm
Dx nn mm	5 cmd r,[X+nnmm]	6 mov [X+nnmm],r	4/7 cmd X+nnmm
Ex nn	4 cmd r,[X+nn]	5 mov [X+nn],r	3/6 cmd X+nn
Fx	3 cmd r,[X]	4 mov [X],r	2/5 cmd X

Read-Modify-Write

Opcode	Clk HINZC Name Syntax		
xC ...	3-6 --NZ- INC INC op	; increment	; op=op+1
xA ...	3-6 --NZ- DEC DEC op	; decrement	; op=op-1
xF ...	3-6 --01- CLR ?? op,00h	; clear	; op=op AND 00h
x3 ...	3-6 --NZ1 COM NOT op	; complement	; op=op XOR FFh
x0 ...	3-6 --NZC NEG NEG op	; negate	; op=00h-op
x9 ...	3-6 --NZC ROL RCL op	; rotate left through carry	
x6 ...	3-6 --NZC ROR RCR op	; rotate right through carry	
x8 ...	3-6 --NZC LSL SHL op	; shift left logical	
x4 ...	3-6 --0ZC LSR SHR op	; shift right logical	
x7 ...	3-6 --NZC ASR SAR op	; shift right arithmetic	
xD ...	3-5 --NZ- TST TEST op,FFh	; test for negative or zero (AND FFh?)	
x1,x2,x5,xB,xE	= Reserved (except for: 42 = MUL)		

Operands can be...

Opcode	Clk RMW	Clk CLR	Clk TST
3x nn	5 cmd [nn]	5 MOV [nn],00h	4 TEST [nn],0FFh
4x	3 cmd A	3 MOV A,00h,slow	3 TEST A,0FFh,slow
5x	3 cmd X	3 MOV X,00h,slow	3 TEST X,0FFh
6x nn	6 cmd [X+nn]	6 MOV [X+nn],00h	5 TEST [X+nn],0FFh
7x	5 cmd [X]	5 MOV [X],00h	4 TEST [X],0FFh

CLR includes a dummy-read-cycle, whilst TST does omit the dummy-write cycle.
The ",slow" RMW opcodes are smaller, but slower than equivalent ALU opcodes.

Bit Manipulation and Bit Test with Relative Jump (to \$+3+-dd)

Opcode	Clk	HINZC	Name	Syntax
00h+i*2 nn dd 5	----	C	BRSET	JNZ [nn].i,dest ;C=[nn].i, branch if set
01h+i*2 nn dd 5	----	C	BRCLR	JZ [nn].i,dest ;C=[nn].i, branch if clear
10h+i*2 nn 5	-----	BSET	SET	[nn].i ;set [nn].i
11h+i*2 nn 5	-----	BCLR	RES	[nn].i ;clear [nn].i

Branch (Relative jump to \$+2+-nn)

Opcode	Clk	HINZC	Name	Syntax
20 nn	3 -----	BRA	JR nn	;branch always
21 nn	3 -----	BRN	NUL nn	;branch never
22 nn	3 -----	BHI	JA nn	;if C=0 and Z=0, higher ?
23 nn	3 -----	BLS	JBE nn	;if C=1 or Z=1, lower or same ?
24 nn	3 -----	BCC/BHS	JNC/JAE nn	;if C=0, carry clear, higher.same
25 nn	3 -----	BCS/BLO	JC/JB nn	;if C=1, carry set, lower
26 nn	3 -----	BNE	JNZ/JNE nn	;if Z=0, not equal / not zero
27 nn	3 -----	BEQ	JZ/JE nn	;if Z=1, equal / zero
28 nn	3 -----	BHCC	JNH nn	;if H=0, half-carry clear
29 nn	3 -----	BHCS	JH nn	;if H=1, half-carry set
2A nn	3 -----	BPL	JNS nn	;if S=0, plus / not signed
2B nn	3 -----	BMI	JS nn	;if S=1, minus / signed
2C nn	3 -----	BMC	JEI nn	;if I=0, interrupt mask clear
2D nn	3 -----	BMS	JDI nn	;if I=1, interrupt mask set
2E nn	3 -----	BIL	JIL nn	;if XX=LO, interrupt line low
2F nn	3 -----	BIH	JIH nn	;if XX=HI, interrupt line high
AD nn	6 -----	BSR	CALL relative nn	;branch to subroutine always

Control/Misc

Opcode	Clk	HINZC	Name	Syntax
9D	2 -----	NOP	NOP	;no operation
97	2 -----	TAX	MOV X,A	;transfer A to X
9F	2 -----	TXA	MOV A,X	;transfer X to A
9C	2 -----	RSP	MOV SP,00FFh	;reset stack pointer (SP=00FFh)
42	11 0---0	MUL	MUL X,A	;X:A=X*A (unsigned multiply)
81	6 -----	RTS	RET	;return from subroutine
80	9 xxxxx	RTI	RETI	;return from interrupt
99	2 ----1	SEC	STC	;set carry flag
98	2 ----0	CLC	CLC	;clear carry flag
9B	2 -1---	SEI	DI	;set interrupt mask (disable ints)
9A	2 -0---	CLI	EI	;clear interrupt mask (enable ints)
8E	.2 -0---	STOP	STOP	?
8F	.2 -0---	WAIT	WAIT	?
83	10 -1---	SWI	SWI	;software interrupt ...? PC=[FFFCh]

<IRQ>	? ????? Interrupt	;?	PC=[FFFxh]
<RESET>	? ????? Reset	;?	PC=[FFFEh]
82,84..8D,90..96,9E = Reserved			

MUL isn't supported in original "M146805 CMOS" family (MUL is used/supported in PSX cdrom controller).

Registers

A	8bit accumulator
X	8bit index register
SP	6bit stack pointer (range 00C0h..00FFh)
PC	16bit program pointer (range 0000h..FFFFh)
CCR	5bit condition code register (flags) (111HINZC)

Pushed on IRQ are:

SP.highest	PC.lo
	PC.hi
X	
A	
SP.lowest	Flags (CCR, 5bit condition code register) (111HINZC)

Addressing Modes

nn	immediate	;00h..FFh
[nn]	direct address	:[0000h..00FFh]
[nnmm]	extended address	:[0000h..FFFFh]
[X]	indexed, no offset	:[0000h..00FFh]
[X+nn]	indexed, 8bit offset	:[0000h..01FEh]
[X+nnmm]	indexed, 16bit offset	:[0000h..FFFFh]
[nn].i	bit	:[0000h..00FFh].bit0..7
dd	relative	:\$+2..3+(-80h..+7Fh)

Notes:

operand "X+nn" performs an unsigned addition, and can address 0000h..01FEh.
 16bit operands (nnmm) are encoded in BIG-ENDIAN format (same for pushed PC).

Exception Vectors

Exception vectors are 16bit BIG-ENDIAN values at FFF0h-FFFFh (or at FFE0h-FFEFh when running in Motorola Bootstrap mode).

Vector	Prio	Usage
FFF0h	7=lo	TBI Vector (Timebase)
FFF2h	6	SSPI Vector (SPI bus) (SPI1 and SPI2)
FFF4h	5	Timer 2 Interrupt Vector (Timer 2 Input/Compare)
FFF6h	4	Timer 1 Interrupt Vector (Timer 1 Input/Compare/Overflow)
FFF8h	3	KWI Vector (Key Wakeup) (KWI0..7 pins)
FFFAh	2	External Interrupt Vector (/IRQ1 and /IRQ2 pins)
FFFCh	none	Software Interrupt Vector (SWI opcode) ;\regardless of
FFFEh	1=hi	Reset Vector (/RESET signal and COP) ;CPU's "I"

Directives/Pseudos (used by a22i assembler; in no\$psx utility menu)

.hc05	select HC05 instruction set (default would be .mips)
.nocash	select nocash syntax (default would be .native opcode names)
db ...	define 8bit byte(s), or quoted ascii strings
dw ...	define 16bit word(s) in BIG ENDIAN (for HC05 exception vectors)
org nnnn	change origin for following opcodes
end	end of file
mov c,[nn].i	alias for "jnz [nn].i,\$+3" (dummy jump & set carry=[nn].i)

27.2 CDROM Internal HC05 On-Chip I/O Ports

HC05 Port 3Eh - MISC - Miscellaneous Register (R/W)

0	OPTM	Option Map Select (bank-switching for Port 00h..0Fh)
1	FOSCE	Fast (Main) Oscillator Enable (0=Disable OSC, 1=Normal)
2-3	SYS	System Clock Select (0=OSC/2, 1=OSC/4, 2=OSC/64, 3=XOSC/2)
4-5	-	Not used (0)
6	STUP	XOSC Time Up Flag (R)
7	FTUP	OSC Time Up Flag (R) (0=Busy, 1=Ready/Good/Stable)

Note: For PSX, OSC is 4.0000MHz (PU-7/PU-8), 4.2336MHz (PU-18 and up). SysClk is usually set to OSC/2, ie. around 2MHz.

HC05 Port OPTM=0:00h - PORTA - Port A Data Register (R/W)**HC05 Port OPTM=0:01h - PORTB - Port B Data Register (R)****HC05 Port OPTM=0:02h - PORTC - Port C Data Register (R/W)****HC05 Port OPTM=0:03h - PORTD - Port D Data Register (R/W)****HC05 Port OPTM=0:04h - PORTE - Port E Data Register (R/W)****HC05 Port OPTM=0:05h - PORTF - Port F Data Register (R) (undoc: R/W)**

These are general purpose I/O ports (controlling external pins). Some ports are Input-only, and some can be optionally used for special things (like IRQs, SPI-bus, or as Timer input/output).

PA.0-7	PAn	Port A Bit0..7	Input/Output	(0=Low, 1=High)	(R/W)
PB.0-7	PBn	Port B Bit0..7	Input	/KWI0..7	(0=Low, 1=High) (R)
PC.0	PC0	Port C Bit0	Input/Output	/SDI1 (SPI)	(0=Low, 1=High) (R/W)
PC.1	PC1	Port C Bit1	Input/Output	/SDO1 (SPI)	(0=Low, 1=High) (R/W)
PC.2	PC2	Port C Bit2	Input/Output	/SCK1 (SPI)	(0=Low, 1=High) (R/W)
PC.3	PC3	Port C Bit3	Input/Output	/TCAP (T1)	(0=Low, 1=High) (R/W)
PC.4	PC4	Port C Bit4	Input/Output	/EVI (T2)	(0=Low, 1=High) (R/W)
PC.5	PC5	Port C Bit5	Input/Output	/EVO (T2)	(0=Low, 1=High) (R/W)
PC.6	PC6	Port C Bit6	Input/Output	/IRQ2	(0=Low, 1=High) (R/W)
PC.7	PC7	Port C Bit7	Input/Output	/IRQ1	(0=Low, 1=High) (R/W)
PD.0-7	PDn	Port D Bit0..7	Input/Output		(0=Low, 1=High) (R/W)
PE.0-7	PEn	Port E Bit0..7	Input/Output		(0=Low, 1=High) (R/W)
PF.0-7	PFn	Port F Bit0..7	Input/Undoc	A/D-input	(0=Low, 1=High) (R) (R/W)

HC05 Port OPTM=1:00h - DDRA - Port A Data Direction Register (R/W)**HC05 Port OPTM=1:02h - DDRC - Port C Data Direction Register (R/W)****HC05 Port OPTM=1:03h - DDRD - Port D Data Direction Register (R/W)****HC05 Port OPTM=1:04h - DDRE - Port E Data Direction Register (R/W)****HC05 Port OPTM=1:05h - DDRF - Port F Data Direction Register (undoc)**

DDRX.0-7	DDRXn	Port X	Data Direction	Bit0..7	(0=Input, 1=Output)	(R/W)
----------	-------	--------	----------------	---------	---------------------	-------

Officially, there are no DDRB and DDRF registers (Port B and F are always Inputs).
 Although, actually, Motorola's Bootstrap RAM \<does> manipulate DDRF.

HC05 Port OPTM=1:08h - RCR1 - Resistor Control Register 1 (R/W)

HC05 Port OPTM=1:09h - RCR2 - Resistor Control Register 2 (R/W)

RCR1.0	RAL	Port A.Bit0-3 Pullup Resistors (0=Off, 1=On)
RCR1.1	RAH	Port A.Bit4-7 Pullup Resistors (0=Off, 1=On)
RCR1.2	RBL	Port B.Bit0-3 Pullup Resistors (0=Off, 1=On)
RCR1.3	RBH	Port B.Bit4-7 Pullup Resistors (0=Off, 1=On)
RCR1.4	RGL	Port G.Bit0-3 Pullup Resistors (0=Off, 1=On) ;\
RCR1.5	RGH	Port G.Bit4-7 Pullup Resistors (0=Off, 1=On) ; on chips
RCR1.6	RHL	Port H.Bit0-3 Pullup Resistors (0=Off, 1=On) ; with Port G,H
RCR1.7	RHH	Port H.Bit4-7 Pullup Resistors (0=Off, 1=On) ;/
RCR2.0-7	RCn	Port C.Bit0-7 Pullup Resistors (0=Off, 1=On)

HC05 Port OPTM=1:0Ah - WOM1 - Open Drain Output Control Register 1 (R/W)

HC05 Port OPTM=1:0Bh - WOM2 - Open Drain Output Control Register 2 (R/W)

WOM1.0	AWOML	Port A.Bit0-3 Open Drain Mode when DDR=1 (0=No, 1=Open Drain)
WOM1.1	AWOMH	Port A.Bit4-5 Open Drain Mode when DDR=1 (0=No, 1=Open Drain)
WOM1.2	GWOML	Port G.Bit0-3 Open Drain Mode when DDR=1 (0=No, 1=Open Drain)
WOM1.3	GWOMH	Port G.Bit4-5 Open Drain Mode when DDR=1 (0=No, 1=Open Drain)
WOM1.4	HWOML	Port H.Bit0-3 Open Drain Mode when DDR=1 (0=No, 1=Open Drain)
WOM1.5	HWOMH	Port H.Bit4-5 Open Drain Mode when DDR=1 (0=No, 1=Open Drain)
WOM1.6-7	-	Not used (0)
WOM2.0-5	CWOMn	Port C.Bit0..5 Open Drain Mode when DDR=1 (0=No, 1=Open Drain)
WOM2.6-7	-	Not used (always both bits set)

===== Interrupts =====

HC05 Port OPTM=0:08h - INTCR - Interrupt Control Register (R/W)

0-1	-	Not used (0)
2	IRQ2S	IRQ2 Select Edge-Sensitive Only (0=LowLevelAndNegEdge, 1=NegEdge)
3	IRQ1S	IRQ1 Select Edge-Sensitive Only (0=LowLevelAndNegEdge, 1=NegEdge)
4	KWIE	Key Wakeup Interrupt Enable (0=Disable, 1=Enable)
5	-	Not used (0)
6	IRQ2E	IRQ2 Interrupt Enable (0=Disable, 1=Enable)
7	IRQ1E	IRQ1 Interrupt Enable (0=Disable, 1=Enable)

HC05 Port OPTM=0:09h - INTSR - Interrupt Status Register (R and W)

0	RKWIF	Reset Key Wakeup Interrupt Flag (0=No Change, 1=Reset) (W)
1	-	Not used (0)
2	RIRQ2	Reset IRQ2 Interrupt Flag (0=No Change, 1=Reset) (W)
3	RIRQ1	Reset IRQ1 Interrupt Flag (0=No Change, 1=Reset) (W)
4	KWIF	Key Wakeup Interrupt Flag (PB/KWI) (0=No, 1=IRQ) (R)
5	-	Not used (0)
6	IRQ2F	IRQ2 Interrupt Flag (PC6) (0=No, 1=IRQ) (R)
7	IRQ1F	IRQ1 Interrupt Flag (PC7) (0=No, 1=IRQ) (R)

HC05 Port OPTM=1:0Eh - KWIE - Key Wakeup Interrupt Enable Register (R/W)

0-7	KWIEn	Port B.Bit0..7 Key Wakeup Interrupt Enable (0=Disable, 1=Enable)
-----	-------	--

===== SPI Bus =====

HC05 Port OPTM=0:0Ah - SPCR1 - Serial Peripheral Control Register 1 (R/W)

0	SPRn	SPI Clock Rate (0=ProcessorClock/2, 1=ProcessorClock/16)
1-3	-	Not used (0)
4	MSTRn	SPI Master Mode Select (0=Slave/SCK.In, 1=Master/SCK.Out)
5	DORDn	SPI Data Transmission Order (0=MSB First, 1=LSB First)
6	SPEn	SPI Enable (SPI1:PortC, SPI2:PortG) (0=Disable, 1=Enable)
7	SPIEn	SPI Interrupt Enable (... ack HOW?) (0=Disable, 1=Enable)

HC05 Port OPTM=0:0Bh - SPSR1 - Serial Peripheral Status Register 1 (R)

0-5	-	Not used (0)
6	DCOLn	SPI Data Collision Occurred (0=No, 1=Collision)
7	SPIFn	SPI Transfer Complete Flag (0=Busy, 1=Complete) (R)

Note: SPSR1.7 appears to be reset after reading SPSR1 (probably same for SPSR1.6, and maybe also same for whatever SPI IRQ signal).

HC05 Port OPTM=0:0Ch - SPDR1 - Serial Peripheral Data Register 1 (R/W)

0-7	BITn	Data to be sent / being received
-----	------	----------------------------------

===== Time Base / Config =====

HC05 Port 10h - TBCR1 - Time Base Control Register 1 (R/W)

```

0-1  T2R   Timer2 Prescaler (0=SysClk, 1=SysClk/4, 2=SysClk/32, 3=SysClk/256)
2-3  T3R   PWM Prescaler (0=CLK3, 1=CLK3/2, 2=CLK3/8, 3=Timer2compare)
4-6  -     Not used (0)
7    TBCLK Time Base Clock (0=XOSC, 1=OSC/128) ;<-- write-able only ONCE

```

HC05 Port 11h - TBCR2 - Time Base Control Register 2 (R/W, some bits R or W)

```

0    COPC  COP Clear 2bit COP timeout divider (0=No Change, 1=Clear) (W)
1    COPE  COP Enable ;<-- write-able only ONCE
2    -     Not used (0)
3    RTBIF Reset Time Base Interrupt Flag (0=No Change, 1=Clear TBIF) (W)
4-5  TBR   Time Base Interrupt Rate (0=TBCLK/128, 1=/4096, 2=/8192, 3=/16384)
6    TBIE  Time Base Interrupt Enable (0=Disable, 1=Enable)
7    TBIF  Time Base Interrupt Flag (0=No, 1=IRQ) (R)

```

HC05 Port OPTM=1:0Fh - MOSR - Mask Option Status Register (R)

```

0-4  -     Not used (0)
5    XOSCR XOSC Feedback Resistor (0=None, 1=Implemented)
6    OSCR  OSC Feedback Resistor (0=None, 1=Implemented)
7    RSTR  /RESET Pullup Resistor (0=None, 1=Implemented)

```

Reading this register returns A0h (on PSX/PSone with 52pin chips).

===== Timer 1 =====

HC05 Port 12h - TCR - Timer 1 Control Register (R/W)

```

0    OLVL  Output Level on TCMP pin on Compare Match? (0=Low, 1=High)
1    IEDG  Input Edge on TCAP pin (0=NegativeEdge, 1=PositiveEdge)
2-4  -     Not used (0)
5    TOIE  Timer Overflow Interrupt Enable (0=Disable, 1=Enable)
6    OC1IE Output Compare Interrupt Enable (0=Disable, 1=Enable)
7    ICIE  Input Capture Interrupt Enable (0=Disable, 1=Enable)

```

HC05 Port 13h - TSR - Timer 1 Status Register (R)

```

0-4  -     Not used (0)
5    TOF   Timer Overflow Flag (0=No, 1=Yes) (R) ;clear by Port 19h access
6    OC1F  Output Compare Flag (0=No, 1=Yes) (R) ;clear by Port 17h access
7    ICF   Input Capture Flag (0=No, 1=Yes) (R) ;clear by Port 15h access

```

HC05 Port 14h - ICH - Timer 1 Input Capture High (undoc)**HC05 Port 15h - ICL - Timer 1 Input Capture Low (undoc)**

0-15 Capture Value

HC05 Port 16h - OC1H - Timer 1 Output Compare 1 High (undoc)**HC05 Port 17h - OC1L - Timer 1 Output Compare 1 Low (undoc)**

0-15 Compare Value

HC05 Port 18h - TCNTH - Timer 1 Counter 1 High (undoc)**HC05 Port 19h - TCNTL - Timer 1 Counter 1 Low (undoc)**

0-15 Counter

HC05 Port 1Ah - ACNTH - Alternate Counter High (undoc)**HC05 Port 1Bh - ACNTL - Alternate Counter Low (undoc)**

0-15 Alternate Counter (uh, what?)

===== Timer 2 =====

HC05 Port 1Ch - TCR2 - Timer 2 Control Register (R/W)

0	OL2	Timer Output 2 Edge (0=Falling, 1=Rising)
1	OE2	Timer Output 2 Enable (EVO) (0=Disable, 1=Enable)
2	IL2	Timer Input 2 Edge/Level (0=Low/Falling, 1=High/Rising)
3	IM2	Timer Input 2 Mode Select for EVI (0=EventMode, 1=GatedByCLK2)
4	T2CLK	Timer 2 Clock Select (0=CLK2 from Prescaler, 1=EXCLK from EVI)
5	-	Not used (0)
6	OC2IE	Output Compare 2 Interrupt Enable (0=Disable, 1=Enable)
7	TI2IE	Timer Input 2 Interrupt Enable (EVI) (0=Disable, 1=Enable)

HC05 Port 1Dh - TSR2 - Timer 2 Status Register (R/W)

0-1	-	Not used (0)
2	ROC2F	Reset Output Compare 2 Interrupt Flag (0>No Change, 1=Clear) (W)

3	RTI2F	Reset Timer Input 2 Interrupt Flag	(0=No Change, 1=Clear) (W)
4-5	-	Not used (0)	
6	OC2F	Output Compare 2 Interrupt Flag	(0=No, 1=Yes) (R)
7	TI2F	Timer Input 2 Interrupt Flag (EVI)	(0=No, 1=Yes) (R)

HC05 Port 1Eh - OC2 - Timer 2 Output Compare Register (R/W)

0-7 Compare Value ("Transferred to buffer on certain events?")

HC05 Port 1Fh - TCNT2 - Timer 2 Counter Register (R) (W=Set Counter to 01h)

0-7 Counter Value, incremented at T2R (set to 01h on Compare Matches)

===== Reserved =====

HC05 Port 3Fh - Unknown/Unused

Reading this port via Sony's test command returns 20h (same as openbus), but reading it via Motorola's selftest function returns 00h (unlike openbus), so it seems to have some unknown/undocumented function; bit5 might indicate selftest mode, or it might reflect initialization of whatever other ports.

HC05 Port OPTM=0:06h..07h,0Dh..0Fh - Reserved

HC05 Port OPTM=1:01h,06h..07h,0Ch..0Dh - Reserved

HC05 Port 20h..3Dh - Reserved

These ports are unused/reserved. Trying to read them on a PSone does return 20h (possibly the prefetched next opcode value from the RAM test command). Other HC05 variants contain some extra features in these ports:

[CDROM Internal HC05 On-Chip I/O Ports - Extras](#)

The PSX CDROM BIOS doesn't use any of these ports - except, it is writing [20h]=2Eh (possibly to disable unused LCD hardware; which might be actually present in the huge 80pin HC05 chips on old PU-7 mainboards).

HC05 Openbus

Openbus values can be read from invalid memory locations, on PSX with 52pin chips:

```
I/O bank 0:    0:06h..07h, 0:0Dh..0Fh
I/O bank 1:    1:01h, 1:06h..07h, 1:0Ch..0Dh, and upper 4bit of 1:05h
Unbanked I/O: 20h..3Dh
Unused Memory: 0240h..0FFFh, 5000h..FDFFh
```

The returned openbus value depends on the opcode's memory operand:

```
[nn], [mmnn], [nn+x], [mmnn+x] --> returns LAST byte of current opcode (=nn)
[x]                                --> returns FIRST byte of following opcode
```

27.3 CDROM Internal HC05 On-Chip I/O Ports - Extras

HC05 Port OPTM=0:0Dh - SPCR2 - Serial Peripheral Control Register 2 (R/W)

HC05 Port OPTM=0:0Eh - SPSR2 - Serial Peripheral Status Register 2 (R)

HC05 Port OPTM=0:0Fh - SPDR2 - Serial Peripheral Data Register 2 (R/W)

This is a second SPI channel, works same as first SPI channel, but using the lower 3bits of Port G (instead of Port C) for the SPI signals.

HC05 Port OPTM=0:06h - PORTG - Port G Data Register (R/W)

HC05 Port OPTM=0:07h - PORTH - Port H Data Register (R/W)

HC05 Port 3Ch - PORTJ - Port J Data Register (R/W)

PG.0	PG0	Port G Bit0	Input/Output /SDI2	(0=Low, 1=High) (R/W)
PG.1	PG1	Port G Bit1	Input/Output /SDO2	(0=Low, 1=High) (R/W)
PG.2	PG2	Port G Bit2	Input/Output /SCK2	(0=Low, 1=High) (R/W)
PG.3	PG3	Port G Bit3	Input/Output /TCMP	(0=Low, 1=High) (R/W)
PG.4	PG4	Port G Bit4	Input/Output /PWM0	(0=Low, 1=High) (R/W)
PG.5	PG5	Port G Bit5	Input/Output /PWM1	(0=Low, 1=High) (R/W)
PG.6	PG6	Port G Bit6	Input/Output /PWM2	(0=Low, 1=High) (R/W)
PG.7	PG7	Port G Bit7	Input/Output /PWM3	(0=Low, 1=High) (R/W)
PH.0-7	PHn	Port H Bit0..7	Input/Output	(0=Low, 1=High) (R/W)
PJ.0-3	PJn	Port J Bit0..3	Output	(0=Low, 1=High) (R/W)
PJ.4-7	-	Not used (0)		

HC05 Port OPTM=1:06h - DDRG - Port G Data Direction Register (R/W)**HC05 Port OPTM=1:07h - DDRH - Port H Data Direction Register (R/W)**

0-7 DDRXn Port X Data Direction Bit0..7 (0=Input, 1=Output) (R/W)

HC05 Port 20h - LCDCR - LCD Control Register (R/W)

0	-	Not used (0)
1	PDH	Select Port D (H) (0=FP35-FP38 pins, 1=PD7-PD4 pins)
2	PEL	Select Port E (L) (0=FP31-FP34 pins, 1=PE3-PE0 pins)
3	PEH	Select Port E (H) (0=FP27-FP30 pins, 1=PE7-PE4 pins)
4	-	Not used (0)
5-6	DUTY	LCD Duty Select (...)
7	LCDE	LCD Output Enable BP and FP pins (0=Disable, 1=Enable)

HC05 Port 21h..34h - LCDDR1..20 - LCD Data Register 1..20 (R/W)

0-3 First Data Unit ;\Fourty 4bit LCD values (in the twenty registers)
 4-7 Second Data Unit ;/(some duties use only the LSBs of that 4bit values)

HC05 Port 34h - PWMCR - PWM Pulse Width Modulation Control Register (R/W)

0-3 CH0-3 PWM Channel 0..3 on Port G.Bit4-7 Enable (0=Disable, 1=Enable)
 4-7 - Not used (0)

HC05 Port 35h - PWMCNT - PWM Counter Register (R) (W=Set Counter to FFh)

0-7 PWM Counter, incremented at PHI2 (range 01h..FFh)

HC05 Port 36h - PWMDR0 - PWM Duty Register 0 (R/W)**HC05 Port 37h - PWMDR1 - PWM Duty Register 1 (R/W)****HC05 Port 38h - PWMDR2 - PWM Duty Register 2 (R/W)****HC05 Port 39h - PWMDR3 - PWM Duty Register 3 (R/W)**

0-7 Duty (N cycles High, 255-N cycles Low)

HC05 Port 3Ah - ADR - A/D Data Register (R)

```
0-3  A/D Conversion result (probably unsigned, 00h=Lowest, FFh=Max voltage?)
```

HC05 Port 3Bh - ADSCR - A/D Status and Control Register (R/W)

```
0-3  CH0-3 A/D Channel (0..7=PortF.Bit0-7, 8..0Fh=Reserved/Vref/FactorTest)
4    -      Not used (0)
5  ADON  A/D Charge Pump enable (0=Disable, 1=Enable)
6  ADRC  A/D RC Oscillator On (0=Normal/Use CPU Clock, 1=Use RC Clock)
7  COCO  A/D Conversion Complete (0=Busy, 1=Complete) (R)
```

HC05 Port 3Dh - PCR - Program Control Register (R/W) (for EPROM version)

```
0    PGM    EPROM Program Command (0=Normal, 1=Apply Programming Power)
1    ELAT   EPROM Latch Control (0=Normal/Read, 1=Latch/Write)
2-7  RES    Reserved for Factory Testing (always 0 in user mode)
```

27.4 CDROM Internal HC05 I/O Port Usage in PSX

Port A - Data (indexed via Port E)

```
porta.0-7 i/o CXD1815Q.Data (indexed via Port E)
porta.0  in  debug.dta.serial.in ;\normally unused (exists in early bios)
porta.1  out debug.dta.serial.out ; (prototype/debug_status stuff)
porta.2  out debug.clk.serial.out ;/(with portc.5 = debug.select)
```

Port B - Inputs

```
portb.0  in  F-BIAS ;unused
portb.1  in  SCEx input (serial 250 baud, received via 1000Hz timer2 irq)
portb.2  in  LMTSW aka /POS0          ;\pos0 and door switches
portb.3  in  DOOR   aka SHELL_OPEN   ;/
portb.4  in  TEST2
portb.5  in  TEST1 (CL316) enter test mode (instead of mainloop)
portb.6  in  COUT   ;<-- unused, extra pin, not "SENSE=COUT"
portb.7  in  CXD2510Q.SENSE ;-from CXD2510Q (and forwarded from CXA1782BR)
```

Port C - Inputs/Outputs

```
portc.0  in  CXD2510Q.SUBQ  ;\
portc.1  in? NC (SPI.OUT)   ; used via SPDR1 to receive SPI bus SUBQ data
```

```

portc.2  out  CXD2510Q.SQCK  ;/
portc.3  out  SPEED
portc.4  out  ="SPEED XOR 1" ... AL/TE ... or CG ... or MIRR ?
portc.5  out  ROMSEL: debug.select (or "SCLK" on later boards??)
portc.6  in   CXD1815Q.XINT/IRQ2 ;unused (instead INTSTS bits are polled)
portc.7  in   CXD2510Q.SCOR/IRQ1 ;used via polling INTSR.7 (not as irq)

```

Port D - Outputs

```

portd.0  out  NC           ;-unused (always 1)
portd.1  out  CXD2510Q.DATA ;\serial bus for CXD2510Q
portd.2  out  CXD2510Q.XLAT ; (and also forwarded to CXA1782BR)
portd.3  out  CXD2510Q.CLOK ;/
portd.4  out  CXD1815Q.DECCS ;\
portd.5  out  CXD1815Q.DECWR ; control for data/index on Port A/E
portd.6  out  CXD1815Q.DECRD ;/
portd.7  out  LDON ... IC723.Pin11 ... maybe "laser on" ?

```

Port E - Index (for data on Port A)

```

porte.0-4 out  CXD1815Q.Index (for data on Port A)
porte.5   out  NC, not used
porte.6   out  NC, see "idx_4xh" maybe test signal ???
porte.7   out? NC, TEST? configured as OUTPUT... but used as INPUT?

```

Port F - Motorola Bootstrap Serial I/O (not used in cdrom bios)

```

portf.0  out  NC, TX      ;\
portf.1  in   NC, RX      ; not used by sony's cdrom bios
portf.2  out  NC, RTS     ; (but used by motorola's bootstrap rom)
portf.3  out  NC, DTR     ;/
portf.0  in   Serial Data In (from daughterboard) ;\
portf.1  out  Serial Data Out (to daughterboard) ; usage in SCPH-5903
portf.2  out  Serial Clock Out (to daughterboard) ; (PSX with Video CD)
portf.3  out  Audio/Video Select (0=Normal, 1=VCD) ;/
portf.4-7 -  NC, not used (probably pins don't even exist)

```

Other HC05 I/O Ports

```

SPI 1  - used for receiving SUBQ (via Port C)
IRQ 1  - used for latching/polling SUBQ's "SCOR" (not used as interrupt)
IRQ 2  - connects to CXD1815Q.XINT, but isn't actually used at all
Timer 1 - unused
Timer 2 - generates 1000Hz interrupts (for 250 baud "SCEEx" string transfers)
DDRx  - data directions for Port A-F (as listed above)

```

Note: The PSX has the HC05 clocked via 4.00MHz oscillator (older boards), or via 4.3MHz signal from SPU (newer boards); internally, the HC05 is clocked at half of those frequencies (ie. around 2 MHz).

27.5 CDROM Internal HC05 Motorola Selftest Mode

52-pin HC05 chips (newer psx cdrom controllers)

52-pin chips are used on LATE-PU-8 boards, and on later boards ranging from PU-18 up to PM-41(2).

[CDROM Internal HC05 Motorola Selftest Mode \(52pin chips\)](#)

80-pin HC05 chips (older psx cdrom controllers)

80-pin chips are used PU-7, EARLY-PU-8, and PU-9 boards.

[CDROM Internal HC05 Motorola Selftest Mode \(80pin chips\)](#)

32-pin HC05 chips (joypad/mouse)

Sony's Digital Joypad and Mouse are using 32pin chips (with TQFP-32 package), which are probably containing Motorola HC05 CPUs, too. Unknown if/how those chips can be switched into bootstrap/dumping modes.

Pinouts

[Pinouts - HC05 Pinouts](#)

27.6 CDROM Internal HC05 Motorola Selftest Mode (52pin chips)

Motorola Bootstrap ROM

The Motorola MC68HC05 chips are including a small bootstrap ROM which gets activated upon /RESET when having two pins strapped to following levels:

```
Pin30 PortC.6 (/IRQ2) ----> wire to 3.5V (VCC)
Pin31 PortC.7 (/IRQ1)  (SCOR)  ----> wire to 7V (2xVCC)
```

Moreover, two pins are needed on /RESET for selecting a specific test mode:

```
Pin16 PortB.0 ----> ModeSelectBit0 (0=GND, 1=3.5V)
Pin17 PortB.1 ----> ModeSelectBit1 (0=GND, 1=3.5V)
```

The selectable four modes are:

```
Mode0: Jump to RAM Address 0040h (useless when RAM is empty)
Mode1: Semifunctional Selftest (useless)
Mode2: Upload 200h bytes to RAM & jump to 0040h (allows fast/custom dumping)
Mode3: Download ROM as ASCII hexdump (nice, but very slow)
```

The upload/download functions are using following additional pins:

```
Pin50 PortF.0 ----> TX output (11bytes: 0Dh,0Ah," AAAA DD ")
Pin51 PortF.1 <---- RX input (1byte: "!" to request next 11 bytes)
Pin52 PortF.2 ----> RTS output or so (not needed)
Pin1 PortF.3 ----> DTR output or so (not needed)
Ground ----- GND for RX/TX
```

RX/TX are RS232-like serial signals (but using other voltages, 0=0V and 1=3.5V).

Transfer format is 8-N-1, ie. one startbit(0), 8 databits LSB first, no parity, one stopbit(1). Baudrate is OSC/2/208 (ie. 9616 bps for 4.000MHz, or 10176 bps for 4.2336MHz clock derived from CXD2545Q/CXD2938Q).

Note: Above pins may vary on some chips (namely on chips that don't have PortF). The pins for entering bootstrap mode (PortC in this case) should be described in datasheets; but transfer protocol and mode selection (PortB) and transmission (PortF) aren't officially documented.

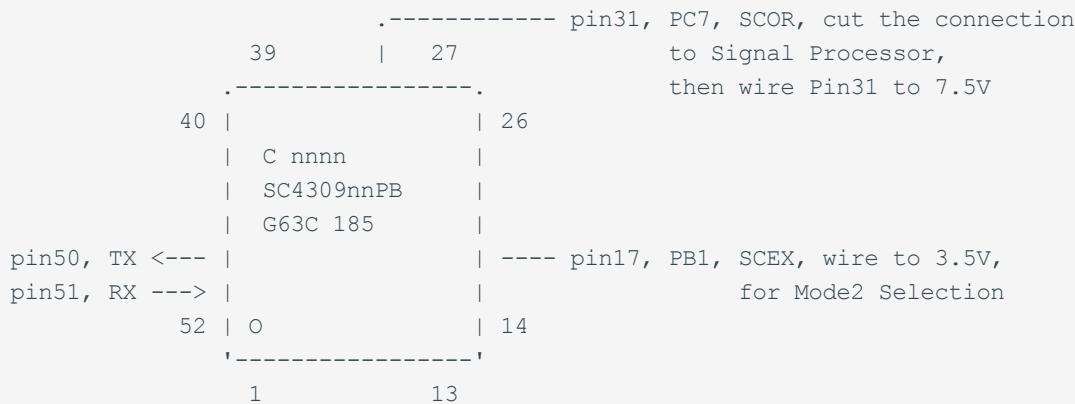
Mode2: Upload 200h bytes to RAM & jump to 0040h

This mode is very simple and powerful: After /RESET, you send 200h bytes to the RX input (without any response on TX output), the bytes are stored at 0040h..023Fh in RAM, and the chip jumps to 0040h after transferring the last byte. The uploaded program can contain a custom highspeed dumping function, or perform hardware tests, etc. A custom dumping function for PSX/PSone can be found at:

```
http://www.psxdv.net/forum/viewtopic.php?f=70&t=557
```

After uploading the 200h-byte dumping function it will respond by send 4540h bytes (containing some ASCII string, the 16.5Kbyte ROM image, plus dumps for RAM and (banked) I/O port region, plus openbus tests for unused memory and I/O regions.

Wiring for Mode2 on PSX/PSone consoles with 52-pin HC05 chips



Good places to pick 3.5V and 7.5V from nice solder pads are:

```
CN602.Pin1 = 7.5V ;\on PSX boards (with either 5pin or
CN602.Pin3 = 3.5V ;/ 7pin CN602 connectors)
IC601.Pin1 = 7.5V ;-on PSone boards (3pin 78M05 voltage regulator)
IC102.Pin32 = 3.5V ;-on PSone boards (32pin Main BIOS ROM chip)
```

The SCOR trace on Pin31, connects to Signal Processor...

```
CXD2510Q.Pin63 (eg. on PU-8 boards) ;\
CXD2545Q.Pin74 (eg. on PU-18 boards) ; either one of these, depending
CXD1817R.Pin49 (eg. on PU-20 boards) ; on which chipset you have
CXD2938Q.Pin77 (eg. on PM-41 boards) ;
CXD2941R.Pin85 (eg. PM-41(2) boards) ;/
```

cut that trace (preferably on the PCB between two vias or test points, so you can later repair it easily) (better don't try to lift Pin31, it breaks off easily)

Note: Mode2 also requires Pin16=Low, and Pin30=High (but PSX/PSone boards should have those pins at that voltages anyways).

Mode3: Download ROM as ASCII hexdump

This mode is very slow and not too powerful. But it may useful if you can't get Mode2 working for whatever reason. Wiring for Mode3 is same as above, plus PortB.0=3.5V. In this mode, the chip will send one 0Dh,0Ah," AAAA DD " string immediately after /RESET (with 16bit address "AAAA" (initially 1000h), and 8bit data "DD"). Thereafter the chip will wait for incoming commands:

```
4-digit ASCII HEX address --> change address, and return 0Dh,0Ah," AAAA DD "
chr(00h) --> increment address, and return 0Dh,0Ah," AAAA DD "
```

```
chr(07h) --> jump to current address (not so useful)
other characters --> same as chr(00h)
All digits/characters sent to RX input will produce an echo on TX output.
```

Basic setup would be wiring RX to GND (the chip will treat that as infinite stream of start bits with chr(00h), so it will respond by sending data from increasing addresses automatically; the increment wraps from 4FFFh to FE00h (skipping the gap between Main ROM and Bootstrap ROM), and also wraps from FFFFh to 0000h; transfer is ultraslow: 13 characters needed per dumped byte: chr(00h) to chip, chr(00h) echo from chip, and 0Dh,0Ah," AAAA DD " from chip.

27.7 CDROM Internal HC05 Motorola Selftest Mode (80pin chips)

80pin Sony 4246xx chips

And for anyone else planning to try this, these are the connections:

```
Pin PortC
46 PC7/IRQ1 (SCOR) disconnect from PCB, then wire the pin to Vtst (7.6V)
45 PC6/IRQ2 (/XINT) wire to Vdd (3.5V) (you have to solder to the pin)
```

In bootstrap mode, Port A is used as follows:

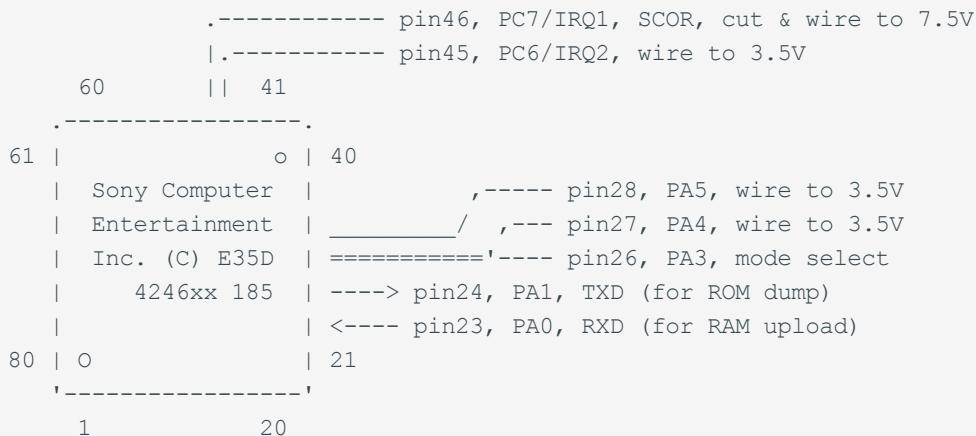
Pin	PortA	DDRA	Usage
23	PA0	in	RXD
24	PA1	out	TXD
25	PA2	in	-
26	PA3	in	Testmode.bit0 (GND=0, 3.5V=1)
27	PA4	in	Testmode.bit1 (GND=0, 3.5V=1)
28	PA5	in	Testmode.bit2 (GND=0, 3.5V=1)
29	PA6	out	RTS (don't care)
30	PA7	out	-

The selectable testmodes are:

PA5	PA4	PA3	Effect
0	x	x	Jump to 0040h ;\
1	0	0	Test (complex) ; not so useful
1	0	1	Test (simple loop) ;/
1	1	0	ROM Dump 4200h bytes (plain binary, non-ASCII)
1	1	1	RAM Upload 100h bytes to 0040h..013Fh, then jump to 0040h

RX/TX are plain binary (non-ASCII), baudrate is 9600 (when using 4.000MHz oscillator), transfer format is 8,N,2 (aka 8,N,1 with an extra pause bit).

Wiring for Upload/Download on PSX consoles with 80-pin HC05 chips



Good places to pick 3.5V and 7.5V from nice solder pads are:

```
CN602.Pin1 = 7.5V ;\on PSX boards (with 7pin CN602 connectors)
CN602.Pin3 = 3.5V ;/
```

Credits to TriMesh for finding the 80pin chip's bootstrap signals.

Other 80pin chips

DTL-H100x uses 80pin chip with onchip PROM (chip text "(M) MC68HC705L15", instead of "Sony [...] 4246xx"), wiring for serial dumping on that is unknown (the bootstrap ROM may be a little different because it should contain PROM burning functions). PU-9 boards seem to use a similar PROM (with some sticker on it).

DTL-H2000 uses 80pin CXP82300 chip with socketed piggyback 32pin EPROM - that chip is a Sony SPC700 CPU, not a Motorola HC05 CPU. Accordingly there's no Motorola Bootstrap mode in it, but of course one could simply dump the EPROM with standard eprom utilities, but nobody did do so yet).

27.8 CDROM Internal CXD1815Q Sub-CPU Configuration Registers

00h - DRVIF - Drive Interface (W)

0-1 "L"	Reserved (should be 0)
2	LSB 1st CD DSP DATA order (0=MSB first, 1=LSB first)
3-4 BCK MD	CD DSP Number of BCLKs per WCLK (0=16, 1=24, 2=32, 3=Reserved)
5	BCK RED Strobe DATA on BLCK Edge (0=Falling Edge, 1=Rising Edge)

6	LCH LOW Channel on LRCK=Low	(0=Right, 1=Left)
7	C2PL1st	... C2PO lower byte 1st

01h - CONFIG 1 - Configuration 1 (W)

0	HCLKDIS	HCLK Pin Output (0=8.4672MHz, 1=Disable; Fixed Low)
1	CLKDIS	CLK Pin Output (0=16.9344MHz, 1=Disable; Fixed Low)
2	9BITRAM	SRAM Databus width (0=8bit/normal, 1=9bit)
3-4	RAM SZ	SRMA Address bus (0=32K, 1=64K, 2=128K, 3=Reserved)
5	PRTYCTL	... Priority Control
6	XSLOW	Number of clock cycles per DMA cycle (0=12, 1=4) (for SRAM)
7	"L"	Reserved (should be 0)

02h - CONFIG 2 - Configuration 2 (W)

0	"L"	Reserved (should be 0)
1	DACODIS DAC Out Disable
2	DAMIXEN	Digital Audio Mixer Enable (0=Attenuator/Mixer for CD-DA, 1=No)
3	SMBF2	Number of Sound Map Buffer Surfaces (0=Three, 1=Two)
4	SPMCTL	Sound Parameter Majority Control (0=?); \for ADPCM params
5	SPECTL	Sound Parameter Error Control (0=?); /
6-7	"L"	Reserved (should be 0)

03h - DECCTL - Decoder Control (W)

0-2	DECMD	Decoder Mode (0-7)
	0 or 1	Decoder Disable ;-disable sector reading
	2 or 3	Monitor-only Mode ;\no error correction
	4	Write-only Mode ;/
	5	Real-time Correction Mode ;\with error correction
	6	Repeat Correction Mode ;/
	7	CD-DA Mode ;-audio
3	AUTODIST	Auto Distinction (0=Use MODESEL/FORMSEL bits, 1=Use Sector Hdr) (Error Correction is done according to above MODE/FORM values)
4	FORMSEL	Form Select (0=FORM1, 1=FORM2) (must be 0 for MODE1)
5	MODESEL	Mode Select (0=MODE1, 1=MODE2)
6	ECCSTR	ECC Strategy (0=Normal, 1=Use Error Flags; requires 9bit SRAM)
7	ENDLADR	Enable Drive Last Address ...

07h - CHPCTL - Chip Control (W)

0	"L"	Reserved (should be 0)
1	DBLSPD	Double Speed Mode (0=Normal, 1=Double) (init CD DSP first)
2	RPSTART	Repeat Correction Start (0=No, 1=Start) (automatically cleared)
3	SWOPEN	Sync Window Open (0=SyncControlledByIC, 1=OpenDetectionWindow)
4	CD-DA	CD-DA Play (0=No, 1=Playback CD-DA as audio)
5	CDDAMUTE	CD-DA Mute (0=Normal, 1=Mute CD-DA Audio)

6	RTMUTE	Real-time Mute (0=Normal, 1=Mute CDROM ADPCM)
7	SMMUTE	Sound Map Mute (0=Normal, 1=Mute Sound Map ADPCM)

27.9 CDROM Internal CXD1815Q Sub-CPU Sector Status Registers

00h - ECCSTS - ECC Status (R)

0	CFORM	FORM assumed by Error Correction (0=FORM1, 1=FORM2)
1	CMODE	MODE assumed by Error Correction (0=MODE1, 1=MODE2)
2	ECCOK	ECC Okay (0=Bad, 1=Okay)
3	EDCOK	EDC Okay (0=Bad, 1=Okay)
4	CORDONE	Correction Done (0=None, 1=Error occurred and was corrected)
5	CORINH	Correction Inhibit (0=Okay, 1=AUTODIST couldn't determine MODE/FORM)
6	ERINBLK	Erasure in Block (0=Okay, 1=At least 1 byte is wrong & uncorrected)
7	EDCALL0	EDC all-zero (0=No/EDC Exists, 1=Yes/All four EDC bytes are 00h)

01h - DECSTS - Decoder Status (R)

0	NOSYNC	No Sync (0=Okay, 1=Sector Sync Mark Missing)
1	SHRTSCT	Short Sector (0=Okay, 1=Sector Sync Mark within Sector Data)
2-4	-	Reserved (undefined)
5	RTADPBSY	Real-time ADPCM Busy (0=No, 1=Busy/playback)
6-7	-	Reserved (undefined)

02h - HDRFLG - Header/Subheader Error Flags for HDR/SHDR registers (R)

0	CI	Error in 4th Subheader byte (Coding Info) (0=Okay, 1=Error)
1	SUBMODE	Error in 3rd Subheader byte (Submode) (0=Okay, 1=Error)
2	CHANNEL	Error in 2nd Subheader byte (Channel) (0=Okay, 1=Error)
3	FILE	Error in 1st Subheader byte (File) (0=Okay, 1=Error)
4	MODE	Error in 4th Header byte (MODE) (0=Okay, 1=Error)
5	BLOCK	Error in 3rd Header byte (FF) (0=Okay, 1=Error)
6	SEC	Error in 2nd Header byte (SS) (0=Okay, 1=Error)
7	MIN	Error in 1st Header byte (MM) (0=Okay, 1=Error)

Error flags for current sector are probably stored straight in this register (ie. these flags are probably available even without using 9bit SRAM).

Or maybe not... if the chip supports receiving newer sectors during time-consuming error corrections... then those newer would need to be stored in SRAM, and would thus require 9bit SRAM for the error flags?

03h - HDR - Header Bytes (R)

```
1st read: 1st Header byte (MM)
2nd read: 2nd Header byte (SS)
3rd read: 3rd Header byte (FF)
4th read: 4th Header byte (MODE)
```

04h - SHDR - Subheader Bytes (R)

```
1st read: 1st Subheader byte (File)
2nd read: 2nd Subheader byte (Channel)
3rd read: 3rd Subheader byte (Submode) (SM)
4th read: 4th Subheader byte (Coding Info) (CI)
```

The contents of the HDRFLG, HDR, SHDR registers indicate:

- (1) The corrected value in the real-time correction or repeat correction mode
- (2) Value of the raw data from the drive in the monitor-only or write-only mode

The CMOME? and CMODE bits (bits 1, 0) of ECCSTS indicate the FORM and MODE of the sector the decoder has discriminated by the raw data from the drive.

Due to erroneous correction, the values of these bits may be at variance with those of the HDR register MODE byte and SHDR register submode byte bit5.

Unknown when 1st..4th read indices are reset for HDR and SHDR (maybe on access to certain I/O ports, or maybe anytime when receiving a new sector), also unknown what happens on 5th read and up.

27.10 CDROM Internal CXD1815Q Sub-CPU Address Registers

Drive Address -- used for storing incoming CDROM sectors in Buffer RAM

Host Address -- used for transferring Buffer RAM to (or from) Main CPU

ADPCM Address -- used for Real-time ADPCM audio output from Buffer RAM

05h - CMADR - Drive Current Minute Address (R)

0-6	CMADR	Address bit10-16 (in 1Kbyte steps)
7	-	Reserved (undefined)

Indicates the start address of the most recently decoded sector (called "Minute Address" because it points to the MM byte of the MM:SS:FF:MODE sector header). Normally, CMADR should be forwarded to Host:

```
HADR = (CMADR AND 7Fh) * 400h + offset
HXFR = length OR 4000h
```

Whereas, offset would be usually 00h, 04h, or 0Ch (to start reading from the begin of the sector, or to skip 4-byte MODE1 header, or 12-byte MODE2 header). And length would be usually 800h (normal data sector), or 924h (entire sector, excluding the leading 12 sync-bytes). Length bit14 is undocumented/reserved, but the PSX CDROM BIOS does set that bit for whatever reason.

Alternately, the sector can be forwarded to the Real-time ADPCM decoder:

```
ADPMNT = (CMADR AND 7Fh) OR 80h
```

19h - ADPMNT - ADPCM "MNT" Address (W)

0-6	ADPxxx ADPCM source Address bit10-16 (in 1Kbyte-steps)
7	RTADPEN Real-time ADPCM Enable (0=Disable, 1=Enable Real-time ADPCM)

04h - DLADR-L, Drive Last Address, bit0-7 (W)

05h - DLADR-M, Drive Last Address, bit8-15 (W)

06h - DLADR-H, Drive Last Address, bit16 (W)

0-16	DLADR Addr. bit0-16 ...
17-23	"L" Reserved (should be 0)

10h - DADRC-L - Drive Address Counter, bit0-7 (W)

11h - DADRC-M - Drive Address Counter, bit8-15 (W)

12h - DADRC-H - Drive Address Counter, bit16 (W)

0-16	DADRC Incrementing Drive-to-Buffer Write Address, bit0-16
17-23	"L" Reserved (should be 0)

0Eh - DADRC-L - Drive Address Counter, Bit0-7 (R)**0Fh - DADRC-M - Drive Address Counter, Bit8-15 (R)**

```
0-15 DADRC Address bit0-15 ;bit16 is in Port 0Bh ...
```

0Ch - HXFR-L - Host Transfer Length, bit0-7 (W)**0Dh - HXFR-H - Host Transfer Length, bit8-11 and stuff (W)**

```
0-11 HXFR      number of data bytes, bit0-11 (0..FFFh) ...
12   HADR.16   HADR bit16
13   "L"       Reserved (should be 0)
14   "L" ??    Reserved (should be 0) ;<-- XXX but on PSX: Always 1 !?!
                           ; seems to Disable INT8 !!!!
15   DISHXFRC  Disable HXFRC (0=Use HXFRC, 1=Disable, Infinite-or-Zero Len?)
```

0Eh - HADR-L - Host Transfer Address, bit0-7 (W)**0Fh - HADR-M - Host Transfer Address, bit8-15 (W)**

```
0-15 HADR      Addr. bit0-15 ;bit16 in Port 0Dh ...
```

0Ah - HXFRC-L - Host Transfer Remain Counter, bit0-7 (R)**0Bh - HXFRC-H - Host Transfer Remain Counter, bit8-11, and other bits (R)**

```
0-11 HXFRC Host Transfer Counter bit0-11 (number of remaining bytes)
12   HADRC bit16 ;MSB of Port 0Ch/0Dh
13   DADRC bit16 ;MSB of Port 0Eh/0Fh
14-15 -       Reserved (undefined) (usually both bits set)
```

0Ch - HADRC-L - Host Transfer Address Counter, bit0-7 (R)**0Dh - HADRC-M - Host Transfer Address Counter, bit8-15 (R)**

```
0-15 HADRC Address bit0-15 ;bit16 is in Port 0Bh
```

"This counter keeps the addresses which write or read the data with host into/from the buffer.

When data from the host is written into the buffer or data to the host is read from the

buffer, the HADRC value is output from MA0 to 16. HADRC is incremented each time one byte of data from the drive is read from the buffer (BFRD is high) or written into the buffer (BFWR is high)."

Note

When reading from SRAM, data seems to go through a 8-byte data fifo, the HXFRC (remain) and HADRC (addr) values aren't aware of that FIFO (ie. if there's data in the fifo, then addr will be 8 bigger and remain 8 smaller than what has arrived at the host).

Unclear Notes

"If sound map data is to be transferred before the data is transferred (immediately after the host has set the BFRD and BFWR bits (bits 7 and 6) of the HCHPCTL register high)":

```
900h is loaded into HXFRC
and 600Ch, 6A0Ch, or 740Ch is loaded into HADRC
(at least, supposedly, above addresses , for cases when using 32K SRAM)
```

"At any other time":

```
HADR and HXFR are loaded into HADRC and HXFRC
```

Unknown what the above crap is trying to say exactly.

"At any other time" does apparently refer to cases when transfers get started (whilst during transfer, the address/remain values are obviously increasing/decreasing).
For sound map, theoretically, the SMEN bit should be set, but above does somewhat suggest that BFRD or BFWR (or actually: both BFRD and BFWR) need to be set...?

Sector Buffer Memory Map (32Kx8 SRAM)

```
0000h 1st Sector (at 0000h..0923h) (unused gap at 0924h..0BFFh)
0C00h 2nd Sector (at 0C00h..1523h) (unused gap at 1524h..17FFh)
1800h 3rd Sector (at 1800h..2123h) (unused gap at 2124h..23FFh)
2400h 4th Sector (at 2400h..2D23h) (unused gap at 2D24h..2FFFh)
3000h 5th Sector (at 3000h..3923h) (unused gap at 3924h..3BFFh)
3C00h 6th Sector (at 3C00h..4523h) (unused gap at 4524h..47FFh)
4800h 7th Sector (at 4800h..5123h) (unused gap at 5124h..53FFh)
5400h 8th Sector (at 5400h..5D23h) (unused gap at 5D24h..5FFFh)
6000h Soundmap ADPCM Buffer (at 600Ch..690Bh) (gaps at 6000h and 690Ch)
6A00h Soundmap ADPCM Buffer (at 6A0Ch..730Bh) (gaps at 6A00h and 730Ch)
7400h Soundmap ADPCM Buffer (at 740Ch..7D0Bh) (gaps at 7400h and 7D0Ch)
7E00h Unknown/Unused
```

27.11 CDROM Internal CXD1815Q Sub-CPU Misc Registers

16h - HIFCTL - Host Interface Control (W)

0-2	HINT	Request Host Interrupt (INT1..INT7, or 0=None/No change)
3-7	"L"	Reserved (should be 0)

11h - HIFSTS - Host Interface Status (R)

0-2	HINTSTS	Pending Host Interrupt (INT1..INT7, or 0=None/All acknowledged)
3	DMABUSY	DMA Busy (0=Data FIFO Empty and HXFRC=0, 1=Data Transfer Busy)
4	PRMRRDY	Parameter Read Ready (0=Parameter FIFO Empty, 1=Ready/Not Empty)
5	RSLEMPY	Result Empty (0=Response FIFO Not Empty, 1=Empty)
6	RSLWRDY	Result Write Ready (0=Response FIFO Full, 1=Ready/Not Full)
7	BUSYSTS	Command Busy Status (0=Command Not Empty, 1=Ack'ed by CLRBUSY)

0Ah - CLRCTL - Clear Control (W)

0	RESYNCC	Sync with CD DSP (0=No change, 1=Resync, eg. after speed change)
1-3	"L"	Reserved (should be 0)
4	RTADPCLR	Abort Real-time ADPCM (0=No Change, 1=Abort; when ADPMNT.7=0)
5	CLRRSLT	Clear Reply FIFO (0=No change, 1=Acknowledge; clear FIFO)
6	CLRBUSY	Acknowledge Command (0=No change, 1=Acknowledge; clear BUSYSTS)
7	CHPRST	Chip Reset (0=No change, 1=Do Chip Initialization)

07h - INTSTS - Interrupt Status (R) - (0=No, 1=IRQ)

09h - INTMSK - Interrupt Mask (W) - (0=Disable, 1=Enable)

0Bh - CLRINT - Clear Interrupt Status (W) - (0=No change, 1=Clear/Ack)

0	HCRISD	Host Chip Reset Issued	
1	HSTCMND	Host Command	...
2	DECINT	Decoder Interrupt	..
3	HDMACMP	Host DMA Complete	. <-- PSX: used for retry ?!?!?
4	RTADPEND	Real-time ADPCM end	
5	RSLTEMPT	Result Empty	
6	DECTOUT	Decoder Time Out	
7	DRVOVRN	Drive Overrun	

12h - HSTPRM - Host Parameter (R)

0-7	Param FIFO	(check HIFSTS.4 to see if the FIFO is empty)
-----	------------	--

HIFSTS.4 goes off when all bytes read.

Said to have 8-byte FIFO in CXD1199AQ datasheet.

But, PSX has 16-byte Parameter FIFO...!?

13h - HSTCMD - Host Command (R)

```
0-7  Command (check INTSTS.1 or HIFSTS.7 to see if a command was sent)
```

Command should be ack'ed via CLRINT.1 and CLRCTL.6.

17h - RESULT - Response FIFO (W)

```
0-7  Data (has 8-byte FIFO)
```

Said to have 8-byte FIFO in CXD1199AQ datasheet.

But, PSX has 16-byte Response FIFO...!?

08h - ADPCI - ADPCM Coding Information (R)

0	S/M	ADPCM Stereo/Mono	(0=Mono, 1=Stereo)
1	-	Reserved (undefined)	
2	FS	ADPCM Sampling Frequency	(0=37.8kHz, 1=18.9kHz)
3	-	Reserved (undefined)	
4	BITLNGTH	ADPCM Sample Bit Length	(0=Normal/4bit, 1=8bit)
5	ADPBUSY	ADPCM Decoding	(0=No, 1=Yes/Busy)
6	EMPHASIS	ADPCM Emphasis	(0=Normal/Off, 1=On)
7	MUTE	DA Data is Muted (uh?)	(0=No, 1=Yes/Muted)

Unknown if ADPCI is affected by configurations by Main-CPU's Sound Map ADPCM or by Sub-CPU's Real-time ADPCM (or by both)?

Note: Bit5,7 are semi-undocumented in the datasheet (mentioned in the ADPCI description, but missing in overall register summary).

1Bh - RTCI - Real-time ADPCM Coding Information (W)

0	S/M	ADPCM Stereo/Mono	(0=Mono, 1=Stereo)
1	"L"	Reserved (should be 0)	
2	FS	ADPCM Sampling Frequency	(0=37.8kHz, 1=18.9kHz)
3	"L"	Reserved (should be 0)	
4	BITLNGTH	ADPCM Sample Bit Length	(0=Normal/4bit, 1=8bit)
5	"L"	Reserved (should be 0)	
6	EMPHASIS	ADPCM Emphasis	(0=Normal/Off, 1=On)
7	"L"	Reserved (should be 0)	

06h,09h,10h,14h..1Fh - Reserved (R)

```
0-7 Reserved (undefined)
```

Of these, 09h and 10h are officially unused/reserved. And addresses 06h and 14h..1Fh aren't officially mentioned to exist at all.

Trying to read these registers on a PSone returns Data=C0h for 06h, 09h, 10h, 15h-16h, 18h-1Fh, and Data=FFh for 14h, and Data=DEh for 17h.

08h,13h-15h,18h,1Ah,1Ch-1Fh - Reserved (W)

```
0-7 Reserved (should be 00h) (or don't write at all)
```

Of these, 09h,13h-15h,18h,1Ah are officially unused/reserved. And addresses 1Ch-1Fh aren't officially mentioned to exist at all.

27.12 CDROM Internal Commands CX(0x..3x) - CXA1782BR Servo Amplifier

CXA1782BR - CX(0x) - Focus Servo Control - "FZC" FocusZeroCross at SENS pin

```
23-20 4bit Command (00h)
19    1bit FS4 Focus Servo (0=Off, 1=On)
18    1bit FS3 DEFECT
17    1bit FS2 Enable Focus Search Voltage (0=Off, 1=On)
16    1bit FS1 Select Focus Search Voltage (0=Falling, 1=Rising)
15-0  16bit Unused (don't care)
```

For Focus Search: Keep FS1=on, and toggle FS2 on and off (this will generate a waveform, and SENS will indicate when reaching a good focus voltage).

CXA1782BR - CX(1x) - Tracking/Brake/Sled - "DEFECT" at SENS pin

```
23-20 4bit Command (01h)
19    1bit TG1,TG2 ON/OFF Tracking Servo Gain Up/Normal (hmmm?)
18    1bit Brake Circuit ON/OFF
17-16 2bit PS Sled Kick Height (0=+/-1, 1=+/-2, 2=Undoc, 3="Don't use"?) 
15-0  16bit Unused (don't care)
```

Note: The PSX CDROM BIOS does use the "Undoc" setting (ie. bit17=1), but the effect is undoc/unknown?

Note: CX(1x) works different on CXD2545Q (some bits are moved around, and the "SledKickHeight" bits are renamed to "SledKickLevel" and moved to different/new CX(3X) commands.

CXA1782BR - CX(2x) - Tracking and Sled Servo Control - "TZC" at SENS pin

```

23-20 4bit Command (02h)
19-18 2bit Tracking Control (0=Off, 1=Servo On, 2=F-Jump, 3=R-Jump) ;TM1,3,4
17-16 2bit Sled Control (0=Off, 1=Servo On, 2=F-Fast, 3=R-Fast) ;TM2,5,6
15-0 16bit Unused (don't care)

```

CXA1782BR - CX(3x) - "Automatic Adjustment Comparator Output" at SENS pin

```

23-20 4bit Command (03h)
19 1bit Value to be adjusted (0=Balance, 1=Gain)
18-16 3bit New Balance or Gain value (depending on above bit)
15-0 16bit Unused (don't care)

```

Note: CX(3x) is extended and works very different on CXD2545Q.

CXA1782BR Command 4x..7x - "HIGH-Z" at SENS pin

```
N-N 4bit Command (04h..07h)
```

CXA1782BR Command 8x..Fx - "UNSPECIFIED???" at SENS pin

```
N-N 4bit Command (08h..0Fh)
```

Note

The Servo Amplifier isn't directly connected to the CPU. Instead, it's connected as a slave device to the Signal Processor. There are two ways to access the Servo Amplifier:

- 1) The CPU can send CX(0X..3X) commands to the Signal Processor (which will then forward them to the Servo Amplifier).
- 2) The Signal Processor can send CX(0X..3X) commands to the Servo Amplifier (this happens during CX(4xxx) Auto Sequence command).

27.13 CDROM Internal Commands CX(4x..Ex) - CXD2510Q Signal Processor

CXD2510Q - CX(4xxx) - Auto Sequence

```

23-20 4bit Command (4)
19-16 4bit AS3-0 Auto Sequence Command (see below)
15-12 4bit MT3-0 Max Timer Value (N timer units, or 0=Invalidate Timer)
11    1bit LSSL Timer Units      (0=2.9ms, 1=186ms) (for above MT value)
10-8   3bit Unused (zero)
7-0    8bit Unused (don't care)

```

Values for AS (Auto Sequence Command):

```

00h      Cancel
04h/05h Forward/Reverse Fine Search ;<--sends CX(25h) ;\these do internally
07h      Focus-On           ;<--sends CX(02h) ; send commands to
08h/09h Forward/Reverse 1 Track Jump ;\           ; CXA1782BR
0Ah/0Bh Forward/Reverse 10 Track Jump ;  sends CX(25h) ; and, auto sequence
0Ch/0Dh Forward/Reverse 2N Track Jump ;/           ;/is interrupted?
0Eh/0Fh Forward/Reverse 1N Track Move ;<--CXD2545Q only(Reserved on CXD2510Q)
01h..03h,06h = Reserved

```

CXD2510Q - CX(5x) - Blind,Brake,Overflow Timer

```

23-20 4bit Command (5)
19-16 4bit TR3-0 Timer (N*0.022ms for Blind/Overflow, N*0.045ms for Brake)
15-8   8bit Unused (don't care on CXD2510Q, zero on CXD2545Q)
7-0    8bit Unused (don't care)

```

CXD2510Q - CX(6xx) - SledKick,Brake,Kick Timer

```

23-20 4bit Command (6)
19-16 4bit SD3-0 Timer KICK.D (N*2.9ms for Fine Search? else N*1.45ms?)
15-12 4bit KF3-0 Timer KICK.F (N*0.09ms)
11-8   4bit Unused (don't care on CXD2510Q, zero on CXD2545Q)
7-0    8bit Unused (don't care)

```

CXD2510Q - CX(7xxxx) - Track jump count setting (for Auto Sequence Command)

```

23-20 4bit Command (7)
19-4   16bit Track Jump Count Setting (0..65535) for Command 4x
3-0    4bit Unused (don't care)

```

CXD2510Q - CX(8xx) - MODE Specification

```

23-20 4bit Command (8)
19   1bit CDROM      (0=Audio, 1=CDROM; no average and pre-value stuff)
18   1bit DOUT Mute   (0=Not muted, 1=Mute DOUT)
17   1bit D.out Mute-F (0=Not muted, 1=Mute DA)
16   1bit WSEL        (0=Enhanced Sync Window, 1=Enhanced Anti-Rolling)
15   1bit VCO SEL     (0=Double Correction, 1=Quadruple Correction)
14   1bit ASHS        (0=Double Correction, 1=Quadruple Correction)
13   1bit SOCT        (0=Output SubQ to SQSO, 1=Output Each? to SQSO)
12   1bit Unused (zero)
11-8  4bit Unused (don't care on CXD2510Q, zero on CXD2545Q)
7-0   8bit Unused (don't care)

```

CXD2510Q - CX(9xx) - Function Specification

```

23-20 4bit Command (9)
19   1bit DCLV ON-OFF (complex stuff, related to gain and frequencies)
18   1bit DSPB ON-OFF (0=Normal Speed, 1=Double Speed; fixed pitch)
17   1bit ASEQ ON-OFF (select output on SENS pin)
16   1bit DPLL ON-OFF (0=Analog RFPLL, 1=Digital RFPLL)
15-14 1bit Bilingual Audio (0=Stereo, 1=RightOnly, 2=LeftOnly, 3=Mute)
13   1bit FLFC (normally 0)
12   1bit Unused (zero)
11-8  4bit Unused (don't care on CXD2510Q, zero on CXD2545Q)
7-0   8bit Unused (don't care)

```

CXD2510Q - CX(Axx) - Audio Control

```

23-20 4bit Command (0Ah)
19   1bit Vari Up    (write 1-then-0 to increase pitch by +0.1%)
18   1bit Vari Down   (write 1-then-0 to decrease pitch by -0.1%)
17   1bit Mute (0=Not muted; unless muted elsewhere, 1=Mute & Peak=0)
16   1bit ATT     (0=Attenuation off, 1=Minus 12 dB)
15-14 2bit PCT     (0=Normal, 1=LevelMeter, 2=PeakMeter, 3=Normal) (0-1=QuadC2)
13-12 2bit Unused (zero)
11-8  4bit Unused (don't care on CXD2510Q, zero on CXD2545Q)
7-0   8bit Unused (don't care)

```

Normal: SQSO outputs... WHAT?

PeakMeter: SQSO outputs highest peak ever on any channel (bit15: usually 0)

LevelMeter: SQSO outputs recent peak (with bit15 toggled: 0=Right, 1=Left)

CXD2510Q - CX(Bxxxx) - Traverse Monitor Counter Setting

```

23-20 4bit Command (0Bh)
19-4 16bit Traverse Monitor Count (used when monitored by COMP and COUT) (?)
3-0 4bit Unused (don't care)

```

CXD2510Q - CX(Cxx) - Spindle Servo Coefficient Setting

```

23-20 4bit Command (0Ch)
19-18 2bit Gain MDP for CLVP mode (0=-6dB, 1=0dB, 1=+6dB, 3=Reserved)
17-16 2bit Gain MDS for CLVS/CLVP (0=-12dB, 1=-6dB, 2=0dB, 3=Reserved)
15 1bit Zero (zero)
14 1bit Gain DCLV0 overall gain (0=0dB, 1=+6dB)
13-12 2bit Unused (zero)
11-8 4bit Unused (don't care on CXD2510Q, zero on CXD2545Q)
7-0 8bit Unused (don't care)

```

CXD2510Q - CX(Dx) - CLV Control

```

23-20 4bit Command (0Dh)
19 1bit DCLV PWM MD Digital CLV PWM mode (0=Use MDS+MDP, 1=Ternary MDP)
18 1bit TB Bottom Hold in CLVS/CLVH modes (0=At cycle RFCK/32, 1=RFCK/16)
17 1bit TP Peak Hold in CLVS mode (0=At cycle RFCK/4, 1=RFCK/2)
16 1bit Gain CLVS for CLVS mode (0=0dB, 1=+6dB) (always +6dB in CLVP mode)
15-8 8bit Unused (don't care on CXD2510Q, zero on CXD2545Q)
7-0 8bit Unused (don't care)

```

CXD2510Q - CX(Ex) - CLV Mode

```

23-20 4bit Command (0Eh)
19-16 4bit CM3-0
15-8 8bit Unused (don't care on CXD2510Q, zero on CXD2545Q)
7-0 8bit Unused (don't care)

```

Values for CM (CLV Mode):

00h	Stop	Spindle Motor Stop mode
06h	CLVA	Automatic CLVS/CLVP switching mode, normally used for playback
08h	Kick	Spindle Motor Forward rotation mode
0Ah	Brake	Spindle Motor Reverse rotation mode
0Ch	CLVH	Peak hold at 34kHz
0Eh	CLVS	Rough Servo Mode, RF-PLL related
0Fh	CLVP	PLL Servo mode

N/A - CX(F) - Reserved

23-0	N/A	Don't use
------	-----	-----------

SUBQ Output

80bit subq
15bit peak level (lsb first) (absolute/unsigned value)
1bit peak l/r flag (aka appears as "MSB" of peak level)

L/R is toggled after each SUBQ reading, however the PSX Report mode does usually forward SUBQ only every 10 frames, so it stays stuck in one setting (but may toggle after one second; ie. every 75 frames). And, peak is reset after each read, so 9 of the 10 frames are lost.

CXD2510Q - SENS output

Index	ASEQ=0	ASEQ=1	;	<-- ASEQ can be set via CX(9xx)
0X	HighZ	SEIN (FZC)		; \aka SENS output
1X	HighZ	SEIN (A.S)	...	aka DEFECT ; from CXA1782BR
2X	HighZ	SEIN (T.Z.C)	...	aka TZC ; forwarded through
3X	HighZ	SEIN (SSTOP)	...	aka Gain/Bal ;/CXD2510Q
4X	HighZ	XBUSY		
5X	HighZ	FOK		
6X	HighZ	SEIN (HighZ)		
AX	GFS	GFS		
BX	COMP	COMP		
CX	COUT	COUT		
EX	/OV64	/OV64		
7X-9X, DX, FX	HighZ	0		

Whereas,

FZC	Focus Zero Cross
DEFECT	Defect?
TZC	Tracking Zero Cross
SSTOP	Gain or Balance adjust reached wanted level
XBUSY	Low while the auto sequencer operation is busy
FOK	High for "focus OK" (same as FOK pin)
GFS	High when the played back frame sync is obtained with correct timing
COMP	Measures the number of tracks set with Reg B. High when Reg B is latched, low when the initial Reg B number is input by CNIN
COUT	Measures the number of tracks set with Reg B. High when Reg B is latched, toggles each time the Reg B number is input by CNIN. While \$44 and \$45 are being executed, toggles with each CNIN 8-count instead of the Reg B number

OV64	Low when filtered EFM signal is lengthened by 64 channel clock pulses or more
------	---

27.14 CDROM Internal Commands CX(0x..Ex) - CXD2545Q Servo/Signal Combo

CXD2545Q - CX(0x) and CX(2x) - same as CXA1782BR Servo Amplifier

[CDROM Internal Commands CX\(0x..3x\) - CXA1782BR Servo Amplifier](#)

CXD2545Q - CX(4x..Ex) - same as CXD2510Q Signal Processor

[CDROM Internal Commands CX\(4x..Ex\) - CXD2510Q Signal Processor](#)

One small difference is that the CXD2545Q supports a new "M Track Move" function as part of the CX(4xxx) command. And, some "don't care" bits are now reserved (ie. some commands need to be padded with additional leading "0" bits).

CXD2545Q - CX(1x) - Anti Shock/Brake/Tracking Gain/Filter

23-20	4bit	Command (01h)
19	1bit	Anti Shock (0=Off, 1=On)
18	1bit	Brake (0=Off, 1=On)
17	1bit	Tracking Gain (0=Normal, 1=Up)
16	1bit	Tracking Gain Filter (0=Select 1, 1=Select 2)
15-0	16bit	Unused (don't care)

CXD2545Q - CX(30..33) - Sled Kick Level

23-20	4bit	Command (03h)
19-18	2bit	Subcommand (0)
17-16	2bit	Sled Kick Level (0=+/-1, 1=+/-2, 2=+/-3, 3=+/-4)
15-0	16bit	Unused (don't care)

CXD2545Q - CX(34xxxx) - Write to Coefficient RAM

23-16	8bit	Command (34h)
15	1bit	Zero (0)
14-8	7bit	Address (00h..4Fh = Select Coefficient K00..K4F)
7-0	8bit	Data (00h..FFh = New value)
PLUS	8bit	Eight more bits on PSone (!)

Allows to change the default preset coefficient values,
CDROM Internal Coefficients (for CXD2545Q)

CXD2545Q - CX(34Fxxx) - Write to Special Register

```
23-12 12bit Command (34Fh)
11-10 2bit Index (0=TRVSC, 1=FBIAS, 2=? , 3=?)
9-0   10bit Data (for FBIAS: bit0=don't care)
```

CXD2545Q - CX(35xxxx) - FOCUS SEARCH SPEED/VOLTAGE/AUTO GAIN

```
23-16 8bit Command (35h)
15-14 2bit FT Focus Search-up speed 1
13-8 6bit FS Focus Search limit voltage (default 011000b) (+/-1.875V)
7     1bit FTZ Focus Search-up speed 2
6-0   7bit FG AGF Convergence Gain Setting (default 0101101b)
```

CXD2545Q - CX(36xxxx) - DTZC/TRACK JUMP VOLTAGE/AUTO GAIN

```
23-16 8bit Command (36h)
15     1bit Zero (0)
14     1bit DTZC DTZC Delay (0=4.25us/Default, 1=8.5us)
13-8 6bit TJ Track Jump voltage (default 001110b) (+/-1.09V)
7     1bit Zero (0)
6-0   7bit TG AGT Convergence Gain Setting (default 0101110b)
```

CXD2545Q - CX(37xxxx) - FZSL/SLED MOVE/Voltage/AUTO GAIN

```
23-16 8bit Command (37h)
15-14 2bit FZS XXX pg. 84
13-8 6bit SM Sled Move Voltage
7     1bit AGS
6     1bit AGJ
5     1bit AGGF
4     1bit AGGT
3     1bit AGV1
2     1bit AGV2
1     1bit AGHS
0     1bit AGHT
```

CXD2545Q - CX(38xxxx) - Level/Auto Gain/DFSW (Initialize)

```
23-16 8bit Command (38h)
15     1bit VCLM VC level measurement on/off
14     1bit VCLC VC level compensation for FCS_In Register on/off
```

```

13  1bit  FLM  Focus zero level measurement on/off
12  1bit  FLC0 Focus zero level compensation for FZC Register on/off
11  1bit  RFLM RF zero level measurement on/off
10  1bit  RFLC RF zero level compensation on/off
9   1bit  AGF  Focus automatic gain adjustment on/off
8   1bit  AGT  Tracking automatic gain adjustment on/off
7   1bit  DFSW Defect switch disable (1=disable defect measurement)
6   1bit  LKSW Lock switch (1=disable sled free-running prevention)
5   1bit  TBLS Traverse center measurement on/off
4   1bit  TCLM Tracking zero level measurement on/off
3   1bit  FLC1 Focus zero level compensation for FCS_In Register on/off
2   1bit  TLC2 Traverse center compensation on/off
1   1bit  TLC1 Tracking zero level compensation on/off
0   1bit  TLC0 VC level compensation for TRK/SLD_In register on/off

```

VCLM,FLM,RFLM,TCLM are accepted every 2.9ms.

CXD2545Q - CX(39xx) - Select internal RAM/Registers for serial readout

```

23-16 8bit  Command (39h)
15    1bit  DAC Serial data readout DAC mode on/off
14-8   7bit  SD  Serial readout data select (see below)
7-0    8bit  Unused (don't care)

```

Serial Readout Addresses:

Addr	Data	Content
00h	8bit	VC input signal
01h	8bit	SE input signal
02h	8bit	TE input signal
03h	8bit	FE input signal
04h-07h	9bit	TE AVRG register (mirrored to 04h-07h)
08h-0Bh	9bit	FE AVRG register (mirrored to 08h-0Bh)
0Ch-0Fh	9bit	VC AVRG register (mirrored to 0Ch-0Fh)
12h	8bit	RFDC envelope (peak)
13h	8bit	RFDC envelope (bottom)
1Ch	9bit	TRVSC register
1Dh	9bit	FBIAS register
1Eh	8bit	RFDC input signal
1Fh	8bit	RF AVRG register
20h-3Fh	16bit	Data RAM (M00-M1F)
40h-7Fh	8bit	Coefficient RAM (K00-K3F) (note: K40-K4F cannot be read out)

CXD2545Q - CX(3Ax000) - Focus BIAS addition enable

```

23-16 8bit  Command (3Ah)
15    1bit  Zero (0)
14    1bit  FBON: FBIAS register addition (0=off, 1=Add FBIAS to FCS)
13-0  14bit Zero (0)

```

CXD2545Q - CX(3Bxxxx) - Operation for MIRR/DFCT/FOK

```

23-16 8bit Command (3Bh)
15-14 2bit SFO FOK Slice Level (...depends on SFOX)
13-12 2bit SDF DFCT Slice Level (0=89mV, 1=134mV, 2=179mV, 3=224mV)
11-10 2bit MAX DFCT Maximum Time (0=No Limit, 1=2ms, 2=2.36ms, 3=2.72ms)
9     1bit SFOX FOK Slice Level (...depends on SFO)
8     1bit BTF Bottom Hold Double-Speed Count-Up mode for MIRR (0=off)
7-6   2bit D2V Peak Hold 2 for DFCT (0=22.05kHz, 1=44.1, 2=88.2, 3=176.4)
5-4   2bit D1V Peak Hold 1 for DFCT (0=176.4kHz, 1=352.8, 2=705.6, 3=1411)
3-0   4bit Zero (0)

```

CXD2545Q - CX(3Cxxxx) - TZC for COUT SLCT HPTZC (Default)

```

23-16 8bit Command (3Ch)
15-0  16bit Unused (don't care)

```

CXD2545Q - CX(3Dxxxx) - TZC for COUT SLCT DTZC

```

23-16 8bit Command (3Dh)
15-0  16bit Unused (don't care)

```

CXD2545Q - CX(3Exxxx) - Filter

```

23-16 8bit Command (3Eh)
15-14 2bit F1NDM FCS servo filter 1st stage (1=normal, 2=down)
13-12 2bit F3NUM FCS servo filter 3rd stage (1=normal, 2=up)
11-10 2bit T1NDM TRK servo filter 1st stage (1=normal, 2=down)
9-8   2bit T3NUM TRK servo filter 3rd stage (1=normal, 2=up)
7     1bit DFIS FCS hold filter input extraction node (0=M05, 1=M04)
6     1bit TLCD Mask TLC2 set by D2 of CX(38) only when FOK low
5     1bit RFLP Pass signal from RFDC pin through low-pass-filter
4-0   5bit Zero (0)

```

CXD2545Q - CX(3Fxxxx) - Others

```

23-16 8bit Command (3Fh)          ... XXX pg. 89
15-14 2bit Unused (0)
13-12 2bit XTD
11    1bit Unused (0)
10-8  3bit DRR
7     1bit Unused (0)
6     1bit ASFG
5     1bit Unused (0)
4     1bit LPAS

```

3-2	2bit	SRO
1-0	2bit	Unused (0)

CXD2545Q feedback on 39xx: see pg. 77 (eg. 390C = VC AVRG)

XXX

CXD2545Q - SENS output

Index	ASEQ=0	ASEQ=1	Length
\$0X	Z	FZC	-
\$1X	Z	AS	-
\$2X	Z	TZC	-
\$38	Z	AGOK*1	-
\$38	Z	XAVEBSY*1	-
\$30-37, \$3A-3F	Z	SSTP	-
\$3904	Z	TE Avrg Reg.	9 bit
\$3908	Z	FE Avrg Reg.	9 bit
\$390C	Z	VC Avrg Reg.	9 bit
\$391C	Z	TRVSC Reg.	9 bit
\$391D	Z	FB Reg.	9 bit
\$391F	Z	RFDC Avrg Reg.	8 bit
\$4X	Z	XBUSY	-
\$5X	Z	FOK	-
\$6X	Z	0	-
\$AX	GFS	GFS	-
\$BX	COMP	COMP	-
\$CX	COUT	COUT	-
\$EX	OV64	OV64	-
\$7X-9X, DX, FX	Z	0	-

*1 \$38 outputs AGOK during AGT and AGF command settings, and XAVEBSY during AVRG measurement.

SSTP is output in all other cases.

27.15 CDROM Internal Commands CX(0x..Ex) - CXD2938Q Servo/Signal/SPU Combo

Most commands are same as on CXD2545Q. New/changed commands are:

CXD2938Q - CX(349xxxxx) - New SCEx

Older PSX consoles have received the "SCEx" string at 250 baud via HC05 PortB.bit1, which allowed modchips to inject faked "SCEx" signals to that pin. To prevent that, the

CXD2938Q contains some new 32bit commands that allow to receive somewhat encrypted "SCEx" strings via SPI bus. The used commands are:

```
CX(34910000) NewScexStopReading
CX(3491xy80) NewScexRandomKey(xy)
CX(34920000) NewScexFlushResyncOrSo
CX(34944A00) NewScexInitValue1
CX(3498C000) NewScexInitValue2
CX(349C1000) NewScexThis ;\inverse ;\use CX(3C2080) for COUT selection
CX(349D1000) NewScexThat ;/of COUT ;/
```

The relevant command is NewScexRandomKey(xy) which does send a random value ($x=01h..0Fh$, and $y=01h$), and does then receive a 12-byte response via SPI bus (which is normally used to receive SUB-Q data).

```
1st byte: Unknown/unused (normally ADR/Control) ;\these should be probably
2nd byte: Unknown/unused (normally Track) ; set to some invalid values
3rd byte: Unknown/unused (normally Index/Point) ;/to avoid SUB-Q confusion
4th..10th byte: SCEx data or Dummy bytes (depending on xy.bit7..1)
11th..12th byte: Unknown/unused (normally Audio Peak level)
```

The 12-byte packet does contain one SCEx character encoded in 4th..10th byte corresponding to Flags in "xy" bit 7..1 (in that order):

All bytes with Flag=1 are ORed together to compute a Character byte (those bytes could be all set to 53h for "S", or if more than one flag is set, it could be theoretically split to something like 41h and 12h).

All bytes with Flag=0 are ORed together to compute a Dummy byte. If the Character byte is same as the Dummy byte, then it gets destroyed by setting Character=00h (to avoid that, one could set all dummies to 00h, or set one or more dummies to FFh, for example).

Finally, "xy" bit0=0 indicates that the resulting character byte is inverted (XORed by FFh), however, the CDROM BIOS does always use bit0=1, so the inversion feature is never used.

For the whole SCEx string, there must be at least one 00h byte inserted between each character (or some Char=Dummy mismatch, which results in Char=00h either), and there should be a few more 00h bytes preceding the first character ("S").

Note: Modchips didn't bother to reproduce that new SCEx transfers, instead they have simply bypassed it by injecting the 250 baud SCEx string to some analog lower level signal.

CXD2938Q - CX(3Bxxxx) - Some Changed Bits

Same as in older version, but initialized slightly differently: CXD2545Q used CX(3B2250) whilst CXD2938Q is using CX(3B7250).

CXD2938Q - CX(3Cxxxx) - TzcCoutSelect with New/Changed Extra Bits

The CXD2545Q used two 8bit commands, CX(3C) and CX(3D), for TzcOut selection, which are now replaced by a single 24bit command, CX(3Cxxxx), and which do include a new mode related to New SCEx.

CXD2545Q	CXD2938Q
CX (3C)	CX (3C0080) TzcCoutSelectHPTZC; \ <--formerly CX (3C)
-	CX (3C2080) TzcCoutSelectSCEx ; <--special NewScex mode
CX (3D)	CX (3C4080) TzcCoutSelectDTZC ; / <--formerly CX (3D)

CXD2938Q - CX(8xxxx) - Disc Mode with New/Changed Extra Bits

Command CX(8xx) has been 12bit wide on CXD2545Q, and is now expanded 24bit width (with some changed/unknown bits).

CXD2545Q	CXD2938Q
CX (8180)	CX (810408) MODE = Audio (CD-DA)
CX (8120)	CX (812400) MODE = Audio (CD-DA) (manual SPI bus access)
CX (8980)	CX (890408) MODE = CDROM (Data)
-	CX (898000) MODE = CDROM (Data) (used on RESET)

CXD2938Q - CX(9xx000) - Normal/Double Speed with New Extra Bits

Command CX(9xx) has been 12bit wide on CXD2545Q (with bit12=reserved/zero), and is now expanded 24bit width (with bit12=unknown/one and bit11-0=unknown/zero).

CXD2938Q - CX(Dx0000) and CX(Ex0000) - New Zero Padding

Commands CX(Dx) and CX(Ex) have been 8bit wide on CXD2545Q, and are now zeropadded to 24bit width, ie. CX(Dx0000) and CX(Ex0000). Unknown if the extra bits are hiding any extra features. In practice, the CDROM BIOS is always setting them zero (except in some test commands which are accidentally still using the old 8bit form, resulting in garbage in lower 16bits).

27.16 CDROM Internal Commands CX(xx) - Notes

Serial Command Transmission (for Signal Processor and Servo Amplifier)

Commands are sent serially LSB first via DATA,CLOK,XLAT pins: DATA+CLOK are used to send commands to the chip, command execution is then applied by dragging XLAT low for a moment.

Commands can be up to 24bits in length, but unused LSBs (the "don't care" bits) can be omitted; the PSX BIOS clips the length to 8bit/16bit where possible (due to the LSB-first transfer order, the chip does treat the most recently transferred bit as MSB=bit23, and there's no need to transfer the LSBs if they aren't used).

Aside from being used as command number, the four most recently transferred bits are also used to select SENS status feedback (for the SENS selection it doesn't matter if the four bits were terminated by XLAT or not).

Sled Motor / Track Jumps / Tracking

The Sled motor moves the drive head to the current read position. On a Compact Disc, the term "Track" does normally refer to Audio tracks (songs). But the drive hardware uses the terms "Track" and "Tracking" for different purposes:

Tracking appears to refer to moving the Optics via magnets (ie. moving only the laser/lens, without actually moving the whole sled) (this is done for fine adjustments, and it seems to happen more or less automatically; emulators can just return increasing sectors without needing to handle special tracking commands).

Track jumps refer to moving the entire Sled, one "track" is equal to one spiral winding (1.6 micrometers). One winding contains between 9 sectors on innermost windings, and 22.5 sectors on outermost windings (the PSX cdrom bios is translating the sector-distance to non-linear track-distance, and emulators must undo that translation; otherwise the sled doesn't arrive at the intended location; the cdrom bios will retry seeking a couple of times and eventually settle down at the desired location - but it will timeout if the sled emulation is too inaccurate).

The PSX hardware uses two mechanisms for moving the Sled:

Command CX(4xxx) Forward/Reverse Track Jump: allows to move the sled by 1..131070 tracks (ie. max 210 millimeters), and the hardware does stop automatically after reaching the desired distance.

Command CX(2x) Forward/Reverse Fast Sled: moves the sled continuously until it gets stopped by another command (in this mode, software can watch the COUT signal, which gets toggled each "N" tracks; whereas "N" can be selected via Command CX(Bxxxx),

which is configured to N=100h in PSX).

The PSX cdrom bios is issuing another Fast Sled command (in opposite direction) after Fast Sled commands, emulators must somehow interprete this as "sled slowdown" (rather than as actually moving the sled in opposite direction, which could move the sled miles away from the target). For some reason vC1 BIOS is using a relative short slowdown period, whilst vC2/vC3 are using much longer slowdown periods (probably related to different SledKickHeight aka SledKickLevel settings and/or to different Sled Move Voltage settings).

Focus / Gain / Balance

The hardware includes commands for adjusting & measuring focus/gain/balance. Emulators can just omit that stuff, and can always signalize good operation (except that one should emulate failures for Disc Missing; and eventually also for cases like Laser=Off, or Spindle=Stopped). Focus does obviously refer to moving the lens up/down. Gain does probably refer to reflection level/laser intensity. Balance might refer to tracking adjustments or so.

27.17 CDROM Internal Commands CX(xx) - Summary of Used CX(xx) Commands

The PSX CDROM BIOS versions vC1, vC2, and vC3 are using following CX() commands:

```

<B>  <--vC1-->  <--vC2-->  <--vC3--></B>
<B>  CXD2510Q  CXD2545Q  CXD2938Q</B>
    CX(00)    CX(00)    CX(00)    AllFocusSwitchesOff
    CX(02)    CX(02)    CX(02)    FocusSearchVoltageFalling
    CX(03)    CX(03)    CX(03)    FocusSearchVoltageRising ;ForTestOnly
    CX(08)    CX(08)    CX(08)    FocusServoOn
    CX(0C)    CX(0C)    CX(0C)    FocusServoOnAndDefectOn ;diff.usage vC# ?
    -----
    CX(11)    -         -         SledKickHeight2
    CX(12)    -         -         SledKickHeightInvalid
    CX(19)    -         -         TrackingGainAndSledKickHeight2
    CX(1D)    -         -         TrackingGainBrakeAndSledKickHeight2
    CX(1E)    -         -         TrackingGainBrakeAndSledKickHeightInvalid
    -----
    -         CX(11)    CX(11)    AntiShockOff          ; \
    -         CX(13)    CX(13)    AntiShockOffGainUp   ;
    -         CX(17)    CX(17)    AntiShockOffGainUpBrake ; /
    -----
    CX(20)    CX(20)    CX(20)    SledAndTrackingOff
    CX(21)    CX(21)    CX(21)    SledServoOn        ;ForTestOnly
    CX(22)    CX(22)    CX(22)    SledFastForward

```

CX (23)	CX (23)	CX (23)	SledFastReverse
CX (24)	-	-	TrackingServoOn
CX (25)	CX (25)	CX (25)	SledAndTrackingServoOn
-	CX (26)	CX (26)	SledFastForwardAndTrackingServoOn
CX (28)	CX (28)	CX (28)	TrackingForwardJump ;ForTestOnly
CX (2C)	CX (2C)	CX (2C)	TrackingReverseJump ;ForTestOnly
<hr/>			
CX (30+n)	-	-	BalanceAdjust (0..7)
CX (38+n)	-	-	GainAdjust (0..7)
<hr/>			
-	CX (30)	CX (30)	SetSledKickLevel1 ;\
-	CX (31)	CX (31)	SetSledKickLevel2 ;
-	CX (32)	CX (32)	SetSledKickLevel3 ;/
<hr/>			
-	CX (3400E6)	CX (3400E6)	SetK00toE6hSledInputGain ;def=E0h
-	CX (340730)	CX (340730)	SetK07to30hSledAutoGain ;blah ;def=30h
-	CX (34114A)	CX (34114A)	SetK11to4AhFocusOutputGain ;def=32h
-	CX (341330)	CX (341330)	SetK13to30hFocusAutoGain ;blah ;def=30h
-	CX (341D6F)	CX (341D6F)	SetK1Dto6FhTrackingLowBoostFilterAL ;def=44h
-	CX (341F64)	CX (341F64)	SetK1Fto64hTrackingLowBoostFilterBL ;def=5Eh
-	CX (342220)	CX (342220)	SetK22to20hTrackingOutputGain ;def=18h
-	CX (342330)	CX (342330)	SetK23to30hTrackingAutoGain ;blah ;def=30h
-	CX (342D28)	CX (342D28)	SetK2Dto28hFocusGainDownOutputGain ;def=1Bh
-	CX (343E70)	CX (343E70)	SetK3Eto70hTrackingGainUpOutputGain ;def=57h
-	CX (34910000)	NewScexStopReading ;\	
-	CX (3491x180)	NewScexRandomKey (x)	;
-	CX (34920000)	NewScexFlushResyncOrSo	; SCEX SPECIAL
-	CX (34944A00)	NewScexInitValue1	; see also:
-	CX (3498C000)	NewScexInitValue2	; CX(3C2080)
-	CX (349C1000)	NewScexThis	; \inverse ;
-	CX (349D1000)	NewScexThat	; /of COUT ;/
-	CX (34F000)	CX (34F000)	SetTRVSCto000h
-	CX (34Fxxx)	CX (34Fxxx)	SetFBIAStoNNNh
<hr/>			
-	CX (3740AA)	CX (3740AA)	SetSMto00h ;\set SM to 0,6,7,9
-	CX (3746AA)	CX (3746AA)	SetSMto06h ; (sled move voltage)
-	CX (3747AA)	CX (3747AA)	SetSMto07h ; (and init several
-	CX (3749AA)	CX (3749AA)	SetSMto09h ;/fixed settings)
<hr/>			
-	CX (380010)	CX (380010)	ModeMeasureTrackingZeroLevel ;\Measure modes
-	CX (380800)	CX (380800)	ModeMeasureRfZeroLevel ; (accepted
-	CX (382000)	CX (382000)	ModeMeasureFocusZeroLevel ; every 2.9ms)
-	CX (388000)	CX (388000)	ModeMeasureVcLevel ;/
-	CX (38140A)	CX (38140A)	ModeCompensate
-	CX (38140E)	CX (38140E)	ModeCompensateAndTraverseCenter
-	CX (38148A)	CX (38148A)	ModeCompensateAndDefectOff
-	CX (38148E)	CX (38148E)	ModeCompensateAndDefectOffTraverseCenter
-	CX (3814AA)	CX (3814AA)	ModeCompensateAndStuffAndMeasureTraverse ;!
-	CX (38150A)	CX (38150A)	ModeCompensateAndTrackingAutoGain
-	CX (38150E)	CX (38150E)	ModeCompensateAndTrackingAutoGain
-	CX (38160A)	CX (38160A)	ModeCompensateAndFocusAutoGain
<hr/>			
-	CX (391E)	-	SenseRFDCinputSignalWithoutDAC ;\rather
-	CX (3983)	-	SenseFEinputSignalWithDAC ;/unused

```

-      CX(399C)   -      SenseTRVSCregisterWithDAC      ;\only if
-      CX(399D)   -      SenseFBIASregisterWithDAC      ;/TEST1=LOW
-----
-      CX(3A0000) CX(3A0000) FocusBiasAdditionOff      ;\
-      CX(3A4000) CX(3A4000) FocusBiasAdditionOn       ;/
-      CX(3B2250)!CX(3B7250)!InitOperationForMirrDfctFok <-- vC2/vC3 DIFF
-      CX(3C)    !!!CX(3C0080) TzcCoutSelectHPTZC;\ <--formerly CX(3C)
-      -        !!!CX(3C2080) TzcCoutSelectSCEX ; <--special NewScex mode
-      CX(3D)    !!!CX(3C4080) TzcCoutSelectDTZC ;/ <--formerly CX(3D)
-      CX(3E0000) CX(3E0000) InitFilterBits      ;\
-      CX(3E0008) CX(3E0008) InitFilterBitsInvalid  ;/
-      CX(3F0008) CX(3F0008) InitOtherStuff      ;-
-----
CX(4000) CX(4000) CX(4000) AutoSeqCancel
CX(4700) CX(4700) CX(4700) AutoSeqFocusOn
CX(4800) CX(4800) CX(4800) Forward1track
CX(4900) CX(4900) CX(4900) Reverse1track
CX(4C00) CX(4C00) CX(4C00) Forward2Ntrack
CX(4D00) CX(4D00) CX(4D00) Reverse2Ntrack
-----
CX(54)   CX(54)   CX(54)   BlindBrakeOverflowTimer=4
CX(5A)   CX(5A)   CX(5A)   BlindBrakeOverflowTimer=A
CX(6100) CX(6100) CX(6100) SledKickBrakeKickTimer
CX(70xxxx0) CX(70xxxx0) CX(70xxxx0) TrackJumpCountSetting
CX(8180) CX(8180) !!!CX(810408) MODE = Audio (CD-DA)
-      CX(8120) !!!CX(812400) MODE = Audio (CD-DA) (manual SPI bus access)
-      -      CX(810000/UNUSED)
-      -      CX(812000/UNUSED)
CX(8980) CX(8980) CX(890408) MODE = CDROM (Data)
-      -      CX(898000) MODE = CDROM (Data) (used on RESET)
CX(9B00) CX(9B00) !!!CX(9B1000) NormalSpeed
CX(9F00) CX(9F00) !!!CX(9F1000) DoubleSpeed
CX(A040) CX(A040) CX(A040) Attentuation Off
CX(A140) CX(A140) CX(A140) Attentuation -12 dB
CX(B01000) CX(B01000) CX(B01000) TraverseMonitorCounterSetting
CX(C600) CX(C600) CX(C600) SpindleServoCoefficientSetting
CX(D7)   CX(D7)   CX(D70000) ClvControl (fixed)
CX(E0)   CX(E0)   CX(E00000) SpindleMotorStop
-      -      CX(E02000) <-- aka bugged CX(E0) with CRAP=2000h
CX(E6)   CX(E6)   CX(E60000) AutomaticNormal
CX(E8)   CX(E8)   CX(E80000) SpindleMotorForward
-      -      CX(E8crap) <-- aka bugged CX(E8) with CRAP=xxxxh
CX(EA)   CX(EA)   CX(EA0000) SpindleMotorReverse
-      -      CX(EAcrap) <-- aka bugged CX(EA) with CRAP=xxxxh
CX(EE)   CX(EE)   CX(EE0000) RoughServo
-----
CX(F)    CX(F)    CX(F)    Unused (N/A)
-----
CX(Xx)   CX(Xx)   CX(Xx)   ;\
CX(Xxxx) CX(Xxxx) CX(Xxxx) ; TestCommand (cmd_19h_50h)
CX(Xxxxxxx) CX(Xxxxxxx) CX(Xxxxxxx) ;
-      -      CX(Xxxxxxxxx) ;/
-      CX(Xxxxxxx) CX(Xxxxxxx) SerialSense, CX(Xxxx) with extra 8bit junk

```

Note: for vC2, some CX(38xxxx) values may differ depending on "set_mid_lsb_to_140Eh".

For vC2, CX(Dx) and CX(Ex) should be officially zero-padded to CX(Dx00) and CX(Ex00), but the vC2 BIOS doesn't do that, it still uses short 8bit form.

For vC2, CX(Dx) and CX(Ex) should be apparently zero-padded to CX(Dx0000) and CX(Ex0000), at least, the vC3 BIOS is doing so (except on some test commands that do still use the CX(Ex) short form).

Used Sense Values

```

sense(30) SEIN.BAL      ;vC2: SSTP
sense(38) SEIN.GAIN     ;vC2: AGOK(AGT/AGF) or XAVEBSY(AVRG) or SSTP(else?)
sense(40) XBUSY (low=AutoSeqBusy)
sense(50) FOK (high=FokusOkay)
sense(A0) GFS (high=GoodFrameSync, ie. CorrectPlaybackSpeed)
sense(C5) COUT (toggles each 100h 'tracks') (100h=selected via CX(B01000))
sense(EA) /OV64 (low=EFM too long?)

```

27.18 CDROM Internal Coefficients (for CXD2545Q)

The CXD2545Q contains Preset Coefficients in internal ROM, which are copied to internal Coefficient RAM shortly after Reset. CX(34xxxx) allows to change those RAM settings, and CX(39xxxx) allows to readout some of those values serially.

CXD2545Q - Coefficient Preset Values

Addr	Val	Expl.
K00	E0	Sled input gain
K01	81	Sled low boost filter A-H
K02	23	Sled low boost filter A-L
K03	7F	Sled low boost filter B-H
K04	6A	Sled low boost filter B-L
K05	10	Sled output gain
K06	14	Focus input gain
K07	30	Sled auto gain
K08	7F	Focus high cut filter A
K09	46	Focus high cut filter B
K0A	81	Focus low boost filter A-H
K0B	1C	Focus low boost filter A-L
K0C	7F	Focus low boost filter B-H
K0D	58	Focus low boost filter B-L
K0E	82	Focus phase compensate filter A
K0F	7F	Focus defect hold gain
K10	4E	Focus phase compensate filter B
K11	32	Focus output gain

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K12 20 Anti shock input gain
K13 30 Focus auto gain
K14 80 HPTZC / Auto Gain High pass filter A
K15 77 HPTZC / Auto Gain High pass filter B
K16 80 Anti shock high pass filter A
K17 77 HPTZC / Auto Gain low pass filter B
K18 00 Fix (should not change this preset value)
K19 F1 Tracking input gain
K1A 7F Tracking high cut filter A
K1B 3B Tracking high cut filter B
K1C 81 Tracking low boost filter A-H
K1D 44 Tracking low boost filter A-L
K1E 7F Tracking low boost filter B-H
K1F 5E Tracking low boost filter B-L
K20 82 Tracking phase compensate filter A
K21 44 Tracking phase compensate filter B
K22 18 Tracking output gain
K23 30 Tracking auto gain
K24 7F Focus gain down high cut filter A
K25 46 Focus gain down high cut filter B
K26 81 Focus gain down low boost filter A-H
K27 3A Focus gain down low boost filter A-L
K28 7F Focus gain down low boost filter B-H
K29 66 Focus gain down low boost filter B-L
K2A 82 Focus gain down phase compensate filter A
K2B 44 Focus gain down defect hold gain
K2C 4E Focus gain down phase compensate filter B
K2D 1B Focus gain down output gain
K2E 00 Not used
K2F 00 Not used
K30 80 Fix (should not change this preset value)
K31 66 Anti shock low pass filter B
K32 00 Not used
K33 7F Anti shock high pass filter B-H
K34 6E Anti shock high pass filter B-L
K35 20 Anti shock filter compare gain
K36 7F Tracking gain up2 high cut filter A
K37 3B Tracking gain up2 high cut filter B
K38 80 Tracking gain up2 low boost filter A-H
K39 44 Tracking gain up2 low boost filter A-L
K3A 7F Tracking gain up2 low boost filter B-H
K3B 77 Tracking gain up2 low boost filter B-L
K3C 86 Tracking gain up phase compensate filter A
K3D 0D Tracking gain up phase compensate filter B
K3E 57 Tracking gain up output gain
K3F 00 Not used
K40 04 Tracking hold filter input gain
K41 7F Tracking hold filter A-H
K42 7F Tracking hold filter A-L
K43 79 Tracking hold filter B-H
K44 17 Tracking hold filter B-L
K45 6D Tracking hold filter output gain
K46 00 Not used
K47 00 Not used

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K48	02	Focus hold filter input gain
K49	7F	Focus hold filter A-H
K4A	7F	Focus hold filter A-L
K4B	79	Focus hold filter B-H
K4C	17	Focus hold filter B-L
K4D	54	Focus hold filter output gain
K4E	00	Not used
K4F	00	Not used