

## **Hardware**

<b>COLLABORATORS</b>
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# Chapter 1

## Hardware

### 1.1 Amiga® Hardware Reference Manual: 7 System Control Hardware

This chapter covers the control hardware of the Amiga system, including the following topics:

- \* How playfield priorities may be specified relative to the sprites
- \* How collisions between objects are sensed
- \* How system direct memory access (DMA) is controlled
- \* How interrupts are controlled and sensed
- \* How reset and early powerup are controlled

```
@{ " Video Priorities " link 7-1}           @{ " Interrupts " link 7-4}
@{ " Collision Detection " link 7-2}        @{ " DMA Control " link 7-5}
@{ " Beam Position Detection " link 7-3}    @{ " Reset and Early Startup Operation ↔
      " link 7-6}
```

### 1.2 7 System Control Hardware / Video Priorities

You can control the priorities of various objects on the screen to give the illusion of three dimensions. The section below shows how playfield priority may be changed relative to sprites.

```
@{ " Fixed Sprite Priorities " link 7-1-1}    @{ " Understanding Video Priorities ↔
      " link 7-1-3}
@{ " How Sprites are Grouped " link 7-1-2}    @{ " Setting the Priority Control ↔
      Register " link 7-1-4}
```

### 1.3 7 / Video Priorities / Fixed Sprite Priorities

You cannot change the relative priorities of the sprites. They will always appear on the screen with the lower-numbered sprites appearing in front of (having higher screen priority than) the higher-numbered sprites. This is shown in Figure 7-1. Each box represents the image of the sprite number shown in that box.

---



---

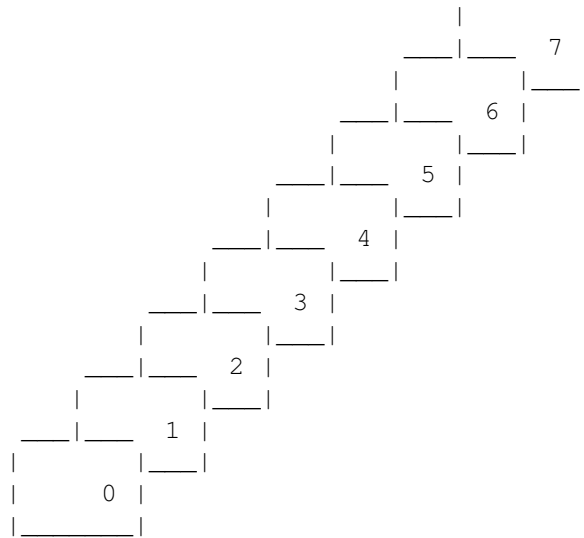


Figure 7-1: Inter-Sprite Fixed Priorities

## 1.4 7 / Video Priorities / How Sprites are Grouped

For playfield priority and collision purposes only, sprites are treated as four groups of two sprites each. The groups of sprites are:

```
Sprites 0 and 1
Sprites 2 and 3
Sprites 4 and 5
Sprites 6 and 7
```

## 1.5 7 / Video Priorities / Understanding Video Priorities

The concept of video priorities is easy to understand if you imagine that four fingers of one of your hands represent the four pairs of sprites and two fingers of your other hand represent the two playfields. Just as you cannot change the sequence of the four fingers on the one hand, neither can you change the relative priority of the sprites. However, just as you can intertwine the two fingers of one hand in many different ways relative to the four fingers of the other hand, so can you position the playfields in front of or behind the sprites. This is illustrated in Figure 7-2.

Figure 7-2: Analogy for Video Priority

Five possible positions can be chosen for each of the two "playfield fingers." For example, you can place playfield 1 on top of sprites 0 and 1 (0), between sprites 0 and 1 and sprites 2 and 3 (1), between sprites 2 and 3 and sprites 4 and 5 (2), between sprites 4 and 5 and sprites 6 and 7 (3), or beneath sprites 6 and 7 (4). You have the same possibilities for playfield 2.

The numbers 0 through 4 shown in parentheses in the preceding paragraph are the actual values you use to select the playfield priority positions. See next section `Setting the Priority Control Register` .

You can also control the priority of playfield 2 relative to playfield 1. This gives you additional choices for the way you can design the screen priorities .

## 1.6 7 / Video Priorities / Setting the Priority Control Register

This register lets you define how objects will pass in front of each other or hide behind each other. Normally, playfield 1 appears in front of playfield 2. The PF2PRI bit reverses this relationship, making playfield 2 more important. You control the video priorities by using the bits in BPLCON2 (for "bitplane control register number 2") as shown in Table 7-1.

Table 7-1: Bits in BPLCON2

Bit Number -----	Name -----	Function -----
15-7		Not used (keep at 0)
6	PF2PRI	Playfield 2 priority
5-3	PF2P2 - PF2P0	Playfield 2 placement with respect to the sprites
2-0	PF1P2 - PF1P0	Playfield 1 placement with respect to the sprites

The binary values that you give to bits PF1P2-PF1P0 determine where playfield 1 occurs in the priority chain as shown in Table 7-2. This matches the description given in the previous section.

Be careful:

PF2P2 - PF2P0, bits 5-3, are the priority bits for normal (non-dual) playfields.

Table 7-2: Priority of Playfields Based on Values of Bits PF1P2-PF1P0

Value -----	Placement ----- (from most important to least important)				
000	PF1	SP01	SP23	SP45	SP67
001	SP01	PF1	SP23	SP45	SP67
010	SP01	SP23	PF1	SP45	SP67
011	SP01	SP23	SP45	PF1	SP67
100	SP01	SP23	SP45	SP67	PF1

In this table, PF1 stands for playfield 1, and SP01 stands for the group of sprites numbered 0 and 1. SP23 stands for sprites 2 and 3 as a group; SP45 stands for sprites 4 and 5 as a group; and SP67 stands for sprites 6 and 7 as a group.

Bits PF2P2-PF2P0 let you position playfield 2 among the sprite priorities in exactly the same way. However, it is the PF2PRI bit that determines which of the two playfields appears in front of the other on the screen. Here is a sample of possible BPLCON2 register contents that would create something a little unusual:

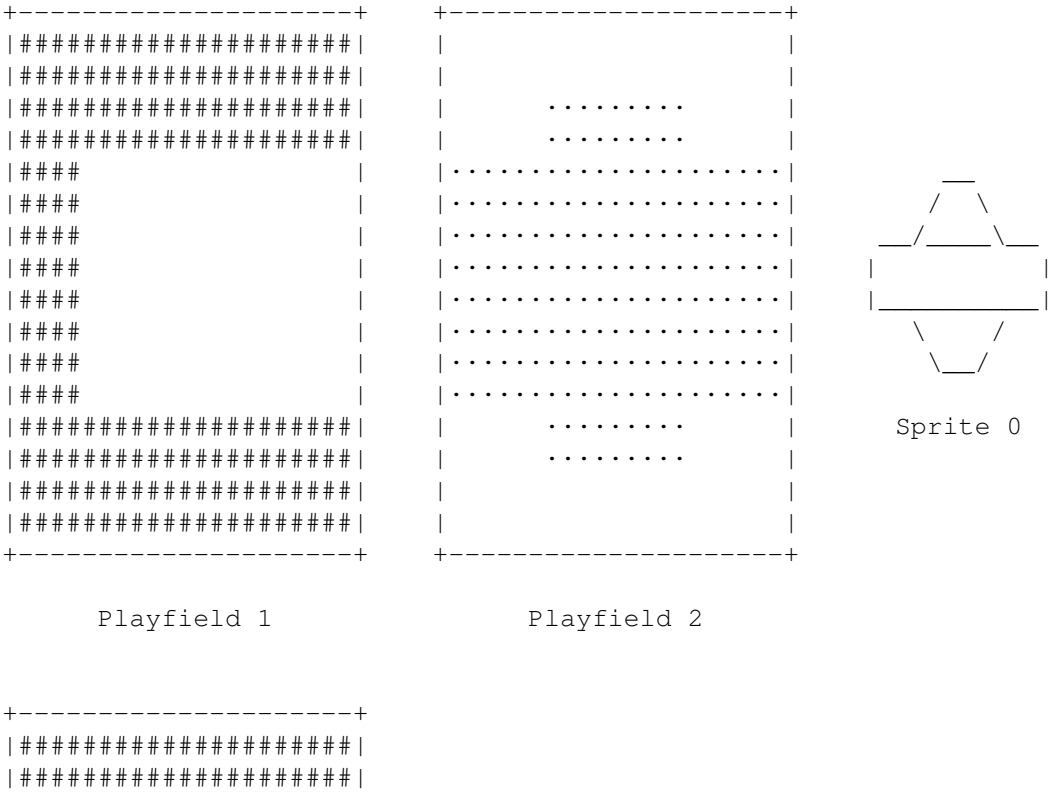
BITS	15-7	PF2PRI	PF2P2-0	PF1P2-0
VALUE	0s	1	010	000

This will result in a sprite/playfield priority placement of:

PF1	SP01	SP23	PF2	SP45	SP67
-----	------	------	-----	------	------

In other words, where objects pass across each other, playfield 1 is in front of sprite 0 or 1; and sprites 0 through 3 are in front of playfield 2. However, playfield 2 is in front of playfield 1 in any area where they overlap and where playfield 2 is not blocked by sprites 0 through 3.

Figure 7-3 shows one use of sprite/playfield priority. The single sprite object shown on the diagram is sprite 0. The sprite can "fly" across playfield 2, but when it crosses playfield 1 the sprite disappears behind that playfield. The result is an unusual video effect that causes the object to disappear when it crosses an invisible boundary on the screen.



```

#####.....#####|
#####-.-.-.-.#####| - - - - -
|...| . _ .....| |
|...| / \ .....|
|...| _ _ \ .....|
|...| _ _ | .....|
|...| _ _ | .....|
|...| _ _ / .....|
|...| \ _ / .....|
|.....|
#####-.-.-.-.#####| - - - - -
#####.....#####|
#####|
#####|
#####|
+-----+

```

When everything is displayed together.  
 sprite 0 is more important than playfield 2  
 but less important than playfield 1.  
 So even though you can't see the boundary,  
 the sprite disappears "behind" the  
 invisible PF1 boundary.

Figure 7-3: Sprite/Playfield Priority

## 1.7 7 System Control Hardware / Collision Detection

You can use the hardware to detect collisions between one sprite group and another sprite group, any sprite group and either of the playfields, the two playfields, or any combination of these items.

The first kind of collision is typically used in a game operation to determine if a missile has collided with a moving player. The second kind of collision is typically used to keep a moving object within specified on-screen boundaries. The third kind of collision detection allows you to define sections of playfield as individual objects, which you may move using the blitter. This is called playfield animation. If one playfield is defined as the backdrop or playing area and the other playfield is used to define objects (in addition to the sprites), you can sense collisions between the playfield-objects and the sprites or between the playfield-objects and the other playfield.

```

@{ " How Collisions are Determined " link 7-2-1}
@{ " How To Interpret the Collision Data " link 7-2-2}
@{ " How Collision Detection is Controlled " link 7-2-3}

```

## 1.8 7 / Collision Detection / How Collisions are Determined

The video output is formed when the input data from all of the bitplanes and the sprites is combined into a common data stream for the display. For each of the pixel positions on the screen, the color of the highest priority object is displayed. Collisions are detected when two or more objects attempt to overlap in the same pixel position. This will set a bit in the collision data register.

## 1.9 7 / Collision Detection / How To Interpret the Collision Data



The collision data register, CLXDAT, is read-only, and its contents are automatically cleared to 0 after it is read. Its bits are as shown in Table 7-3.

Table 7-3: CLXDAT Bits

Bit Number	Collisions Registered
-----	-----
15	not used
14	Sprite 4 (or 5) to sprite 6 (or 7)
13	Sprite 2 (or 3) to sprite 6 (or 7)
12	Sprite 2 (or 3) to sprite 4 (or 5)
11	Sprite 0 (or 1) to sprite 6 (or 7)
10	Sprite 0 (or 1) to sprite 4 (or 5)
9	Sprite 0 (or 1) to sprite 2 (or 3)
8	Even bitplanes to sprite 6 (or 7)
7	Even bitplanes to sprite 4 (or 5)
6	Even bitplanes to sprite 2 (or 3)
5	Even bitplanes to sprite 0 (or 1)
4	Odd bitplanes to sprite 6 (or 7)
3	Odd bitplanes to sprite 4 (or 5)
2	Odd bitplanes to sprite 2 (or 3)
1	Odd bitplanes to sprite 0 (or 1)
0	Even bitplanes to odd bitplanes

About odd-numbered sprites.

-----  
The numbers in parentheses in Table 7-3 refer to collisions that will register only if you want them to show up. The collision control register described below lets you either ignore or include the odd-numbered sprites in the collision detection.

Notice that in this table, collision detection does not change when you select either single- or dual-playfield mode. Collision detection depends only on the actual bits present in the odd-numbered or even-numbered bitplanes. The collision control register specifies how to handle the bitplanes during collision detect.

1.10 7 / Collision Detection / How Collision Detection is Controlled

The collision control register, CLXCON, contains the bits that define certain characteristics of collision detection. Its bits are shown in Table 7-4.

Table 7-4: CLXCON Bits

Bit Number	Name	Function
-----	-----	-----
15	ENSP7	Enable sprite 7 (OR with sprite 6)
14	ENSP5	Enable sprite 5 (OR with sprite 4)

13	ENSP3	Enable sprite 3 (OR with sprite 2)
12	ENSP1	Enable sprite 1 (OR with sprite 0)
11	ENBP6	Enable bitplane 6 (match required for collision)
10	ENBP5	Enable bitplane 5 (match required for collision)
9	ENBP4	Enable bitplane 4 (match required for collision)
8	ENBP3	Enable bitplane 3 (match required for collision)
7	ENBP2	Enable bitplane 2 (match required for collision)
6	ENBP1	Enable bitplane 1 (match required for collision)
5	MVBP6	Match value for bitplane 6 collision
4	MVBP5	Match value for bitplane 5 collision
3	MVBP4	Match value for bitplane 4 collision
2	MVBP3	Match value for bitplane 3 collision
1	MVBP2	Match value for bitplane 2 collision
0	MVBP1	Match value for bitplane 1 collision

Bits 15-12 let you specify that collisions with a sprite pair are to include the odd-numbered sprite of a pair of sprites. The even-numbered sprites always are included in the collision detection. Bits 11-6 let you specify whether to include or exclude specific bitplanes from the collision detection. Bits 5-0 let you specify the polarity (true-false condition) of bits that will cause a collision. For example, you may wish to register collisions only when the object collides with "something green" or "something blue." This feature, along with the collision enable bits, allows you to specify the exact bits, and their polarity, for the collision to be registered.

NOTE:

-----

This register is write-only. If all bitplanes are excluded (disabled), then a bitplane collision will always be detected.

## 1.11 7 System Control Hardware / Beam Position Detection

Sometimes you might want to synchronize the 680x0 processor to the video beam that is creating the screen display. In some cases, you may also wish to update a part of the display memory after the system has already accessed the data from the memory for the display area.

The address for accessing the beam counter is provided so that you can determine the value of the video beam counter and perform certain operations based on the beam position.

NOTE:

-----

The Copper is already capable of watching the display position for you and doing certain register-based operations automatically. Refer to the Copper Interrupts section and Chapter 2,

In addition, when you are using a light pen, this same address is used to read the light pen position rather than the beam position. This is described fully in Chapter 8, "Interface Hardware."

@{ " Using the Beam Position Counter " link 7-3-1}

1.12 7 / Beam Position Detection / Using the Beam Position Counter

There are four addresses that access the beam position counter. Their usage is described in Table 7-5.

Table 7-5: Contents of the Beam Position Counter

VPOSR	Read-only	Read the high bit of the vertical position (V8) and the frame-type bit.
Bit 15		LOF (Long-frame bit). Used to initialize interlaced displays.
Bits 14-1		Unused
Bit 0		High bit of the vertical position (V8). Allows PAL line counts (313) to appear in PAL versions of the Amiga.
VHPOSR	Read-only	Read vertical and horizontal position of the counter that is producing the beam on the screen (also reads the light pen).
Bits 15-8		Low bits of the vertical position, bits V7-V0
Bits 7-0		The horizontal position, bits H8-H1. Horizontal resolution is 1/160th of the screen width.
VPOSW	Write only	Bits same as VPOSR above.
VHPOSW	Write only	Bits same as VHPOSR above. Used for counter synchronization with chip test patterns.

As usual, the address pairs VPOSR,VHPOSR and VPOSW,VHPOSW can be read from and written to as long words, with the most significant addresses being VPOSR and VPOSW.

1.13 7 System Control Hardware / Interrupts

This system supports the full range of 680x0 processor interrupts. The various kinds of interrupts generated by the hardware are brought into the peripherals chip and are translated into six of the seven available interrupts of the 680x0.

@{ " Nonmaskable Interrupt " link 7-4-1}	@{ " Interrupt ↔
Control Registers " link 7-4-4}	
@{ " Maskable Interrupts " link 7-4-2}	@{ " Setting and ↔
Clearing Bits " link 7-4-5}	

@{ " User Interface to the Interrupt System " link 7-4-3}

## 1.14 7 / Interrupts / Nonmaskable Interrupt

Interrupt level 7 is the nonmaskable interrupt and is not generated anywhere in the current system. The raw interrupt lines of the 680x0, IPL2 through IPL0, are brought out to the expansion connector and can be used to generate this level 7 interrupt for debugging purposes.

## 1.15 7 / Interrupts / Maskable Interrupts

Interrupt levels 1 through 6 are generated. Control registers within the peripherals chip allow you to mask certain of these sources and prevent them from generating a 680x0 interrupt.

## 1.16 7 / Interrupts / User Interface to the Interrupt System

The system software has been designed to correctly handle all system hardware interrupts at levels 1 through 6. A separate set of input lines, designated INT2\* and INT6\* have been routed to the expansion connector for use by external hardware for interrupts. These are known as the external low- and external high-level interrupts.

These interrupt lines are connected to the peripherals chip and create interrupt levels 2 and 6, respectively. It is recommended that you take advantage of the interrupt handlers built into the operating system by using these external interrupt lines rather than generating interrupts directly on the processor interrupt lines.

## 1.17 7 / Interrupts / Interrupt Control Registers

There are two interrupt registers, interrupt enable (mask) and interrupt request (status). Each register has both a read and a write address. The names of the interrupt addresses are:

INTENA

Interrupt0 enable (mask) - write only. Sets or clears specific bits of INTENA.

INTENAR

Interrupt enable (mask) read - read only. Reads contents of INTENA.

INTREQ

Interrupt request (status) - write only. Used by the processor to force a certain kind of interrupt to be processed (software interrupt). Also used to clear interrupt request flags once the interrupt process is completed.

---

**INTREQR**

Interrupt request (status) read - read only. Contains the bits that define which items are requesting interrupt service.

The bit positions in the interrupt request register correspond directly to those same positions in the interrupt enable register. The only difference between the read-only and the write-only addresses shown above is that bit 15 has no meaning in the read-only addresses.

## 1.18 7 / Interrupts / Setting and Clearing Bits

Below are the meanings of the bits in the interrupt control registers and how you use them.

@{ " Set and Clear " link 7-4-5-1} 7-4-5-6}	@{ " Audio Interrupts " link ↔
@{ " Master Interrupt Enable " link 7-4-5-2} 7-4-5-7}	@{ " Blitter Interrupt " link ↔
@{ " External Interrupts " link 7-4-5-3} 7-4-5-8}	@{ " Disk Interrupt " link ↔
@{ " Vertical Blanking Interrupt " link 7-4-5-4} link 7-4-5-9}	@{ " Serial Port Interrupts " ↔
@{ " Copper Interrupt " link 7-4-5-5}	

Figure 7-4: Interrupt Priorities

## 1.19 7 // Setting and Clearing Bits / Set and Clear

The interrupt registers , as well as the DMA control register , use a special way of selecting which of the bits are to be set or cleared. Bit 15 of these registers is called the SET/CLR bit.

When you wish to set a bit (make it a 1), you must place a 1 in the position you want to set and a 1 into position 15.

When you wish to clear a bit (make it a 0), you must place a 1 in the position you wish to clear and a 0 into position 15.

Positions 14-0 are bit selectors. You write a 1 to any one or more bits to select that bit. At the same time you write a 1 or 0 to bit 15 to either set or clear the bits you have selected. Positions 14-0 that have 0 value will not be affected when you do the write. If you want to set some bits and clear others, you will have to write this register twice (once for setting some bits, once for clearing others).

## 1.20 7 // Setting and Clearing Bits / Master Interrupt Enable

Bit 14 of the interrupt registers (INTEN) is for interrupt enable. This is the master interrupt enable bit. If this bit is a 0, it disables all other interrupts. You may wish to clear this bit to temporarily disable all interrupts to do some critical processing task.

Warning:

-----

This bit is used for enable/disable only. It creates no interrupt request.

## 1.21 7 // Setting and Clearing Bits / External Interrupts

Bits 13 and 3 of the interrupt registers are reserved for external interrupts.

Bit 13, EXTER, becomes a 1 when the system line called INT6\* becomes a logic 0. Bit 13 generates a level 6 interrupt .

Bit 3, PORTS, becomes a 1 when the system line called INT2\* becomes a logic 0. Bit 3 causes a level 2 interrupt .

## 1.22 7 // Setting and Clearing Bits / Vertical Blanking Interrupt

Bit 5, VERTB, causes an interrupt at line 0 (start of vertical blank) of the video display frame. The system is often required to perform many different tasks during the vertical blanking interval. Among these tasks are the updating of various pointer registers, rewriting lists of Copper tasks when necessary, and other system-control operations.

The minimum time of vertical blanking is 20 horizontal scan lines for an NTSC system and 25 horizontal scan lines for a PAL system. The range starts at line 0 and ends at line 20 for NTSC or line 25 for PAL. After the minimum vertical blanking range, you can control where the display actually starts by using the DIWSTRT (display window start) register to extend the effective vertical blanking time. See Chapter 3, "Playfield Hardware," for more information on DIWSTRT .

If you find that you still require additional time during vertical blanking, you can use the Copper to create a level 3 interrupt . This Copper interrupt would be timed to occur just after the last line of display on the screen (after the display window stop which you have defined by using the DIWSTOP register).

## 1.23 7 // Setting and Clearing Bits / Copper Interrupt

Bit 4, COPER, is used by the Copper to issue a level 3 interrupt . The Copper can change the content of any of the bits of this register, as it can write any value into most of the machine registers. However, this bit has been reserved for specifically identifying the Copper as the interrupt

source.

Generally, you use this bit when you want to sense that the display beam has reached a specific position on the screen, and you wish to change something in memory based on this occurrence.

## 1.24 7 // Setting and Clearing Bits / Audio Interrupts

Bits 10 - 7, AUD3 - 0, are assigned to the audio channels. They are called AUD3, AUD2, AUD1, and AUD0 and are assigned to channels 3, 2, 1, and 0, respectively.

This level 4 interrupt signals "audio block done." When the audio DMA is operating in automatic mode, this interrupt occurs when the last word in an audio data stream has been accessed. In manual mode, it occurs when the audio data register is ready to accept another word of data.

See Chapter 5, "Audio Hardware," for more information about interrupt generation and timing.

## 1.25 7 // Setting and Clearing Bits / Blitter Interrupt

Bit 6, BLIT, signals "blitter finished." If this bit is a 1, it indicates that the blitter has completed the requested data transfer. The blitter is now ready to accept another task. This bit generates a level 3 interrupt.

## 1.26 7 // Setting and Clearing Bits / Disk Interrupt

Bits 12 and 1 of the interrupt registers are assigned to disk interrupts.

Bit 12, DSKSYN, indicates that the sync register matches disk data. This bit generates a level 5 interrupt.

Bit 1, DSKBLK, indicates "disk block finished." It is used to indicate that the specified disk DMA task that you have requested has been completed. This bit generates a level 1 interrupt.

More information about disk data transfer and interrupts may be found in Chapter 8, "Interface Hardware."

## 1.27 7 // Setting and Clearing Bits / Serial Port Interrupts

The following serial interrupts are associated with the specified bits of the interrupt registers.

Bit 11, RBF (for receive buffer full), specifies that the input buffer of the UART has data that is ready to read. This bit generates a

level 5 interrupt .

Bit 0, TBE (for "transmit buffer empty"), specifies that the output buffer of the UART needs more data and data can now be written into this buffer. This bit generates a level 1 interrupt .

1.28 7 // Setting and Clearing Bits / Figure 7-4: Interrupt Priorities

Hardware Priority	Exec Software Priority	Description	Name
	1	transmitter buffer empty	TBE
1	2	disk block complete	DSKBLK
	3	software interrupt	SOFTINT
2	4	external INT2 & CIAA	PORTS
	5	graphics coprocessor	COPER
3	6	vertical blank interval	VERTB
	7	blitter finished	BLIT
	8	audio channel 2	AUD2
4	9	audio channel 0	AUD0
	10	audio channel 3	AUD3
	11	audio channel 1	AUD1
5	12	receiver buffer full	RBF
	13	disk sync pattern found	DSKSYNC
6	14	external INT6 & CIAB	EXTER
	15	special (master enable)	INTEN
7	--	non-maskable interrupt	NMI

1.29 7 System Control Hardware / DMA Control

Many different direct memory access (DMA) functions occur during system operation. There is a read address as well as a write address to the DMA control register so you can tell which DMA channels are enabled.

The address names for the DMA registers are as follows:



DMACONR - Direct Memory Access Control - read-only.  
DMACON - Direct Memory Access Control - write-only.

The contents of this register are shown in Table 7-6 (bit on if enabled).

Bit Number -----	Name ----	Function -----
15	SET/CLR	The set/reset control bit. See description of bit 15 .
14	BBUSY	Blitter busy status - read-only
13	BZERO	Blitter zero status - read-only. Remains 1 if, during a blitter operation, the blitter output was always zero.
12, 11		Unassigned
10	BLTPRI	Blitter priority. Also known as "blitter-nasty." When this is a 1, the blitter has full (instead of partial) priority over the 680x0.
9	DMAEN	DMA enable. This is a master DMA enable bit. It enables the DMA for all of the channels at bits 8-0.
8	BPLEN	Bitplane DMA enable
7	COPEN	Coprocessor DMA enable
6	BLTEN	Blitter DMA enable
5	SPREN	Sprite DMA enable
4	DSKEN	Disk DMA enable
3-0	AUDxEN	Audio DMA enable for channels 3-0 (x = 3 - 0).

Table 7-6: Contents of DMA Control Register

For more information on using the DMA, see the following chapters:

Copper	Chapter 2: Coprocessor Hardware
Bitplanes	Chapter 3: Playfield Hardware
Sprites	Chapter 4: Sprite Hardware
Audio	Chapter 5: Audio Hardware
Blitter	Chapter 6: Blitter Hardware
Disk	Chapter 8: Interface Hardware

Processor Access To Chip Memory

-----

The Amiga chips access Chip memory directly via DMA, rather than utilizing traditional bus arbitration mechanisms. Therefore, processor supplied features for multiprocessor support, such as the 68000 TAS (test and set) instruction, cannot serve their intended purpose and are not supported by the Amiga architecture.

## 1.30 7 System Control Hardware / Reset and Early Startup Operation

When the Amiga is turned on or externally reset, the memory map is in a special state. An additional copy of the system ROM responds starting at memory location \$00000000. The system RAM that would normally be located at this address is not available. On some Amiga models, portions of the RAM still respond. On other models, no RAM responds. Software must assume that memory is not available. The OVL bit in one of the 8520 Chips disables the overlay (See Appendix F for the bit location).

The Amiga System ROM contains an ID code as the first word. The value of the ID code may change in the future. The second word of the ROM contains a JMP instruction (\$4ef9). The next two words are used as the initial program counter by the 680x0 processor.

The 68000 RESET instruction works much like external reset or power on. All memory and AUTOCONFIG(TM) cards disappear, and the ROM image appears at location \$00000000. The difference is that the CPU continues execution with the next instruction. Since RAM may not be available, special care is needed to write reboot code that will reliably reboot all Amiga models.

coldreboot.asm