



16K7RA

User's Manual

16KRA

Dynamic Read/Write Memory Module

User's Manual

**Processor Technology
Corporation**

7100 Johnson Industrial Drive
Pleasanton, CA 94566
Telephone (415) 829-2600

**Copyright 1977, 1978, by Processor Technology Corporation
Fourth Printing, April, 1978
Manual Part No. 730003
All rights reserved.**

TABLE OF CONTENTS

SECTION		PAGE
1	INTRODUCTION AND GENERAL INFORMATION	
1.1	Introduction	1-1
1.2	General Information	1-1
1.2.1	16 KRA Memory Description	1-1
1.2.2	Receiving Inspection	1-1
1.2.3	Replacement Parts	1-1
1.2.4	Service.....	1-2
2	HANDLING PRECAUTIONS AND BOARD LAYOUT	
2.1	Handling Precautions	2-1
2.1.1	Installing and Removing the 16KRA	2-1
2.1.2	Handling MOS Integrated Circuits	2-1
2.1.3	Installing and Removing Integrated Circuits	2-1
2.1.4	Use of Clip Leads	2-1
2.2	Board Layout	2-2
2.2.1	Orientation	2-2
2.2.2	Layout.....	2-2
3	OPERATIONAL TEST	
3.1	16KRA Checkout Procedure.....	3-1
3.2	Pre-operational Check.....	3-1
3.3	Memory Test	3-1
4	OPTION SELECTION	
4.1	Option Selection.....	4-1
4.2	Waiting Time Option (Area A).....	4-1
4.3	Power-up Initialization Option (Area B).....	4-1
4.4	Memory Disable Option (Area C).....	4-1
4.5	DMA Option (Area D).....	4-1
4.6	Ready Line Option (Area E).....	4-2
4.7	Starting Address.....	4-2
5	THEORY OF OPERATION	
5.1	Overview.....	5-1
5.2	S-100 Bus Signals	5-2
5.3	Detailed Description	5-2
5.3.1	Page and Board Selection	5-2
5.3.2	Memory Array and Drivers.....	5-4
5.3.3	Cycles.....	5-4
5.3.4	Operations.....	5-7

SECTION	PAGE
5.4 Refresh	5-9
6 DRAWINGS	
16KRA Assembly Drawing	6-1
16KRA Schematic Diagram	6-2
16KRA Block Diagram	6-3
7 16KRA DIAGNOSTIC TEST	
7.1 Introduction	7-1
7.1.1 General	7-1
7.1.2 Data Path Test	7-1
7.1.3 Addressing Test	7-1
7.1.4 Exerciser	7-2
7.1.5 Numbered Test Selection	7-2
7.2 Introduction to Test Procedure	7-2
7.3 Preliminary Testing	7-2
7.4 The 16KDT Test	7-4
7.5 Overview	7-4
7.5.1 Board Select	7-5
7.5.2 MC	7-5
7.5.3 SR	7-7
7.5.4 RC	7-7
7.5.5 CY	7-7
7.5.6 WE	7-7
7.5.7 AR	7-7
7.5.8 CAE	7-7
7.5.9 CAS	7-7
7.5.10 RAS	7-7
7.5.11 Output Enable	7-7
7.6 Bus Crashes	7-7
7.7 The RAM Chip	7-8
7.7.1 Overview	7-8
7.7.2 Troubleshooting the RAM	7-9
7.8 The Write Request Flip Flop	7-11
7.9 Write Enable Operation - WE	7-11
7.10 Machine Cycle - MC	7-11
7.11 Cycle Flip Flop - CY	7-12
7.12 Synchronous Refresh - SR	7-12
7.13 The Allow Refresh Flip Flop - AR	7-12
7.14 Page Selection	7-13
7.14.1 Overview	7-13
7.14.2 Troubleshooting the Page Select Circuit	7-13

SECTION	PAGE
7.15 Ready Line.....	7-14
7.15.1 Queue Operation - QU.....	7-14
7.15.2 Troubleshooting the Ready Line.....	7-15
7.16 The Wait State Option.....	7-15
7.17 Refresh Cycle Flip Flop - RC.....	7-16
7.18 The Fresh Circuit	7-16
7.18.1 Overview.....	7-16
7.18.2 Troubleshooting Refresh.....	7-16

APPENDICES

1 IC Pin Configurations
2 Memory Test Program

TABLES

4-1 16KRA Starting Address Selection.....	4-3
5-1 Summary of S-100 Bus Signals and Their Use.....	5-3
7-1 Test Addresses.....	7-2
7-2 Resistance Measurements at RAM Pins.....	7-3
7-3 Bus Line-IC Pin Signal Checks	7-8
7-4 LS136 Pin Assignments.....	7-14
7-5 Counter Periods.....	7-16

FIGURES

2-1 Page and Bit Assignments in Memory Array	2-3
4-1 Page and Address Line Assignments for Address Selection Switches.....	4-3
7-1 Connector Jumpers	7-2
7-2 Address Switch Positions.....	7-4
7-3 16KRA Master Timing	7-6
7-4 RAM Chip Pin Assignments.....	7-10
7-5 RAM Address Signal Waveforms	7-10
7-6 Write Request (WR) Timing.....	7-11
7-7 Cycle (CY) Timing.....	7-12
7-8 MEMWRT Pulse Pattern.....	7-13
7-9 Refresh Page Selection Timing.....	7-18
7-10 RAM Address Line Timing During Refresh	7-19
7-11 RAM Refresh Timing - Page 3 and 4	7-20

SECTION 1

INTRODUCTION AND GENERAL INFORMATION

1.1 INTRODUCTION

This manual supplies the information needed to test and use the 16KRA Dynamic Read/Write Memory Module. So that you can use your module most effectively and safely, we suggest that you read the entire manual before attempting to use the 16KRA.

Should you encounter any problem in using the 16KRA, first consult the manual for a possible solution. If you are unable to find the solution, feel free to ask for our help.

1.2 GENERAL INFORMATION

1.2.1 16KRA Memory Description

The 16KRA Dynamic Read/Write Memory Module has a capacity of 16,384 eight bit words and operates in a dynamic mode. Periodic refreshing is done automatically by the module.

It is designed to operate in the Sol S-100 bus and a number of other 8080-based computers such as the Altair 8800 and IMSAI 8080. Lines interfacing to the S-100 bus are fully buffered, and extensive noise immunity circuitry is used.

The 16KRA features switch selectable address selection. It is organized into four "pages" of 4096 bytes each. Each page may be independently assigned to any of 16 starting addresses at 4096 byte intervals, starting with address 0000 (hexadecimal).

This module will operate in Sol and other 8080-based computers which have a 2 MHz $\phi 2$ rate without imposing wait states during normal operation. Access and cycle times are 400 and 520 nsec respectively.

The 16KRA Memory requires + 7.5 to + 10 V dc at 0.8 amp max., + 15 to + 18 V dc at .15 amp max., and -15 to -18 V dc at .02 amp max. An on-board battery connector is also included for connecting standby power to provide long term data retention during power loss.

The 16KRA board that you have received has several modifications made at the factory, shown on the schematic and assembly drawing in Section 6, and covered in the text. Five jumper wires have been added to the trace side of the board, all at ground potential, to improve ground return paths. Parts have been added which insure that the timing of the Spontaneous Refresh Timer is within existing specifications, eliminating possible harmless but unnecessary WAIT states.

1.2.2 Receiving Inspection

When your module arrives, examine the shipping container for signs of possible damage to the contents during transit. Then inspect the contents for damage. (We suggest you save the shipping materials for use in returning the module to your dealer, in case they need to ship it to the factory.) If your 16KRA is damaged, please contact the carrier immediately, and write us describing the condition of both the shipping container and its contents so that we can take appropriate action.

1.2.3 Replacement Parts

Order replacement parts by Processor Technology part number, component nomenclature (e.g., DM8131) and/or a complete description (e.g., 6.8 ohm, 1/2 watt, 5% resistor). Your dealer may have a limited selection of replacement parts on hand.

1.2.4 Service

Service on all Processor Technology equipment, in or out of warranty, is the responsibility of the selling dealer. If you have difficulty in making your system work, or have subsequent failures that you cannot service yourself, ask for your dealer's help.

SECTION 2

HANDLING PRECAUTIONS AND BOARD LAYOUT

2.1 HANDLING PRECAUTIONS ****IMPORTANT****

Though the 16KRA is already assembled and tested, you may have a future need to replace components and/or make measurements on the board. Integrated circuits (IC's) can be damaged by improper handling. Also, the module itself can be damaged by indiscriminate use of clip test leads as well as improperly installing it in, or removing it from, the computer.

It is important, therefore, that you carefully read and observe the following precautions before testing or using the 16KRA or replacing any IC.

2.1.1 Installing And Removing The 16KRA

To avoid any possible static electricity discharge damage to the MOS elements used on the 16KRA, always place one hand on the computer chassis before touching the module and use your other hand for the module. (Just remember to handle the module so that *no discharge* flows through it and you'll do fine.) This precaution holds true whether you are installing or removing the 16KRA.

NEVER install the 16KRA in, or remove it from, the computer with the power on. To do so can damage the module or the computer.

When installing the module, first make sure that you have it oriented correctly in relation to the bus pins. That is, be sure that pin 1 on the module edge connector mates with pin 1 of the bus connector. (If you install it reversed, you can damage the 16KRA or computer when power is turned on.) Slide module into card guides until its edge connector just enters the bus connector. Then push on module until it is fully seated in the bus connector.

2.1.2 Handling MOS Integrated Circuits

The memory IC's used on the 16KRA are MOS devices. They can be damaged by static electricity discharge. Always handle MOS IC's so that *no discharge* will flow *through* the IC. Also, avoid unnecessary handling and wear cotton—rather than synthetic—clothing when you do handle these IC's.

2.1.3 Installing And Removing Integrated Circuits

NEVER install or remove integrated circuits while power is applied to the 16KRA. To do so can damage the IC.

2.1.4 Use of Clip Leads

Clip leads attached to the ends of the module are apt to short to IC pins.

Always attach ground clips to the *lower* edge of the board near edge connector pin 50 which is located at the right end of the connector when the board is oriented as specified in Paragraph 2.2.1. (A terminal (wire) is attached to pin 50 to provide a convenient grounding point.)

NOTE

The heat sink bar is a poor ground since its finish is nonconducting.

2.2 BOARD LAYOUT

2.2.1 Orientation

With the component (front) side of the module facing up and the edge connector at the bottom, the heat sink bar will be near the top edge of the circuit board. Subsequent position references in the next paragraph assume this orientation. (See Assembly Drawing in Section 6, page 6-1.)

2.2.2 Layout

On the component side of the board, edge connector pin 1 is at the left end of the connector and pin 50 is at the right end. Pins 51 and 100 are at the left and right ends respectively on the solder (back) side.

In the upper left corner are the address (page) selection switches. (See Section 4 for the page and address line assignments for these switches.) Across the top half of the module is the memory array, two rows of 32 memory IC's separated in the middle by five drivers. Figure 2-1 shows the page and bit assignments for the memory IC's. The heat sink bar runs across the board between the two rows of memory IC's.

Moving down to the lower half of the board you see all of the control logic for the 16KRA. In the lower left corner is the battery backup power connector.

TOP OF BOARD

U1	Pg 1	Bit ∅	U2	Pg 2	Bit ∅	U3	Pg 1	Bit 1	U4	Pg 2	Bit 1	U5	Pg 1	Bit 2	U6	Pg 2	Bit 2	U7	Pg 1	Bit 3	U8	Pg 2	Bit 3	U9	Pg 1	Bit 4	U10	Pg 2	Bit 4	U11	Pg 1	Bit 4	U12	Pg 2	Bit 4	U13	Pg 1	Bit 5	U14	Pg 2	Bit 5	U15	Pg 1	Bit 6	U16	Pg 2	Bit 6	U17	Pg 1	Bit 7	U18	Pg 2	Bit 7	U19	Pg 3	Bit ∅	U20	Pg 4	Bit ∅	U21	Pg 3	Bit ∅	U22	Pg 4	Bit ∅	U23	Pg 3	Bit 1	U24	Pg 4	Bit 1	U25	Pg 3	Bit 2	U26	Pg 4	Bit 2	U27	Pg 3	Bit 3	U28	Pg 4	Bit 3	U29	Pg 3	Bit 4	U30	Pg 4	Bit 4	U31	Pg 3	Bit 5	U32	Pg 4	Bit 5	U33	Pg 3	Bit 6	U34	Pg 4	Bit 6	U35	Pg 3	Bit 7	U36	Pg 4	Bit 7	U37	Pg 3	Bit ∅	U38	Pg 4	Bit ∅	U39	Pg 3	Bit ∅	U40	Pg 4	Bit ∅
----	------	-------	----	------	-------	----	------	-------	----	------	-------	----	------	-------	----	------	-------	----	------	-------	----	------	-------	----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------	-----	------	-------

Figure 2-1. Page And Bit Assignments in Memory Array.

SECTION 3

OPERATIONAL TEST

3.1 16KRA CHECKOUT PROCEDURE

Your 16KRA Memory Module is fully inspected and tested before shipment to insure that it is operating correctly and that it meets specifications. It is then packaged for safe transit under normal shipping conditions. Your module should, therefore, arrive in your hands ready for use.

We nevertheless recommend that you precheck your 16KRA as outlined in the following paragraphs before using it.

3.2 PRE-OPERATIONAL CHECK

Before installing the module in your computer, visually inspect it for obvious physical damage. Also check that all integrated circuits (IC's) are fully seated in their sockets. If physical damage exists, follow the instructions given in Section 1, Paragraph 1.2.2. If your inspection reveals no problems, proceed with the memory test.

3.3 MEMORY TEST

Install the 16KRA in your computer and test it for proper operation. Test programs and instructions for testing the module are provided in Appendix 2.

CAUTION

**NEVER INSTALL OR REMOVE 16KRA WITH COMPUTER
POWER ON.**

SECTION 4

OPTION SELECTION

4.1 OPTION SELECTION

Jumper options that control five operating parameters are provided on the 16KRA Memory Module. They are: waiting time, power-up initialization, phantom memory disable, DMA waiting time, and ready line option. The starting address for each page is switch-selectable. Use the following option selection instructions in conjunction with the assembly drawing in Section 6.

NOTE

We recommend you use #24 bare wire for jumpers. Simply bend a small loop of wire and insert about 1/4 inch of wire into each Augat pin.

4.2 WAITING TIME OPTION (AREA A)

Since the 16KRA operates at maximum speed, you normally will not enable the waiting time option. To configure the 16KRA for *no waiting time*, install a jumper between the W and 0 pins in *Area A*.

For special applications, you may want to enable the waiting time option which provides one wait state that is 0.5 usec long. To *enable the wait state*, install a jumper between the W and 1 pins in *Area A*.

4.3 POWER-UP INITIALIZATION OPTION (AREA B)

The jumper arrangement in *Area B* determines whether the 16KRA will come up in the protected or unprotected mode when power is initially applied or restored after a power failure. In the protect mode a random operation cannot improperly rewrite retained data.

To select the *power-up protect mode*, install a jumper between the CLR and P pins in *Area B*.

To select the *power-up unprotect mode*, install a jumper between the CLR and U pins in *Area B*.

NOTE

If your computer does not use the PROT (protect) and UNPROT (unprotect) lines, PROT (S-100 Bus pin 70) must be connected to zero volts.

4.4 MEMORY DISABLE OPTION (AREA C)

Select the phantom option if the 16KRA will be used at address 0 in conjunction with a system which uses a phantom start-up procedure, such as the Processor Technology Sol, GPM, or ALS-8 Firmware Module. To enable this option, install a jumper between the two pins in *Area C*. With this jumper installed, the 16KRA will be disabled by the signal PHANTOM, supplied on S-100 pin 67.

If the 16KRA is not to be used at address 0, or is not to go in a system using phantom start-up, do not install the jumper.

4.5 DMA OPTION (AREA D)

The jumper arrangement in *Area D* determines when the refresh timer (Q1 and U63-8) is reset to zero. Two options are available.

The first, DN, is normally used. With this option selected, the refresh timer is reset to zero at every refresh cycle. A DMA device which sends no read request for 6 usec will encounter a wait state while refresh is done. With this option a DMA device must observe PRDY or be prepared to accept data errors if its requests are coincident with spontaneous refresh. To select this option, install a jumper between the D and DN pins in Area D.

If DR is enabled...

...the refresh timer is reset to zero after read and write cycles as well as after refresh cycles.

...a DMA device which sends a read or write request within 6 useconds will not encounter wait states.

...loss of refresh may occur on long DMA transfers that contain no read requests.

To enable this option, install a jumper between the D and DR pins in Area D.

DO NOT select this option unless it is absolutely necessary. If you do use this option, remember that REFRESH IS THE RESPONSIBILITY OF THE DMA DEVICE. Check with us before using the DR option.

4.6 READY LINE OPTION (AREA E)

The 16KRA requires a wait period under certain unusual circumstances. The wait period is generated when pin 23, Ready, of the 8080 microprocessor is pulled low. The Ready line is driven by S-100 bus signals XRDY (pin 3) and PRDY (pin 72). Different computers require the use of one of these two signals with their memory boards. Consult the manual for your computer to determine which to use. (The Sol Terminal Computer uses PRDY.)

To select PRDY, jumper pin C to pin P in Area E.

To select XRDY, jumper pin C to pin X in Area E.

NOTE

Revision D and E 16KRA circuit boards are wired for the PRDY option only. Connection to XRDY may be made by cutting a trace and soldering a jumper in place.

4.7 STARTING ADDRESS

Each of the four 4096 byte pages in the 16KRA can be independently addressed with the dual inline (DIP) switches located in the upper left corner of the module (board oriented as specified in Section 2). Page and address line assignments for these switches are shown in Figure 4-1.

You can assign the same starting address to two, three or all four pages on *one* 16KRA module with no ill effect.

In general, you may not assign any memory space to a 16KRA that is already assigned to another 16KRA module—or any other memory module—if they are to share the same bus simultaneously. To do so will cause the bus drivers to “fight” for possession of the bus which will result in improper operation or damage. (One exception to this general rule is if you enable the phantom memory disable option which allows the ALS-8 to share address zero with a 16KRA.)

To select the desired starting address for a page, set the four DIP switches associated with the page as shown in Table 4-1. (Only the indicated starting addresses are available. No intermediate addresses can be used.)

Table 4-1. 16KRA Starting Address Selection.

STARTING ADDRESS		DIP SWITCH SETTINGS			
Decimal	Hex	A15	A14	A13	A12
0	0000	X	X	X	X
4,096	1000	X	X	X	C
8,192	2000	X	X	C	X
12,288	3000	X	X	C	C
16,384	4000	X	C	X	X
20,480	5000	X	C	X	C
24,576	6000	X	C	C	X
28,672	7000	X	C	C	C
32,768	8000	C	X	X	X
36,864	9000	C	X	X	C
40,960	A000	C	X	C	X
45,056	B000	C	X	C	C
49,152	C000	C	C	X	X
53,248	D000	C	C	X	C
57,344	E000	C	C	C	X
61,440	F000	C	C	C	C

X = switch open, or OFF (in down position)
 C = switch closed, or ON (in up position)

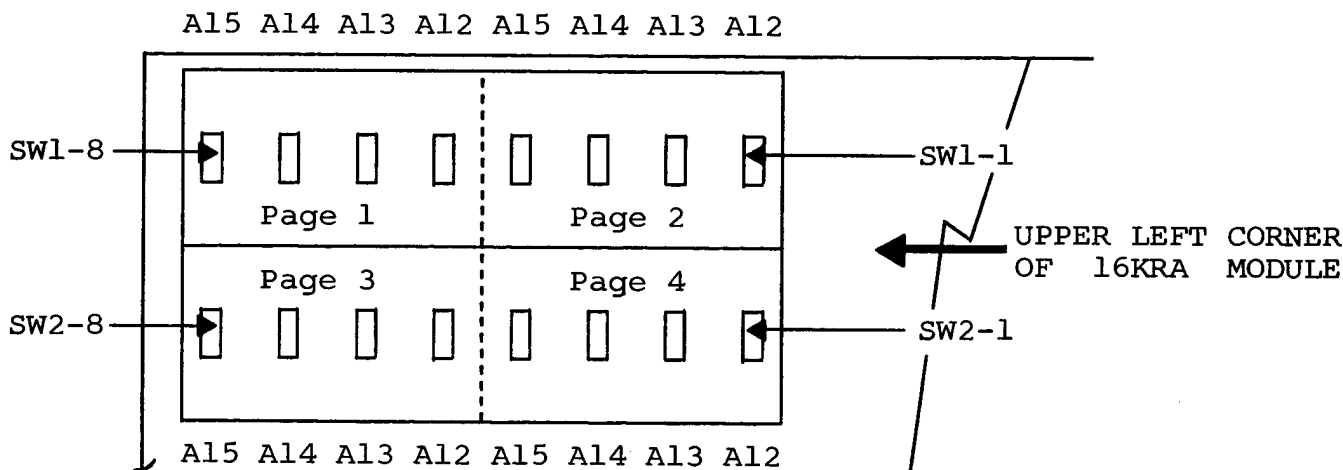


Figure 4-1. Page and Address Line Assignments for Address Selection Switches.

SECTION 5

THEORY OF OPERATION

5.1 OVERVIEW

Refer to 16KRA schematic in Section 6, page 6-2, and 16KRA Block Diagram, page 6-3.

In the 16KRA a cycle is a timed sequence of events that perform one memory access. There are six kinds of cycles—read, write, refresh, unselected, coincidence and null—and all are initiated by RC or MC. One or a group of cycles intended to accomplish a desired result is called an “operation.” A number of operation types are possible in the 16KRA, but there are four *intended* operations: read, ready write, unready write and spontaneous refresh. All other operations are variations of the intended operations and result from asynchronous coincidence between intended operations.

Since the memory IC's (2104) used in the 16KRA are dynamic memories in which the data cells operate by stored electrical charge, stored data must be read and restored periodically. Otherwise, current leakage would eventually change the stored data. The restoring process is called “refreshing” the memory, or simply “refresh.”

The 16KRA provides memory refresh as required without any external intervention. In most cases it is done without introducing any delay to the CPU or DMA device controlling the module.

Address lines A12-A15 are compared to four sets of four switches to select one or none of four 4K memory arrays called “pages.” Each page consists of eight 2104 memory IC's.

Address lines A0 thru A11 are applied to a four-input multiplexer (U65-U67) in two groups of six. These two groups are selected in succession to the memory address drivers (U10, U31, parts of U9, U29), which drive the memory address inputs.

Row Address Strobe (RAS) is applied to the eight memory IC's of the selected page. Its leading edge causes these eight IC's to store the first group of six address bits (A0-A5), called the row address, and start a memory cycle.

Subsequently, column address strobe (CAS) is applied to all of the memory IC's. It causes them to release their data outputs to the 3rd state (open circuited). Its leading edge causes those selected by RAS to store the second group (A6-A11), called the column address.

CAS samples Write Enable (WE) to determine whether this cycle is to write data into memory, or read data from memory.

The contents of the Data Out Bus (DO0-DO7) are applied to the Data In pins of the memory array by eight Memory Data drivers (U50, U51). One bit from the Data Out bus is applied to four memory IC's, one in each of the four pages.

In a memory write operation, CAS causes the selected eight memory IC's to store the data found on their Data In pins in an input latch. This data is subsequently stored at the location described by the row and column addresses.

In a memory read operation, the selected eight memory IC's receive data from the address indicated, send it to their output latches, and enable their output drivers.

Shortly after the end of RAS and CAS, the read data is latched into the output register (U52, U53), and sent to the Data In Bus (DI0-DI7) by the DI Bus Drivers (U68, U69) if these are enabled.

Addressing is summarized here:

A0 -A5	Selects Row inside memory chips
A6 -A11	Selects Column inside memory chips
A12-A15	Selects one (or none) of four pages and selects (or deselected) this board.

5.2 S-100 BUS SIGNALS

The host machine and 16KRA communicate with one another over the S-100 Bus. Table 5-1 identifies these signals and their source and defines their function.

NOTE

The 16KRA ignores all S-100 Bus signals except those listed in Table 5-1.

5.3 DETAILED DESCRIPTION

5.3.1 Page and Board Selection

Page and board selection depends on address bits A12-A15 and on four groups of four switches.

Each group of four switches describes one of 16 possible starting addresses. Each group of four switches corresponds to one page of eight memory IC's.

The contents of each group of four switches is compared to address bits A12-A15 by four open collector exclusive OR gates (U19, U20, U40, U41). If a match is found, the (wire AND'ed) output line common to that group of four is allowed to rise. These four lines are called match lines.

Table 5-1. Summary of S-100 Bus Signals And Their Use.

SIGNAL	SOURCE	FUNCTION
MEMWRT	Computer	Leading edge may initiate write operation.
PSYNC	Processor	Enables O2 trailing edge to request a Read cycle. PSYNC trailing edge samples SMEMR and SWO to govern refresh.
$\phi 2$	Computer	Trailing edge during SYNC or QU sets QU (deferred) if a cycle is in process, or clears QU and starts a read cycle if no cycle is in process. It also clocks wait binary.
DO0-7	Processor	Data source for write operation.
A0-11	Processor	Address source for memory array.
A12-15	Processor	Input source for page and board selection.
SINP	Processor	Inhibits board selection.
SOUT	Processor	Inhibits board selection.
SMEMR	Processor	Allows output data drivers to be enabled on read. Inhibits clocked refresh during write operation.
SWO	Processor	Inhibits spontaneous refresh during write operation.
PDBIN	Processor	Allows output drivers to be enabled on read.
PWR	Processor	When high at leading edge of MEMWRT, indicates a <i>front panel</i> write and requests a read so the front panel will display the new data.
PHANTOM (optional)	Computer	Inhibits board selection.
PROT	Computer	Write protects 16KRA if high and board is selected. (Wire it low if your machine doesn't provide it.)
UNPROT	Computer	Unprotects 16KRA if high and board is selected.
DI0-7	16KRA	Data delivered here after a read. <i>Drivers</i> are enabled by BOARD SELECT and PHANTOM and SMEMR and PDBIN.
PS	16KRA	Indicates selected board is write protected if low.
PRDY	16KRA	Indicates selected board is ready if high.
XRDY	16KRA	Alternate to PRDY.

Each match line corresponds to a page. A one (high) on any match line causes those of higher page number to be held at 0, thus only one page can be enabled (that with the lowest page number) even though more than one switch set may match A12-A15. This feature allows the 16KRA board to be used in systems where less than 16K is needed.

During memory cycles, the four match lines are selected by the multiplexer (U42) to drive the four PAGE lines. The PAGE lines select one or none of four RAS drivers. The PAGE lines are or'ed together in pairs to enable one or none of the two groups of six memory address drivers.

Only half of the address inputs of the memory array are driven at any one time. This is done to reduce peak current surges in the memory array.

A section of U60 forms the signal SINP+ SOUT. The four match lines are and'ed with this signal and OR'ed together onto one line by U43 and appear at U44-8 as BOARD SELECT. BOARD SELECT • PHANTOM enables the PS and PRDY drivers (U63-11).

U62-8 forms BOARD SELECT • SMEMR • PDBIN • PHANTOM which enables the DI Bus Drivers, sending the contents of the output register to the DI Bus only during read operations when this board is selected.

The binary WR is clocked by the leading edge of MEMWRT. A low at WR will result in a WRITE operation. WR can be clocked low only if this board is selected and not write protected. The gates at U70-3, U61-3 and U63-8 provide the necessary signal at the K input of the binary WR.

5.3.2 Memory Array and Drivers

The memory array consists of 32 2104 4K dynamic IC's arranged in four groups of eight. Each 2104 can store 4096 bits, and each group of eight stores 4096 bytes.

The 2104 is a 16 pin package. Four pins provide power (0V, + 5V, + 12V, -5V). One pin connects data in and another connects data out. Six pins carry address data (12 bits in two six bit samples). The remaining four pins control memory operation. RAS provides selection and timing, CAS provides timing, WE selects read or write, and CS (chip select) is wired to 0V (enabled) since selection is being done by RAS.

In the manufacturer's data some of these 12 signals are defined to be active low. (WE, CS, RAS, CAS). Others are defined active high, but all are arbitrary (six Addresses, Data In, Data Out).

In the 16KRA Module, all 12 signals at the memory pins are defined to be active low.

All memory inputs on the 16KRA Module are driven by special memory drivers (seven packages of 75365's). 2104's are nominally TTL compatible, but better noise margins are achieved by using external drivers.

5.3.3 Cycles

The timing of all six cycles (Read, Write, Refresh, Unselected, Coincidence and Null) is identical. Each consists of a nominal 370 nsec active period and a nominal 150 nsec recovery period.

Either of two signals, MC or RC, can initiate a cycle. RC describes a refresh cycle and MC describes a read or write cycle.

MC and RC are or'ed in U61, with the output on pin 8 being applied to U71. U71 is a delay line with outputs which reproduce MC+ RC delayed by 100 nsec (pin 14), 150 nsec (pin 4), 250 nsec (pin 12) and 350 nsec (pin 6). This is a passive delay line consisting of LC sections and TTL drivers built into the input and output lines.

These four delayed outputs are connected to a four-input nand gate (U57-6), the output of which is used to reset the binaries producing RC and MC. This reset will occur 350 nsec after the rise of RC or MC. RC+ MC will then fall, and 100 nsec later U57-6 will rise again, releasing the resets of RC and MC.

The above cycle contains passive delays totaling 450 usec, and propagation delays through logic stages totaling 50 nsec min., 70 nsec typical. RC or MC will be on for about 370 nsec and off for about 150 nsec, giving a cycle duration of about 520 nsec.

Each cycle is described by the signal CY which is set to 1 at two propagation delays after the rise of MC+ RC, and clocked to a 0 by the trailing (rising) edge of U57-6. Thus a cycle can be defined as the time during which CY is on.

MC+ RC causes RAS (row address strobe) at the selected page of memory IC's. The signal WE (write enable) determines whether an MC is a read or a write. It controls the WE inputs to all memory IC's. The signal QU describes a failed attempt to perform a memory cycle. Presence of QU requests that another attempt at a memory cycle be made, and causes an unready (low on PRDY) if this board is selected.

The signal CAE (column address enable) is clocked to a 1 by the 100 nanosecond delay tap, only if MC is high. Its presence causes the address multiplexer to present the second group of six address lines to the memory address drivers. It is reset to 0 by the removal of MC+ RC.

The signal CAS (column address strobe) is clocked to a 1 by the 150 nsec delay tap, unless RC and MC are both on. Its presence causes CAS to be applied to all memory IC's. It is reset to 0 by the same signal which resets MC and RC.

In summary, a cycle starts with MC or RC. RAS comes on and samples the row address. At 100 nsec the column address is presented. At 150 nsec CAS usually comes on, sampling the column address, write enable, and the input data (DO Bus) if a write. At 350 nsec RAS and CAS are removed, and output data may be clocked to the output register. At 520 nsec a new cycle may start.

Read Cycle

This normal cycle retrieves data from the indicated address. If SYNC or QU is present, the trailing edge of $\phi 2$ clocks MC to a 1 to start a cycle. RC remains at 0. RAS occurs at the selected page of memory, causing the row address to be saved, and starting a cycle within each of eight memory IC's. CY goes to 1.

After 100 nsec CAE is clocked to a 1. The column address is presented to the memory address drivers.

After 150 nsec, CAS is clocked to a 1. CAS occurs at all memory IC's, causing all to release their data output to the third state. Within the eight memory IC's selected by RAS, the column address is saved, and WE is sampled. This is a read cycle, so WE is high, and the input data is ignored. At some time before 350 nsec from the start, each of the eight selected chips will enable its output pin which will contain valid data.

After 350 nsec, reset occurs and both MC and CAS become 0. RAS is removed and CAE becomes 0. Output data is clocked to the output register and enabled to the DI Bus (if this board is selected, and SMEMR and DBIN are high).

After 520 nsec, CY goes to 0 and a new cycle may start.

Write Cycle

This normal cycle stores data at the indicated address.

The signal WE becomes a 1. This causes MC to become a 1 to start a new cycle. RAS occurs at the selected page of memory, causing the row address to be saved and starting a cycle within each of the eight selected memory IC's. CY becomes a 1. RC remains at 0.

After 100 nsec CAE is clocked to a 1. The column address is presented to the memory address drivers.

After 150 nsec CAS is clocked to a 1. CAS occurs at all memory IC's, causing all to release their data outputs to the third state. Within the eight memory IC's selected by RAS, the column address is saved, and WE is sampled. WE is found to be low. Sometime before 350 nsec, the input data will be stored at the indicated address. At some other time before 350 nsec, the selected eight memory IC's will enable their outputs, and present 1's there.

After 350 nsec, reset occurs. MC, CAS, and WE become 0. RAS is removed, CAE becomes 0. Output data (all 1's) is clocked to the output register, but not enabled to the DI Bus since SMEMR and PDBIN are low.

After 520 nsec CY becomes a 0 and a new cycle may start.

Refresh Cycle

This normal cycle refreshes the data in one row in the eight memory IC's of one page. Since there are 64 rows in each IC, and four pages on this board, a complete refresh will require 256 refresh cycles. The eight bit refresh counter (U49, U64) indicates one of these 256 states.

RC becomes a 1. The address multiplexer selects the high order six bits of the refresh counter as the source of address for the memory address drivers. The page multiplexer selects the four outputs of U58 as the source of

data for the page lines (instead of the match lines). U58 enables one of four lines selected by the two least significant bits of the refresh counter.

RAS occurs at the selected page of memory, causing the row address (from the refresh counter) to be saved, and starting a cycle within each of the eight selected memory IC's. CY becomes a 1.

After 100 nsec CAE is clocked, but does not go to 1 since MC is low. The address multiplexer continues to present the row address.

After 150 nsec, CAS is clocked to a 1. CAS occurs at all memory IC's, causing all to release their data outputs to the third state. The column address is saved and WE is sampled and found to be high. Input data is ignored. Before 350 nsec the data described (which is irrelevant) is presented at the outputs.

After 350 nsec, reset occurs. RC and CAS become 0. RAS is removed, CAE is already 0, so CAE is high, and the refresh counter counts 1. CAE, being high already, does not rise, so the output data is not clocked to the output register. The output data remains the same.

After 520 nsec, CY becomes 0, and a new cycle may start.

To the Memory IC's selected, this seems to be a normal read cycle. They are designed to refresh all data within a row each time that row is accessed by a RAS, regardless of the details of a cycle.

Unselected Cycle (CAS only cycle)

This normal cycle has no external purpose. It is the result of the method used to accomplish refresh.

If SYNC or QU is present, the trailing edge of $\phi 2$ clocks MC to 1 to start a cycle. RC remains at 0. The address does not represent any page on this board, so no page is selected, and BOARD SELECT is low.

Since no page is selected, no memory chips receive RAS, none start a cycle.

After 100 nsec CAE is clocked to a 1. The column address is presented to the address drivers.

After 150 nsec, CAS is clocked to 1 and CAS occurs at all memory IC's, causing all to release their data outputs to the third state. No memory IC's have been started by RAS, so no address storage and read occur. WE is high, but isn't used anyway.

After 350 nsec, reset occurs, MC and CAS become 0. CAE becomes 0. The output pins are third state and this indeterminate data is clocked to the output register destroying the previous data. The output does not get enabled to the DI Bus because this board is not selected.

After 520 nsec, CY goes to 0, and a new cycle may start.

Coincidence Cycle

This is an abnormal cycle which occurs when two asynchronous requests for memory occur at times such as to set both RC and MC to 1 at approximately the same time.

Normally RC and MC do not both occur in one cycle, since the presence of each is intended to prevent the other. Due to propagation delays, it is impossible to make them totally mutually exclusive, however, it is guaranteed that if both are to occur, the second will follow the first by only a few stage delays (typically less than 50 nsec). The COINCIDENCE CYCLE is an example of this.

RC or MC occurs. Before inhibition is complete the other of RC or MC occurs. Subsequent events in the cycle are timed by the first of the two. WE may be in either state.

RAS occurs at the selected page of memory, causing the row address to be saved and starting cycles in these eight memory IC's. Shortly after both RC and MC = 1, RC • MC becomes a 0. This signal forces QU to 1, indicating a failed attempt and a request for a new attempt. QU causes PRDY to go low since this board is selected.

After 100 nsec, CAE is clocked to a 1 and column address 0 is presented to the memory drivers.

After 150 nsec, CAS is clocked, but it does not go to 1 since its J input (MC • RC) is low. No CAS occurs. The memory IC's selected by RAS execute a RAS only cycle. This refreshes some row of memory and has no consequences external to the memory IC's. WE does not get sampled, and no memory chips change the state of their outputs.

After 350 nsec, reset occurs. MC, RC become 0. RAS is removed. Since CAE is low, the refresh counter does not advance. (Coincidence cycle is not counted as a good refresh.) CAE is reset to 0, clocking unknown data into the output register which is enabled to the DI Bus. (The processor or DMA device must observe the low on the PRDY line. This is bad data.)

After 520 nsec, CY goes to 0 and a new cycle may start. Note that if the coincidence cycle started at a $\phi 2$ trailing edge, then the next $\phi 2$ trailing edge has already occurred. In this case, QU remains set and the next subsequent $\phi 2$ trailing edge will start a new cycle. Thus a coincidence cycle may cause two consecutive wait states.

Null Cycle

The NULL Cycle is a coincidence cycle which is also an unselected cycle.

Both RC and MC occur at approximately the same time. The address does not represent any page on this board, so all four match lines, and BOARD SELECT are low. The row address chosen is the refresh address, so one page line (from the refresh counter via U58) is high. RAS occurs at the selected eight memory IC's, causing each to store the row address and start a memory cycle. Shortly after MC and RC become a 1, MC • RC becomes a 0, and sets QU to a 1, indicating a failed attempt and a request for a new attempt. QU does not cause PRDY to go low since this board is not selected. This is the difference between a NULL CYCLE and a COINCIDENCE CYCLE.

After 100 nsec, CAE is clocked to a 1. Column address 0 is presented to the memory drivers.

After 150 nsec, CAS is clocked, but it does not go to 0 since its J input (RC • MC) is low. No CAS occurs. The memory IC's selected by RAS execute a RAS only cycle. This refreshes some row of memory and has no consequences external to the memory IC's. WE does not get sampled, and no memory chips change the state of their outputs.

After 350 nsec, reset occurs. MC and RC become 0. RAS is removed. Since CAE is low, the refresh counter does not advance. (The NULL CYCLE is not counted as a good refresh.) CAE is reset to 0, clocking unknown data into the output register which is not enabled to the output bus since this board is not selected. (This bad data may appear on the DI Bus next time this board is selected, but it will be replaced by the requested data during that cycle.)

After 520 nsec, CY goes to 0 and a new cycle may start.

The QU caused by a NULL CYCLE remains only for the duration of SYNC. PRDY does not go low since this board is not selected.

5.3.4 Operations

An operation is a group of one or more cycles which achieves a desired result.

There are four intended operations. They are: READ, READY WRITE, UNREADY WRITE, and SPONTANEOUS REFRESH.

Many other operation types occur, but all are variations of these intended operations which arrive at their intended result by an abnormal sequence because of the occurrence of an abnormal cycle (COINCIDENCE or NULL CYCLE), or because of deselection from one of several sources.

Read Operation

SYNC occurs. It remains for 1 clock period, rising after a $\phi 2$ leading edge, and falling after the next $\phi 2$ leading edge. To the 16KRA module, SYNC is a request for an operation.

The $\phi 2$ trailing edge during SYNC clocks MC to a 1 to start a READ CYCLE.

Soon PDBIN and SMEMR become 1, defining this as a READ operation. About 400 nsec after the $\phi 2$ trailing edge, the data from memory appears on the DI Bus.

The trailing edge of SYNC clocks SR to a 1 since its J input (SMEMR) is high, requesting a RESET CYCLE.

At 500 usec or before, the next $\phi 2$ trailing edge finds SYNC removed and does not set MC. At 520 nsec, CY is reset, and the trailing edge of CY clocks RC to a 1, starting the requested RESET CYCLE. SR is reset to 0. At 1040 nsec the refresh cycle ends. CY is reset to 0, and the READ operation is complete.

Note that the READ operation accomplished the requested memory read, and also did one refresh. When controlled by an 8080 with a $\phi 2$ rate of 2 MHz, the refresh cycles which occur in read operations provide all the refresh required, and no wait states occur. Operation at $\phi 2$ rates greater than 3 cycles per 1040 nsec (2.88 MHz) will cause wait states to occur.

Ready Write Operation

READY WRITE is the normal operation for placing data in memory. It occurs with the processor or DMA device active (sending SYNCs).

SYNC occurs. It rises after a $\phi 2$ leading edge and falls after the next $\phi 2$ leading edge. To the 16KRA module, SYNC is a request for an operation. The $\phi 2$ trailing edge during SYNC clocks MC to a 1 to start a READ CYCLE. SMEMR and PDBIN do not rise; therefore the data read from memory appears in the output register, but not on the DI Bus.

At 520 nsec, CY will become 0, ending the read cycle.

At some time before or after 520 nsec, PWR will go low to cause MEMWRT to become a 1. If this board is selected, unprotected, and PHANTOM is a 1, the leading edge of MEMWRT will set WR to 0. MEMWRT must be present for about 50 nsec or longer to do this. This is because of the slow rise of the signal at the clock input of WR. It has been deliberately loaded with a capacitor (C48) to prevent write cycles from originating from noise spikes on MEMWRT.

WR • CY is applied to the clock input of WE. If no cycle is in progress, WE is clocked by the leading edge of WR. If the read cycle is still in progress when WR rises, WE is clocked by the trailing edge of the cycle. WE is clocked to a 1, and sets MC to a 1 to start a WRITE CYCLE.

At about 520 nsec after WE is clocked, CY becomes 0, ending the write cycle and the READY WRITE OPERATION.

The timing of PWR in the READY WRITE operation is likely to determine the maximum $\phi 2$ frequency which the 16KRA module can serve without causing wait states. If PWR comes early enough, this could be equal to the similar frequency limit for read operations (3 cycles per 1040 nsec, or 2.88 MHz). PWR will probably not come this early and the frequency limit for READY WRITE will probably be lower.

Note that at the trailing edge of SYNC, SR was clocked but remained a 0 since SMEMR was low. The trailing edge of CY clocks RC, but it remains a 0 since SR is 0. No refresh cycle occurs during the READY WRITE operation.

Unready Write Operation

The UNREADY WRITE operation is the normal sequence for storing data in memory from the front panel of an S100 microcomputer.

These machines provide a "RUN/STOP" switch. When STOP is used, the front panel sends an unready signal (typically XRDY low).

Memory write from the front panel is done by operating a "DEPOSIT" Switch which ultimately fires a deposit oneshot which pulses MEMWRT. Before and during this MEMWRT pulse, the 8080 is in WAIT, and *there are no SYNC pulses*.

If this board is selected, unprotected, and PHANTOM is a 1, the leading edge of MEMWRT will charge the capacitor at the clock input of WR, and if MEMWRT is long enough it will set WR to a 1.

WE will be clocked to a 1, setting MC and starting a WRITE CYCLE.

At the leading edge of MEMWRT, PWR is high since this MEMWRT is caused by DEPOSIT, and the processor is in WAIT. The leading edge of WR clocks SQ to a 1. This sets QU to a 1 to request a read cycle. PRDY goes low, but this doesn't matter since XRDY is already low.

At the first $\phi 2$ trailing edge after the WRITE CYCLE is complete, MC is clocked to 1 to start a READ CYCLE, and QU is clocked to 0, raising PRDY.

This read cycle places the data just stored on the DI Bus for display on the front panel.

Since there was no SYNC, no RC results.

Spontaneous Refresh Operation

At any time that there has been no RC for 6 usec, current thru R12 will have charged capacitor C46 to a voltage high enough to fire the Schmidt trigger, U62-6. This will set RC to a 1, starting a refresh cycle.

Presence of a 1 on RC causes Q1 to discharge C46 which resets the 6 usec timeout.

The SPONTANEOUS REFRESH operation consists of only 1 cycle, a refresh cycle.

Other Types of Operations

The four operations just described represent the four intended operations in their simplest forms. Each is subject to variations due to asynchronous coincidence with one of the others, and some have variations due to factors such as deselection by BOARD SELECT, PHANTOM and WRITE PROTECT. Detailed descriptions of these variations is beyond the scope of this manual.

5.4 REFRESH

Refresh is normally accomplished by the READ operation which slips a refresh cycle in after each memory read access. When the computer is running, executing normal 8080 code, read operations are attempted so often that no spontaneous refresh operations ever occur. This is true because all instruction fetches are read operations.

When no read operation has been requested for 6 usec, a spontaneous refresh will occur. This may happen during WAIT (front panel operation), HOLD, or HALT (or when the computer is off if this board is battery supported).

A spontaneous refresh will occur every 6 usec as long as normal operation is suspended.

When normal operation is resumed, a coincidence with a read or write request may occur, and this may result in one or two wait states as described above.

Direct Memory Access (DMA) is accomplished by a DMA controller which requests HOLD. The processor sends PHLDA when ready, and stops operation. The DMA device then disables the processor from the bus, enables itself to the bus, and usurps the role of the CPU. The usual object of this is to transfer a large block of data between some external device and memory.

In general, the 16KRA will operate satisfactorily with DMA devices which obey the normal 8080 conventions. Due to the large variety of possible DMA devices, we recommend that compatibility of any specific DMA device be verified.

Jumper option D (Area D) allows the choice of two options, DN (normal), and DR (Reset).

Normally option DN is used. The refresh 6 usec timer is reset to 0 at every refresh cycle. A DMA device which sends no read request for 6 usec will encounter a wait state while refresh is being done.

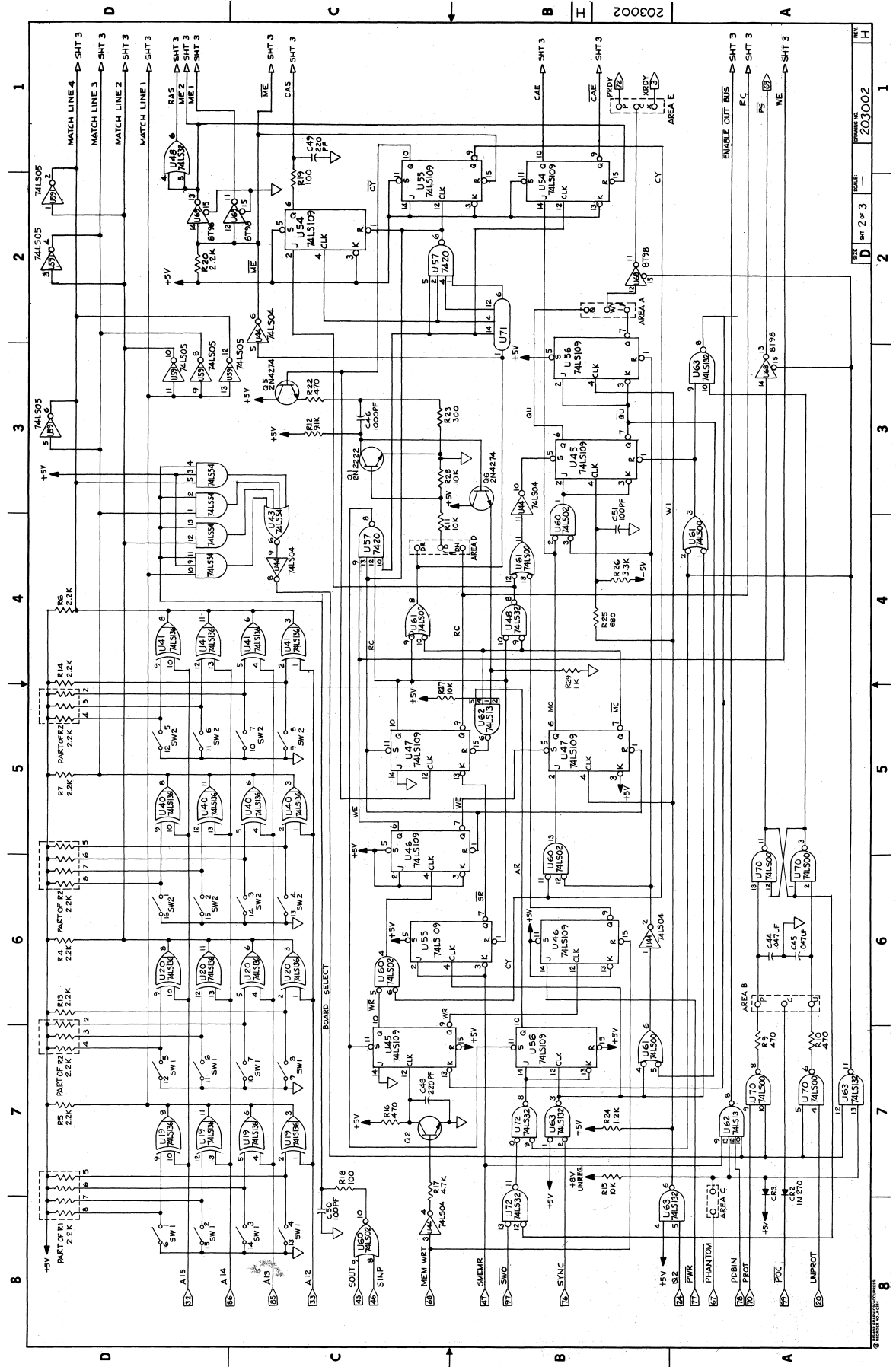
If option DR is used, the refresh timer is reset to 0 after refresh cycles, and also after read and write cycles. A DMA device which sends a read or write request every 6 usec will not encounter wait states.

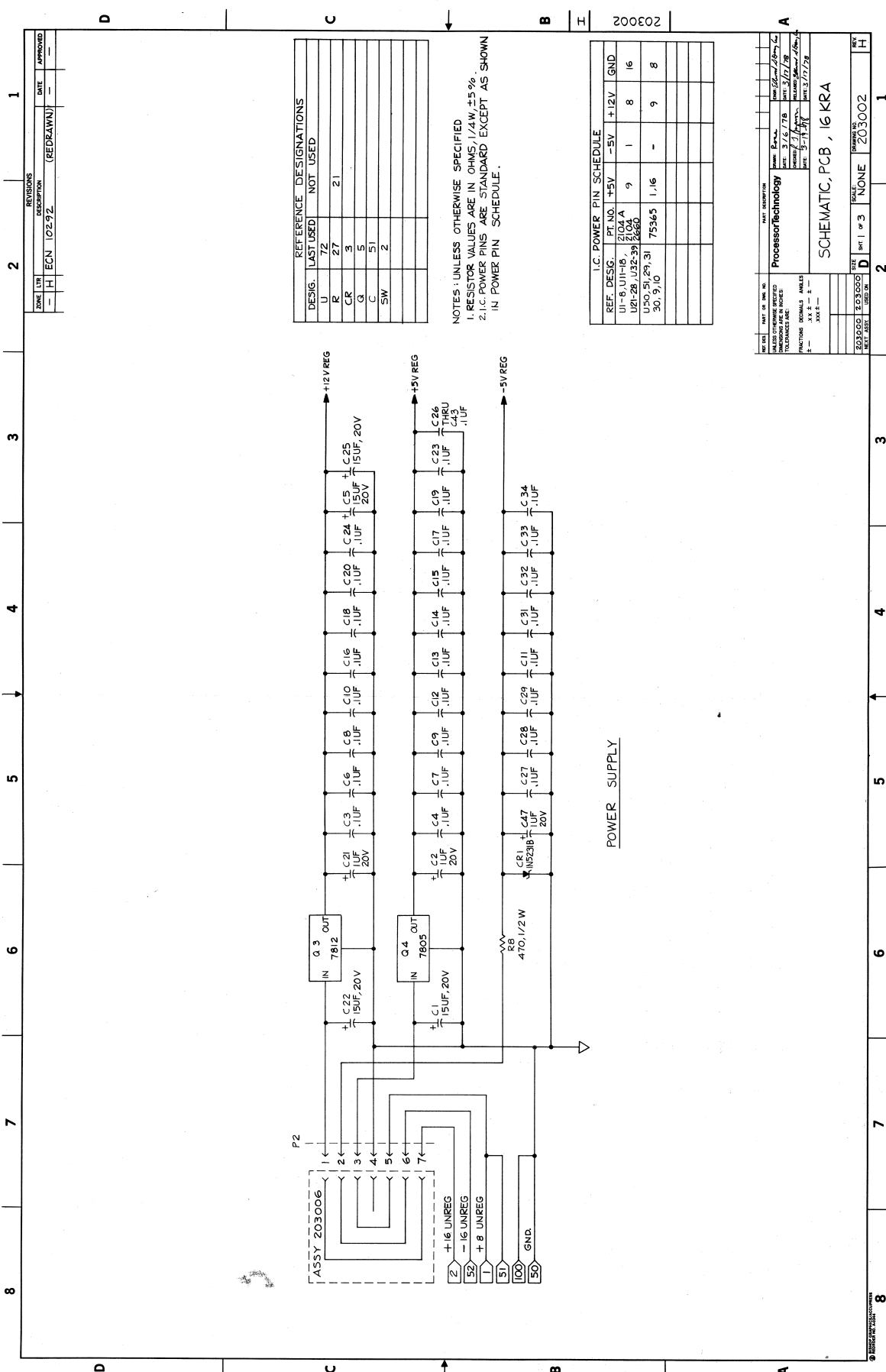
Loss of refresh may occur on long DMA transfers containing no read requests.

The DR option makes it possible to use write only DMA devices which will not tolerate a wait for refresh. Note that if DR is used, the DMA device or the program must assume responsibility for refresh.

SECTION 6

DRAWINGS





DESIG.	LAST USED	REFERENCE DESIGNATIONS	NOT USED
U	72		
R	27		21
CR	3		
G	5		
C	51		
SW	2		

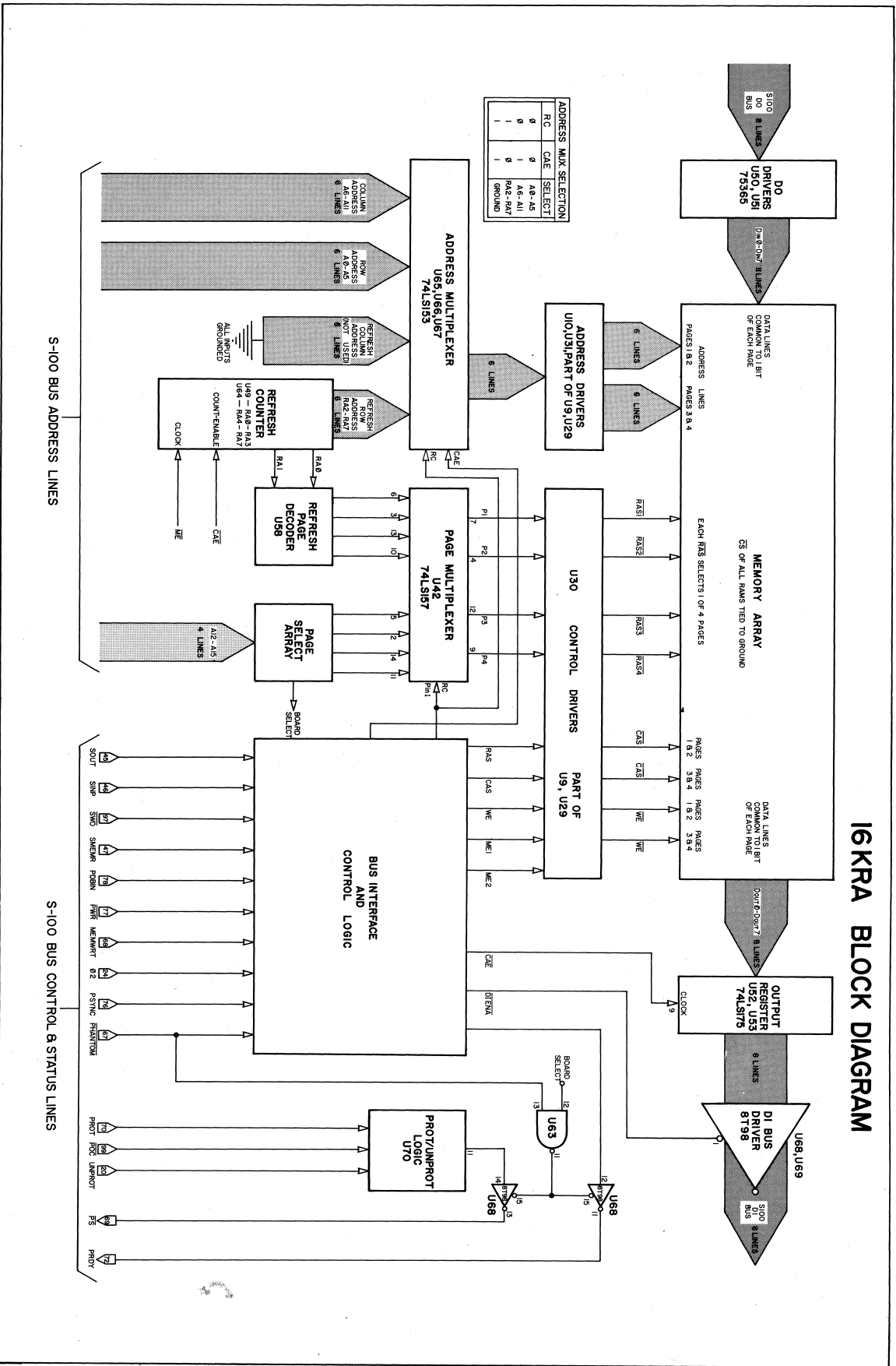
NOTES: UNLESS OTHERWISE SPECIFIED
 1. RESISTOR VALUES ARE IN OHMS, 1/4W, ±5%
 2. I.C. POWER PINS ARE STANDARD EXCEPT AS SHOWN
 IN POWER PIN SCHEDULE.

REF. DESIG.	PT. NO.	+5V	-5V	+12V	GND
U1	1				
U2	2				
U3	3				
U4	4				
U5	5				
U6	6				
U7	7				
U8	8				
U9	9				
U10	10				
U11	11				
U12	12				
U13	13				
U14	14				
U15	15				
U16	16				
U17	17				
U18	18				
U19	19				
U20	20				
U21	21				
U22	22				
U23	23				
U24	24				
U25	25				
U26	26				
U27	27				
U28	28				
U29	29				
U30	30				
U31	31				
U32	32				
U33	33				
U34	34				
U35	35				
U36	36				
U37	37				
U38	38				
U39	39				
U40	40				
U41	41				
U42	42				
U43	43				
U44	44				
U45	45				
U46	46				
U47	47				
U48	48				
U49	49				
U50	50				

REV. NO.	DATE	DESCRIPTION
1	3/16/78	INITIAL DESIGN
2	3/17/78	REVISIONS
3	3/17/78	REVISIONS
4	3/17/78	REVISIONS
5	3/17/78	REVISIONS
6	3/17/78	REVISIONS
7	3/17/78	REVISIONS
8	3/17/78	REVISIONS
9	3/17/78	REVISIONS
10	3/17/78	REVISIONS
11	3/17/78	REVISIONS
12	3/17/78	REVISIONS
13	3/17/78	REVISIONS
14	3/17/78	REVISIONS
15	3/17/78	REVISIONS
16	3/17/78	REVISIONS
17	3/17/78	REVISIONS
18	3/17/78	REVISIONS
19	3/17/78	REVISIONS
20	3/17/78	REVISIONS
21	3/17/78	REVISIONS
22	3/17/78	REVISIONS
23	3/17/78	REVISIONS
24	3/17/78	REVISIONS
25	3/17/78	REVISIONS
26	3/17/78	REVISIONS
27	3/17/78	REVISIONS
28	3/17/78	REVISIONS
29	3/17/78	REVISIONS
30	3/17/78	REVISIONS
31	3/17/78	REVISIONS
32	3/17/78	REVISIONS
33	3/17/78	REVISIONS
34	3/17/78	REVISIONS
35	3/17/78	REVISIONS
36	3/17/78	REVISIONS
37	3/17/78	REVISIONS
38	3/17/78	REVISIONS
39	3/17/78	REVISIONS
40	3/17/78	REVISIONS
41	3/17/78	REVISIONS
42	3/17/78	REVISIONS
43	3/17/78	REVISIONS
44	3/17/78	REVISIONS
45	3/17/78	REVISIONS
46	3/17/78	REVISIONS
47	3/17/78	REVISIONS
48	3/17/78	REVISIONS
49	3/17/78	REVISIONS
50	3/17/78	REVISIONS

REV. NO.	DATE	DESCRIPTION
1	3/16/78	INITIAL DESIGN
2	3/17/78	REVISIONS
3	3/17/78	REVISIONS
4	3/17/78	REVISIONS
5	3/17/78	REVISIONS
6	3/17/78	REVISIONS
7	3/17/78	REVISIONS
8	3/17/78	REVISIONS
9	3/17/78	REVISIONS
10	3/17/78	REVISIONS
11	3/17/78	REVISIONS
12	3/17/78	REVISIONS
13	3/17/78	REVISIONS
14	3/17/78	REVISIONS
15	3/17/78	REVISIONS
16	3/17/78	REVISIONS
17	3/17/78	REVISIONS
18	3/17/78	REVISIONS
19	3/17/78	REVISIONS
20	3/17/78	REVISIONS
21	3/17/78	REVISIONS
22	3/17/78	REVISIONS
23	3/17/78	REVISIONS
24	3/17/78	REVISIONS
25	3/17/78	REVISIONS
26	3/17/78	REVISIONS
27	3/17/78	REVISIONS
28	3/17/78	REVISIONS
29	3/17/78	REVISIONS
30	3/17/78	REVISIONS
31	3/17/78	REVISIONS
32	3/17/78	REVISIONS
33	3/17/78	REVISIONS
34	3/17/78	REVISIONS
35	3/17/78	REVISIONS
36	3/17/78	REVISIONS
37	3/17/78	REVISIONS
38	3/17/78	REVISIONS
39	3/17/78	REVISIONS
40	3/17/78	REVISIONS
41	3/17/78	REVISIONS
42	3/17/78	REVISIONS
43	3/17/78	REVISIONS
44	3/17/78	REVISIONS
45	3/17/78	REVISIONS
46	3/17/78	REVISIONS
47	3/17/78	REVISIONS
48	3/17/78	REVISIONS
49	3/17/78	REVISIONS
50	3/17/78	REVISIONS

16KRA BLOCK DIAGRAM



ADDRESS MUX SELECTION

RC	CAE	SELECT
0	1	A0-A5
0	1	A6-A7
1	0	RA2-RA7
1	1	GROUND

SECTION 7

DIAGNOSTIC TEST

7.1 INTRODUCTION

7.1.1 General

The 16KRA Diagnostic Test (16KDT) checks a 16KRA Dynamic Read/Write Memory Module (16KRA) addressed at 4000 hexadecimal (hex) as a 16K continuous block. It contains four different tests which are described in this section (7.1). The rest of Section 7 contains the trouble-shooting procedures using these tests and additional theory of operation.

The four tests are contained on a CUTS format cassette tape which has been supplied to all Processor Technology dealers. These tests are not copyrighted and may be duplicated by 16KRA owners at the store which originally sold the board.

7.1.2 Data Path Test

The Data Path Test checks the logic which carries data through the board. To accomplish this it writes and reads back a "marching" pattern at one address only. This address is normally 4000 Hex, but any address may be specified by entering the desired address, a space, and an asterisk at the appropriate point in the test. (Example: 4567 * <CR>) This will run the Data Path Test at address 4567 Hex. The display shows three columns of eight-bit words. Each word in the display represents the contents of the byte at the specified address.

The left column shows a sequence of sixteen words which were written during the brief period of the test. The first word at the top shows all zeros, the second word from the top contains all zeros except the right-most bit. The third word contains all zeros except the two right-most bits. Going down the column in this manner, the ninth word has all ones. Then zeros start appearing at the right end of the word, one bit per word. Finally, the last word at the bottom contains all zeros. Thus, eight ones have "marched" across the column, representing the flow of ones through the byte at address 4000 Hex or the specified address.

The middle column shows the words which were read back. If the 16KRA is working properly, the words read back are identical to the words being written. The right column on the display marks with an "X" those bits which are not identical. Identical bits are indicated by a "-".

7.1.3 Addressing Test

The Addressing Test checks for non-functional address lines, using the results of the Data Path Test. Since it relies on these results, it may only be run immediately following the Data Path Test. The test first writes ones in all working bits at location 4000 Hex, then writes zeros to the first address given in Table 7-1. Each of the addresses in Table 7-1 differs from address 4000 Hex in only one address bit. If the address line which controls this bit is bad, then location 4000 Hex will be written to instead of the specified address. By checking to see if any working bit at address 4000 Hex has changed to zero, the test identifies non-functional address lines. By writing to all the addresses in Table 7-1, all address lines are checked. The display indicates which address lines are bad when the test is complete.

Table 7-1. Test Addresses

ADDRESS LINE	ADDRESS (HEX)	ADDRESS LINE	ADDRESS (HEX)
A0.....	4001H	A7	4080H
A1.....	4002H	A8	4100H
A2.....	4004H	A9	4200H
A3.....	4008H	A10.....	4200H
A4.....	4010H	A11.....	4800H
A5.....	4020H	A12.....	5000H
A6.....	4040H	A13.....	6000H

The Addressing Test is designed to find address lines which are shorted or open before they reach the RAM drivers, and to find bad drivers or bad address multiplexers. Shorts in the address lines occurring after the RAM drivers will not usually be detected by the test, for the following reason. When two address lines are shorted, and one of the lines is low, the low line will usually pull the other line low also. The test addresses used by the Addressing Test, after inversion by the RAM address drivers, consist of one low bit in a field of high bits. If a short occurs between two address lines at this point, both lines will go low, generating an address other than 4000 Hex, so that no bits at that address are changed.

7.1.4 Exerciser

The Exerciser program writes and reads a specified byte of data at a specified address. At the time when the Exerciser program appears, there is an option to run the Data Path Test at a specified address.

7.1.5 Numbered Test Selection

This feature allows selection of any of the tests after the Exerciser has been run.

7.2 INTRODUCTION TO TEST PROCEDURE

This test procedure is designed for use with a Sol system. It is dependent upon the 16KDT diagnostic test cassette. Also, a dual-trace scope with a delayed sweep will be necessary.

7.3 PRELIMINARY TESTING

Before the board is plugged into the S-100 bus it is necessary to check for power supply shorts. Use an ohmmeter that is set to a scale which will show 100 ohms clearly. Position the board with the ICs up and the S-100 bus towards you. In the lower left corner is a brown connector plug with 3 jumper wires on it. (See Figure 7-1.)

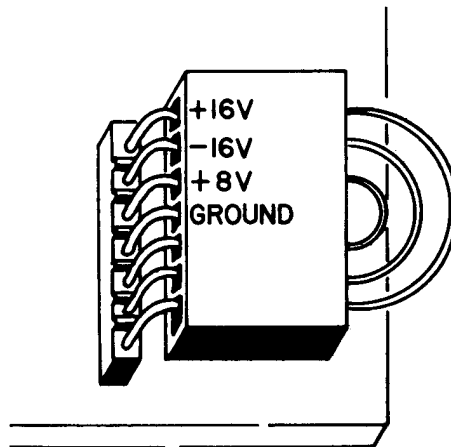


Figure 7-1. Connector Jumpers

Connect the negative probe of the ohmmeter to the center pin (GND). Be sure the voltage at the ohmmeter probes is the same as the marked polarity. To check this, use a common diode of any type. The ohmmeter will show a low resistance when the negative lead is connected to the end of the diode with the dark band near it. Frequently, ohmmeters will have the polarity reversed so it is important to check.

With the negative probe connected to the center, ground pin, touch the positive probe to the right three pins, one at a time. All of the readings should be greater than 100 ohms. Next measure between the +8V and -16V, the +8V and the +16V, and finally between the -16V and +16V. The polarity of the probes is not important for the last three measurements. If any of the readings were less than 100 ohms, the board should not be plugged into the S-100 bus until the cause is determined and corrected.

This preceding procedure will show any shorts before the voltage regulators, such as shorted capacitors, shorted regulators, or shorts between traces (usually solder bridges). It is also necessary to check for shorts on the regulated side of the voltage regulators. This can be done by measuring at the pins of any RAM chip. Table 7-2 lists the required resistance readings. "Positive Probe" in the table means the probe supplying positive voltage.

Table 7-2. Resistance Measurements at RAM Pins

Positive Probe	Negative Probe	Approximate Resistance
pin 16	pin 9	8 ohms
pin 16	pin 8	13
pin 16	pin 1	500
pin 1	pin 16	8
pin 8	pin 16	100
pin 9	pin 16	30
pin 9	pin 8	150
pin 8	pin 9	75

If any of the preceding readings are much lower than indicated in Table 7-2, it can be assumed that a problem exists on the board. At this point, a check should be made to see that all IC types correspond to the 16KRA Assembly Drawing (page 6-1) and that pin 1 of each IC is in the indicated position.

Also inspect the back of the board to see if any blobs of solder bridge two adjacent pins or traces. These can be removed with a soldering iron. If any shorts cannot be visually located, it will be necessary to use a DVM with a low ohms scale to find the short.

If the preliminary resistance checks are found acceptable, the board is ready to be plugged into a S-100 bus connector. Insert the board with the power off and connect a voltmeter between ground (pin 16) and +5V (pin 9) on any RAM chip. Turn on the power and immediately read the voltage. If it is not 4.75 to 5.25V turn off the power immediately. Repeat the procedure with pin 8 (+12V) and pin 1 (-5V). If these voltages are not within 1/2 volt of the nominal value, remove the board from the system until the cause is determined. If these voltages check OK, leave the power on but check for overheating of the regulators. They should not be too hot to touch. Check if any individual ICs are hot to the touch. If any are found, they can be presumed defective.

Now, look at the screen of the video display. Do the cursor and prompt look right? If so, proceed to the next section. If any other characters have appeared, the board has "crashed the bus", or interfered with the operation of the rest of the system.

7.4 THE 16KDT TEST

If the cursor and prompt have appeared properly, with no other characters displayed, address the switches as 4, 5, 6, and 7 as shown in Figure 7-2. Before attempting to load the test, make sure that there is at least 1K Hex of memory addressed as a block starting at zero. The test is not relocatable.

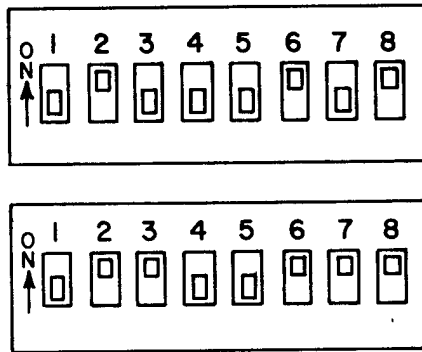


Figure 7-2. Address Switch Positions

To load the cassette, first type CA <CR>, to activate the cassette motor, and rewind the cassette. Next type the Mode Select key to return to command mode. The command XEQ <CR> will now load in the tape and cause the tape to stop when done. The Data Path Test should appear on the screen. Press the space bar to proceed. Study the display carefully. The left column shows what was written, the center column shows what was read back, and the right column marks any differences between the two. Are there any observable patterns? Are there X's centered in a particular column? Does any column have all ones or zeros read from it? Are the errors random? Are all ones or zeros read from memory? The display is organized with bit 7 on the left and bit 0 on the right as a binary number would be written. Press the space bar twice again. Study the display. Are any of the address lines indicated defective?

To use the Exerciser, enter a number between 4000-7FFF hex and the data to be written. The data is written into memory as one byte of 8 bits, derived from the two hexadecimal data characters entered. Entering 00 Hex for data writes a byte of all zeros; FF writes all ones. A typical entry might be 4000 FF <CR>. To stop the Exerciser, press the Escape key. At this point a choice of any of the four tests or a return to SOLOS can be made.

If no errors are found in #4, the Memory Test, press Escape to continue. If an error is found, the address of the bad byte will be displayed. Since the test can only find one bad byte at a time, repeat the test until no errors are displayed. To further pinpoint the error, dump nearby memory using the command DU <low address> <high address>. Select the addresses for this command to include the error, but not to exceed the capacity of the video display, 240 decimal bytes. If the error occurred at 4567 for example, dump address 4500 to 45EF. Usually a dump from XX00 to XXEF will include the error. When running the memory test, the following data pattern is written into successive locations in memory: 00, 01, 02, 04, 08, 10, 20, 40, 80, 00, etc. When examining a dump in the vicinity of an error, look for irregularities in this pattern. For example, if the dump shows an area containing 00, 01, 02, 04, 08, 10, 22, 40, 80, the 22 is incorrect. To locate the bad bit at this location convert both the correct and incorrect data words into binary patterns. The correct word 20 is 00100000; the incorrect word 22 is 00100010. Thus the error is in bit one, the second from from the right.

If many errors are revealed by a dump, it is likely the problem is not bad storage locations in RAM chips. Instead look for timing problems. See Section 7.5 below.

The memory on the card is organized as 4 pages. Each page contains 1000 Hex (4K decimal) bytes of data. Each RAM chip is a 4K by one-bit storage so there is one RAM chip used to store one bit of data per byte. Eight chips are thus used to store the eight bits in one data byte. Figure 2-1, page II-3, relates the chip location to the page and bit location.

7.5 OVERVIEW

Figure 7-3 presents the timing relationships during the typical operation of the 16KRA. All of the signals shown are critical to the proper operation. A quick check of these signals, using the procedures given later, will often reveal the source of the malfunction. To the left of Figure 7-3 is a column giving the names of the signals shown, as they appear on the schematic and block diagrams. The second column gives an IC pin

number where the signal may be found. Three signals: $\phi 2$ CLOCK, SYNC, and MEMWRT, come from the processor, via the S-100 bus. A brief description of the remaining signals, which are all generated on the 16KRA board, is given below.

7.5.1 BOARD SELECT

This signal indicates that the processor has put the address on the address bus and that the page selection circuitry has found a match between the high order 4 bits of address and one of the four page address assignment switches. The first BOARD SELECT occurs when the processor is writing to the 16KRA. The second one occurs when it is reading the data back to the 16KRA.

7.5.2 MC

A machine cycle (MC) usually occurs when the $\phi 2$ trailing edge occurs during SYNC. The MC labelled "write" is initiated by MEMWRT. Notice that there is a MC before the "write" MC while the board is selected, called a "spare read." Notice that no refresh (RC) follows it. The "spare read" occurs during the write operation, initiated by a $\phi 2$ trailing edge during SYNC. It is not used during normal operations when installed in a Sol, but during a DMA transfer it is used to enable the QU flip flop to request a WAIT state if a spontaneous refresh is occurring.

EXERCISER RUNNING

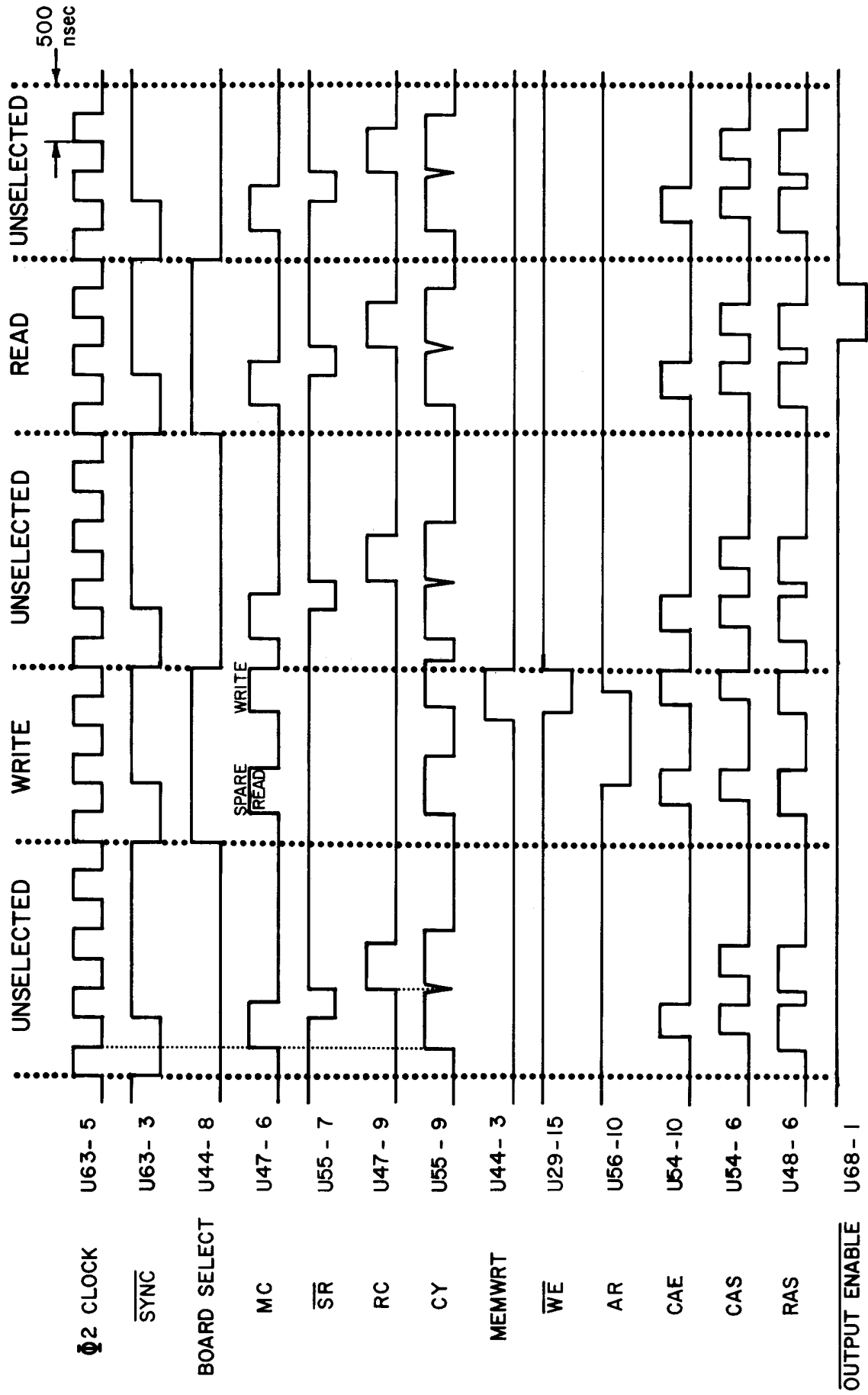


Figure 7-3. 16KRA Master Timing

7.5.3 SR

The synchronous refresh (SR) flip flop is clocked by the trailing edge of SYNC when the status indicates a read operation by the processor. When SR is set, the end of CY will trigger an RC.

7.5.4 RC

In normal operation there are no spontaneous refresh cycles (RC). Refresh is accomplished after every MC unless inhibited by SR during a write operation.

7.5.5 CY

A cycle (CY) will occur whenever there is an MC or an RC.

7.5.6 WE

WE is initiated by MEMWRT when the processor is addressing the 16KRA.

7.5.7 AR

The allow refresh (AR) circuit prevents a spontaneous refresh during a write operation.

7.5.8 CAE

The column address enable (CAE) occurs every MC unless an RC occurs at the same time.

7.5.9 CAS

The column address strobe (CAS) occurs during RAS. It is applied to all RAM chips to store the high order six bits of the address. The chips that receive both CAS and RAS will have their outputs enabled.

7.5.10 RAS

A row address strobe (RAS) occurs for each MC or RC, and is used for page selection, and to store the low order six bits of the address.

7.5.11 OUTPUT ENABLE

OUTPUT ENABLE occurs when the processor reads from the 16KRA and PDBIN is occurring.

7.6 BUS CRASHES

If your board interferes with the operation of the processor through the S100 bus, use the following procedure. Bus crashing is normally due to either a completely incorrect signal or a signal being put on the S-100 bus at the incorrect time. The surest way to locate these problems is to open up each line, one at a time, until the problems clear. However, many times the problems can be traced by looking at the S-100 bus for a signal that is stuck high or low or has an intermediate value at times. The following S-100 bus signals are used by the 16KRA.

DO Bus: 35, 36, 38, 39, 40, 88, 89, 90 or U50, (3, 6, 11, 14), U51 (3, 6, 11, 14)

Address Lines In: 29, 30, 31, 32, 33, 34, 37, 79, 80, 81, 82, 83, 84, 85, 86, 87

DIO Bus: 95, 94, 41, 42, 91, 92, 93, 43 or U68, (3, 5, 7, 9)/ U69, (3, 5, 7, 9)

With the scope time base set at 1 usec per division look at each one of the above signals. All signals should be a series of pulses which switch between ground and 4 to 5 volts clearly with no ramps or intermediate values. If these signals appear correct, check the lines listed in Table 7-3 below.

Table 7-3. Bus Line - IC Pin Signal Checks

Bus Pin	Name	IC #	Response
45	SOUT	U60-9	Low at all times or Signal
46	SINP	U60-8	Signal
97	SWO	U72-13	Signal
47	SMEMR	U55-2	Signal
78	PDBIN	U62-12	Signal
67	Phantom	U62-13	5-6Volts
68	MEMWRT	U44-3	Signal
24	$\phi 2$	U63-5	ClockSignal
77	PWR	U46-14	Signal
76	SYNC	U63-2	Signal
69	PS	U68-13	High
72	PRDY	U68-11	Signal
3	XRDY	"	"
70	PROT	U70-9	Low
20	UNPROT	U70-4	Floating 2V in Sol
99	POC	Jumper Area B	High

If this still doesn't help locate the trouble, try insulating the S-100 bus contacts to locate the pin with the interfering signal. This can be conveniently done by folding a piece of paper over one half of the edge contacts before inserting the board. Use progressively narrow pieces of paper until the interfering pin is pinpointed. Correct the problem or keep this pin insulated. Clear the bus so that the test program can be loaded and run for further diagnosis.

Many times the problem arises because data is enabled onto the bus at the incorrect time. To disable the outputs, remove the jumper from area C and ground the pin above the "C" of area C. Then proceed with testing.

7.7 THE RAM CHIP

7.7.1 Overview

The RAM chip is organized as 4K by 1-bit storage. Internally, the memory is organized in a matrix of 64 rows by 64 columns. With the 2104, the lower 12 address bits from the processor are divided into two 6-bit sections. The lower six bits (A0-A5) form the row address and the higher six bits (A6-11) form the column address. These two 6-bit addresses are presented to the RAM sequentially. When the Row Address Strobe (RAS) arrives at pin 4 of the RAM, the lower 6 bits are stored in an internal register. Also an internal timing sequence is started. After a 100 nsec delay, the RAM has enabled itself to receive the column address. 150 nsec after RAS the Column Address Strobe (CAS) is applied to the RAM. This stores the higher six bits and begins another internal timing cycle. The leading edge of CAS will cause the output to enter the high impedance condition. A fixed time later the data will appear at the output pin. This data is internally latched and will remain stable until the next CAS arrives. If CAS is applied to a RAM with no RAS, the output will be at the high impedance state until the next cycle.

Chip selection is accomplished as follows: The chip select pins are always enabled. CAS is applied to all four pages. The selected page will also receive RAS. The output pins of all 4 RAMS that store a given bit of data are tied together. The three unselected pages will have their outputs enter the high impedance state while the

chips that received both RAS and CAS will enable their data output. The cycle is the same for both read and write—the only difference being the state of Write Enable (WE). When WE is low, data will be written into a chip, when high, data is read. A bad RAM can cause a bit on all four pages to appear bad.

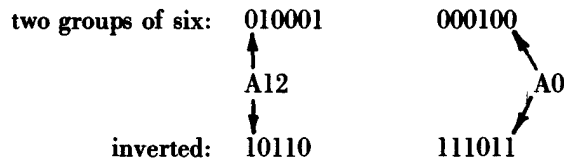
7.7.2 Troubleshooting the RAM

It is possible to examine the complete operation of a RAM by using the Exerciser program with the scope. Trigger the scope on pin 3 (WE) of any RAM. While WE is low, the address inputs will correspond to the selected address. During RAS the addresses may be correct or they may originate from the refresh cycle. To examine the operation of a bit of data in a given RAM chip, two things are necessary. First the address must be entered into the exerciser, then a space, then the data to be written into the selected byte must be entered. A byte is represented by two hex numbers for the Exerciser program. If all zeros are desired, enter 00. If all ones, enter FF, etc. All of the signals on the RAM chip itself are inverted with respect to the corresponding inputs to the 16KRA from the bus. This occurs because the driver chips that buffer all pins on the RAM invert the signals. With the Exerciser running, set the scope to 5 usec per division. Look at pin 3 on the RAM. The scope should show 2 negative pulses; the pulse being triggered on and another 45 usec later. Put the scope in the intensified mode with a delayed sweep rate of .2 usec per division. Center the light section on the central WE pulse and hit the delay mode button. Now look at every other signal on the RAM, as follows: First check the voltages on any RAM that isn't working properly. Then check to see that RAS appears only at the selected RAM page. Check to see CAS is there, then check the address lines.

To understand signals appearing on the RAM address pins, write out the address given to the Exerciser in binary. Divide the low order 12 bits into two groups of six. The invert each bit to see how it actually looks at the RAM. For example: 4444 Hex in the Exerciser program translated into binary, will be

0100 0100 0100 0100

The first 4 digits select a page and provides RAS to the chosen page. The lower 12 bits can be divided into 2 groups of six, then inverted -



This will correspond to the addresses seen by the RAM during each half of the address input cycle. The lower six bits, A0 through A5 will appear first, then the higher six bits, A6 through A11. Figure 7-4 shows which RAM pins correspond to which address lines.

If everything looks correct at this point, look at the data-out line as follows: First, set the scope probe on OUTPUT ENABLE U68-1. Still triggering on WE, set the delayed sweep to .2 usec per division, and switch to intensified mode. When this signal goes low, the data from the RAM is placed on the data bus. For the Exerciser program, this is about 3 usec after WE. Move the delayed sweep vernier so the intensified portion is centered over the signal on U68-1, and switch to delayed mode. At this time, examine pin 14, Data Out, on the RAM. It should correspond to the data input during WE. This signal, as all others on the board, should be clearly high or low while U68-1 is low. However, the outputs will float at 2 volts for a short time after CAS. If any signals at the RAM output appear stuck high or low or occasionally have an intermediate value except after CAS, this is incorrect. However, because all the RAM outputs are tied together, it may be necessary to isolate the outputs to locate the problem. The Data Path Test can help locate bad RAMs. The Data Path Test is run at address 4000 only, but by using the paging switches, you can address any page to 4000. If the Data Path Test fails on three pages and runs well on the last, unlikely as it may seem, this good page probably has the bad RAM.

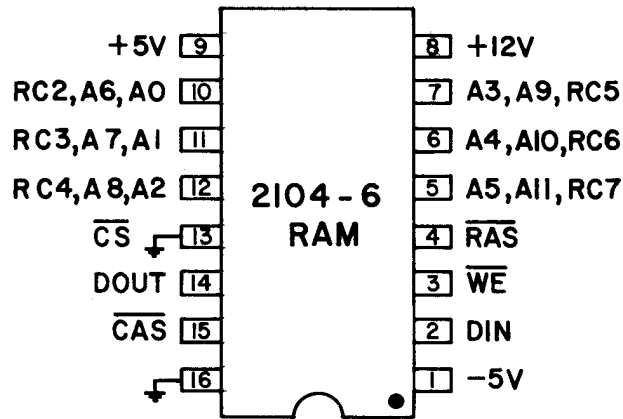


Figure 7-4. RAM Chip Pin Assignments

There are several test addresses used with the Exerciser to find addressing problems.

If the memory passes the Data Path Test but the Addressing Test shows several bad lines, there are two addresses: 4FC0 and 403F, which will test for problems in the multiplexers.

The signals shown in Figure 7-5 should be found at the RAM on all the address inputs at the selected page during WE while the Exerciser is running. The top two waveforms are for address 4FC0 and the bottom two are for 403F. Any data word can be entered for this test.

When using these two addresses, any address line shorted to Vcc or ground will be evident. Measure the pulse width on the address multiplexer outputs at pins 7 and 9 of U65, U66 and U67 while the Exerciser is running at address 403F. If any pulse width is greater than 145 usec, the corresponding multiplexer may have a gate that is too slow. Sometimes, two RAM lines are shorted together. Two test numbers will help find these. 4AAA and 4555 will cause the addresses to alternate on adjacent pins. If a short is present, the address lines shorted will usually have an intermediate value when the two lines have opposite values. If the addressing test says bit 12 or 13 is bad, look to U42 for a page selection problem or to the drivers to the RAMS.

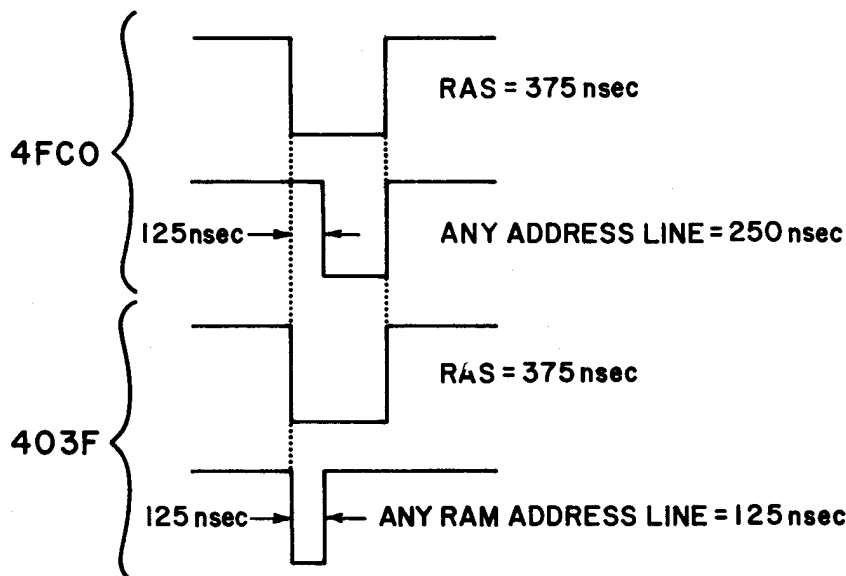


Figure 7-5. RAM Address Signal Waveforms

7.8 THE WRITE REQUEST FLIP FLOP

Refer to Figure 7-6. The operation of the Write Request (WR) flip flop starts with a write operation to the 16KRA board. If the board is unprotected (U70-3 high), selected (63-11 low), and a write operation is in progress, input to K, U63-8, will go low. Input to clock will go high for .5 usec, 1.5 usec later. This will clock the WR flip flop and cause the WR signal on pin 10 to go low. This will initiate a chain of events which will lead to WE being clocked, MC being set, the delay line being triggered, and eventually U57-8 and U45-11 going low for 200 nsec which resets WR through pin 11. This reset normally happens about 150 nsec later under normal circumstances (no CY in progress).

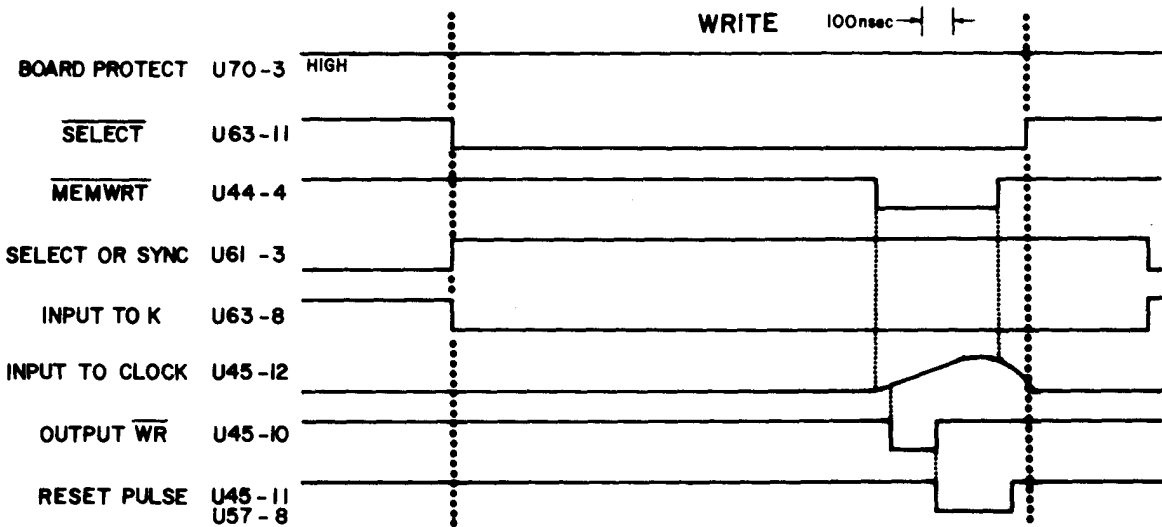


Figure 7-6. Write Request (WR) Timing

7.9 WRITE ENABLE OPERATION - WE

Refer to Figure 7-7.

When WR (U45-10) is clocked low, 2 things are possible, depending on the status of CY. CY may be high for a maximum of 520 nsec. After this time it will go low and cause U60-4 to go high. CY may be low, in which case U60-4 will go high immediately. In both cases, the WE flip flop will be clocked, and WE (U46-7) will go low. This will set the MC flip flop and start a machine cycle. Also WE (U46-6) will go high and along with ME1 and ME2, and enable the memory drivers. When the machine cycle is started, the delay line is driven. After 350 nsec U57-6 generates a reset pulse which resets MC and WE.

7.10 MACHINE CYCLE - MC

Refer to Figure 7-7.

A machine cycle (MC) occurs under two different sets of circumstances. It is about 350 nsec long and is always reset through U57-6 going low from the delay line. During a write operation, it is set by the WE flip flop. However, most of the MCs are caused by read operations, and originate from a clocked mode. MC is clocked whenever the $\phi 2$ clock goes low while SYNC is present or the Queue (QU) flip flop is set. If a refresh cycle is in progress when $\phi 2$ goes low, MC will not be clocked immediately. Instead the QU flip flop will be set and then MC will be clocked as soon as the next $\phi 2$ comes along. After the MC is over, refresh cycle is initiated by the end of CY. This inserts refresh cycles often enough to prevent spontaneous refresh cycles from occurring.

7.11 CYCLE FLIP FLOP - CY

Refer to Figure 7-7.

The Cycle (CY) flip flop is set to its active mode (U55-9) high whenever an MC or RC is initiated, through its R input (pin 15). It is clocked to its inactive mode when U57-6 from the delay line goes high. In effect it starts when there is an MC or RC and ends 100 nsec after MC or RC is reset. This flip flop is used to insure that the cycle which caused it is finished before any new cycle can be initiated.

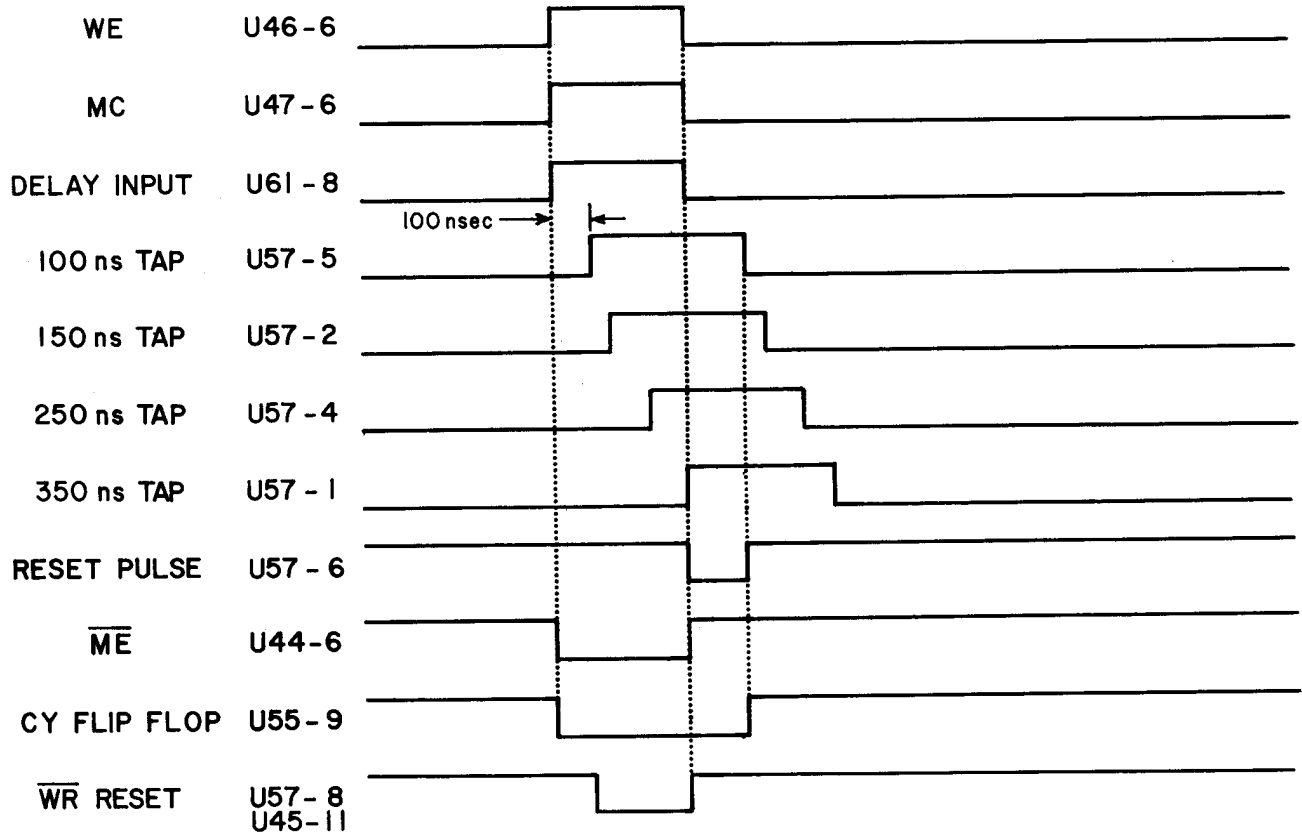


Figure 7-7 Cycle (CY) Timing

7.12 SYNCHRONOUS REFRESH - SR

See Figure 7-3.

The synchronous refresh (SR) flip flop controls the normal initiation of the refresh cycle. S_{MEMR} is a status signal put out by the processor. It is put on the data bus during SYNC. It is latched by ϕ_2 going low during SYNC and remains stable on the S-100 bus until the next SYNC pulse. S_{MEMR}, when high, indicates an instruction fetch, memory read, or stack read. It will be low during any write operation. When S_{MEMR} is high, the end of SYNC will clock the SR flip flop so that SR goes low. ϕ_2 going low during SYNC will also initiate an MC and therefore a CY. When CY ends, and SR is low, RC will be clocked to start a refresh cycle. As soon as the RC is started, it will reset the SR flip flop so that only one RC occurs for a given SYNC pulse.

7.13 THE ALLOW REFRESH FLIP FLOP - AR

See Figure 7-3.

The allow refresh (AR) flip flop has one purpose. This is to prevent a spontaneous refresh at critical times during a write cycle. S_{WO} is a status signal put out by the processor. It will go low whenever the processor

begins a write operation. It will be put on the data bus during a SYNC signal. Then it is latched when $\phi 2$ goes low and will remain stable on the bus until the next $\phi 2$ low during SYNC. If SWO is low, the board is selected, and unprotected, the AR flip flop will be clocked low at the end of SYNC. This will prevent a spontaneous refresh until AR is set high by the same signal that resets WR. If SWO goes low but the board is not selected, SWO will not reach the AR flip flop.

7.14 PAGE SELECTION

7.14.1 Overview

Each page consists of 4K bytes. Each 4K page can be set to one of 16 different starting addresses. This choice is done through the paging switches and the LS136 exclusive-OR open collector ICs, U19, 20, 40 and 41. Each set of four switches can be set from 0 to F Hex. This corresponds to a starting address of 0000 through 61,440 decimal. Each LS136 contains 4 exclusive-OR gates. The outputs of these 4 gates are connected together. Because the outputs are open collector, there will be no conflict if some of them are high and some low at the same time. However, in order for an output line to go high, all four gates that are tied together must go high at the same time. Then the pull-up resistor will pull the line up to a high condition. In order for all four outputs to go high simultaneously, a match is necessary at the inputs to each of the four gates. When a switch is pushed up, (ON), it grounds one end of the exclusive-OR input. When the address line connected to the other input goes high, that particular gate will remove its low from the output line. Only when all four gates are matched can a particular starting address be selected.

A memory system must not have more than one page set to start at the same address. If this is accidentally done, both pages will fight for control of the bus. In order to prevent this problem, the 16KRA contains an inhibit circuit. This circuit consists of 6 open collector inverters. The inverters are wired to establish an order of priority. If two or more pages on this board are set to the same starting address, only one will respond. The switch in the top left corner will inhibit the other three. The top right will inhibit the lower 2 switches, and the lower left will inhibit the lower right.

7.14.2 Troubleshooting the Page Select Circuit

To test to see if a paging IC is operating correctly at all possible addresses, Jumper U44-8 to ground. Load the 16KDT diagnostic test. Proceed to the Exerciser and enter F000 00 <CR>. Push all the switches to the up (ON) position. Put channel 2 of the scope on U45-12, (delayed MEMWRT) with the Exerciser running. Set the scope at 5 usec per division. Figure 7-8 shows the required pulse pattern.

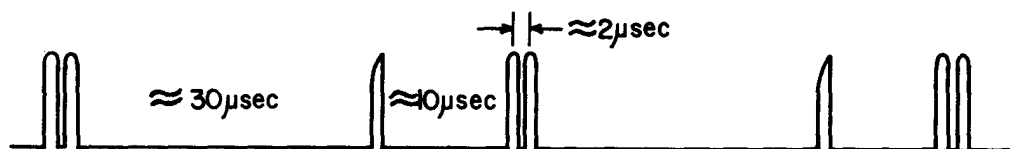


Figure 7-8. MEMWRT Pulse Pattern

Notice the one thin pulse near the group of 2 wider pulses. Set the scope to the intensified mode and the delayed sweep to 1 usec per division. Center the intensified area around the thin pulse and change to delayed trigger. You should have one pulse visible about 500 nsec wide. Now look at U19-8 with the other probe. Two pulses about 2 usec wide, separated by 1.5 usec, should be observed. These pulses represent selection of a particular page on the 16KRA by the diagnostic test. The first pulse occurs when the test is writing to the 16KRA. The second one occurs when the test is reading back from the same location. This shows that the highest priority page has been selected.

Next look at pin 8 of U20, U40, and U41. They should all be low. Push switch 1 (top row) down to remove the inhibition by the first page and look at U20-8. It should now look like U19-8 did. Push switch 5 (top) down and look for the same waveform at U40-8. Now push 1 (bottom row) down and look for the same waveform at U41-8. This test checked the page inhibit IC U59.

To check individual pages now, go back to all switches high. Now push 1 (top row) down and see that U19-8 goes low, then push it up and push 2 down and see that U19-8 goes low. Repeat with switches 3 and 4. Now leave 1 down and proceed to 5, 6, 7, 8. Start with all up and check U20-8 to see the board select signal.

Repeat the same procedure, switching one down at a time while checking U20-8. Then leave 5 down and go to the lower switch. Look at U40-8 for switches 1-4 and U41-8 for switches 5-8.

This procedure has checked for most of the paging problems but to be certain, the whole procedure has to be repeated with the address switches low. Press the escape key and 3 to get the Exerciser. Now type 0900 00 <CR>. The memory test is stored at 0000 addresses to 0800 so don't be tempted to enter address 0000 to the Exerciser. Push all the switches low and check U19-8. In this case it will be a long pulse followed by 2 short ones. Push switch 1 up and check U19-8 for a low level. Push 1 down and 2 up and check again. Repeat for 3 and 4. Then leave 4 up and repeat with 5-8, one switch up at a time while looking at U20-8. Leave 8 up and check page 3 by switching up the lower switches 1 to 4 one at a time while looking at U40-8. Leave 4 up and repeat with 5-8 while checking U41-8. This procedure will catch all possible page address assignments problems but if an intermittent problem occurs, suspect the switches themselves.

Check to be sure that the two SIP resistor networks are not installed backwards. First set all 16 address switches off. Check the resistance between the two pins on each network farthest from the edge of the board. The resistance should be 2.2K. 4.4K indicates a backwards installation. Both networks must be mounted correctly, or the paging will not work properly.

If a problem is found while testing the page select circuitry, check the address lines and switch lines at the suspected IC, using Table 7-4.

Before proceeding to the next test, remove the jumper from U44-8.

Table 7-4. LS136 Pin Assignments

Address Line#	Input Pin toLS136	Switch Number	Matched with LS136Pin
A12	1	1 or 5	2
A13	4	2 or 6	5
A14	13	3 or 7	12
A15	10	4 or 8	9

7.15 READY LINE

7.15.1 Queue Operation - QU

The Queue (QU) flip flop, U45, controls the Ready line to the processor, PRDY, or XRDY, as selected in Jumper area E. If QU goes high while the board is selected, the processor will receive a request to enter the wait state. The operation of the QU flip flop is complicated because it is normally clocked both high and low and, also is set and reset through its asynchronous inputs. In normal operation, the QU flip flop is never used. A wait state is only required when a spontaneous refresh interferes with the normal board operation. No spontaneous refreshes are generated in normal operation; refreshes are generated through the operation of the synchronous refresh (SR) flip flop. During a write operation it is important that nothing interferes with the write operation after the WR flip flop has been clocked. The WR flip flop is clocked after the time for requesting a wait state has passed. To insure that a spontaneous refresh never occurs during this critical period, the AR flip flop inhibits spontaneous refresh until the write cycle is started. When the write cycle has started, CY inhibits refresh. Only after the write cycle is completed can a refresh finally occur. A write cycle is normally preceded by a spare read cycle. When the trailing edge of ϕ_2 occurs during SYNC, MC is clocked. At this point there are several possibilities. If a spontaneous refresh is in progress, MC will not be clocked high. Instead QU will be clocked high. If MC is clocked high but a spontaneous refresh has also started at that exact moment, before inhibition is complete, QU will be set high indicating a coincidence cycle. QU is held reset unless the board is selected or SYNC is present. If QU is high, it will be reset as soon as SYNC is over unless the board is selected. Although QU may be set any time that ϕ_2 and SYNC are present, the READY line will not be pulled low unless the board is selected.

In a read or "spare read during write" cycle, MC is clocked by ϕ_2 trailing edge with SYNC present. However, if a refresh cycle is in progress when MC is clocked, CY will be high and this will force the MC J input low. MC will remain low. Because MC remains low and SYNC is present, the J input on the QU flip flop will be

high. When $\phi 2$ delayed occurs approximately 30 nsec later, QU will be clocked high. The processor will enter a wait state after T2 of the processor cycle is complete. All of the bus lines will remain stable except for $\phi 2$. With QU set, U61-6 is high, even though SYNC is no longer present. When the refresh cycle is over, the J input on MC will be high. When $\phi 2$ occurs, MC will be clocked high. With MC high, the J input of QU will be low. Thirty nsec later when $\phi 2$ delayed occurs, QU will be clocked low. The processor will start at the beginning of the T3-processor cycle. The processor will then complete the write or read cycle as if no wait had occurred.

7.15.2 Troubleshooting The Ready Line

In order for the 16KRA to request a wait state through the Ready line, the QU flip flop must be set and the board selected. These signals are combined in U68. Problems with Board Select will usually crash the bus or prevent the 16KDT test from working. If the processor stops accepting inputs from the keyboard, it is most likely caught in a wait state. To clear the processor, remove the Area A jumper and ground the W pin. If the processor is still caught, refer to Section 7.6, Bus Crashes. With the CPU working, load the 16KDT tape and troubleshoot the 16KRA. Normally no wait states are generated, so deactivating the Ready line driver has no effect on the diagnostic test. The 16KRA can cause a permanent wait state if something is preventing the MC flip flop from being clocked. In this case the QU flip flop will be clocked high but never clocked low again. Because the wait state option is not normally used, the 16KRA may appear to be operating properly until a DMA is attempted. If the 16KRA passes both memory tests, but will not work with a DMA device, the operation of QU must be checked. The QU flip flop will go high when it is either clocked or set. It is necessary to test both clocked and set modes of operation to be certain it is operating correctly. The following procedure will test both modes of operation. Replace the jumper in Area A.

First load the 16KDT and advance to the Exerciser. Enter an address that will select the board and start the Exerciser. Set channel 2 of the scope on pin 3, WE, of any RAM chip. Set the sweep to 5 usec division and adjust for a stable display. Now connect a 20K pot across R12. Put the scope probe for channel 1 on U48-8 and adjust the pot until several pulses are evident. Set the delayed sweep to .2 usec per division and intensified mode. Center the bright area on one of the U-48 pulses and switch to delayed sweep. Note where this pulse now appears on the screen and put the channel 1 probe on the jumper to Area A. In the same place on the scope screen there should be a pulse of the same duration. This checks the operation of the set and reset inputs of QU. Now switch the scope back to the intensified mode and put the probe on the Area A jumper again. It should be possible to adjust the pot so that many more QU pulses appear than U48-8 pulses. This tests the clocked inputs. The QU pulses are normal because the board is not selected. If you pass both these tests and the DMA still does not work, try the Page Selection test, Section 7.14. Remove the pot before proceeding. In many cases the address switches are set differently for the DMA device than they are for the memory tests. If the address selection is not working properly on the DMA addresses, the DMA won't work. Also check the AR flip flop and the spontaneous refresh generation. With the Ready line held low, there should be a refresh cycle every 4-6 usec. If all these tests are good, suspect a slow RAM chip, or a problem with U70.

7.16 THE WAIT STATE OPTION

If the jumper in Area A is put to 1 instead of 0, the following sequence of events occurs. The QU flip flop is not set so QU is high and the J input on U56 is high. U56 is held reset when SYNC is present, keeping its Q output high, causing a request for a wait state through U68 on the PRDY or XRDY lines. On the $\phi 2$ trailing edge, MC will be clocked, starting a machine cycle. The processor will recognize the request and enter a wait state after T2 is over. By this time SYNC will have gone low, removing the reset. The next $\phi 2$ trailing edge, 500 nsec later, will now clock U56, ending the wait request on PRDY or XRDY. While the processor is in the wait state, it samples the Ready line which is now high, and begins T3 exactly one clock period later than it would have without a wait request. Later, when SYNC goes high again, U56 will be reset and a new cycle may start. The processor only samples the Ready line at a point near the trailing edge of $\phi 2$ during T2 so the fact that the Ready line is low for the greater part of the cycle doesn't affect the processor operation. If the QU flip flop is set because MC wasn't clocked, U56 will be held reset until MC is clocked. When MC is clocked, QU will be clocked low 30 nsec later. SYNC will still be high so U56 will continue to be reset until SYNC ends, extending the period that the Ready line is held low. When the processor samples the line again and finds it low, it prolongs the wait state.

7.17 REFRESH CYCLE FLIP FLOP - RC

Refer to Figure 7-3.

The time the Refresh Cycle (RC) flip flop is high defines a refresh cycle. It is the same length as an MC and is reset by the same signal. It is initiated through two different mechanisms. Every time RC is high, Q1 is turned on and its collector goes to ground and discharges C46, provided the Area D jumper is installed between D and DN. After the RC is over, Q1 is turned off and C46 starts to charge. After about 4-6 usec, C46 will have charged enough to trigger U62, a Schmidt trigger gate. This can initiate another RC which will turn on Q2 and discharge C46. This process will repeat unless inhibited. Normally this spontaneous cycle does not occur because RC is clocked more often than 6 usec. This cycle takes over if the processor stops for more than 6 usec, as in a wait state. This spontaneous refresh cycle is not synchronized with the processor clock, and several mechanisms are needed to inhibit it at unwanted times. If a CY is in progress, the Schmidt trigger, U62, will be disabled until the CY is over. Also the refresh is inhibited by the AR flip flop in preparation for a write cycle. Under normal circumstances, RC is clocked when CY ends if the SR flip flop is set. This inserts a refresh after almost every MC.

7.18 THE REFRESH CIRCUIT

7.18.1 Overview

Refer to Figure 7-9, Refresh Page Selection Timing. The refresh addressing circuit is controlled by two 4-bit counters, U49 and U64, connected as an 8-bit counter. The counters have two inputs. Pin 10 is an enable input, connected to CAE. The column address enable flip flop (CAE) has its J input connected to the MC flip flop. When there is no MC cycle the J input is low and CAE will not be clocked high. If an RC is triggered, CAE will be high, the counters will be enabled, and ME will advance the counters on rising, (trailing) edge. The counter will remain stable until the next RC is over, when it will be advanced again. The enable input of the high order counter U64, is connected to the carry out input of U49. The carry out is only enabled when CAE has enabled the low order counter, U49. Pins 13 & 14 of U49 are the two least significant bits and are used to form the paging. This has the effect of sequentially refreshing pages 1-4 at a given address, then advancing the address counter by 1. The six address lines from the counter are switched by the multiplexers to the address lines of the RAMS when an RC is present and CAE is low. RC is connected to pin 1 of U42. When RC is high and a refresh is in progress, U58 will act as a 2-bit to 4-line binary decoder. The multiplexer U42 selects the 4 outputs of U58 to drive the 4-page lines.

The six high order outputs of the counter are stable for 4 entire refresh cycles. The three address multiplexers will output the counter address during an entire RC because there is no CAE during an RC. This counter address is gated by U48-3 (page 1 or 2) or U48-11 (page 3 or 4) at the address drivers of the RAM chips. The RAS Pulse is gated by the 4 page lines at the RAS drivers (U30). The page of memory which receives RAS refreshes its row specified by the refresh address.

7.18.2 Troubleshooting Refresh

Refer to Figure 7-10, RAM Address Line During Refresh, and Figure 7-11, RAM Refresh Timing, Page 3 and 4. To simplify troubleshooting the refresh circuit, ground pin U68-11. This will put the processor in a wait state and prevent any MCs from occurring. Look at U49-2. You should see a waveform that repeats a negative pulse 400 nsec long at about 4 usec intervals. If you don't see this, the problem is in the generation of the spontaneous RC cycle. If this is present, check to see that U49-10 is high. This enables the counters. Then look at all the output pins from the counters. Each output should have a square wave signal with the periods listed in Table 7-5 (based on a 4-usec interval).

U49-14 =	8 usec	U64-14 =	128 usec
U49-13 =	16 usec	U64-13 =	256 usec
U49-12 =	32 usec	U64-12 =	512 usec
U49-11 =	64 usec	U64-11 =	1024 usec

Table 7-5. Counter Periods.

If these are acceptable, test U58. Set the scope to 5 usec per division, and trigger on U49-11 and examine U58, 4, 7, 9, 12. Each signal should appear as shown in Figure 7-9. You should find a positive pulse about 4 usec wide, occurring every 16 usec. Then check U42. With the scope still triggered by U49-11, examine U42, 4, 7, 9, 12. There should be a positive pulse about 400 nsec wide, occurring every 16 usec. If all of these tests are

checked OK, the problem is probably not in the refresh addresses. All of the signals at this point are multiplexed into the rest of the address circuitry. If the rest of the memory card is working, the refresh is most likely working also. As a final check, trigger is on U64-11 with the sweep set at .1 msec per division. Refer to Figures 7-10 and 7-11. Figure 7-11 represents a more detailed view of some signals in Figure 7-10. Looking at any RAM chip pins 10, 11, 12, you should see groups of 2, 4, and 8 respectively, negative pulses. Looking at RAM pins 7, 6, 5, you should see groups of 16, 32, and 64 negative going pulses. This checks the operation of the address multiplexers U65, U66, U67.

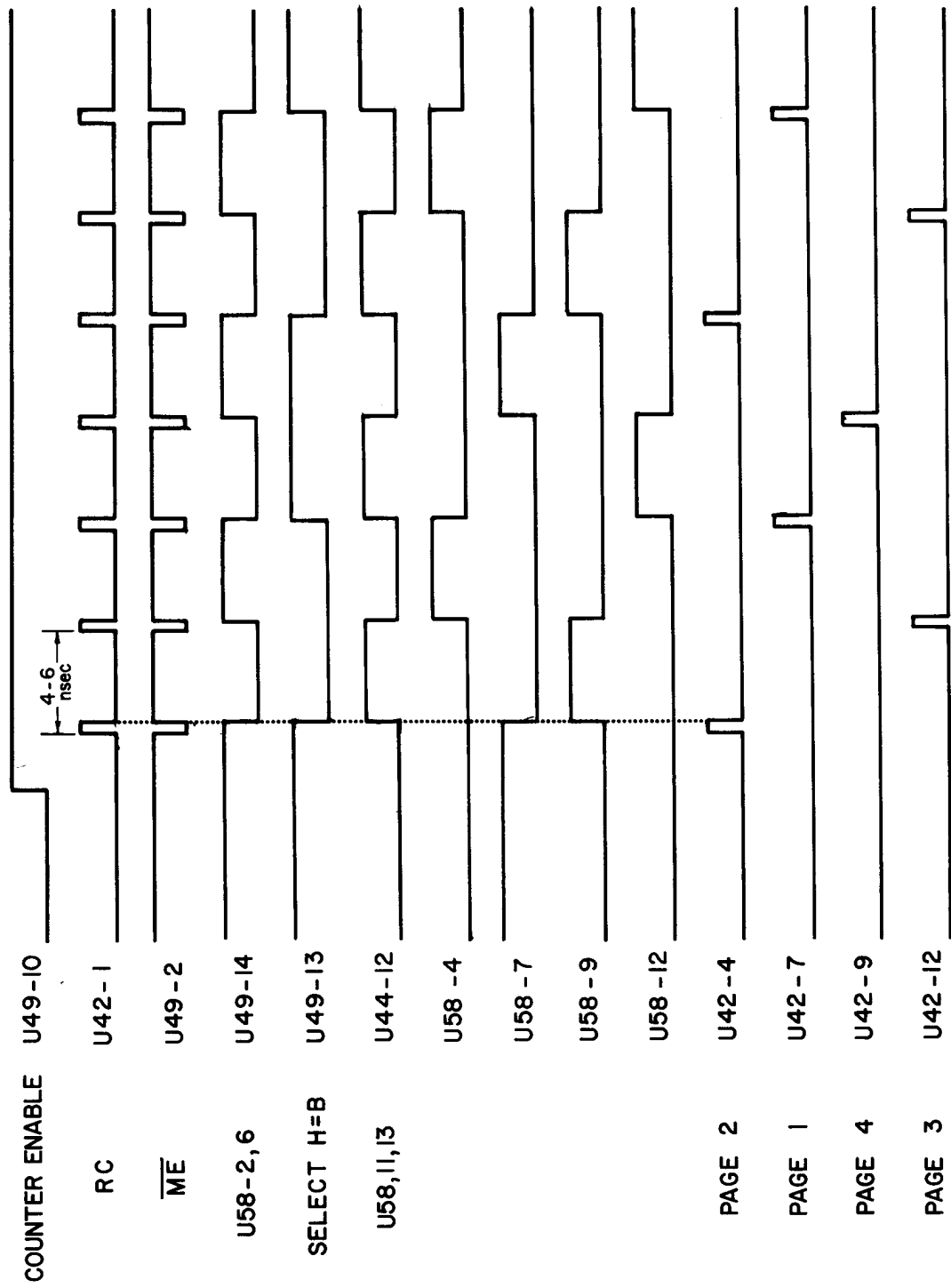


Figure 7-9. Refresh Page Selection Timing.

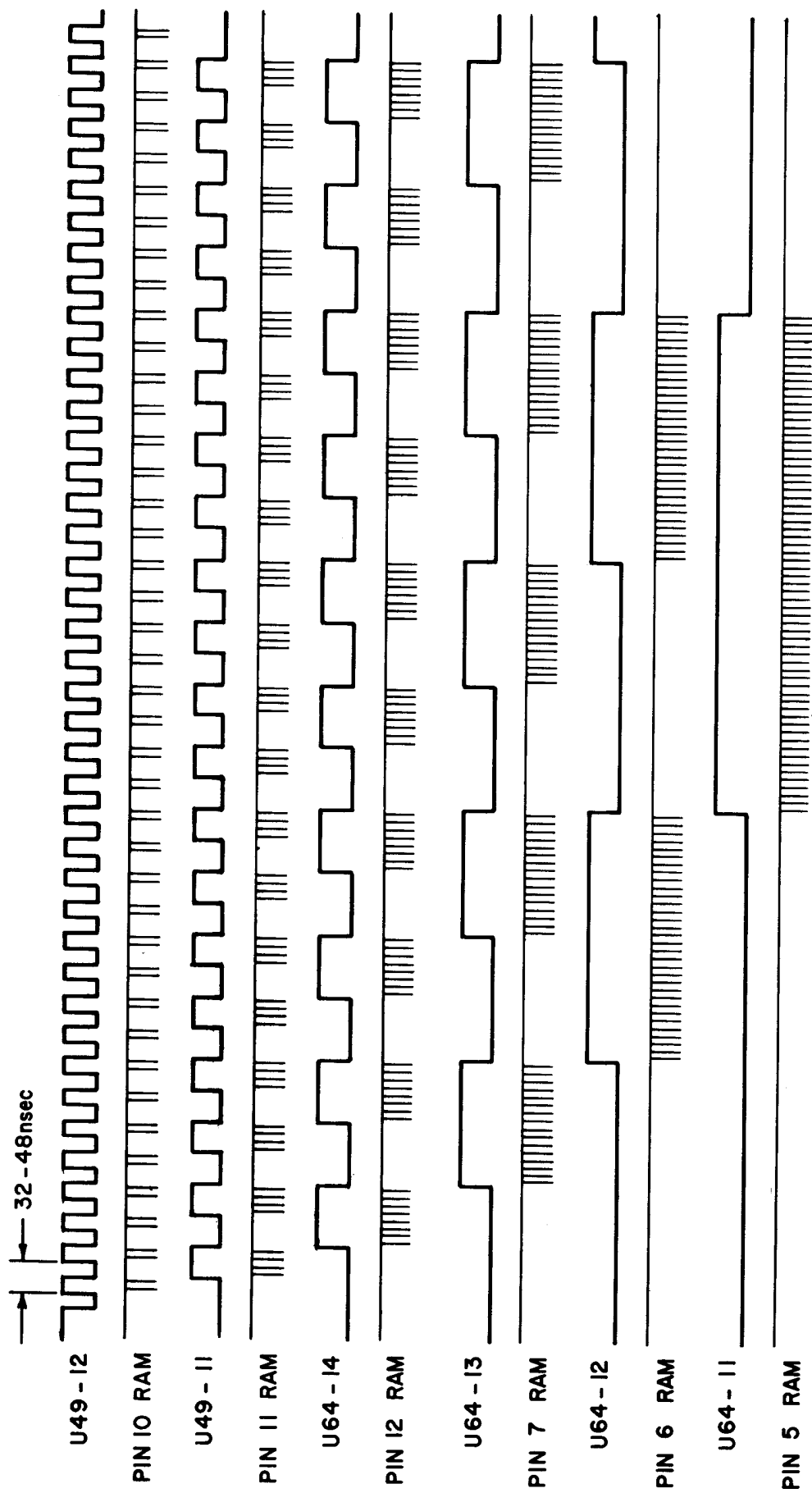


Figure 7-10. RAM Address Line Timing During Refresh

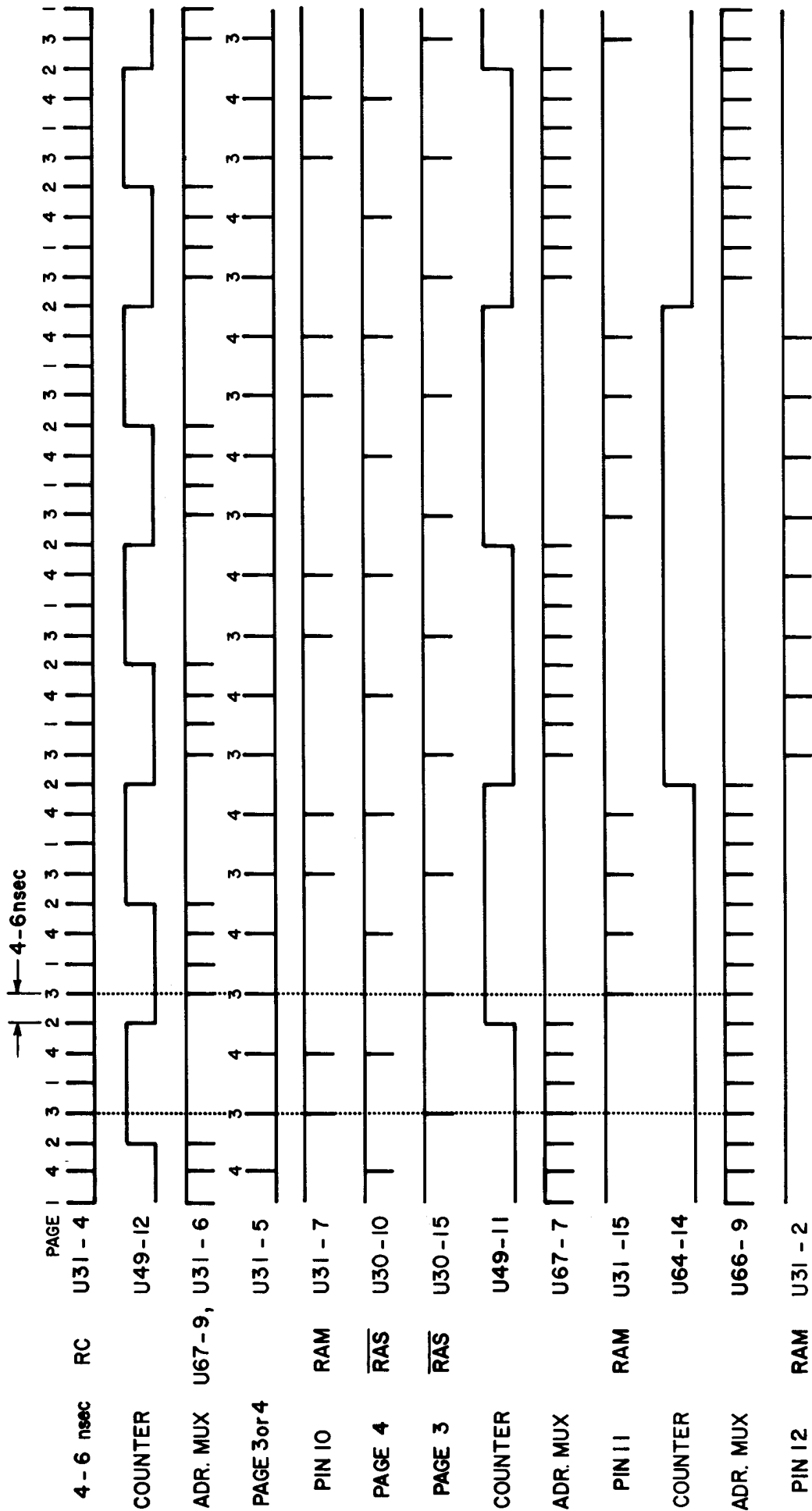


Figure 7-11. RAM Refresh Timing - Page 3 and 4.

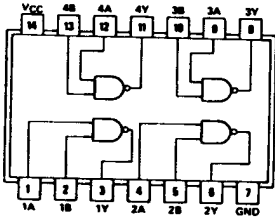
APPENDICES

- 1 IC Pin Configurations**
- 2 Memory Test Programs**

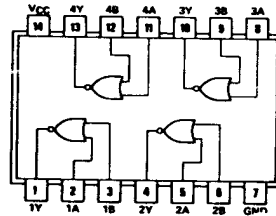
APPENDIX 1

IC PIN CONFIGURATIONS

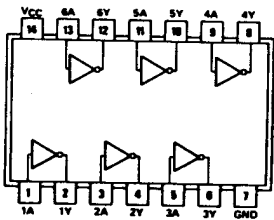
7400



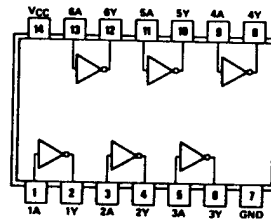
7402



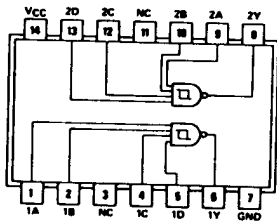
7404



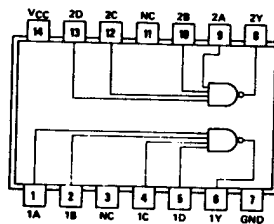
7405



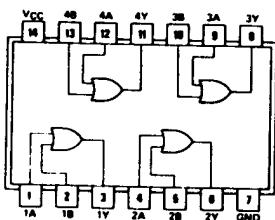
7413



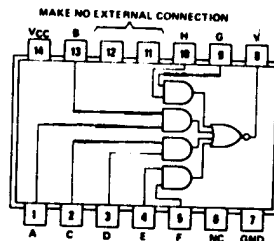
7420



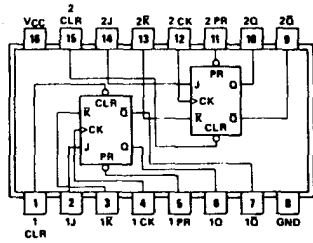
7432



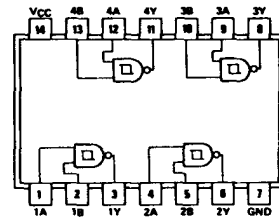
7454



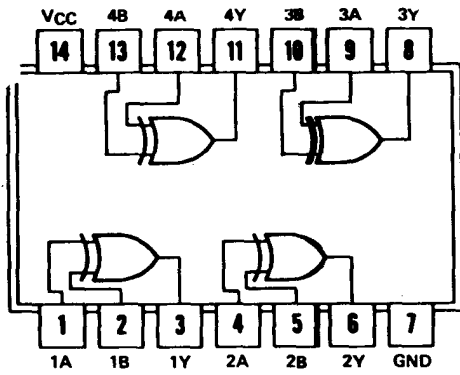
74109



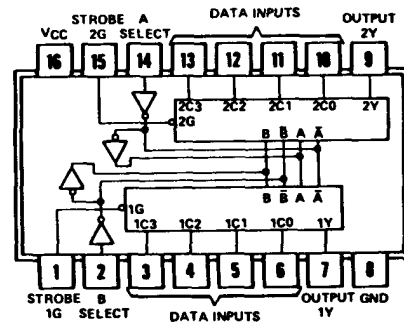
74132



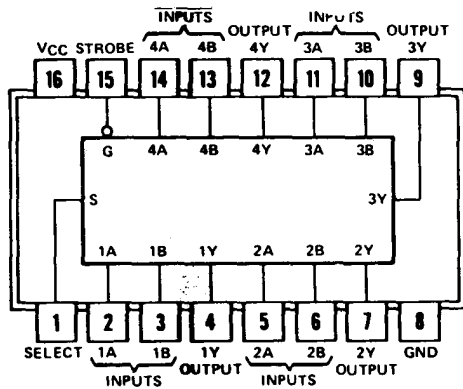
74136



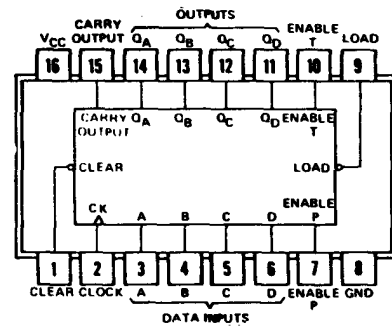
74153



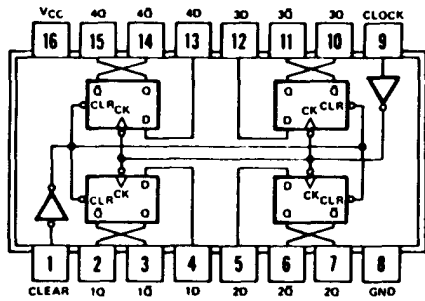
74157



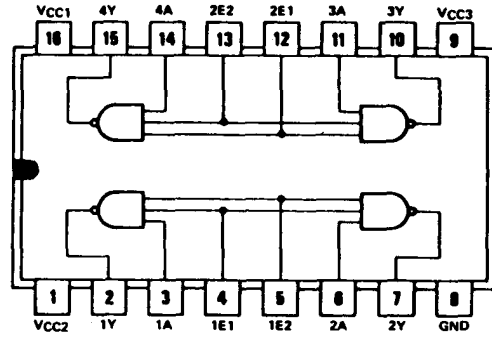
74163



74175



75365



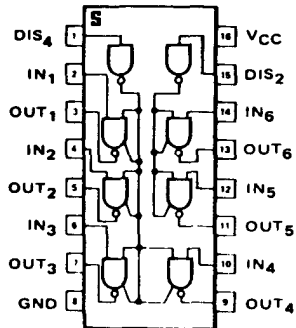
7805 or 7812



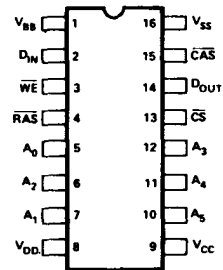
Pin 1: Input (Base)
 Pin 2: Output (Emitter)
 Pin 3: Ground (Collector)

Heat sink surface connected to pin 3

8T98



2104



PIN NAMES

A ₀ - A ₅	ADDRESS INPUTS	WE	WRITE ENABLE
CAS	COLUMN ADDRESS STROBE	V _{BB}	POWER (-5V)
CS	CHIP SELECT	V _{CC}	POWER (+5V)
DIN	DATA IN	V _{DD}	POWER (+12V)
DOUT	DATA OUT	V _{SS}	GROUND
RAS	ROW ADDRESS STROBE		

APPENDIX 2

MEMORY TEST PROGRAMS

16KRA Short Memory Test Program

The test program on the following page is designed to check the 16KRA Dynamic Read/Write Memory Module for proper operation. It is a short test which may be easily loaded. For a more thorough test, use the long memory test which follows.

NOTE

This test program is written for use with Processor Technology SOLOS or CUTER monitor programs. If you are not using either, you will need to modify the program to work with your monitor.

To use the program, proceed as follows:

- 1) Set the Page Select Switches (SW1 and SW2) for continuous memory from 0 to 16K. The switches in Figure 4-1 are set in this configuration.
- 2) Load the program on the following page into memory at C900 (Hex). The Sol computer contains built-in system memory at the necessary locations. The program could be reassembled to run at a different address if necessary.
- 3) To run the program EXECute C900. The program runs continuously unless an error is encountered; then it returns control to SOLOS/CUTER. If it runs for 10 minutes without the SOLOS/CUTER prompt appearing, you may consider the 16KRA as having passed the test. You may then return control to SOLOS/CUTER by pressing the UPPER CASE and REPEAT keys together.
- 4) Once the test is loaded into memory and runs correctly, you may want to save it on cassette tape for later use, using the SOLOS/CUTER SAVE command.

When the program reads data which does not match the data written, it stores the address where the error occurred, the data written, and the error data read, in four locations of memory. To display this information, enter the command DU C949 C94C <CR> and refer to the source listing for interpretation.

The longer test is more useful for diagnosis since it displays a complete map of errors rather than just the first bad location encountered.

```

*
C900          ORG      0C900H
              XEQ      0C004H
*
** 16KRA SHORT MEMORY TEST **
*
C900 2E 04    MVI      L,4
C902 22 47 C9 SHLD     RTRN      FOR RETURN TO SOLOS/CUTER
*
C905 AF       XRA      A
C906 37       STC      .         CREATE MASTER PATTERN
C907 F5       PUSH     PSW       SAVE IT ON STACK
C908 F5       PUSH     PSW       AND A COPY TO WORK WITH
*
C909 21 00 00 LOOP    LXI      H,0    FILL MEMORY FROM 0 TO 3FFF
*
C90C F1       WRITE   POP      PSW     GET WORKING PATTERN
C90D 77       MOV      M,A        TO MEMORY
*
C90E 17       RAL      .         NEW PATTERN
C90F F5       PUSH     PSW       BACK TO STACK
*
C910 23       INX     H          NEXT MEMORY ADDRESS
C911 7C       MOV     A,H
C912 FE 40    CPI     40H       PAST 3FFF ?
C914 C2 0C C9 JNZ     WRITE    NOT YET
*
C917 F1       POP     PSW       WORKING PATTERN
C918 F1       POP     PSW       MASTER PATTERN
C919 F5       PUSH    PSW       BACK TO STACK
C91A F5       PUSH    PSW       AND A COPY TO WORK WITH
*
C91B 21 00 00 LXI     H,0        CHECK FROM 0 3FFF
*
C91E F1       READ1  POP     PSW     GET WORKING PATTERN
C91F F5       PUSH    PSW       THEN SAVE IT
C920 BE       CMP     M         DOES MEMORY MATCH ?
C921 C2 36 C9 JNZ     ERROR NO. IT'S WRONG !
*
C924 F1       POP     PSW       GET WORKING PATTERN
C925 17       RAL     .         NEW WORKING PATTERN
C926 F5       PUSH    PSW       BACK TO STACK
*
C927 23       INX     H          NEXT MEMORY ADDRESS
C928 7C       MOV     A,H
C929 FE 40    CPI     40H       PAST 3FFF ?
C92B C2 1E C9 JNZ     READ1    NOT YET
*
C92E F1       POP     PSW       WORKING PATTERN
C92F F1       POP     PSW       MASTER PATTERN
C930 17       RAL     .         NEW MASTER
C931 F5       PUSH    PSW       BACK TO STACK
C932 F5       PUSH    PSW       AND A COPY TO WORK WITH
C933 C3 09 C9 JMP     LOOP    ON AND ON
*
C936 56       ERROR  MOV     D,M    GET INCORRECT DATA
C937 5F       MOV     E,A    AND WHAT IT SHOULD BE
C938 EB       XCHG
C939 22 4B C9 SHLD    SAVE+2    TO REPORT AREA
C93C EB       XCHG    .         GET ADDRESS OF ERROR
C93D 54       MOV     D,H
C93E 65       MOV     H,L    PUT IN CORRECT ORDER

```



```

C93F 6A          MOV      L,D
C940 22 49 C9   SHLD     SAVE      TO REPORT AREA
*
C943 2A 47 C9   LHLD     RTRN      GET SOLOS/CUTER RETURN ADD.
C946 E9         PCHL     .        GO THERE
*
C947           RTRN     DS        2
*
* REPORT AREA:  BYTES ONE AND TWO ARE THE ADDRESS WHERE
*               THE ERROR OCCURED,MOST SIGNIFICANT BYTE FIRST
*
*               BYTE THREE IS THE CORRECT DATA.
*
*               BYTE FOUR IS THE ERRONEOUS DATA.
*
C949           SAVE     EQU      $
*
C949           DS       1        BYTE ONE STORED HERE
C94A           DS       1        BYTE TWO STORED HERE
C94B           DS       1        BYTE THREE STORED HERE
C94C           DS       1        BYTE FOUR STORED HERE
*

```

16KRA Long Memory Test Program

This long test provides a more thorough test than the preceding short test and also prints out a map which simplifies identification of defective components. Your Processor Technology dealer may have this program on a tape which you may copy, to avoid having to key in such a long program. As an owner of the 16KRA, you have a right to copy this program without violation of the copyright.

To use the long program, proceed as follows:

- 1) Set the Page Select Switches (SW1 and SW2) for continuous memory from 0 to 16K. The switches in Figure 4-1 are set in this configuration.
- 2) Load the program on the following pages into memory at C900 (Hex). The Sol computer contains built-in system memory at the necessary locations. The program could be reassembled to run at a different address if necessary.
- 3) To run the program, EXECute 0000 <CR>. The test displays a copyright notice and allows one of two options to be selected with a keystroke:
 - A) "1" to run one complete test cycle, display a map of ICs which gave errors, and return control to SOLOS/CUTER.
 - B) "C" to run the test continuously (repeatedly), accumulating a record of errors useful for long term testing. After each pass through the test, the map of ICs which gave errors is updated. Pressing the ESCAPE key (or UPPER CASE and REPEAT keys) at any time returns control to SOLOS/CUTER.
- 4) Below is the map which would be displayed if one error caused by U23 were discovered:

```
GG GG GG GG      GG GG GG GG
GG XG GG GG      GG GG GG GG
```

Each character in the map represents one of the 32 memory ICs: U1-8, U11-18, U21-28, or U32-39. If the 16KRA board is viewed so that the assembly legend is in normal reading position, each character in the map is in a position which corresponds to an IC on the board. The upper left-hand "G" in the display represents U1, while the bottom right-hand "G" represents U39, etc. "G" means the IC is good, "X" means bad.

- 5) Once the test is loaded into memory and runs correctly, you may want to save it on cassette tape for later use, using the SOLOS/CUTER SAVE command.

```

1000 *** TEST FOR PROCESSOR TECHNOLOGY 16KRA ***
1002 *
1004 * COPYRIGHT (C) 1977
1006 * SOFTWARE TECHNOLOGY CORPORATION
1008 *
1010 * THIS VERSION OF THE 16KRA TEST IS WRITTEN
1012 * TO BE LOADED INTO RAM AT ADDRESS 0000 .
1014 *
1016 * THE 16KRA TO BE TESTED MUST BE AT ADDRESS
1018 * 1000 HEX. AS A CONTIGUOUS BLOCK OF 16K.
1020 *
1022 * THE TEST MAY BE TERMINATED AT ANY TIME BY
1024 * HITTING THE ESCAPE KEY ON THE KEYBOARD.
1026 *
1028 * THIS PROGRAM USES SOLOS OR CUTER FOR I/O
1030 * IT MUST BE MODIFIED IF OTHER OPERATING
1032 * SYSTEMS ARE USED.
1034 *
1036 *
1038 *
0000 0000
0000 22 8B 01
0003 21 00 00
0006 22 8F 01
0009 22 91 01
000C 22 93 01
000F 26 10
0011 22 8D 01
0014 97
0015 32 95 01
0018 32 96 01
001B 001B
001B 3A 96 01
001E 07
001F CD 29 01
0022 97
0023 37
0024 0024
0024 F5
0025 CD 04 01
0028 1E 03
002A 002A
002A CD 1F 01
002D 1D
002E C2 2A 00
0031 3A 96 01
0034 07
0035 CD 42 01
0038 F1
0039 1F
003A D2 24 00
1040 INIT EQU $ **** INITIALIZATION ****
1042 SHLD IOADR SAVE CALLER'S I/O TABLE ADDRESS
1044 LXI H,0 CLEAR WORKING STORAGE
1046 SHLD COUNT
1048 SHLD ROW1
1050 SHLD ROW2
1052 *
1054 MVI H,10H
1056 SHLD BDADR
1058 SUB A
1060 STA PAGE PAGE NUMBER
1062 STA FILL STATIC TEST FILLER
1064 *
1066 MAIN EQU $ **** MAIN ****
1068 LDA FILL FILL STATIC TEST PAGE
1069 RLC
1070 CALL WRITE
1072 SUB A START WITH 1 BIT PATTERN
1074 STC . CARRY HAS THE BIT
1076 *
1078 LOOP1 EQU $ **** LOOP 1 ****
1080 PUSH PSW SAVE MASTER PATTERN
1082 CALL NXTPG GO PAST STATIC TEST PAGE
1084 MVI E,3 TEST NEXT 3 PAGES
1086 *
1088 TEST1 EQU $ **** TEST 1 ****
1090 CALL TEST TEST PAGE
1092 DCR E 3 PAGES TESTED?
1094 JNZ TEST1 NO, DO NEXT ONE
1096 *
1098 LDA FILL CHECK STATIC TEST PAGE
1099 RLC
1100 CALL READ FOR DROPPED BITS
1102 *
1104 POP PSW RESTORE MASTER PATTERN
1106 RAR . PERMUTE
1108 JNC LOOP1 REPEAT UNTIL CARRY COMES AROUND
1110 *

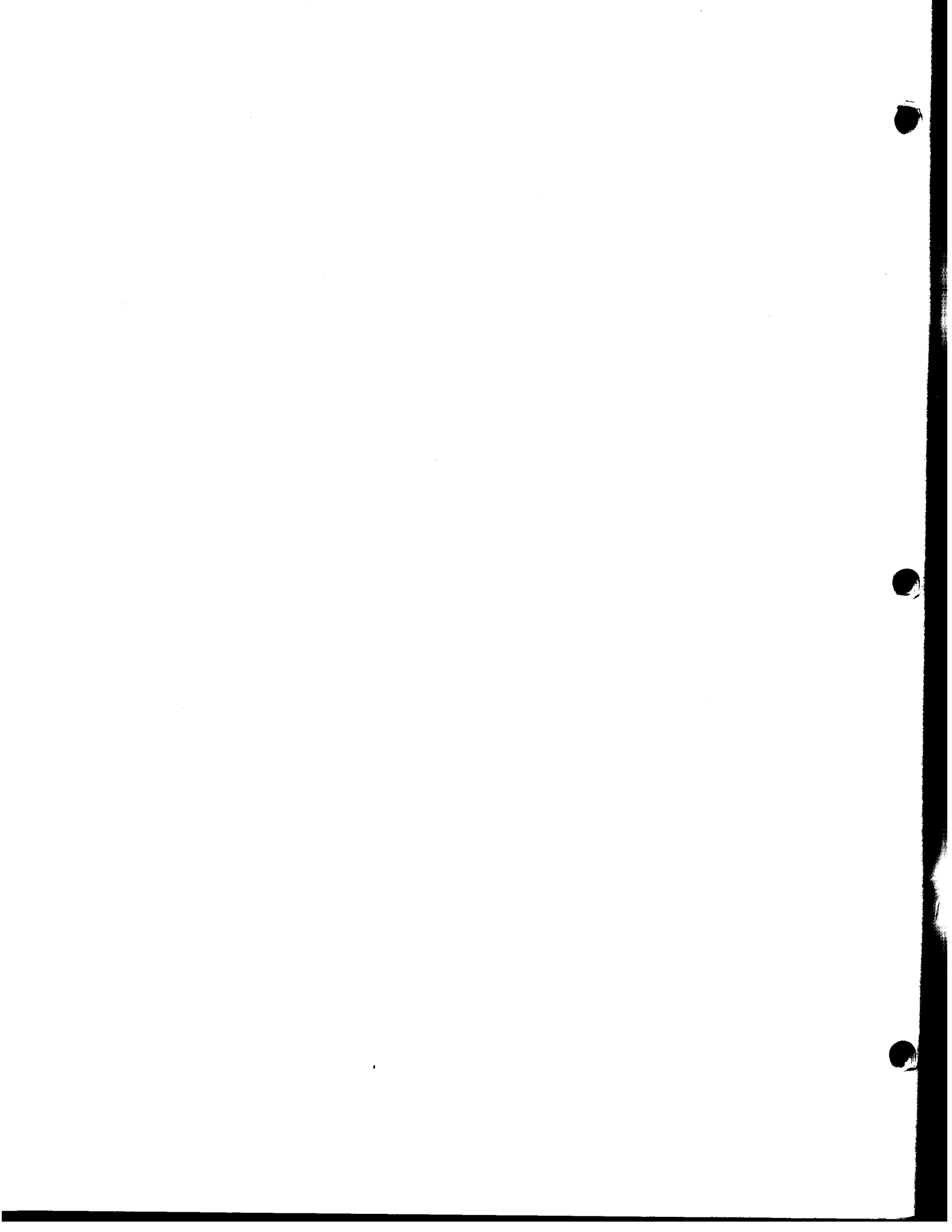
```

003D BF	1112	CMP	A	CLEAR CARRY
003E 3E FF	1114	MVI	A,0FFH	7 BIT PATTERN
	1116 *			
0040	1118 LOOP2	EQU	\$	**** LOOP 2 ****
0040 F5	1120	PUSH	PSW	SAVE MASTER PATTERN
0041 CD 04 01	1122	CALL	NXTPG	SKIP PAST STATIC TEST PAGE
0044 1E 03	1124	MVI	E,3	TEST REMAINING 3 PAGES
	1126 *			
0046	1128 TEST2	EQU	\$	
0046 CD 1F 01	1130	CALL	TEST	TEST PAGE
0049 1D	1132	DCR	E	3 PAGES TESTED?
004A C2 46 00	1134	JNZ	TEST2	NO, DO NEXT ONE
	1136 *			
004D 3A 96 01	1138	LDA	FILL	CHECK STATIC TEST PAGE
0050 07	1139	RLC		
0051 CD 42 01	1140	CALL	READ	FOR DROPPED BITS
	1142 *			
0054 F1	1144	POP	PSW	RESTORE MASTER PATTERN
0055 1F	1146	RAR	.	PERMUTE
0056 DA 40 00	1148	JC	LOOP2	REPEAT UNTIL CARRY COMES AROUND
	1150 *			
0059 CD 04 01	1152	CALL	NXTPG	REPEAT ENTIRE TEST
005C 3A 95 01	1154	LDA	PAGE	STARTING WITH
005F B7	1156	ORA	A	NEXT PAGE IF WE HAVEN'T
0060 C2 1B 00	1158	JNZ	MAIN	BEEN AROUND 4 TIMES ALREADY
	1160 *			
0063 3A 96 01	1162	LDA	FILL	INVERT FILLER
0066 2F	1164	CMA	.	
0067 32 96 01	1166	STA	FILL	AND TEST AGAIN
006A B7	1168	ORA	A	WITH COMPLIMENT
006B C2 1B 00	1170	JNZ	MAIN	UNLESS ALREADY DONE
	1172 *			
006E CD 7A 00	1174	CALL	MAP	OUTPUT CHIP MAP
0071 21 79 01	1176	LXI	H,CMLPT	'COMPLETED'
0074 CD F7 00	1178	CALL	STRNG	OUTPUT LINE
0077 C3 1B 00	1180	JMP	MAIN	AND CONTINUE TEST
	1182 *			
007A	1184 MAP	EQU	\$	**** MAP ****
007A CD BF 00	1186	CALL	CRLF	
007D 2A 91 01	1188	LHLD	ROW1	DISPLAY CHIPS IN ROW 1
0080 CD 8A 00	1190	CALL	LINE	FORMAT THE LINE
0083 2A 93 01	1192	LHLD	ROW2	DISPLAY CHIPS IN ROW 2
0086 CD 8A 00	1194	CALL	LINE	FORMAT THE LINE
0089 C9	1196	RET	.	RETURN
	1198 *			
008A	1200 LINE	EQU	\$	**** LINE ****
008A 16 04	1202	MVI	D,4	# OF BITS PER QUADRANT
008C 1E 02	1204	MVI	E,2	# OF ROWS
	1206 *			
008E	1208 QUAD	EQU	\$	**** QUAD ****
008E 7D	1210	MOV	A,L	PAGE 0 OR 2
008F 1F	1212	RAR	.	CARRY MEANS CHIP HAD ERRORS
0090 6F	1214	MOV	L,A	REMAINING BITS GO BACK
0091 CD B3 00	1216	CALL	CHIP	DISPLAY CHIP STATUS
	1218 *			
0094 7C	1220	MOV	A,H	PAGE 1 OR 3
0095 1F	1222	RAR	.	TEST BIT, CARRY IS N.G.
0096 67	1224	MOV	H,A	RETURN THE REST
0097 CD B3 00	1226	CALL	CHIP	DISPLAY CHIP STATUS

009A CD AE 00	1228 *			
009D 15	1230	CALL	SPACE	FOR READABILITY
009E C2 8E 00	1232	DCR	D	QUADRANT DONE?
	1234	JNZ	QUAD	NO
	1236 *			
00A1 16 04	1238	MVI	D,4	YES, RESTORE CHIP COUNT
00A3 CD AE 00	1240	CALL	SPACE	SEPARATE QUADRANTS
00A6 1D	1242	DCR	E	IS LINE DONE?
00A7 C2 8E 00	1244	JNZ	QUAD	NO, FORMAT OTHER QUADRANT
00AA CD BF 00	1246	CALL	CRLF	LINE IS DONE
00AD C9	1248	RET	.	RETURN
	1250 *			
00AE	1252	SPACE EQU	\$	**** SPACE ****
00AE 3E 20	1254	MVI	A,' '	WRITE A SPACE
00B0 C3 BA 00	1256	JMP	MARK	
	1258 *			
00B3	1260	CHIP EQU	\$	**** CHIP ****
00B3 3E 47	1262	MVI	A,'G'	MARK CHIP 'G'
00B5 D2 BA 00	1264	JNC	MARK	IT'S OK, ELSE
00B8 3E 58	1266	MVI	A,'X'	MARK CHIP 'X'
	1268 *			
00BA CD CA 00	1270	MARK CALL	PUT	OUTPUT MARK
00BD BF	1272	CMP	A	CLEAR CARRY BIT
00BE C9	1274	RET	.	RETURN
	1276 *			
00BF	1278	CRLF EQU	\$	**** CRLF ****
00BF 3E 0D	1280	MVI	A,0DH	OUTPUT CARRIAGE RETURN
00C1 CD CA 00	1282	CALL	PUT	
00C4 3E 0A	1284	MVI	A,0AH	FOLLOWED BY A LINE FEED
00C6 CD CA 00	1286	CALL	PUT	
00C9 C9	1288	RET	.	AND RETURN
	1290 *			
00CA	1292	PUT EQU	\$	**** PUT ****
00CA E5	1294	PUSH	H	SAVE
00CB 01 19 00	1296	LXI	B,SOUT	OUTPUT ROUTINE JUMP LOCATION
00CE 2A 8B 01	1298	LHLD	IOADR	ADDRESS OF 'CUTER'/'SOLOS'
00D1 09	1300	DAD	B	FORM TRUE ADDRESS
00D2 47	1302	MOV	B,A	CHARACTER TO O/P IN B
00D3 E3	1304	XTHL	.	RESTORE H
00D4 C9	1306	RET	.	DESTINATION IS ON TOP OF STACK
	1308 *			
00D5	1310	GET EQU	\$	**** GET ****
00D5 01 E3 00	1312	LXI	B,CHECK	RETURN ADDRESS
00D8 C5	1314	PUSH	B	PUT ON STACK
00D9 E5	1316	PUSH	H	SAVE
00DA 01 1F 00	1318	LXI	B,SINP	INPUT ROUTINE JUMP LOCATION
00DD 2A 8B 01	1320	LHLD	IOADR	ADDRESS OF 'CUTER'/'SOLOS'
00E0 09	1322	DAD	B	FORM TRUE ADDRESS
00E1 E3	1324	XTHL	.	RESTORE H
00E2 C9	1326	RET	.	DESTINATION IS TOS, RETURNS TO CHECK
	1328 *			
00E3	1330	CHECK EQU	\$	**** CHECK ****
00E3 FE 1B	1332	CPI	1BH	ESCAPE KEY?
00E5 C0	1334	RNZ	.	NO, CONTINUE TESTING
	1336 *			
00E6	1338	ABORT EQU	\$	**** ABORT ****
00E6 CD 7A 00	1340	CALL	MAP	OUTPUT WHAT WE'VE GOT SO FAR
00E9 21 83 01	1342	LXI	H,TERM	'ABORTED'
00EC CD F7 00	1344	CALL	STRNG	OUTPUT LINE

00EF 2A 8B 01	1346	LHLD	IOADR	ADDRESS OF 'SOLOS'/'CUTER'
00F2 23	1348	INX	H	BUMP TO RETURN TO COMMAND PROCESSOR
00F3 23	1350	INX	H	
00F4 23	1352	INX	H	
00F5 23	1354	INX	H	
00F6 E9	1356	PCHL	.	EXIT TO OUR CALLER
	1358 *			
00F7	1360	STRNG	EOU	\$\$\$ STRING \$\$\$
00F7 7E	1362		MOV	A,M GET CHARACTER FROM STRING
00F8 23	1364		INX	H BUMP STRING POINTER
00F9 FE 0D	1366		CPI	0DH IS IT CR?
00FB CA BF 00	1368		JZ	CRLF YES, END OF STRING
00FE CD CA 00	1370		CALL	PUT NO, OUTPUT CHARACTER
0101 C3 F7 00	1372		JMP	STRNG CONTINUE
	1374 *			
0104	1376	NXTPG	EOU	\$\$\$ NEXT PAGE \$\$\$
0104 F5	1378		PUSH	PSW SAVE
0105 CD D5 00	1380		CALL	GET LOOK FOR 'ESCAPE' KEY
0108 3A 95 01	1382		LDA	PAGE GET CURRENT PAGE NUMBER
010B C6 10	1384		ADI	10H ADD 4K
010D E6 30	1386		ANI	30H WRAP AROUND
010F 32 95 01	1388		STA	PAGE SAVE
0112 F1	1390		POP	PSW RESTORE
0113 C9	1392		RET	. AND RETURN
	1394 *			
0114	1396	GETPG	EOU	\$\$\$ GET PAGE \$\$\$
0114 F5	1398		PUSH	PSW SAVE
0115 3A 95 01	1400		LDA	PAGE GET PAGE NUMBER
0118 2A 8D 01	1402		LHLD	BDADR BOARD ADDRESS
011B 84	1404		ADD	H ADD PAGE #
011C 67	1406		MOV	H,A SET PAGE ADDRESS
011D F1	1408		POP	PSW RESTORE
011E C9	1410		RET	. RETURN
	1412 *			
011F	1414	TEST	EOU	\$\$\$ TEST \$\$\$
011F CD 29 01	1416		CALL	WRITE WRITE TEST PATTERN
0122 CD 42 01	1418		CALL	READ AND READ IT BACK
0125 CD 04 01	1420		CALL	NXTPG BUMP PAGE POINTER
0128 C9	1422		RET	. THEN RETURN
	1424 *			
0129	1426	WRITE	EOU	\$\$\$ WRITE \$\$\$
0129 F5	1428		PUSH	PSW SAVE
012A CD 14 01	1430		CALL	GETPG GET PROPER HL
012D 16 10	1432		MVI	D,10H COUNT 4K
	1434 *			
012F	1436	WRIT1	EOU	\$\$\$ WRITE 1 \$\$\$
012F F5	1438		PUSH	PSW SAVE WORKING PATTERN
0130 77	1440		MOV	M,A TRY TO STORE
0131 AE	1442		XRA	M IS DATA GOOD?
0132 C4 5A 01	1444		CNZ	BITER RECORD BIT IF NOT
0135 F1	1446		POP	PSW RESTORE PATTERN
0136 17	1448		RAL	. PERMUTE
0137 2C	1450		INR	L BUMP STORAGE ADDRESS
0138 C2 2F 01	1452		JNZ	WRIT1
013B 24	1454		INR	H BUMP BY 256
013C 15	1456		DCR	D ENOUGH FOR 4K
013D C2 2F 01	1458		JNZ	WRIT1
0140 F1	1460		POP	PSW RESTORE
0141 C9	1462		RET	. AND RETURN

	0142	1464 *			
0142	F5	1466 READ	EOU	\$	**** READ ****
0143	CD 14 01	1468	PUSH	PSW	SAVE
0146	16 10	1470	CALL	GETPG	GFT PROPER HL
		1472	MVI	D,10H	COUNT 4K
	0148	1474 *			
0148	F5	1476 READ1	EOU	\$	**** READ 1 ****
0149	AE	1478	PUSH	PSW	SAVE WORKING PATTERN
014A	C4 5A 01	1480	XRA	M	IS DATA STILL GOOD ?
014D	F1	1482	CNZ	BITER	ACCUMULATE ERRORS
014E	17	1484	POP	PSW	RESTORE PATTERN
014F	2C	1486	RAL	.	PERMUTE
0150	C2 48 01	1488	INR	L	BUMP STORAGE ADDRESS
0153	24	1490	JNZ	READ1	
0154	15	1492	INR	H	BUMP BY 256
0155	C2 48 01	1494	DCR	D	ENOUGH FOR 4K
0158	F1	1496	JNZ	READ1	
0159	C9	1498	POP	PSW	RESTORE
		1500	RET	.	AND RETURN
	015A	1502 *			
015A	E5	1504 BITER	EOU	\$	**** BIT ERROR ****
015B	47	1506	PUSH	H	SAVE REGS
015C	21 91 01	1508	MOV	B,A	ERROR BIT
015F	3A 95 01	1510	LXI	H,BITS	ERROR BIT TABLE
0162	07	1512	LDA	PAGE	GET CURRENT PAGE
0163	07	1514	RLC	.	SHIFT TO
0164	07	1516	RLC	.	LOW ORDER
0165	07	1518	RLC	.	TWO BITS
0166	85	1520	RLC	.	
0167	6F	1522	ADD	L	DISPLACE BY PAGE #
0168	7E	1524	MOV	L,A	INTO BIT TABLE
0169	B0	1526	MOV	A,M	GET BITS ACCUMULATED SO FAR
016A	77	1528	ORA	B	ADD NEW ONES
		1530	MOV	M,A	AND PUT IN TABLE
		1532 *			
016B	2A 8F 01	1534	LHLD	COUNT	ERROR COUNT
016E	23	1536	INX	H	BUMP
016F	22 8F 01	1538	SHLD	COUNT	
0172	7C	1540	MOV	A,H	HAS COUNT
0173	B5	1542	ORA	L	GONE AROUND TO 0?
0174	CA E6 00	1544	JZ	ABORT	YES, TERMINATE TEST
0177	E1	1546	POP	H	RESTORE
0178	C9	1548	RET	.	AND RETURN TO TEST
		1550 *			
0179	43 4F 4D 50	1552 CMPLT	ASC	'COMPLETED'	
	4C 45 54 45				
	44				
0182	0D	1554	DB	0DH	
0183	41 42 4F 52	1556 TERM	ASC	'ABORTED'	
	54 45 44				
018A	0D	1558	DB	0DH	
		1560 *			
0019		1562 SOUT	EOU	19H	DISPLACEMENT TO JUMP
001F		1564 SINP	EOU	1FH	DISPLACEMENT TO JUMP
		1566 *			
018B		1568 RAM	EOU	\$	DEFINE WRITABLE STORAGE AREA
		1570 *			
018B		1572 IOADR	DS	2	ADDRESS OF CALLER'S JUMP TABLE
018D		1574 BDADR	DS	2	ADDRESS OF 16KRA UNDER TEST
018F		1576 COUNT	DS	2	ERROR COUNT
	0191	1578 BITS	EOU	\$	CHIP MAP, MUST NOT CROSS 256 BYTE BOUNDR
0191		1580 ROW1	DS	2	BIT MAP FOR BITS IN ROW 1
0193		1582 ROW2	DS	2	BIT MAP FOR BITS IN ROW 2
0195		1584 PAGE	DS	1	CURRENT PAGE
0196		1586 FILL	DS	1	STATIC TEST BYTE



16KRA & 32KRA Update 731041

Subjects: Modification to correct marginal memory address timing.
Errata in Long Memory Test Appendix.

This update describes modifications to 16KRA and 32KRA circuit boards being made at the factory. If you receive this update with a new or factory board, it describes the changes that were made. Instructions are also included for performing these modifications in the field. However, field modification should only be attempted in conjunction with a new test and verification procedure to be supplied to Processor Technology dealers.

The modifications correct a marginal timing condition. When RAS is issued, address information must be stable at the RAM chips. During read/write operation, this "set-up" time is adequate, but during refresh, an additional propagation delay is introduced by the Page Multiplexers. In certain boards RAS occurs before address information is stable, and the wrong memory location is refreshed. If this occurs, memory locations may lose stored data because they were not refreshed. Boards with this problem show intermittent read errors.

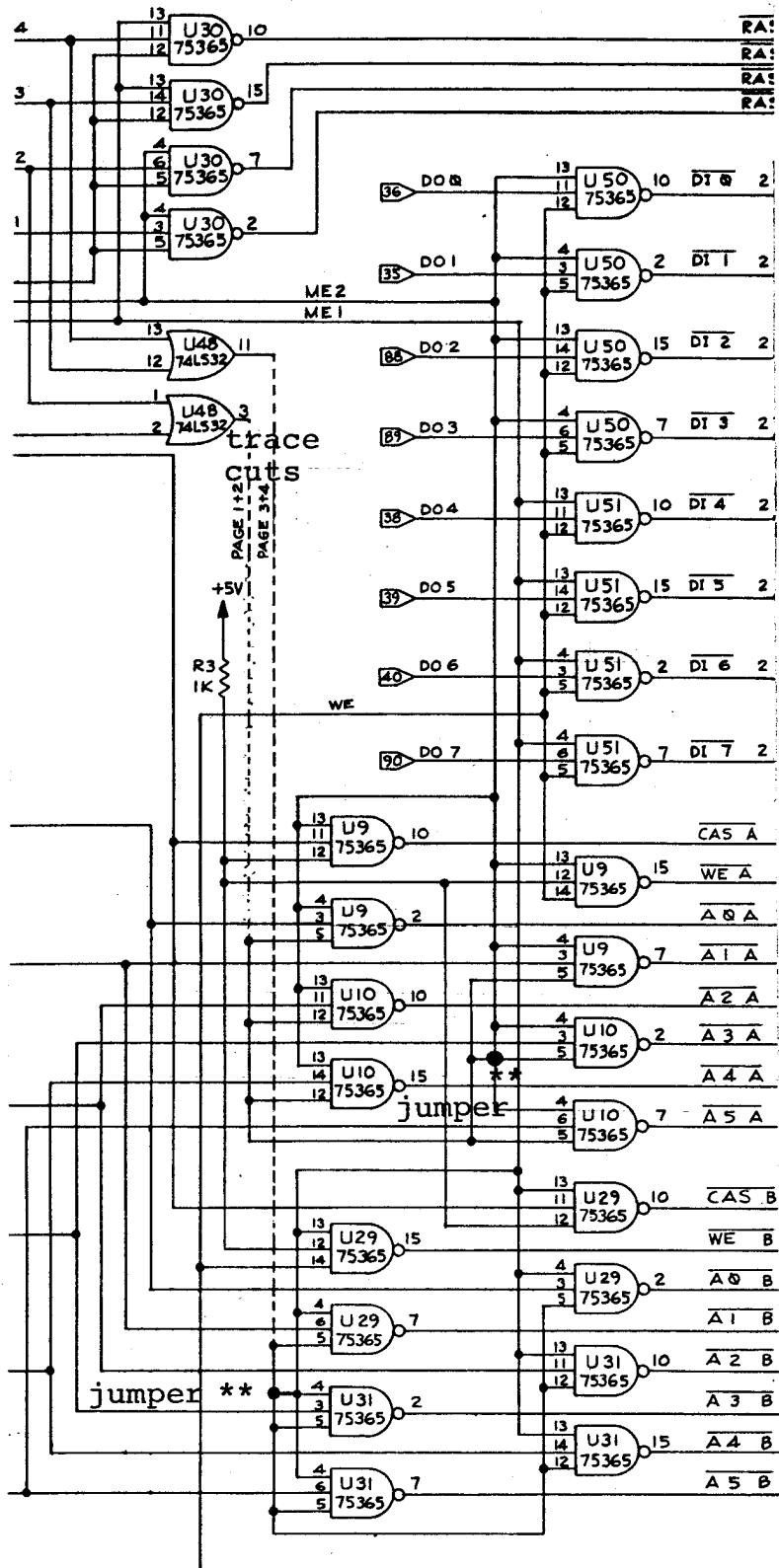
This problem, or potential problem, is corrected by making two trace cuts and inserting two short jumpers. The resulting circuit is shown in the portion of the 16KRA schematic below. Before the modification, the last signals to arrive at the address drivers, and thus the limiting factor in set-up time, were PAGE 1 & 2, and PAGE 3 & 4. The modification eliminates these signals. The corresponding inputs to the address drivers are connected instead to the signals ME1 and ME2. This change provides adequate set-up time by removing the propagation time in U48. These changes are identical on the 32KRA, except that additional inputs to address drivers in U73 are tied to ME1 and ME2. To make the modifications in the field on a 16KRA or 32KRA in conjunction with the test and verification procedure, follow these steps, referring to the assembly detail below:

- 1) On the solder side of the board, cut the single trace which connects to U48-pin 3, close to pin 3.
- 2) On the component side, cut the single trace which connects to U48-pin 11, close to pin 11 (before it connects with the the nearby feedthrough pad.)
- 3) Using two 1/4" pieces of #22 bus wire, connect U10, pins 4 and 5, and U31, pins 4 and 5.

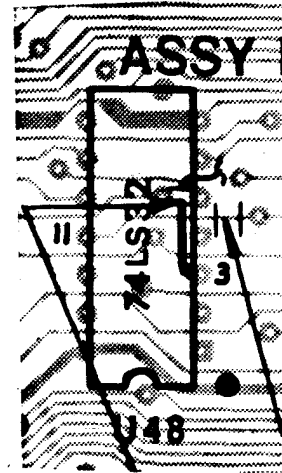
Please make appropriate corrections in your manual.

Please note that the instructions for the 16KRA Long Memory Test on page A2-4 of the fourth printing of the 16KRA manual ask you to load the test into memory at address C900H, but the program listing which follows shows an assembly at address 0000. The program can run in built-in system RAM at C900 if the source code for the program is reassembled with this origin. If the program is used as listed, it can run in a 4K memory board addressed at 0000, to test a 16K memory board addressed at 1000 as stated in the listing.

Please note also that the program listing for the 32KRA Long Memory Test, which begins on page A2-5 of the 32KRA manual (first printing) is not in order. After page A2-7, the listing continues on page A2-10, then A2-9, then A2-8. This listing is shown properly assembled at address C900.



TRACE CUTS



component side

solder side

16KRA & 32KRA Update 731066

New modifications to the 16KRA and 32KRA circuit boards involving three trace cuts and three jumpers are being made by the factory. If you receive this update with a new or factory-serviced board, it describes the modifications that were made. If you receive this update separately, it contains the instructions to make the modifications in the field.

Boards without the changes sometimes have very sharp noise pulses on the four $\overline{\text{RAS}}$ signals during Coincidence cycles. The changes, shown in Figure 1, ensure that the trailing edge of the four $\overline{\text{RAS}}$ signals go high before the four PAGE signals change, by gating U30 from a new signal, ME, instead of ME1 and ME2. The new ME signal occurs two gate delays earlier.

If you have a board that is exhibiting problems, it is recommended that you perform the modifications, whether or not you are sure there are noise spikes on the $\overline{\text{RAS}}$ lines. If you have a board that is working reliably, it is not necessary to make the changes. The modifications do not interact with any previous modifications or revision levels, and may be made on any board, without bringing it up to the current revision level. The instructions below assume that you have a 16KRA board that has "REV D", "REV E", or "REV F" etched in copper on the lower right-hand corner of the solder side of the board, or a 32KRA board that is marked "REV B". There is only one small difference between modifying a 16KRA or a 32KRA board, which is explained below.

- 1) On the component side of a 16KRA board, cut the trace that connects U30-pin 13 and U29-pin 4, and the trace that connects U31-pin 13 and U30-pin 13, as shown in Figure 2. On a 32KRA board cut the trace between U30-pin 13 and the nearby feedthrough pad, and the trace that connects U31-pin 13 and U30-pin 13, as shown in Figure 3.
- 2) On a "REV F" 16KRA or "REV B" 32KRA, cut the trace on the solder side that goes to U30-pin 4, adjacent to pin 4's pad, as shown in Figure 4. On a "REV D" or "REV E" 16KRA there are two traces to pin 4, instead of the triangle of copper shown. Cut both traces, and solder a jumper on the solder side between U50-pin 13 and U10-pin 13.
- 3) Using 30 AWG solid insulated wire, install the three jumpers on the solder side shown in Figure 4. They connect:

U30-pin 4 to U30-pin 13,
U30-pin 13 to U44-pin 5, and
U29-pin 4 to U31-pin 13.

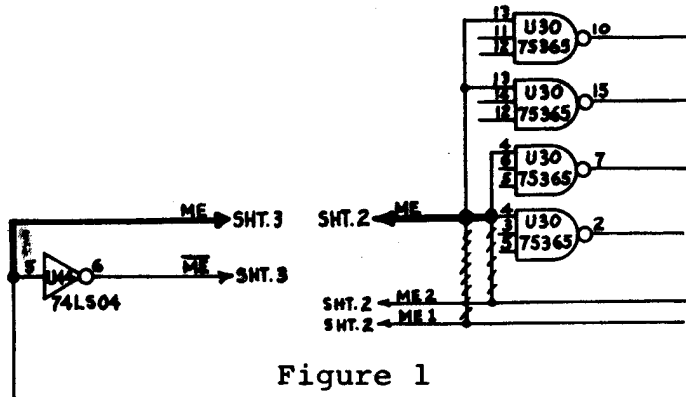


Figure 1

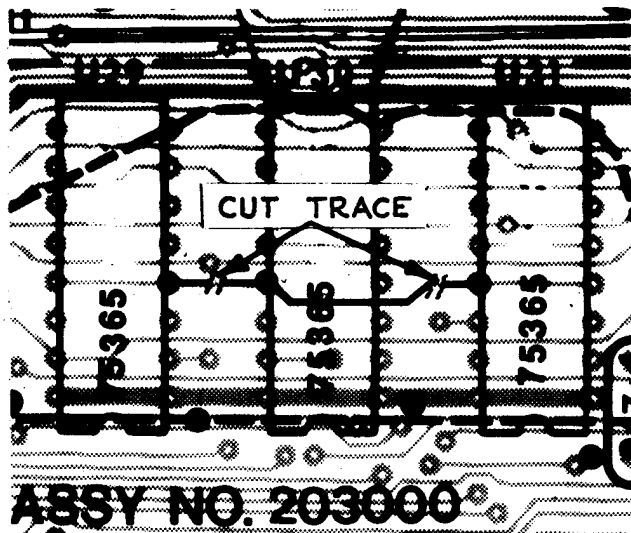


Figure 2

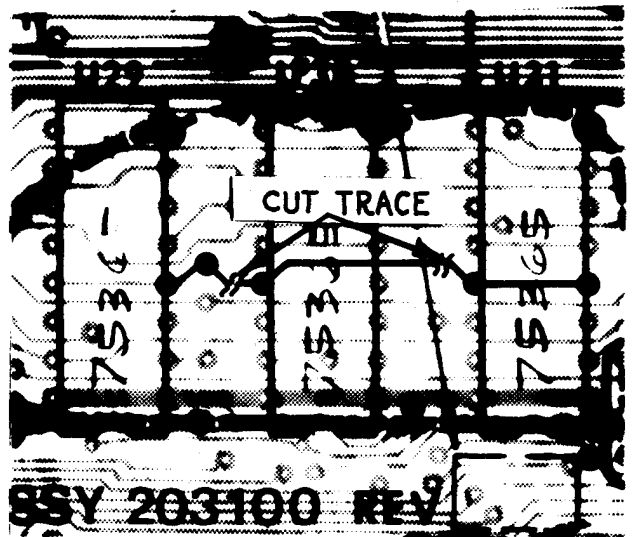


Figure 3

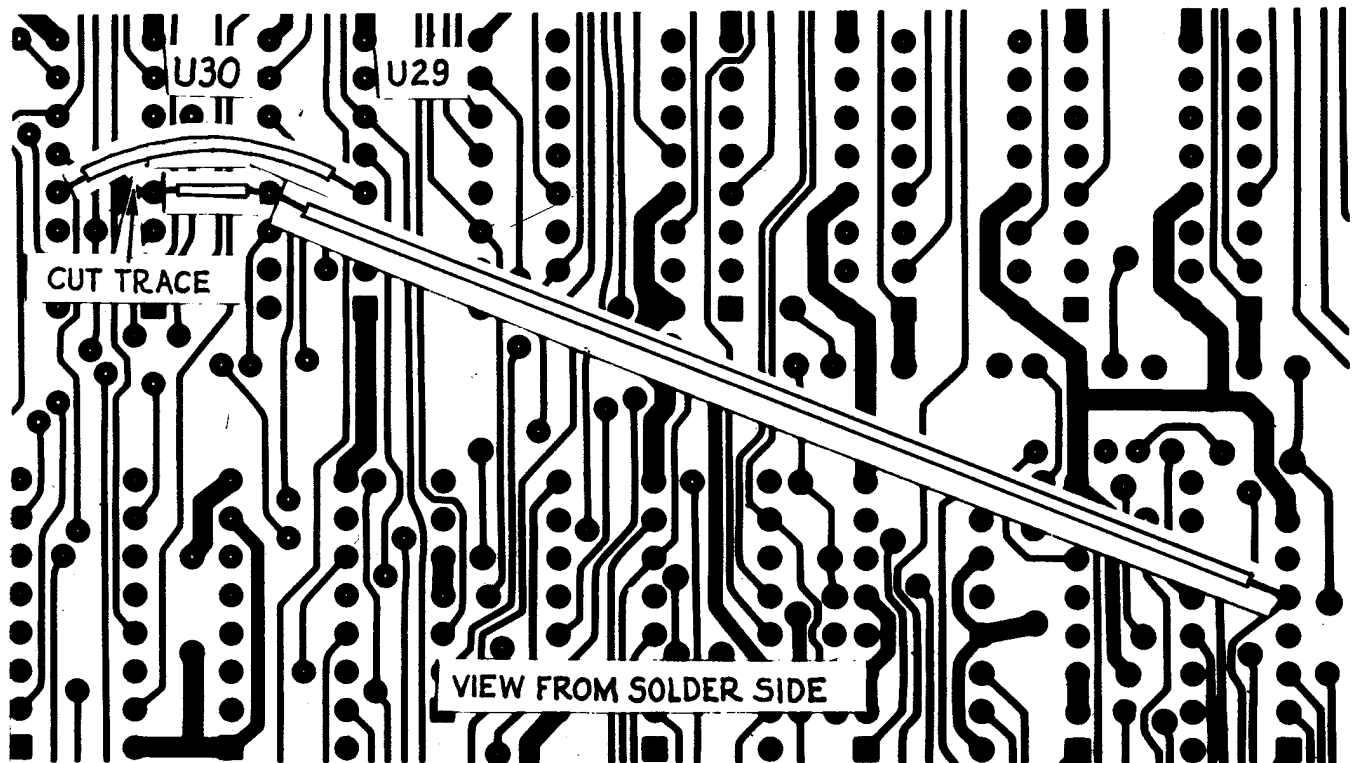


Figure 4