THE MILL

TECHNICAL BRIEFING

THE MILL is an extension board for the Apple* containing the Motorola 6809 Processor Chip.

DOCUMENTATION ENCLOSED

With the extension board containing the 6809 chip you will receive this document , a MC6809 Preliminary Programming Manual, and the Motorola Semiconductors Advance Information data sheet on the MC6809E 8-Bit Microprocessing Unit. Extensive technical information is contained in the two accompanying manuals, which will tell you how to program your new board. HOWEVER, WHERE THIS DATA SHEET DIFFERS FROM THE MANUALS, IT TAKES PRECEDENCE. Follow the directions on this sheet in case of discrepancy.

YOUR PACKAGE CONTAINS

1) THE MILL, a single printed circuit board designed to plug in to any of your Apple II I/O slots.

2) The book "Assembly Language Programming" by Lance Leventhal. This contains a programmer's introduction to the 6809 and has explanations and examples of the advanced programming architecture provided by THE MILL.

3) The Motorola Data Sheet "Advance Information - MC6809E". This document explains the electrical and timing characteristics of the MC6809E, which is the processor variant used in THE MILL. Also explained here is the operation and significance of the AVMA and $\overline{\text{VMA}}$ states of the MC6809.

4) Your Warantee/User Registration Slip. This slip should be filled out and returned to STELLATION TWO. Upon receipt of this document you will be registered in the Millionaires User Group, which will be a clearing house for software developed by yourself and other Millionaires.

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STELLATION TWO

This document is a
PRELIMINARY RELEASE

STELLATION TWO, Box 2342, Santa Barbara, CA 93120 - phone (805) 966-1140

FUNCTIONS OF THE MILL

The Motorola 6809 processor resides in your Apple alongside the 6502 and does not interfere with the running of your familiar Applesoft or Apple Integer Basic programs AS LONG AS YOUR PROGRAM INSTRUCTIONS FOLLOW PRESCRIBED RULES ON THIS SHEET. Some 6809 instruction sequences which are recognized as legal by the 6809 processor will interfere with the 6502. If you are interested in Assembly Language Programming see the section SYSTEM TIMING CONSIDERATIONS. Otherwise you need not worry about this caveat.

While your 6502 is running its familiar programs, the 6809 can perform additional tasks at double the speed of the normal Apple, permitting you to use your Apple as a true multi-tasking multiprocessor. The 6809 has been selected as the heart of THE MILL for several very good reasons:

1) hardware similarity to the philosophy of the 6502. This allows the associated circuitry of THE MILL to be kept as simple and hence as reliable as possible.

2) 16 bit registers and operations. Since over half of the data manipulated by today's personal computers are 16 bit quantities (addresses and integers), it makes sense to have the capability to manipulate these quantities directly.

3) multiprogramming capability. The stacks, addressing modes, and position independence of code are just a few features of the 6809 designed for multiprogramming support. The inability to perform multiprogramming was one of the chief weaknesses of the 6502 with its fixed stack and special purpose 'page zero'.

4) superior addressing modes. Much of the time spent in any computation is involved with getting the data from storage into the internal registers rather than actual computing. This time can be shortened considerably using the 6809's data access modes.

BOTH the 6809 and the 6502 are able to work for the user, AT THE SAME INSTANT. This means that the 6809 can perform the actual computation and data manipulation while the 6502 SIMULTANEOUSLY is performing input-output functions. This exclusive feature of THE MILL opens new applications for the Apple II in the area of process control and monitoring.

Various alternatives for utilizing THE MILL are open to the user. One can simply run regular Apple software unchanged, and not use the 6809 at all. Next one can re-code appropriate sections of these programs, where fast performance would be optimal, into short critical subroutines in 6809 machine language. A third method is to use one of the standard operating systems such as FLEX which runs on the 6809.* The fourth way is to access the total power of THE MILL - Apple II combination with a true multiprogramming operating system such as Microware's OS9.*

Access to the 6809 is provided by calling up the monitor mode by whatever method is recommended by your Apple reference manual.

*FLEX is the trademark of Technical Systems Consultants, Inc, Box 2570 West Lafayette, In 47906 (317) 463-2502. OS-9 is the trademark of MicroWare Systems Corp, 5835 Grand Avenue, Des Moines, Iowa 50304, (515) 279-8844

INTERACTION OF THE 6809 WITH THE 6502

THE CONTROL REGISTER

The Control Register affects the operation of the 6809 and also the 6502. It may be read by reading up any of the sixteen locations in the Apples Device region. The address of the device region for a particular slot is (slot*16+$C080_{16}$ to slot*16+$C08F_{16}$).

For example, if THE MILL is in slot #3 the control register could be read by any location from C0B0 to C0BF. The bits in the control register are numbered from 7 to 0 (high bit is 7), and correspond to:

bit number	function
7	BA signal from 6809 will be low when running
6	BS signal (see MC6809 data sheet)
5	IRQ status into 6809 (interrupt)
4	FIRQ request to 6809 (interrupt)
3	NMI request to 6809 (interrupt)
2	ReSET request to 6809 (low to reset)
1	HALT request to 6809 (low to stop)
0	IRQ to 6502 (low to interrupt)

high

BS and BA are read-only. To change the status of the bits of the control register, write into the high bit of address device slot + bit number. This is shown in the table below, which assumes the slot number is 3.

bit number	address	set bit to write data	clear
0	C0B0	80_{16}	00
1	C0B1	80_{16}	00
2	C0B2	80_{16}	00
3	C0B3	80_{16}	00
4	C0B4	80_{16}	00
5	C0B5	80_{16}	00
6	C0B6	80_{16}	00
7	C0B7	80_{16}	00

A further explanation of Bits 6 and 7.

Bit 6 controls the ROM enable. When Bit 6 is reset the ROM is not used. When Bit 6 is set the ROM will be mapped into the 6809's address at $F000_{16}$ to $FFFF_{16}$ (2732's) or $F800_{16}$ to $FFFF_{16}$ (2716's). The ROM is able to be accessed only by the 6809. It cannot be read directly by the 6502. (2532's)

Bit 7 controls the address mapping for A15 as presented to the Apple and to the on-board ROM. When disabled this bit puts the 6809's reset vectors in the middle of the Apple's RAM (at Apple's 7FF0-7FFF).

When Bit 7 is enabled the address mapping feature is defeated, and 6809 addresses agree exactly with the Apple's addresses.

Figure 1 (Mode 1) results on system reset and when Bits 6 and 7 are both zero.

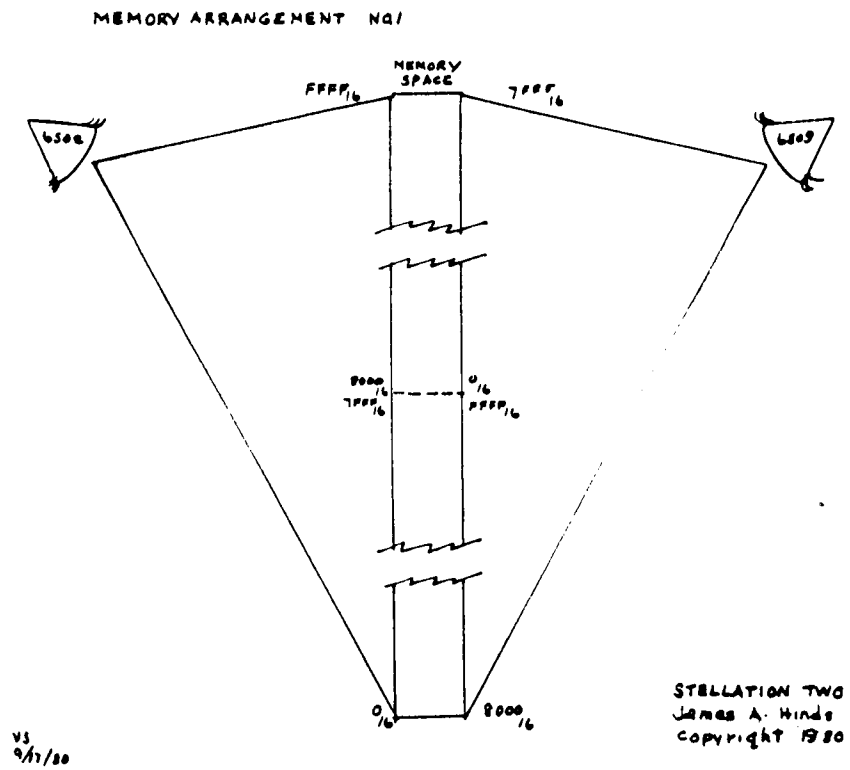
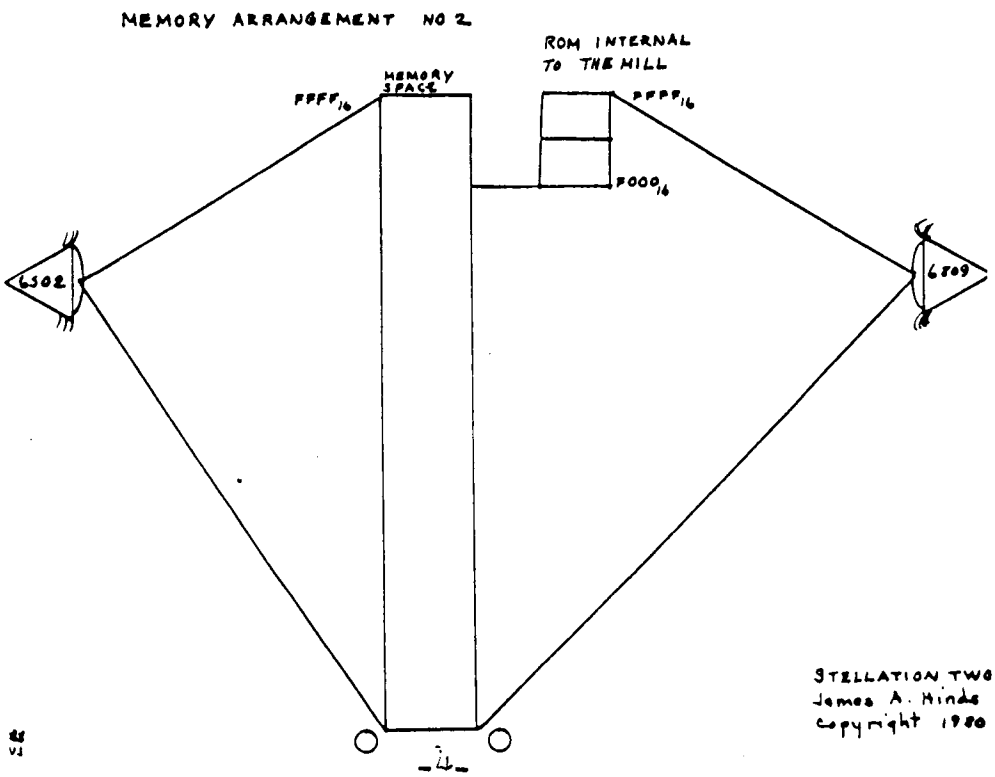


Figure 2 (Mode 2) results when both Bits 6 and 7 are on.



SYSTEM TIMING CONSIDERATIONS

The 6502 processor in your Apple needs to access the system at least once every 20 microseconds to refresh its internal registers. When the 6089 is running the 6502 gains access to the system during the "dead" cycles of the 6809. These are one micresecond long periods when the 6809 is busy doing internal processing and not accessing any of the Apple's resources.

On the average, these "dead" or $\overline{VMA}$ cycles occur about once in five microseconds. This will allow the 6502 to compute at about 20% of its normal speed. However, THERE ARE SOME INSTRUCTIONS WHICH PRODUCE NO $\overline{VMA}$ CYCLES. IF TOO MANY OF THESE OPERATIONS ARE PUT ONE AFTER ANOTHER, THE 6502 WILL LOSE ITS INTERNAL DATA. For this reason it is prudent to place a "transfer A to A" (TFR A,A -- 1 $F8_{16}$) instruction among those sequences which will not generate sufficient $\overline{VMA}$ cycles.
Fortunately, there are only a few of these sequences which would arise in normal programming. Those operations which are the culprits are the 8-bit inherent instructions and the 16 bit loads and stores when used with the no-offset indexing mode. When grouping a set of sensitive instructions, it is wise to throw in a few TFR A,A instructions for protection.

Fortunately, even the most time-critical 6809 code sequences would normally generate sufficient dead cycles to permit adequate access by the 6502. An example of protective coding is shown below:

Functional sequence:	Should be changed to:
ASLA	ASLA
ASLA	ASLA
ASLA	ASLA
ASLA	ASLA
ASLA	TFR A,A (generates 4 $\overline{VMA}$
ASLA	ASLA cycles)
ASLA	ASLA
	ASLA

KEYBOARD AND DISPLAY PROCESSING

Each of the two processors now resident in the Apple II runs independently, but on occasion may be accessing the same data structure. Performing simultaneous operations on the same data requires that each processor be locked out from access until certain functions are completed. Proper code sequences to assure this result are discussed in this section.

One effective way to use THE MILL is to have the 6809 do all the rapid internal processing and utilize the 6502 to handle the slower requirements of the keyboard input and display output. This section will demonstrate an imaginary higher level language program for this purpose. The equivalent Assembler language routines are on the following pages.

For keyboard input the 6502 will do the following:

```
6502 __Procedure Scankey;
          If Byte_at($C000) less than 128 then exit;  REM  no key
          If keyloc ≠ Ø
     A:      then exit;     REM wait until 6809 has read old key pressed
           keyloc:= Byte at($C000)# AND #$7F; REM convert to true ASCII
           read Byte_at($C01Ø);               REM to clear keyboard strobe
           END;
```

The 6809 would do the following:

```
6809__PROCEDURE readkey;ASCII;
  if NOT keyready
     then wait;
  readkey:=keyloc;
  keyloc:=Ø; REM this will allow 6502
                to proceed at point A
  END;
```

```
6809__PROCEDURE keyready: BOOLEAN;
     keyready:=(keyloc ≠ Ø);
     END;
```

For display output the 6809 would do the following:

```
6809__PROCEDURE display (character);

   C:   if tvloc≠Ø; then wait;
           tvloc := character;
        END;
```

The 6502 will do:

```
6502__PROCEDURE display;

     if tvloc = Ø; then exit;
     CALL monitor COUT with tvloc;
     tvloc:=Ø:  REM this would unlock the 6809 if it is waiting
                     at point C
     END;
```

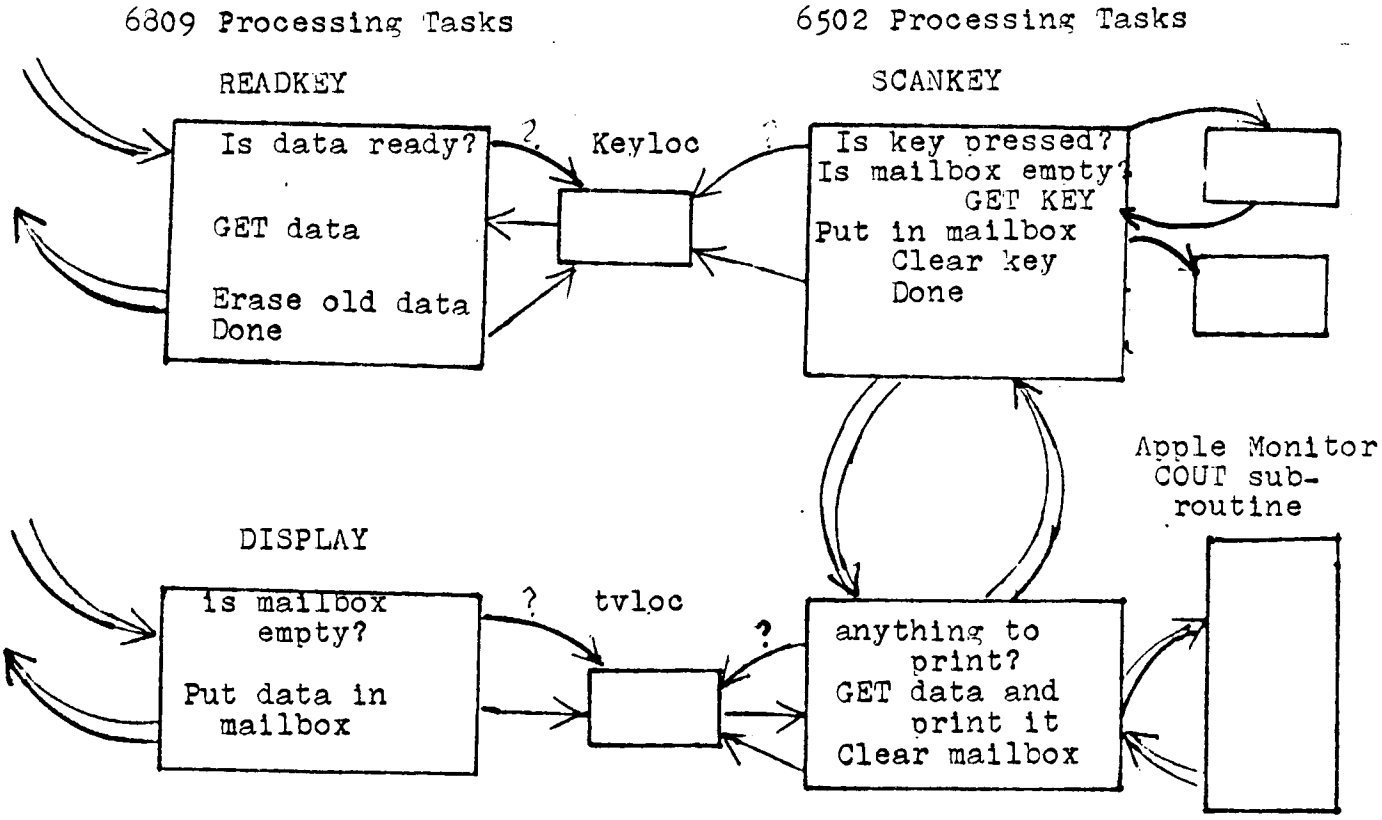
The main program for the 6502 is simply:

```
1: CALL display;
   CALL scankey;
   GOTO 1:
   END;
```

A block diagram for this coordinated effort is shown on the next page, followed by the assembly language versions.

We can think of the 68Ø9 and the 65Ø2 as separate people who talk only by sending mail to each other. The mail consists of letters of data (in this case one byte quantities), and the mailboxes are only able to hold one letter. (The locations keyloc and tvloc are one memory location each. The value zero is a convenient flag to indicate no letter is present.)

The 6809 is controlled by any manner of operating system and is a true general purpose computing facility; the 65Ø2 on the other hand is very limited in the present situation. It is only responsible for the control of the keyboard and display, and so can handle those tasks in the most efficient manner.



Block diagram - Keyboard and Display Interaction

ASSEMBLY LANGUAGE ROUTINES

KEYBOARD AND DISPLAY CONTROL

6502 PROCESSOR

```
7C00-  A9 00     LDA  #$00     ;prepare to zero out and initialize
7C02-  8D A1 C0  STA  $C0A1    ;halt the 6809
7C05-  8D A2 C0  STA  $C0A2    ;reset the 6809
7C08-  8D A6 C0  STA  $C0A6    ;disable THE MILL's ROM-enable mapping
7C0B-  8D FE 7B  STA  $7BFE    ;set keyloc mailbox as empty
7C0E-  8D FF 7B  STA  $7BFF    ;set tvloc mailbox as empty
7C11-  A9 80     LDA  #$80     ;prepare to raise the control lines
7C13-  8D A3 C0  STA  $C0A3    ;raise 6809 IRQ (no interrupt)
7C16-  8D A4 C0  STA  $C0A4    ;raise 6809 FIRQ (no interrupt)
7C19-  8D A5 C0  STA  $C0A5    ;raise 6809 NMI  (no interrupt)
7C1C-  8D A1 C0  STA  $C0A1    ;start the 6809
7C1F-  8D A2 C0  STA  $C0A2    ;and allow to proceed out of reset mode
7C22-  AD 00 C0  LDA  $C000    ;PROCEDURE  scankey;
```

6502 ASSEMBLY ROUTINES CONT.

```
7025-  78          SEI
7026-  EA          NOP
7027-  10 27       BPL   $7C50    ;if byte_at ($c000) less than 128 then exit;
7029-  C9 82       CMP   #$82     ; if key pressed is control B then
702B-  F0 10       BEQ   $7C3D        ;GOTO BREAK to APPLE MONITOR
702D-  AE FE 7B    LDX   $7BFE    ;if keyloc ≠ 0 then
7030-  D0 1E       BNE   $7C50        ;EXIT
7032-  AE 10 C0    LDX   $C010    m ; clear keyboard strobe
7035-  29 7F       AND   #$7F     ;convert character in A to true ASCII
7037-  8D FE 7B    STA   $7BFE    ;store in keyloc
703A-  4C 50 7C    JMP   $7C50    ;EXIT
703D-  AE 10 C0    LDX   $C010      ;BREAK to APPLE monitor on operator
                                   ;press of CONTROL B
7040-  A9 00       LDA   #$00
7042-  8D A1 C0    STA   $C0A1      ;halt 6809 so we can poke safely around
                                   ;charred remains of possible program crash
7045-  8D A0 C0    STA   $C0A0    ; clear possible 6502 interrupt request
7048-  00          BRK              ;BREAK to APPLE II monitor
7049-  EA          NOP              ; no operation for BHK instruction
704A-  A9 80       LDA   #$80   ;we get here only if operator has done a
                                ; G (go) from APPLE monitor
704C-  8D A1 C0    STA   $C0A1      ;start up 6809 again
704F-  EA          NOP
                                   ;and fall into
7050-  AD FF 7B    LDA   $7BFF  ;PROCEDURE display;
7053-  F0 CD       BEQ   $7C22    ;IF tvloc is empty then exit;
7055-  C9 0A       CMP   #$0A     ;IF character to print is line feed
                                   ;we may ignore it on tv display
7057-  F0 0B       BEQ   $7C64
7059-  C9 60       CMP   #$60     ;is character in lowercase-if so convert to
705B-  90 02       BCC   $7C5F    ;if not then just print it                upper
705D-  29 5F       AND   #$5F     ;convert lower to upper case
705F-  09 80       ORA   #$80     ;set high order bit for normal text on APPLE
7061-  20 F0 FD    JSR   $FDF0    ;CALL MONITOR COUT1-(tv display subroutine)
7064-  A9 00       LDA   #$00     ;
                                  ;clear tvloc mailbox
7066-  8D FF 7B    STA   $7BFF
7069-  4C 22 7C    JMP   $7C22    ;EXIT
```

ASSEMBLY LANGUAGE ROUTINES - KEYBOARD AND DISPLAY CONTROL
6809 PROCESSOR

```
                        STTL    *** TERMINAL I/O ROUTINES ***
                *       NOTE THE HIGH ORDER ADDRESS BIT
                *       OF ALL 6809 ADDRESSES IS OPPOSITE
                *       OF THE CORRESPONDING APPLE (6502) ADDRESS
          FBFE  KEYLOC  EQU     $FBFE
          FBFF  TVLOC   EQU     $FBFF
FC70                    ORG     $FC70
                *
                * READKEY       INPUT CHAR TO A
                *
FC70 1E   00    IDLE    EXG     D,D         WASTE TIME
FC72 B6   FBFE  READKEY LDA     KEYLOC
FC75 27   F9            BEQ     IDLE        NO KEY HERE
FC77 7F   FBFE          CLR     KEYLOC      CLEAR OUT FOR NEXT BYTE
                * FALL INTO DISPLAY FOR ECHO
                *
                * DISPLAY     OUTPUT CHAR IN A
                *
FC7A 1E   00    IDLE1   EXG     D,D         WASTE TIME
FC7C 7D   FBFF  DISPLAY TST     TVLOC
FC7F 26   F9            BNE     IDLE1
FC81 B7   FBFF          STA     TVLOC       SEND TO APPLE
FC84 39                 RTS

0 ERROR(S) DETECTED

SYMBOL TABLE:

DISPLA FC7C   IDLE   FC70   IDLE1  FC7A   KEYLOC FBFE   READKE FC72
TVLOC  FBFF
```

ON BOARD PROMS

THE MILL circuit board contains a chip socket with electrical connections compatible with 2716 or 2732 type PROM chips.

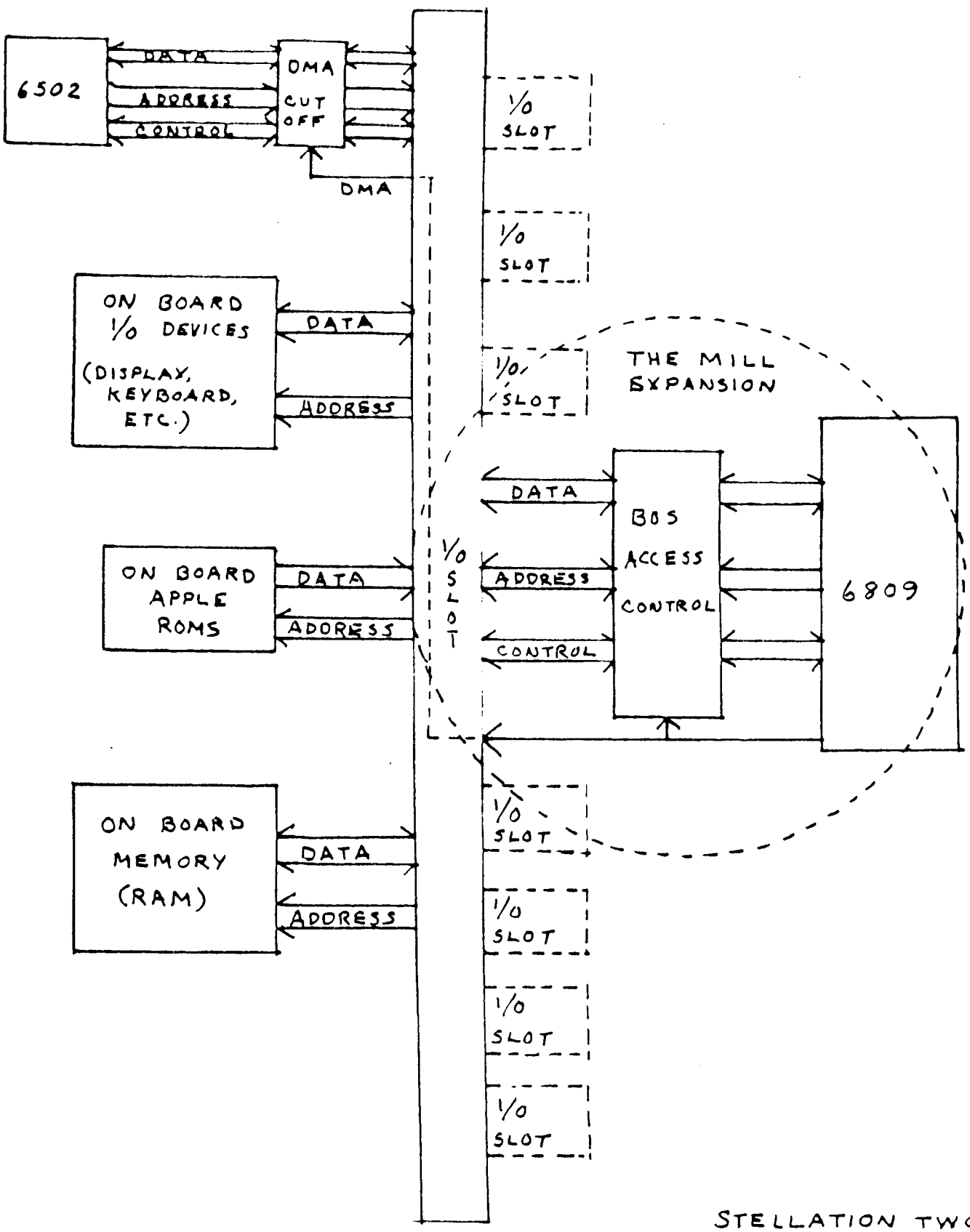
The location of this chip socket is shown on the circuit board diagram in the Appendix. It is chip part U11 on the right hand side of the board.

This PROM can be enabled under software control and is accessible only to the 6809 processor.

When inserting a 2732 or 2716 chip, be sure to follow the directional indication on the chip. The indentation is placed toward the top of the board.

APPENDIX

1. Logical Block Diagram
2. Schematic of THE MILL expansion board for the Apple II
3. Circuit board with chip locations
4. Parts List
5. Warranty



STELLATION TWO
James A. Hinds

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9/17/80

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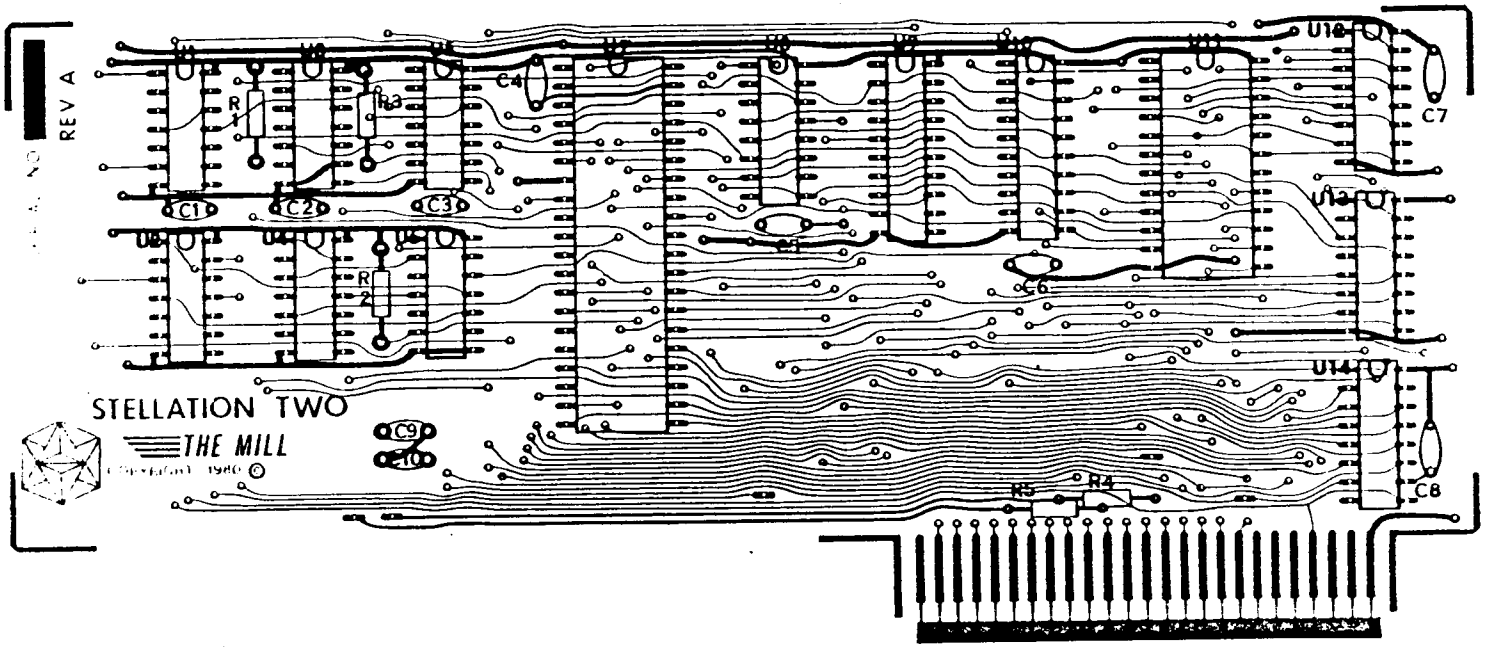
REVISIONS			
REV	DESCRIPTION	DATE	APPR



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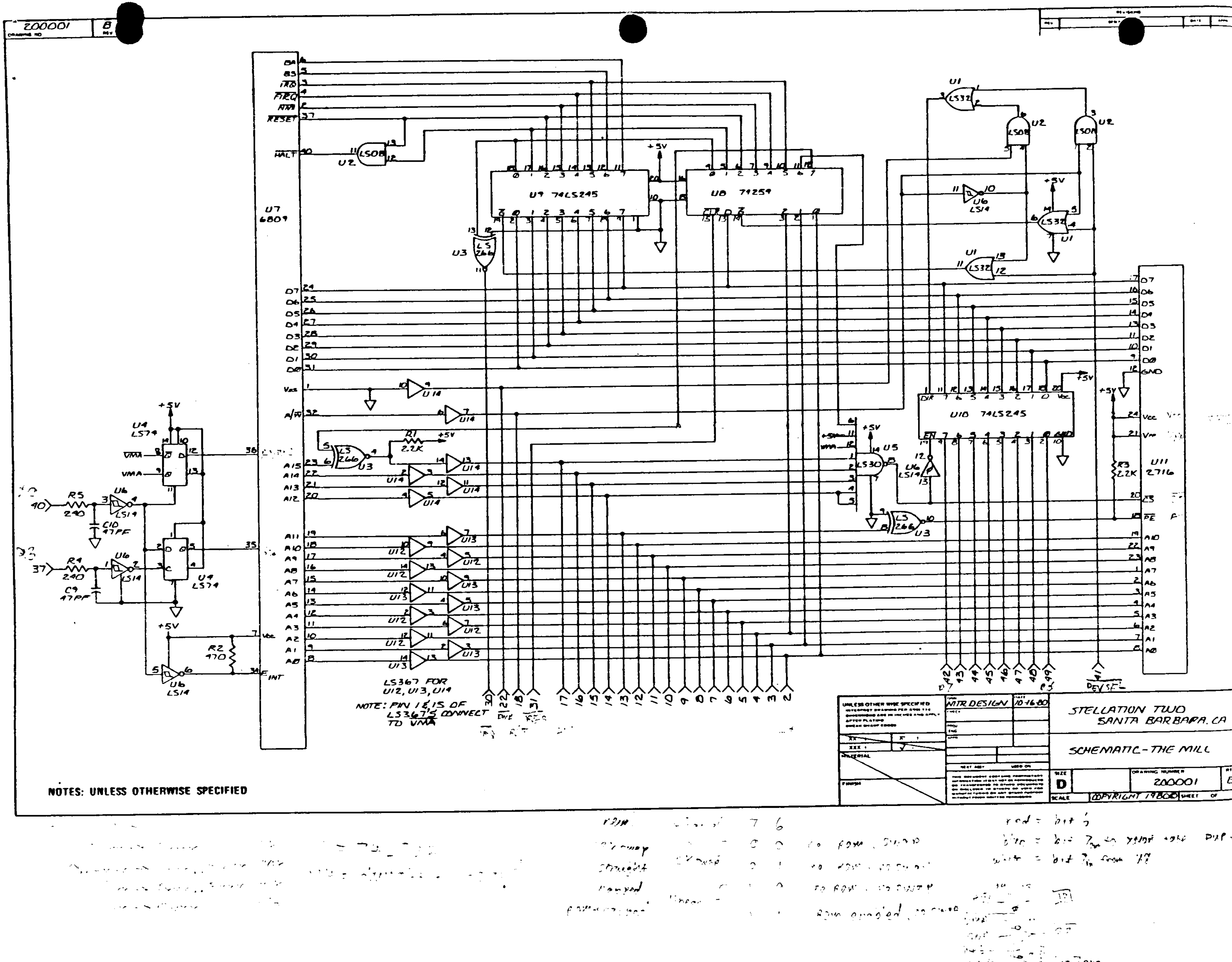

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B
U7
6809
U9 74LS245
U8 74259
U10 74LS245
U11
2716
LS367 FOR
U12, U13, U14
NOTE: PIN 1 & 15 OF
LS367'S CONNECT
TO VMA
NOTES: UNLESS OTHERWISE SPECIFIED
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TITLE ASSY-THE MILL

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PARTS LIST

PAGE __ OF __

ITEM NO.	QTY	PART NUMBER	DESCRIPTION	REF NO	MFG
1	1	6809	INTEGRATED CIRCUIT	U7	
2	1	2716		U11	
3	1	74LS14		~~U1~~	
4	1	74LS08		U2	
5	1	74LS74		~~U3~~	
6	1	74LS32		U4	
7	1	74LS30		U5	
8	1	74LS266		~~U6~~	
9	1	74LS259		U8	
10	2	74LS245		U9, U10	
11	3	74LS367		U12, U13, U4	
12					
13					
14					
15	8	Z5U-1	CAPACITOR	C1 THRU C8	
16					
17	2		RESISTOR-470 1/4 W	R1,	
18	3		RESISTOR-10K 1/4 W	R2, R3	
19				~~R4~~ REPEATED	
20				BY JUMPER	
21					
22					
23					
24					
25					
26					

REV	DATE	APPR	DCR	REV	DATE	APPR	DCR	REV	DATE	APPR	DCR	REV	DATE	APPR	DCR	REV	DATE	APPR	DCR	REV	DATE	APPR	DCR	DWG NO

STELLATION TWO'S ONE YEAR WARRANTY ON THE MILL:

Your Serial Number:_____

FOR INFORMATION AND ASSISTANCE:

If you ever have ANY problem with THE MILL, we urge you to seek help promptly, after first, of course, reading the instructions ! With our assistance, you may avoid all sorts of gremlins and glitches. It is barely possible that there might be a combination of peripheral and circuit boards which may be put in Apple slots with which THE MILL could conceivably not function. We will make every attempt to assist you in achieving a working system configuration, but we do not guarantee that THE MILL will work in any or all arbitrary combinations.

For assistance, write to STELLATION TWO,P.O.Box 2342, Santa Barbara, CA, 91320, or call (805) 966-1140. If you write, please enclose sample runs and explain as clearly as possible the conditions in which the problem occurred. Do this before sending back the card itself. Be sure to include a clearly printed return address.

If it is necessary to return THE MILL board, it must be returned, prepaid and fully insured, in the original packaging container or in a similarly-constructed container. Because of the increased percentage of losses occurring in the Postal Service, we recommend registering as well as insuring your package. If you do not receive an acknowledgment of its receipt within a reasonable time,start a tracer with the Post Office. Enclose a letter, explaining the problems, with your name and address, INSIDE the package.

THE MILL USERS'GROUP

THE MILL Users' Group is designed to give you continued assistance with your 6809 board and provide a forum of exchange of software applications on THE MILL. The Newsletter will be sent to you free of charge on a timely basis when you have returned your Warranty Registration.

WARRANTY

THE MILL was designed to give trouble-free service and it was built with care and skill. Nevertheless, we recognize the possibility that something in it may get out of order, and we offer the following warranty to you, as the original owner.

If THE MILL proves to be defective within one year of the original purchase date, we will repair or,at our option, replace it free of charge. The replacement unit will be warranted for the remainder of the original one-year period or 90 days, whichever is longer. We will make no charges for labor, service, and parts.

This warranty does not cover damage caused by accident, misuse, or tampering with the board. A charge will be made to repair such damage.

THERE ARE NO WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THOSE OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, WHICH EXTEND BEYOND THE DESCRIPTION AND DURATION SET FORTH HEREIN.

WARRANTY (CONTINUED)

STELLATION TWO'S SOLE OBLIGATION UNDER THIS WARRANTY IS LIMITED TO THE REPAIR OR REPLACEMENT OF A DEFECTIVE PRODUCT AND STELLATION TWO SHALL NOT, IN ANY EVENT, BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY KIND RESULTING FROM USE OR POSSESSION OF THIS PRODUCT. (Some states do not allow (1) limitations on how long an implied warranty lasts, or (2) the exclusion or limitation of incidental or consequential damages. Please check your local laws. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.)

PLEASE MAIL THIS SLIP IN THE ENCLOSED ADDRESSED POSTPAID ENVELOPE TO ACTIVATE YOUR WARRANTY AND REGISTER WITH THE MILL USERS GROUP:

- -

WARRANTY REGISTRATION

I have purchased THE MILL Serial #____________________

Name:____
First Middle Last

Address:____
Street Apt. #

____
City State ZIP

PLEASE PRINT PLAINLY

Your Comments Are Welcome!!!: