

# Hardware

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WRITTEN BY		March 14, 2022	

**REVISION HISTORY**

NUMBER	DATE	DESCRIPTION	NAME

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## Chapter 1

# Hardware

### 1.1 Amiga® Hardware Reference Manual: 6 Blitter Hardware

This chapter covers the operation of the Amiga's blitter, the high speed line drawing and block movement component of the system. The discussion is divided into three parts: blitter basics, blitter area fill mode, and blitter line draw mode. Some example blitter operations are listed at the end of the chapter.

For information concerning the blitter hardware in the Enhanced Chip Set, see Appendix C .

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### 1.2 6 Blitter Hardware / What is the Blitter?

The blitter is one of the two coprocessors in the Amiga. Part of ←  
the  
Agnus chip, it is used to copy rectangular blocks of memory around and to draw lines. When copying memory, it is approximately twice as fast as the 68000, able to move almost four megabytes per second. It can draw lines at almost a million pixels per second.

In block move mode, the blitter can perform any logical operation on up to three source areas, it can  
    shift  
    up to two of the source areas by one to  
fifteen bits, it can

fill  
 outlined shapes, and it can  
 mask  
 the first  
 and last words of each raster row. In  
 line mode  
 , any pattern can be  
 imposed on a line, or the line can be drawn such that only one pixel per  
 horizontal line is set.

The blitter can only access Chip memory -- that portion of memory accessible by the display hardware. Attempting to use the blitter to read or write Fast or other non-Chip memory may result in destruction of the contents of Chip memory.

A "blit" is a single operation of the blitter -- perhaps the drawing of a line or movement of a block of memory. A blit is performed by initializing the blitter registers with appropriate values and then starting the blitter by writing the

BLTSIZE  
 register. As the blitter is

an asynchronous coprocessor, the 680x0 CPU continues to run as the blit is executing.

### 1.3 6 Blitter Hardware / Memory Layout

The blitter is a word blitter, not a bit blitter. All data fetched, modified, and written are in full 16-bit words. Through careful programming, the blitter can do many "bit" type operations.

The blitter is particularly well suited to graphics operations. As an example, a 320 by 200 screen set up to display 16 colors is organized as four bitplanes of 8,000 bytes each. Each bitplane consists of 200 rows of 40 bytes or 20 16-bit words. (From here on, a "word" will mean a 16-bit word.)

### 1.4 6 Blitter Hardware / DMA Channels

The blitter has four DMA channels -- three source channels, ←  
 labeled A, B,  
 and C, and one destination channel, called D. Each of these channels has  
 separate address pointer, modulo and data registers and an enable bit. Two  
 have

shift registers  
 , and one has a first and last word  
 mask register

All four share a single blit size register.

The address pointer registers are each composed of two words, named BLTxPTH and BLTxPTL. (Here and later, in referring to a register, any "x"

in the name should be replaced by the channel label, A, B, C, or D.) The two words of each register are adjacent in the 68000 address space, with the high address word first, so they can both be written with one 32-bit write from the processor. The pointer registers should be written with an address in bytes. Because the blitter works only on words, the least significant bit of the address is ignored. Because only Chip memory is accessible, some of the most significant bits will be ignored as well. On machines with 512 KB of Chip memory, the most significant 13 bits are ignored. On machines with more Chip memory, fewer bits will be ignored. A valid, even, Chip memory address should always be written to these registers.

Set unused bits to zero.

-----  
 Be sure to write zeros to all unused bits in the custom chip registers. These bits may be used by later versions of the custom chips. Writing non-zero values to these bits may cause unexpected results on future machines.

Each of the DMA channels can be independently enabled or disabled. The enable bits are bits SRCA, SRCB, SRCC, and DEST in control register zero ( BLTCON0 ).

When disabled, no memory cycles will be executed for that channel and, for a source channel, the constant value stored in the data register of that channel will be used for each blitter cycle. For this purpose, each of the three source channels have preloadable data registers, called BLTxDAT.

Images in memory are usually stored in a linear fashion; each word of data on a line is located at an address that is one greater than the word on its left. i.e. Each line is a "plus one" continuation of the previous line.

20	21	22	23	24	25	26
27	28	29	30	31	32	33
34	35	36	37	38	39	40
41	42	43	44	45	46	47
48	49	50	51	52	53	54
55	56	57	58	59	60	61

Figure 6-1: How Images are Stored in Memory

The map in Figure 6-1 represents a single bitplane (one bit of color) of

an image at word addresses 20 through 61. Each of these addresses accesses one word (16 pixels) of a single bitplane. If this image required sixteen colors, four bitplanes like this would be required in memory, and four copy (move) operations would be required to completely move the image.

The blitter is very efficient at copying such blocks because it needs to be told only the starting address (20), the destination address, and the size of the block (height = 6, width = 7). It will then automatically move the data, one word at a time, whenever the data bus is available. When the transfer is complete, the blitter will signal the processor with a  
flag  
and an interrupt.

NOTE:

-----

This copy (move) operation operates on memory and may or may not change the memory currently being used for display.

All data copy blits are performed as rectangles of words, with a given width and height. All four DMA channels use a single blit size register, called BLTSIZE, used for both the width and height. The width can take a value of from 1 to 64 words (16 to 1024 bits). The height can run from 1 to 1024 rows. The width is stored in the least significant six bits of the BLTSIZE register. If a value of zero is stored, a width count of 64 words is used. This is the only parameter in the blitter that is given in words. The height is stored in the upper ten bits of the BLTSIZE register, with zero representing a height of 1024 rows. Thus, the largest blit possible with the current Amiga blitter is 1024 by 1024 pixels. However,

                  shifting  
                  and  
                  masking  
                  operations may require an extra word be  
fetched for each raster scan line, making the maximum practical horizontal  
width 1008 pixels.

Blitter counting.

-----

To emphasize the above paragraph: Blit width is in words with a zero representing 64 words. Blit height is in lines with a zero representing 1024 lines.

The blitter also has facilities, called modulus, for accessing images smaller than the entire bitplane. Each of the four DMA channels has a 16-bit modulo register called BLTxMOD. As each word is fetched (or written) for an enabled channel, the address pointer register is incremented by two (two bytes, or one word). After each row of the blit is completed, the signed 16-bit modulo value for that DMA channel is added to the address pointer. (A row is defined by the width stored in BLTSIZE.)

About blitter modulus.

-----

The modulo values are in bytes, not words. Since the blitter can only operate on words, the least significant bit is ignored. The value is sign-extended to the full width of the address pointer registers. Negative modulus can be useful in a variety of ways, such as repeating a row by setting the modulo to the negative of the width

---







0	0	0	?	0	$\overline{ABC}$
0	0	1	?	1	$\overline{ABC}$
0	1	0	?	2	$\overline{ABC}$
0	1	1	?	3	$\overline{ABC}$
1	0	0	?	4	$\overline{ABC}$
1	0	1	?	5	$\overline{ABC}$
1	1	0	?	6	$\overline{ABC}$
1	1	1	?	7	$\overline{ABC}$

This information is collected in a standard format, the LF (Logic Function) control byte in the BLTCON0 register. This byte programs the blitter to perform one of the 256 possible logic operations on three sources for a given blit.

To calculate the LF control byte in BLTCON0, fill in the truth table with desired values for D, and read the function value from the bottom of the table up.

For example, if we wanted to set all bits in the destination where the corresponding A source bit is 1 or the corresponding B source bit is 1, we would fill in the last four entries of the truth table with 1 (because the A bit is set) and the third, fourth, seven, and eight entries with 1 (because the B bit is set), and all others (the first and second) with 0, because neither A nor B is set. Then, we read the truth table from the bottom up, reading 11111100, or \$FC.

For another example, an LF control byte of \$80 (= 1000 0000 binary) turns on bits only for those points of the D destination rectangle where the corresponding bits of A, B, and C sources were all on (ABC = 1, bit 7 of LF on). All other points in the rectangle, which correspond to other combinations for A, B, and C, will be 0. This is because bits 6 through 0 of the LF control byte, which specify the D output for these situations, are set to 0.

```
@{ " Designing the LF Control Byte with Minterms " link 6-4-1}
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```

## 1.6 6 / Function Generator / Designing the LF Control Byte with Minterms

One approach to designing the LF control byte uses logic equations ↔ . Each of the rows in the truth table corresponds to a "minterm", which is a particular assignment of values to the A, B, and C bits. For instance,

the first minterm is usually written:

$$\overline{ABC}$$

or "not A and not B and not C". The last is written as  $\overline{ABC}$ .

Blitter logic.

-----  
Two terms that are adjacent are AND'ed, and two terms that are separated by "+" are OR'ed. AND has a higher precedence, so  $AB + BC$  is equal to  $(AB) + (BC)$ .

Any function can be written as a sum of minterms. If we wanted to calculate the function where D is one when the A bit is set and the C bit is clear, or when the B bit is set, we can write that as:

$$\overline{AC} + B$$

or "A and not C or B". Since "1 and A" is "A":

$$D = \overline{AC} + B$$

$$D = A(1)\overline{C} + (1)B(1)$$

Since either A or  $\overline{A}$  is true ( $1 = A + \overline{A}$ ), and similarly for B, and C; we can expand the above equation further:

$$D = A(1)\overline{C} + (1)B(1)$$

$$D = A(B + \overline{B})\overline{C} + (A + \overline{A})B(C + \overline{C})$$

$$D = \overline{A}BC + A\overline{B}\overline{C} + AB(C + \overline{C}) + \overline{A}B(C + \overline{C})$$

$$D = \overline{A}BC + A\overline{B}\overline{C} + ABC + \overline{A}BC + \overline{A}BC + \overline{A}\overline{B}C$$

After eliminating duplicates, we end up with the five minterms:

$$\overline{AC} + B = \overline{A}BC + A\overline{B}\overline{C} + ABC + \overline{A}BC + \overline{A}\overline{B}C$$

These correspond to BLTCON0 bit positions of 6, 4, 7, 3, and 2, according to our

truth table  
, which we would then set, and clear the

rest.

The wide range of logic operations allow some sophisticated graphics techniques. For instance, you can move the image of a car across some pre-existing building images with a few blits. Producing this effect requires predrawn images of the car, the buildings (or background), and a car "mask" that contains bits set wherever the car image is not transparent. This mask can be visualized as the shadow of the car from a light source at the same position as the viewer.

About mask bitplanes.

-----  
The mask for the car need only be a single bitplane regardless of the depth of the background bitplane. This mask can be used in turn on

each of the background bitplanes.

To animate the car, first save the background image where the car will be placed. Next copy the car to its first location with another blit. Your image is now ready for display. To create the next image, restore the old background, save the next portion of the background where the car will be, and redraw the car, using three separate blits. (This technique works best with beam-synchronized blits or double buffering.)

To temporarily save the background, copy a rectangle of the background (from the A channel, for instance) to some backup buffer (using the D channel). In this case, the function we would use is "A", the standard copy function. From Table 6-1, we note that the corresponding LF code has a value of \$F0.

To draw the car, we might use the A  
DMA channel  
to fetch the car mask,  
the B  
DMA channel  
to fetch the actual car data, the C DMA channel to  
fetch the background, and the D  
DMA channel  
to write out the new image.

Warning:

-----

We must fetch the destination background before we write it, as only a portion of a destination word might need to be modified, and there is no way to do a write to only a portion of a word.

When blitting the car to the background we would want to use a function that, whenever the car mask (fetched with

DMA channel  
A) had a bit set,

we would pass through the car data from B, and whenever A did not have a bit set, we would pass through the original background from C. The corresponding function, commonly referred to as the cookie-cut function,

is  $AB+AC$ , which works out to an LF code value of \$CA.

To restore the background and prepare for the next frame, we would copy the information saved in the first step back, with the standard copy function (\$F0).

If you shift the data and the mask to a new location and repeat the above three steps over and over, the car will appear to move across the background (the buildings).

NOTE:

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This may not be the most effective method of animation, depending on the application, but the cookie-cut function will appear often.

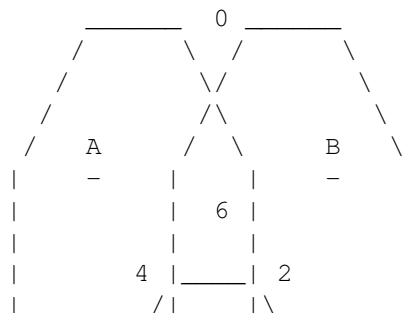
Table 6-1 lists some of the most common functions and their values, for easy reference.

Table 6-1: Table of Common Minterm Values

Selected Equation	BLTCON0 LF Code	Selected Equation	BLTCON0 LF Code
$D = A$	\$F0	$D = \overline{A}B$	\$C0
$D = \overline{A}$	\$0F	$D = \overline{A}\overline{B}$	\$30
$D = B$	\$CC	$D = \overline{A}\overline{B}$	\$0C
$D = \overline{B}$	\$33	$D = \overline{\overline{A}B}$	\$03
$D = C$	\$AA	$D = BC$	\$88
$D = \overline{C}$	\$55	$D = \overline{BC}$	\$44
$D = AC$	\$A0	$D = \overline{BC}$	\$22
$D = \overline{AC}$	\$50	$D = \overline{\overline{AC}}$	\$11
$D = \overline{A}C$	\$0A	$D = A + \overline{B}$	\$F3
$D = \overline{A}\overline{C}$	\$05	$D = \overline{A} + \overline{B}$	\$3F
$D = A + B$	\$FC	$D = A + \overline{C}$	\$F5
$D = \overline{A} + B$	\$CF	$D = \overline{A} + \overline{C}$	\$5F
$D = A + C$	\$FA	$D = B + \overline{C}$	\$DD
$D = \overline{A} + C$	\$AF	$D = \overline{B} + \overline{C}$	\$77
$D = B + C$	\$EE	$D = \overline{AB} + \overline{AC}$	\$CA
$D = \overline{B} + C$	\$BB		

### 1.7 6 / Function Generator / Designing LF Control Byte with Venn Diagrams

Another way to arrive at a particular function is through the use of Venn diagrams: ↔



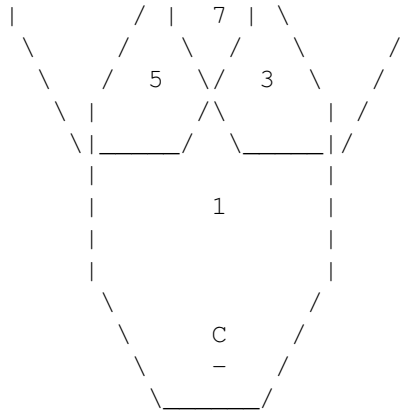


Figure 6-3: Blitter Minterm Venn Diagram

- To select a function  $D=A$  (that is, destination = A source only), select only the minterms that are totally enclosed by the A-circle in the Figure above. This is the set of minterms 7, 6, 5, and 4. When written as a set of 1s for the selected minterms and 0s for those not selected, the value becomes:

Minterm Number	7	6	5	4	3	2	1	0	
Selected Minterms	1	1	1	1	0	0	0	0	
	-----								
	F	0							equals \$F0

- To select a function that is a combination of two sources, look for the

minterms by both of the circles (their intersection). For example, the combination AB (A "and" B) is represented by the area common to both the A and B circles, or minterms 7 and 6.

Minterm Numbers	7	6	5	4	3	2	1	0	
Selected Minterms	1	1	0	0	0	0	0	0	
	-----								
	C	0							equals \$C0

- To use a function that is the inverse, or "not", of one of the sources, such as  $\bar{A}$ ,

take all of the minterms not enclosed by the circle represented by A on the above Figure. In this case, we have

minterms  
0, 1, 2, and 3.

Minterm Numbers	7	6	5	4	3	2	1	0	
Selected Minterms	0	0	0	0	1	1	1	1	
	-----								
					0	F			equals \$0F

4. To combine

minterms  
, or "or" them, "or" the values together. For example, the equation  $AB+BC$  becomes

Minterm Numbers	7	6	5	4	3	2	1	0	
AB	1	1	0	0	0	0	0	0	
BC	1	0	0	0	1	0	0	0	
	-----								
AB+BC	1	1	0	0	1	0	0	0	
					C	8			equals \$C8

## 1.8 6 Blitter Hardware / Shifts and Masks

Up to now we have dealt with the blitter only in moving words of memory around and combining them with logic operations. This is sufficient for

moving graphic images around, so long as the images stay in the same position relative to the beginning of a word. If our car image has its leftmost pixel on the second pixel from the left, we can easily draw it on the screen in any position where the leftmost pixel also starts two pixels from the beginning of some word. But often we want to draw that car shifted left or right by a few pixels. To this end, both the A and B

DMA channels have a barrel shifter that can shift an image between 0 and 15 bits.

This shifting operation is completely free; it requires no more time to execute a blit with shifts than a blit without shifts, as opposed to shifting with the 680x0. The shift is normally towards the right. This shifter allows movement of images on pixel boundaries, even though the pixels are addressed 16 at a time by each word address of the bitplane image.

So if the incoming data is shifted to the right, what is shifted in from the left? For the first word of the blit, zeros are shifted in; for each subsequent word of the same blit, the data shifted out from the previous word is shifted in.

The shift value for the A channel is set with bits 15 through 12 of BLTCON0 ; the B shift value is set with bits 15 through 12 of BLTCON1 . For most operations, the same value will be used for both shifts. For shifts of greater than fifteen bits, load the





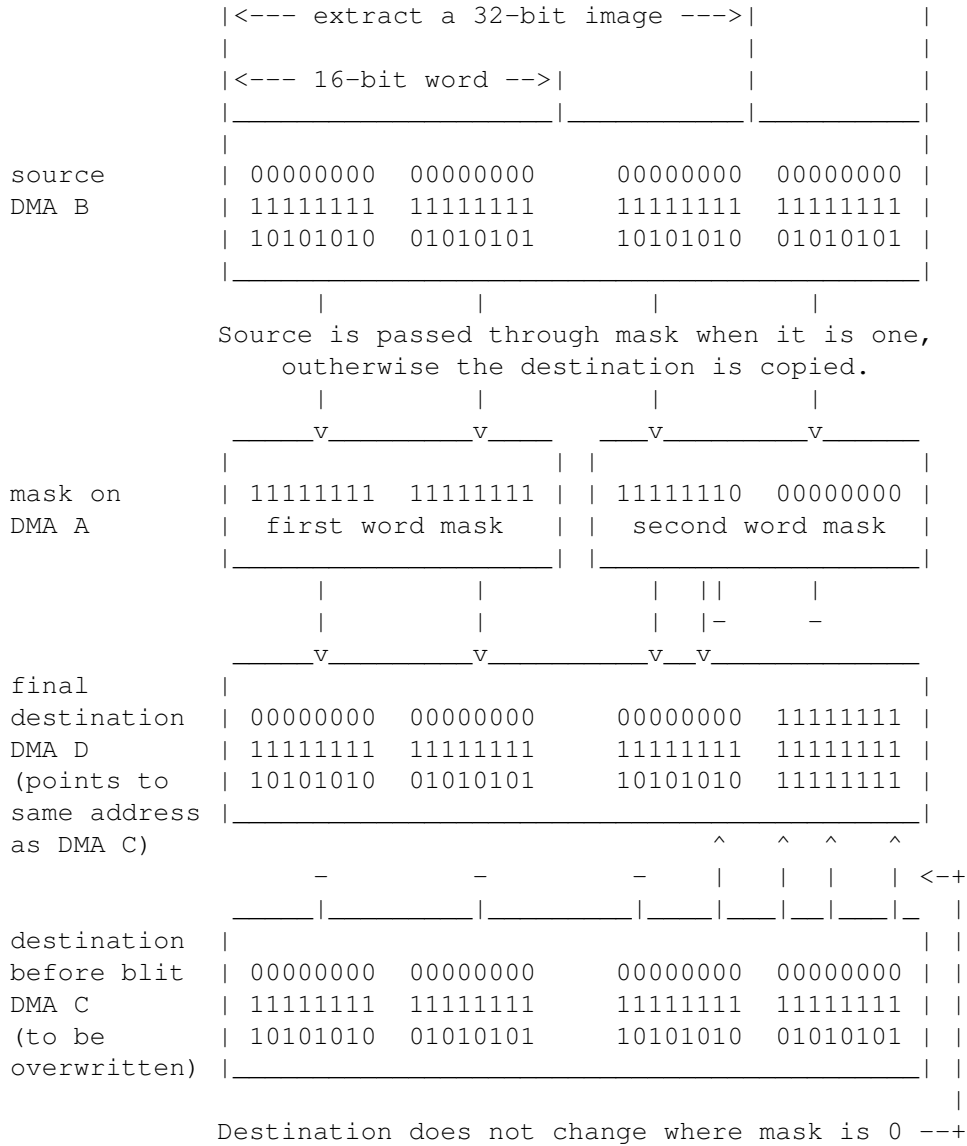


Figure 6-4: Extracting a Range of Columns

To do this, we point the B DMA channel at the bitmap containing the source image, and the D DMA channel at the screen bitmap. We use a shift value of 5. We also point the C DMA channel at the screen bitmap. We use a blit width of 2 words. What we need is a simple copy operation, except we wish to leave the first five bits of the first word, and the last four bits (2 times 16, less 23, less 5) of the last word alone. The A DMA channel comes to the rescue. We preload the A data register

with  
 \$FFFF (all ones), and use a first word mask with the most significant five bits set to zero (\$07FF) and a last word mask with the least significant four bits set to zero (\$FFF0). We do not enable the A DMA channel, but only the B, C, and D channels, since we want to use the A channel as a simple row mask. We then wish to pass the B (source) data along wherever the A channel is 1 (for a minterm of AB) and pass along the original destination data (from the C channel) wherever A is 0 (for a minterm of AC),

yielding our classic cookie-cut function of  $AB+AC$ , or  $\$CA$ .

About disabling.

-----  
 Even though the A channel is disabled, we use it in our logic function and preload the data register. Disabling a channel simply turns off the memory fetches for that channel; all other operations are still performed, only from a constant value stored in the channel's data register.

An alternative but more subtle way of accomplishing the same thing is to use an A shift of five, a first word mask of all ones, and a last word mask with the rightmost nine bits set to zero. All other registers remain the same.

Warning:

-----  
 Be sure to load the blitter immediate data registers only after setting the shift count in BLTCON0/BLTCON1, as loading the data registers first will lead to unpredictable results. For instance, if the last person left BSHIFT to be "4", and I load BDATA with "1" and then change BSHIFT to "2", the resulting BDATA that is used is "1<<4", not "1<<2". The act of loading one of the data registers "draws" the data through the machine and shifts it.

## 1.9 6 Blitter Hardware / Descending Mode

Our standard memory copy blit works fine if the source does not overlap the destination. If we want to move an image one row down (towards increasing addresses), however, we run into a problem -- we overwrite the second row before we get a chance to copy it! The blitter has a special mode of operation -- descending mode -- that solves this problem nicely.

Descending mode is turned on by setting bit one of BLTCON1 (defined as BLITREVERSE). If you use descending mode the address pointers will be decremented by two (bytes) instead of incremented by two for each word fetched. In addition, the modulo values will be subtracted rather than added.

Shifts are then towards the left, rather than the right, the first word mask masks the last word in a row (which is still the first word fetched), and the last word mask masks the first word in a row.

Thus, for a standard memory copy, the only difference in blitter setup (assuming no

shifting or masking) is to initialize the address pointer registers to point to the last word in a block, rather than the first word. The modulo values, blit size, and all other parameters should be set the same.

NOTE:

-----

This differs from predecrement versus postincrement in the 680x0, where an address register would be initialized to point to the word after the last, rather than the last word.

Descending mode is also necessary for area filling, which will be covered in a later section.

## 1.10 6 Blitter Hardware / Copying Arbitrary Regions

One of the most common uses of the blitter is to move arbitrary rectangles of data from one bitplane to another, or to different positions within a bitplane. These rectangles are usually on arbitrary bit coordinates, so

shifting  
and  
masking

are necessary. There are further complications.

It may take several readings and some experimentation before everything in this section can be understood.

A source image that spans only two words may, when copied with certain

shifts  
, span three words. Our 23 pixel wide rectangle above, for

instance, when

shifted  
12 bits, will span three words. Alternatively, an

image spanning three words may fit in two for certain

shifts  
. Under all

such circumstances, the blit size should be set to the larger of the two values, such that both source and destination will fit within the blit size. Proper

masking  
should be applied to mask out unwanted data.

Some general guidelines for copying an arbitrary region are as follows.

1. Use the A

DMA channel  
, disabled, preloaded with all ones and the

appropriate

mask  
and  
shift values  
, to mask the  
cookie-cut  
function.

Use the B channel to fetch the source data, the C channel to fetch the destination data, and the D channel to write the destination data. Use the

cookie-cut  
function \$CA.

2. If

shifting  
, always use ascending mode if bit shifting to the right,

and use

descending mode  
if bit shifting to the left.

NOTE:

-----

These shifts are the shifts of the bit position of the leftmost edge within a word, rather than

absolute shifts  
, as explained previously.

3. If the source and destination overlap, use ascending mode if the

destination has a lower memory address (is higher on the display) and

descending mode  
otherwise.

4. If the source spans more words than the destination, use the same

shift  
value for the A channel as for the source B channel and set the  
first and last word  
masks  
as if they were masking the B source data.

5. If the destination spans more words than the source, use a

shift  
value of zero for the A channel and set the first and last word  
masks  
as if they were masking the destination D data.

6. If the source and destination span the same number of words, use the  
A channel to

mask  
either the source, as in 4, or the destination, as  
in 5.

Warning:

-----

Conditions 2 and 3 can be contradictory if, for instance, you are  
trying to move an image one pixel down and to the right. In this  
case, we would want to use

descending mode  
so our destination does

not overwrite our source before we use the source, but we would want  
to use ascending mode for the right

shift  
. In some situations, it is

possible to get around general guideline 2 above with clever  
masking

But occasionally just

masking  
the first or last word may not be

sufficient; it may be necessary to mask more than 16 bits on one or  
the other end. In such a case, a mask can be built in memory for a  
single raster row, and the A

DMA channel  
enabled to explicitly fetch

this mask. By setting the A modulo value to the negative of the width  
of the mask, the mask will be repeatedly fetched for each row.

## 1.11 6 Blitter Hardware / Area Fill Mode

In addition to copying data, the blitter can simultaneously ↔  
perform a fill

operation during the copy. The fill operation has only one restriction -- the area to fill must be defined first by drawing untextured lines with only one bit set per horizontal row. A special

line draw mode

is

available for this operation. Use a standard copy blit (or any other blit, as area fills take place after all

shifts

,

masks

and logical

combination of sources).

Descending mode

must be used. Set either the

inclusive-fill-enable bit (FILL\_OR, or bit 3) or the exclusive-fill-enable bit (FILL\_XOR, or bit 4) in BLTCON1. The inclusive fill mode fills between lines, leaving the lines intact. The exclusive fill mode fills between lines, leaving the lines bordering the right edge of filled regions but deleting the lines bordering the left edge. Exclusive fill yields filled shapes one pixel narrower than the same pattern filled with inclusive fill.

For instance, the pattern:

```
00100100-00011000
```

filled with inclusive fill, yields:

```
00111100-00011000
```

with exclusive fill, the result would be

```
00011100-00001000
```

(Of course, fills are always done on full 16-bit words.)

There is another bit (FILL\_CARRYIN or bit 3 in BLTCON1) that forces the area "outside" the lines be filled; for the above example, with inclusive fill, the output would be

```
11100111-11111111
```

with exclusive fill, the output would be

```
11100011-11110111
```

before

after

	_____						_____				
	1	1	1	1			11111	11111			
	1	1	1	1			1111	1111			
	1	1	1	1			111	111			
	11		11				11	11			
	1	1	1	1			111	111			

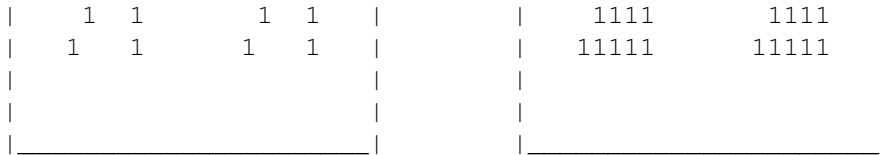


Figure 6-5: Use of the FCI Bit - Bit Is a 0

If the FCI bit is a 1 instead of a 0, the area outside the lines is filled with 1s and the area inside the lines is left with 0s in between.

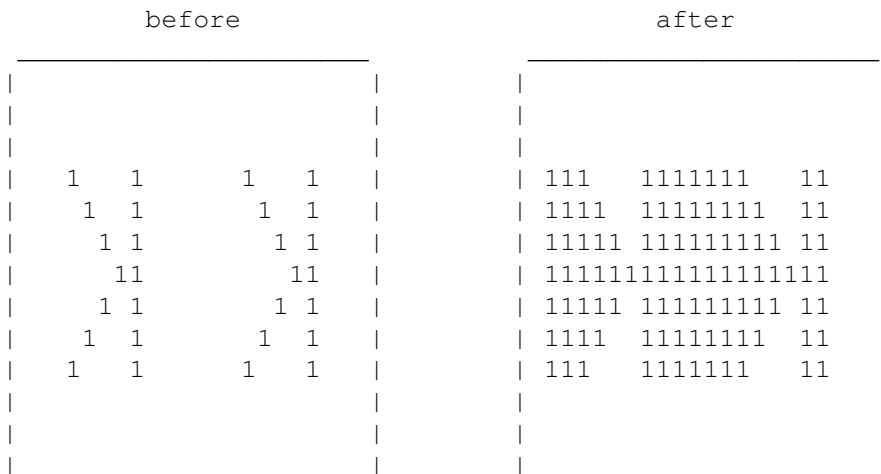


Figure 6-6: Use of the FCI Bit - Bit Is a 1

If you wish to produce very sharp, single-point vertices, exclusive-fill enable must be used. Figure 6-7 shows how a single-point vertex is produced using exclusive-fill enable.

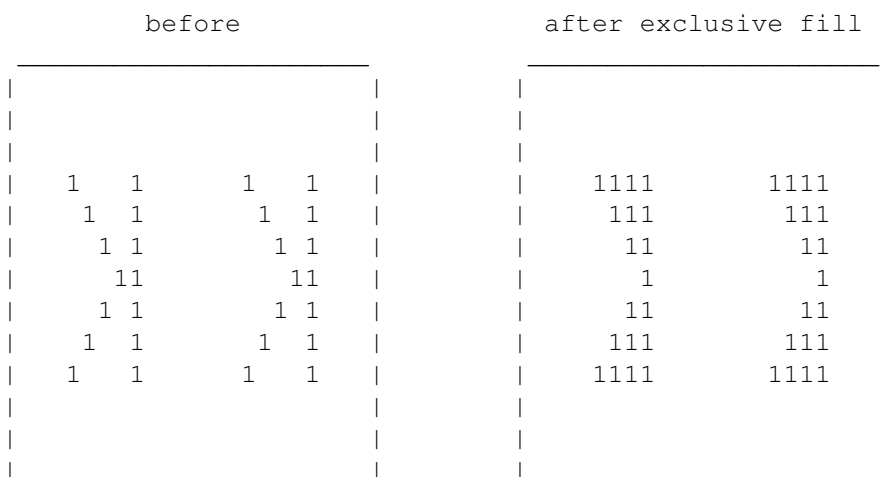


Figure 6-7: Single-Point Vertex Example

The blitter uses the fill carry-in bit as the starting fill state

beginning at the rightmost edge of each line. For each "1" bit in the source area, the blitter flips the fill state, either filling or not filling the space with ones. This continues for each line until the left edge of the blit is reached, at which point the filling stops.

## 1.12 6 Blitter Hardware / Blitter Done Flag

When the BLTSIZE register is written the blit is started. The processor does not stop while the blitter is working, though; they can both work concurrently, and this provides much of the speed evident in the Amiga. This does require some amount of care when using the blitter.

A blitter done flag, also called the blitter busy flag, is provided as DMAF\_BLTDONE (bit 14) in DMACONR. This flag is set when a blit is in progress.

About the blitter done flag.

-----  
 If a blit has just been started but has been locked out of memory access because of, for instance, display fetches, this bit may not yet be set. The processor, on the other hand, may be running completely uninhibited out of Fast memory or its internal cache, so it will continue to have memory cycles.

The solution is to read a chip memory or hardware register address with the processor before testing the bit. This can easily be done with the sequence:

```
btst.b #DMAB_BLTDONE-8,DMACONR(a1)
btst.b #DMAB_BLTDONE-8,DMACONR(a1)
```

where a1 has been preloaded with the address of the hardware registers. The first "test" of the blitter done bit may not return the correct result, but the second will.

NOTE:

-----  
 Starting with the Fat Agnus the blitter busy bit has been "fixed" to be set as soon as you write to BLTSIZE to start the blit, rather than when the blitter gets its first DMA cycle. However, not all machines will use these newer chips, so it is best to rely on the above method of testing.

@{ " Multitasking and the Blitter " link 6-9-1}

## 1.13 6 / Blitter Done Flag / Multitasking and the Blitter



When a blit is in progress, none of the blitter registers should be written. For details on arbitration of blitter access in the system, please refer to the ROM Kernel Manual. In particular, read the discussion about the OwnBlitter() and DisownBlitter() functions. Even after the blitter has been "owned", a blit may still be finishing up, so the blitter

done flag should be checked before using it even the first time. Use of the ROM kernel function WaitBlit() is recommended.

You should also check the blitter done flag before using results of a blit. The blit may not be finished, so the data may not be ready yet. This can lead to difficult to find bugs, because a 68000 may be slow enough for a blit to finish without checking the done flag, while a 68020, perhaps running out of its cache, may be able to get at the data before the blitter has finished writing it.

Let us say that we have a subroutine that displays a text box on top of other imagery temporarily. This subroutine might allocate a chunk of memory to hold the original screen image while we are displaying our text box, then draw the text box. On exit, the subroutine might blit the original imagery back and then free the allocated memory. If the memory is freed before the blitter done flag is checked, some other process might allocate that memory and store new data into it before the blit is finished, trashing the blitter source and, thus, the screen imagery being restored.

## 1.14 6 Blitter Hardware / Interrupt Flag

The blitter also has an interrupt flag that is set whenever a blit finishes. This flag, INTF\_BLIT, can generate a 680x0 interrupt if enabled. For more information on interrupts, see Chapter 7: "System Control Hardware."

## 1.15 6 Blitter Hardware / Zero Flag

A blitter zero flag is provided that can be tested to determine if the logic operation selected has resulted in zero bits for all destination bits, even if those destination bits are not written due to the D

DMA channel being disabled. This feature is often useful for

collision detection , by performing a logical "and" on two source images to test for overlap. If the images do not overlap, the zero flag will stay true.

The Zero flag is only valid after the blitter has completed its operation and can be read from bit (13) DMAF\_BLTNZERO of the DMACONR register.

### 1.16 6 Blitter Hardware / Pipeline Register

The blitter performs many operations in each cycle --  
 shifting  
 and

masking  
 source words, logical combination of sources, and  
 area fill

and zero detect on the output. To enable so many things to take place so

quickly, the blitter is pipelined. This means that rather than performing all of the above operations in one blitter cycle, the operations are spread over two blitter cycles. (Here "cycle" is used very loosely for simplicity.) To clarify this, the blitter can be imagined as two chips connected in series. Every cycle, a new set of source operations come in, and the first chip performs its operations on the data. It then passes the half-processed data to the second chip to be finished during the next cycle, when the first chip will be busy at work on the next set of data. Each set of data takes two "cycles" to get through the two chips, overlapped so a set of data can be pumped through each cycle.

What all this means is that the first two sets of sources are fetched before the first destination is written. This allows you to shift

a

bitmap up to one word to the right using ascending mode, for instance, even though normally parts of the destination would be overwritten before they were fetched.

USE Code in BLTCON0	Active Channels	Cycle Sequence
F	A B C D	A0 B0 C0 - A1 B1 C1 D0 A2 B2 C2 D1 D2
E	A B C	A0 B0 C0 A1 B1 C1 A2 B2 C2
D	A B D	A0 B0 - A1 B1 D0 A2 B2 D1 - D2
C	A B	A0 B0 - A1 B1 - A2 B2
B	A C D	A0 C0 - A1 C1 D0 A2 C2 D1 - D2
A	A C	A0 C0 A1 C1 A2 C2
9	A D	A0 - A1 D0 A2 D1 - D2
8	A	A0 - A1 - A2
7	B C D	B0 C0 - - B1 C1 D0 - B2 C2 D1 - D2
6	B C	B0 C0 - B1 C1 - B2 C2
5	B D	B0 - - B1 D0 - B2 D1 - D2
4	B	B0 - - B1 - - B2

3	C D	C0 - - C1 D0 - C2 D1 - D2
2	C	C0 - C1 - C2
1	D	D0 - D1 - D2
0	none	- - - -

Table 6-2: Typical Blitter Cycle Sequence

Here are a few caveats to keep in mind about Table 6-2.

- \* No fill.
- \* No competing bus activity.
- \* Three-word blit.
- \* Typical operation involves fetching all sources twice before the first destination becomes available. This is due to internal pipelining. Care must be taken with overlapping source and destination regions.

Warning:

-----

This Table is only meant to be an illustration of the typical order of blitter cycles on the bus. Bus cycles are dynamically allocated based on blitter operating mode; competing bus activity from processor, bitplanes, and other

DMA channels

; and other factors.

Commodore Amiga does not guarantee the accuracy of or future adherence to this chart. We reserve the right to make product improvements or design changes in this area without notice.

## 1.17 6 Blitter Hardware / Line Mode

In addition to all of the functions described above, the blitter can draw patterned lines. The line draw mode is selected by setting bit 0 (LINEMODE) of BLTCON1, which changes the meaning of some other bits in BLTCON0 and BLTCON1. In line draw mode, the blitter can draw lines up to 1024 pixels long, it can draw them in a variety of modes, with a variety of textures, and can even draw them in a special way for simple

area fill

.

Many of the blitter registers serve other purposes in line-drawing mode. Consult Appendix A for more detailed descriptions of the use of these registers and control bits. You should also see Appendix C for the new limits on line-drawing mode in the Enhanced Chip Set (ECS).

In line mode, the blitter draws a line from one point to another, which can be viewed as a vector. The direction of the vector can lie in any of the following eight octants. (In the following diagram, the standard Amiga convention is used, with x increasing towards the right and y increasing down.) The number in parenthesis is the octant numbering; the

other number represents the value that should be placed in bits 4 through 2 of BLTCON1 .

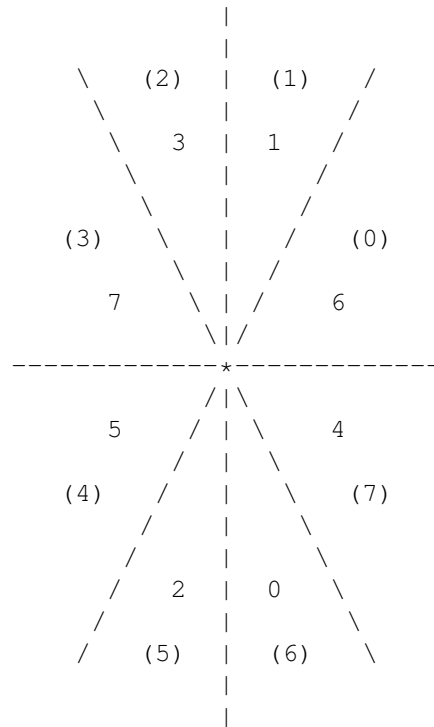


Figure 6-8: Octants for Line Drawing

Line drawing based on octants is a simplification that takes advantage of symmetries between  $x$  and  $-x$ ,  $y$  and  $-y$ . The following Table lists the octant number and corresponding values:

Table 6-3: BLTCON1 Code Bits for Octant Line Drawing

BLTCON1	Code Bits	Octant #
4	3 2	
-	- -	
1	1 0	0
0	0 1	1
0	1 1	2
1	1 1	3
1	0 1	4
0	1 0	5
0	0 0	6
1	0 0	7

We initialize BLTCON1 bits 4 through 2 according to the above Table. Now, we introduce the variables  $dx$  and  $dy$  and set them to the absolute values of the difference between the  $x$  coordinates and the  $y$  coordinates of the endpoints of the line, respectively.

```
dx = abs(x2 - x1) ;
dy = abs(y2 - y1) ;
```

Now, we rearrange them if necessary so dx is greater than dy.

```
if (dx < dy)
{
    temp = dx ;
    dx = dy ;
    dy = temp ;
}
```

Alternately, set dx and dy as follows:

```
dx = max(abs(x2 - x1), abs(y2 - y1)) ;
dy = min(abs(x2 - x1), abs(y2 - y1)) ;
```

These calculations have the effect of "normalizing" our line into octant 0; since we have already informed the blitter of the real octant to use, it has no difficulty drawing the line.

We initialize the A

```
pointer register
to 4 * dy - 2 * dx. If this value
is negative, we set the sign bit (SIGNFLAG in BLTCON1 ), otherwise we
clear it. We set the A
```

```
modulo register
to 4 * (dy - dx) and the B
```

```
modulo register
to 4 * dy.
```

The A

```
data register
should be preloaded with $8000. Both word
masks
should be set to $FFFF. The A
shift
value should be set to the x
coordinate of the first point (x1) modulo 15.
```

The B

```
data register
should be initialized with the line texture pattern,
if any, or $FFFF for a solid line. The B
shift
value should be set to
the bit number at which to start the line texture (zero means the last
significant bit.)
```

The C and D

```
pointer registers
should be initialized to the word
containing the first pixel of the line; the C and D
modulo registers
should be set to the width of the bitplane in bytes.
```

The SRCA, SRCC, and DEST bits of BLTCON0 should be set to one, and the SRCB flag should be set to zero. The OVFLAG should be cleared. If only a single bit per horizontal row is desired, the ONEDOT bit of BLTCON1 should be set; otherwise it should be cleared.

The logic function remains. The C DMA channel represents the original source, the A channel the bit to set in the line, and the B channel the pattern to draw. Thus, to draw a line, the function

$$AB + \bar{A}$$

is the most common. To draw the line using exclusive-or mode, so it can be easily erased by drawing it again, the function

$$ABC + \bar{A}C$$

can be used.

We set the blit height to the length of the line, which is  $dx + 1$ . The width must be set to two for all line drawing. (Of course, the BLTSIZE register should not be written until the very end, when all other registers have been filled.)

@{ " Register Summary for Line Mode " link 6-13-1}

## 1.18 6 / Line Mode / Register Summary for Line Mode

Preliminary setup:

The line goes from  $(x1,y1)$  to  $(x2,y2)$ .

```
dx = max(abs(x2 - x1), abs(y2 - y1)) ;
dy = min(abs(x2 - x1), abs(y2 - y1)) ;
```

Register setup:

```
BLTADAT
= $8000

BLTBDAT
= line texture pattern ($FFFF for a solid line)

BLTAFWM
= $FFFF

BLTALWM
= $FFFF
```

```

BLTAMOD
= 4 * (dy - dx)

BLTBMOD
= 4 * dy

BLTCMOD
= width of the bitplane in bytes

BLTDMOD
= width of the bitplane in bytes

BLTAPT
= (4 * dy) - (2 * dx)

BLTBPT
= unused

BLTCPT
= word containing the first pixel of the line

BLTDPT
= word containing the first pixel of the line

BLTCON0 bits 15-12 = x1 modulo 15
BLTCON0 bits SRCA, SRCC, and SRCD = 1
BLTCON0 bit SRCB = 0
If exclusive-or line mode:
    then BLTCON0
    LF control byte
    = ABC + AC
    else BLTCON0
    LF control byte
    = AB + AC

BLTCON1 bit
    LINEMODE
    = 1

BLTCON1 bit
    OVFLAG
    = 0

BLTCON1 bits 4-2 =
    octant number
    from table

BLTCON1 bits 15-12 = start bit for line texture (0 = last significant
If ((4 * dy) - (2 * dx)) < 0):
    then BLTCON1 bit
    SIGNFLAG
    = 1
    else BLTCON1 bit
    SIGNFLAG
    = 0
If one pixel/row:
    then BLTCON1 bit
    ONEDOT

```

---

```

= 1
    else BLTCON1 bit
ONEDOT
= 0

```

```

BLTSIZE
bits 15-6 = dx + 1

```

```

BLTSIZE
bits 5-0 = 2

```

Warning:

-----

You must set the

```
BLTSIZE
```

```
register last as it starts the blit.
```

## 1.19 6 Blitter Hardware / Blitter Speed

The speed of the blitter depends entirely on which DMA channels are

enabled. You might be using a

```
DMA channel
```

```
as a constant, but unless it
```

is enabled, it does not count against you. The minimum blitter cycle is four ticks; the maximum is eight ticks. Use of the A register is always free. Use of the B register always adds two ticks to the blitter cycle. Use of either C or D is free, but use of both adds another two ticks.

Thus, a copy cycle, using A and D, takes four clock ticks per cycle; a copy cycle using B and D takes six ticks per cycle, and a generalized bit copy using B, C, and D takes eight ticks per cycle. When in

```
line mode
```

```
,
```

each pixel takes eight ticks.

The system clock speed for NTSC Amigas is 7.16 megahertz (PAL Amigas 7.09 megahertz). The clock for the blitter is the system clock. To calculate the total time for the blit in microseconds, excluding setup and DMA contention, you use the equation (for NTSC):

$$t = \frac{n * H * W}{7.16}$$

For PAL:

$$t = \frac{n * H * W}{7.09}$$

where t is the time in microseconds, n is the number of clocks per cycle, and H and W are the height and width (in words) of the blit, respectively.



For instance, to copy one bitplane of a 320 by 200 screen to another bitplane, we might choose to use the A and D channels. This would require four ticks per blitter cycle, for a total of

$$\frac{4 * 200 * 20}{7.16} = 2235 \text{ microseconds.}$$

These timings do not take into account blitter setup time, which is the time required to calculate and load the blitter registers and start the blit. They also ignore DMA contention.

## 1.20 6 Blitter Hardware / Blitter Operations and System DMA

The operations of the blitter affect the performance of the rest of the system. The following sections explain how system performance is affected by blitter direct memory access priority, DMA time slot allocation, bus sharing between the 680x0 and the display hardware, the operations of the blitter and Copper, and different playfield display sizes.

The blitter performs its various data-fetch, modify, and store operations through DMA sequences, and it shares memory access with other devices in the system. Each device that accesses memory has a priority level assigned to it, which indicates its importance relative to other devices.

Disk DMA, audio DMA, display DMA, and sprite DMA all have the highest priority level. Display DMA has priority over sprite DMA under certain circumstances. Each of these four devices is allocated a group of time slots during each horizontal scan of the video beam. If a device does not request one of its allocated time slots, the slot is open for other uses. These devices are given first priority because missed DMA cycles can cause lost data, noise in the sound output, or on-screen interruptions.

The Copper has the next priority because it has to perform its operations at the same time during each display frame to remain synchronized with the display beam sweeping across the screen.

The lowest priorities are assigned to the blitter and the 68000, in that order. The blitter is given the higher priority because it performs data copying, modifying, and line drawing operations much faster than the 68000.

During a horizontal scan line (about 63 microseconds), there are 227.5 "color clocks", or memory access cycles. A memory cycle is approximately 280 ns in duration. The total of 227.5 cycles per horizontal line includes both display time and non-display time. Of this total time, 226 cycles are available to be allocated to the various devices that need memory access.

The time-slot allocation per horizontal line is:

4 cycles for memory refresh  
3 cycles for disk DMA

- 4 cycles for audio DMA (2 bytes per channel)
- 16 cycles for sprite DMA (2 words per channel)
- 80 cycles for bitplane DMA (even- or odd-numbered slots according to the display size used)

Figure 6-9 shows one complete horizontal scan line and how the clock cycles are allocated.

Figure 6-9: DMA Time Slot Allocation

The 68000 uses only the even-numbered memory access cycles. The 68000 spends about half of a complete processor instruction time doing internal operations and the other half accessing memory. Therefore, the allocation of alternate memory cycles to the 68000 makes it appear to the 68000 that it has the memory all of the time, and it will run at full speed.

Some 68000 instructions do not match perfectly with the allocation of even cycles and cause cycles to be missed. If cycles are missed, the 68000 must wait until its next available memory slot before continuing. However, most instructions do not cause cycles to be missed, so the 68000 runs at full speed most of the time if there is no blitter DMA interference.

Figure 6-10 illustrates the normal cycle of the 68000.

Avoid the TAS instruction.

-----

The 68000 test-and-set instruction (TAS) should never be used in the Amiga; the indivisible read-modify-write cycle that is used only in this instruction will not fit into a DMA memory access slot.

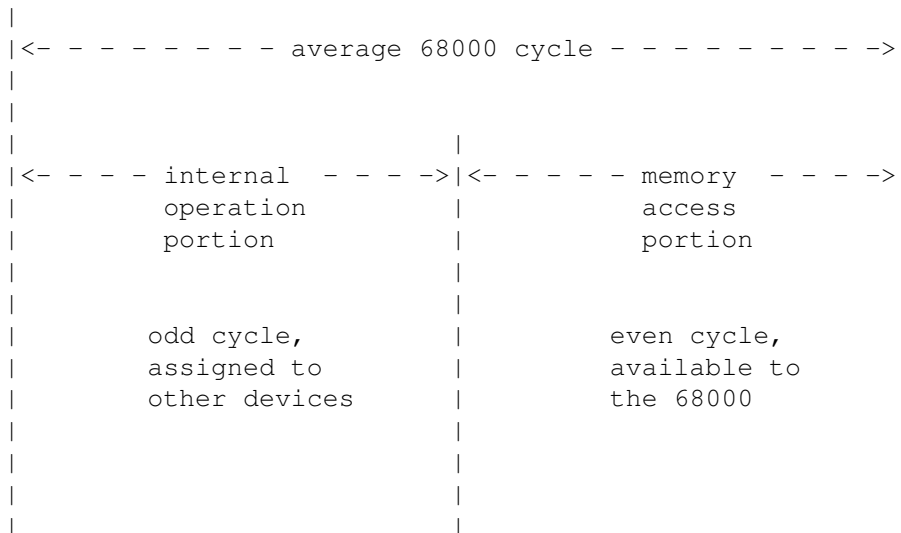


Figure 6-10: Normal 68000 Cycle

If the display contains four or fewer low resolution bitplanes, the 68000 can be granted alternate memory cycles (if it is ready to ask for the cycle and is the highest priority item at the time). However, if there are more than four bitplanes, bitplane DMA will begin to steal cycles from the 68000 during the display.

During the display time for a six bitplane display (low resolution, 320 pixels wide), 160 time slots will be taken by bitplane DMA for each horizontal line. As you can see from Figure 6-11, bitplane DMA steals 50 percent of the open slots that the processor might have used if there were only four bitplanes displayed.

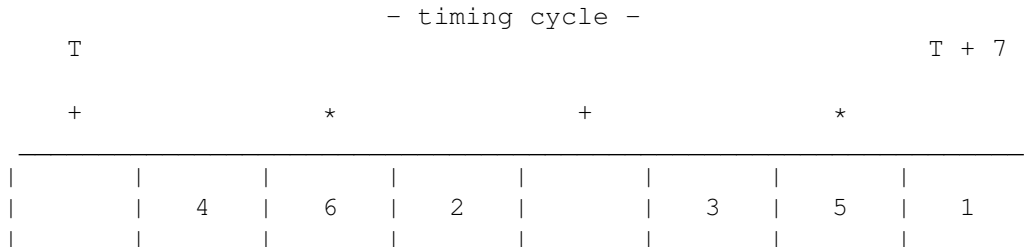


Figure 6-11: Time Slots Used by a Six Bitplane Display

If you specify four high resolution bitplanes (640 pixels wide), bitplane DMA needs all of the available memory time slots during the display time just to fetch the 40 data words for each line of the four bitplanes ( $40 * 4 = 160$  time slots). This effectively locks out the 68000 (as well as the blitter or Copper) from any memory access during the display, except during horizontal and vertical blanking.

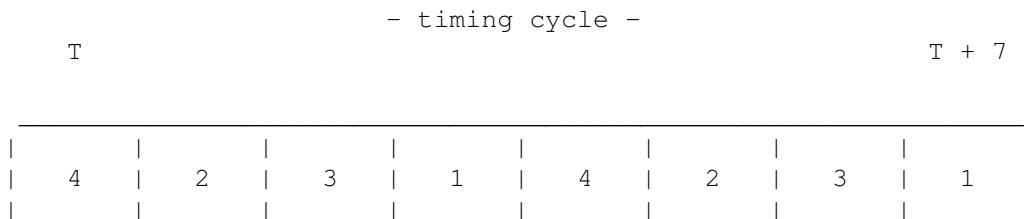


Figure 6-12: Time Slots Used by a High Resolution Display

Each horizontal line in a normal, full-sized display contains 320 pixels in low resolution mode or 640 pixels in high resolution mode. Thus, either 20 or 40 words will be fetched during the horizontal line display time. If you want to scroll a playfield, one extra data word per line must be fetched from the memory.

Display size is adjustable (see Chapter 3, "Playfield Hardware"), and bitplane DMA takes precedence over sprite DMA. As shown in Figure 6-9 larger displays may block out one or more of the highest-numbered sprites, especially with scrolling.

As mentioned above, the blitter normally has a higher priority than the processor for DMA cycles. There are certain cases, however, when the blitter and the 68000 can share memory cycles. If given the chance, the blitter would steal every available Chip memory cycle. Display, disk, and audio DMA take precedence over the blitter, so it cannot block them from bus access. Depending on the setting of the blitter DMA mode bit, commonly referred to as the "blitter-nasty" bit, the processor may be

blocked from bus access. This bit is called DMAF\_BLITHOG (bit 10) and is in register DMACON .

If DMAF\_BLITHOG is a 1, the blitter will keep the bus for every available Chip memory cycle. This could potentially be every cycle (ROM and Fast memory are not typically Chip memory cycles).

If DMAF\_BLITHOG is a 0, the DMA manager will monitor the 68000 cycle requests. If the 68000 is unsatisfied for three consecutive memory cycles, the blitter will release the bus for one cycle.

## 1.21 6 Blitter Hardware / Blitter Block Diagram

Figure 6-13 shows the basic building blocks for a single bit of a 16-bit wide operation of the blitter. It does not cover the line-drawing hardware.

Figure 6-13: Blitter Block Diagram

- \* The upper left corner shows how the first-- and last-- word masks are applied to the incoming A-source data. When the blit shrinks to one word wide, both masks are applied.
- \* The shifter (upper right and center left) drawing illustrates how 16 bits of data is taken from a specified position within a 32-bit register, based on the A shift or B shift values shown in BLTCON0 and BLTCON1 .
- \* The minterm generator (center right) illustrates how the minterm select bits either allow or inhibit the use of a specific minterm .
- \* The drawing shows how the fill operation works on the data generated by the minterm combinations. Fill operations can be performed simultaneously with other complex logic operations.
- \* At the bottom, the drawing shows that data generated for the destination can be prevented from being written to a destination by using one of the blitter control bits.

- \* Not shown on this diagram is the logic for zero detection, which looks at every bit generated for the destination. If there are any 1-bits generated, this logic indicates that the area of the blit contained at least one 1-bit (zero detect is false.)

## 1.22 6 Blitter Hardware / Blitter Key Points

This is a list of some key points that should be remembered when programming the blitter.

- \* Write `BLTSIZE` last; writing this register starts the blit.
- \* Modulos and pointers are in bytes; width is in words and height is in pixels. The least significant bit of all pointers and modulos is ignored.
- \* The order of operations in the blitter is
  - masking
  - ,
  - shifting
  - ,
  - logical combination of sources,
  - area fill
  - ,
  - and zero flag setting.
- \* In ascending mode, the blitter increments the pointers, adds the modulos, and
  - shifts to the right.
- \* In descending mode, the blitter decrements the pointers, subtracts the modulos, and shifts to the left.
- \* Area fill only works correctly in descending mode.
- \* Check `BLTDONE` before writing blitter registers or using the results of a blit.
- \* Shifts are done on immediate data as soon as it is loaded.

ECS blitter .

-----

For information relating to the blitter hardware in the Enhanced Chip Set, see Appendix C .

```
@{ " Example:  Clearmem " link ADCD_v1.2:Reference_Library/Hardware/Hard_examples/ ↵
clearmem.asm/MAIN}
@{ " Example:  Simpleline " link ADCD_v1.2:Reference_Library/Hardware/ ↵
Hard_examples/simpleline.asm/MAIN}
@{ " Example:  Rotatebits " link ADCD_v1.2:Reference_Library/Hardware/ ↵
Hard_examples/rotatebits.asm/MAIN}
```