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MARTIN MARIETTA

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**NONDESTRUCTIVE X-RAY MICROANALYSIS
BIDIRECTIONAL SCANNING AND DATA
ACQUISITION SYSTEM**

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BIDIRECTIONAL SCANNING AND DATA ACQUISITION SYSTEM

R.L. LAWSON

9/12/89

TABLE OF CONTENTS

INTRODUCTION	3
PREVIOUS SYSTEMS	3
OVERALL USE	3
SYSTEM HARDWARE	3
SOFTWARE	4
FUNCTIONAL DESCRIPTION	4
BIDIRECTIONAL SCAN OFFSET	6
USING THE SOFTWARE	7
PROGRAMMING	9
FILE DESCRIPTIONS	9
COMPILING AND LINKING THE FILES	10
PROGRAMMING/HARDWARE PECULIARITY	10
DETAILED FUNCTIONAL DESCRIPTION	11
MEANING OF ERROR FLAG VALUES	14
APPENDIX A LINK PROGRAM COMMAND FILE	16
FILENAME: BFSCAN.LNK	16
APPENDIX B SOFTWARE FLOW DIAGRAMS	17
APPENDIX C MAIN PROGRAM AND SUBROUTINE FILES	23
FILENAME: BFSCAN.FOR	23
FILENAME: CLEAR.FOR	30
FILENAME: FISR.MAC	31
FILENAME: GETBDS.FOR	49
FILENAME: SAVDAT.FOR	57
FILENAME: UNXPFG.FOR	59
FILENAME: GRINFO.FOR	61
FILENAME: PREPAR.FOR	62
APPENDIX D EXAMPLE UNIX C PROGRAM	63

INTRODUCTION

A system for making fast scans of specimens and acquiring data was developed at the Oak Ridge Y-12 Plant. An LSI 11/23 computer using the RT11 operating system controls the scan and data acquisition. Scan software was written which would program a Unidex III stepping motor controller to make the scan motions while the position was monitored and the data acquired through the computer's timer/counter boards from the multichannel analyzer's four region of interest (ROI) outputs. Small areas of a part or specimen are scanned by moving the part back and forth in the x-ray beam using stepping motor actuated tables. A detector receives the scattered x-rays from the part and sends a signal to the multichannel analyzer which digitizes it. After the data has been acquired using the scan computer, the data is then transferred to a PC to where it is processed and an image is generated and displayed for analysis.

PREVIOUS SYSTEMS

This scanning and data acquisition system resulted after several previous attempts to acquire the complete spectrum data at high rates through the multichannel analyzer failed. Software generated for the previous system configurations included code to communicate with the multichannel analyzer through its serial interface, its bus interface (GPIB), and the programs to get the data and store it in a data file.

OVERALL USE

This data acquisition system is part of a larger system which is used for non-destructive x-ray microanalysis of parts. The image generated on the PC from the scan data is used for studying part abnormalities. With four regions of interest, the distributions of four chemical elements in a part can be imaged. This information can be used to determine the composition of unusual features on a part which may cause part failure.

SYSTEM HARDWARE

The system hardware consists of an x-ray machine, x-ray detector, translation tables, a multichannel analyzer, stepping motor controllers, and an LSI 11/23 computer. The x-ray detector feeds the multichannel analyzer indirectly through other conditioning devices. The computer has five timer/counter boards installed in it. One board uses the stepping pulses to control the other four counter boards which count the data pulses from the four region of interest outputs of the multichannel analyzer. An internal

connection was made in the Unidex III stepping motor controller to output the stepping pulses to the counter board for position tracking and data acquisition by the computer.

SOFTWARE FUNCTIONAL DESCRIPTION

The following functional description of the scan program can best be understood using the block diagram of figure 1. First, an example scan setup is given as :

NUMBER OF X POINTS = 100
 X POINT SIZE (MICRONS) = 10.0
 TIME per X POINT (SECONDS) = 0.1
 NUMBER OF Y POINTS = 100
 Y MOVE (MICRONS) = 10.0
 TIME per Y MOVE (SECONDS) = .1
 NUMBER OF ROIs = 4
 SPECIMEN SCAN QUADRANT = 4

Using this information, the computer will calculate the number of steps and the feedrate to perform the scan. The NUMBER OF X POINTS is the number of data points to collect for one scan of the x axis. The X POINT SIZE is the distance over which counts are taken for each data point. Therefore, the total distance in microns covered along the x axis will be equal to the NUMBER OF X POINTS multiplied by the X POINT SIZE. Since the Unidex III moves the specimen 1 micron per step, this number is equal to the number of steps required to scan the x axis. For this example, the total number of steps is 1000 and the feedrate is 100 steps per second. Since the step counter board's overflow output triggers the ROI counters, an extra step must be added to the total # of steps. For this example, the total number of steps to scan the x axis would be 1001. With the scan program now defined, the LSI 11/23 computer will load it into the Unidex III stepping motor controller through the GPIB interface. After loading the scan program, the Step Counter ST2 interrupt routine will be enabled, then the Unidex scan program will be started. When the Unidex starts its scan program, it will send a beginning of x axis scan pulse which will cause the Step counter to start counting the stepping motor pulses. The first stepping motor pulse will cause a counter overflow which will start the ROI counter boards running. After this first overflow, the step counter will only overflow on every 10th pulse for this example. Each time an overflow occurs, the ROI counter boards will save their present count in a buffer, zero their counter, and start counting again. The computer will detect the step counter overflow and will read the ROI counter buffers while the boards are counting. The computer stores the count data

Figure 1
Scan Hardware Block Diagram

for each ROI in memory. When the scan is complete, the computer will get the data from memory and save it in the specified data file.

BIDIRECTIONAL SCAN OFFSET

A result of using a stepping pulse to start/reset the ROI counters is an offset in the scan data. The reverse scanned data offset is unknown but could be as much as 1 micron (1 step) or 0.1 micron if the microstepper is used. Figure 2 is a scan example that demonstrates the offset.

Figure 2

This example is for a scan that would acquire 2 data points of 2 micron widths for each x axis scan. Now consider the first data point that would be acquired. When the ROI counter boards receive the forward overflow pulse, they will start counting. Although unmeasured, the forward overflow pulse should occur before the specimen has moved from the first position. This is when the ROI counter is started. When the next forward overflow pulse occurs 2 steps later, the ROI counter board will save the data and start counting again. Therefore, assuming again that the overflow pulse occurs faster than the specimen can be moved, the first data point will be an average of the counts for the area from position 1 to position 3. The second data point will be read from the counter board when the third forward overflow pulse occurs. (The additional step was needed here to cause the step counter to generate the third overflow pulse.) Therefore, the second data point will be an average of the area from position 3 to 5. Now

consider the reverse scan. The beam starts at position 6 on the specimen. When the first step occurs, an overflow pulse will be generated to start the ROI counters. Two steps later, another overflow pulse will occur to save the ROI counts and restart counting. Still assuming that the counters are started before the specimen is moved, the third data point will be an average over the area from 6 to 4 and the fourth data point will be an average of the area from positions 4 to 2. Since most of the features imaged by this system are several microns in size and most data points consist of an average of 5 to 10 microns, a 1 micron offset between the forward and reverse scan data should not present a problem.

The sequence described above is the worst case. The best case would be to assume that the stepping motors move the specimen very quickly and spend most of their time sitting in one of the positions represented in figure 2. If this were the case, then an average of the counts for positions 2 and 3 would represent the first data point, 4 and 5 for the second data point, 5 and 4 for the third data point, and 3 and 2 for the fourth data point. In this case the offset between the forward and reverse scans would be zero microns. Slow scans will approach the best case and fast scans will approach the worst case. Since the stepping motors can move the specimen at about 400 steps per second without the speed being ramped up, then a slow scan could be any scan which moves the specimen at 100 steps per second or less. Although the offset caused by the data acquisition system is present in the data, other elements such as the beam width and backlash must also be considered to determine the overall affect on the data.

USING THE SOFTWARE

To start the bidirectional scan program, the command 'RUN BFSCAN' must be entered at the system prompt. When the scan program is started, a main menu is displayed.

Main Menu

- 0. STOP
- 1. Bidirectional Scan
- 2. Retrieve data from Memory

Enter # of Choice >

The option to retrieve the data from memory is needed only when the scan program crashes. Most crashes occur after the data has

been acquired and when the computer attempts to put the data in a disk file. These crashes are usually due to insufficient space on the disk to put the data. When this happens, the user can free up space on the data disk by either squeezing the free space or deleting some old data files. When the space is available for storing the data, the scan program can be rerun and the retrieve option selected to save the data to a file.

The scan option pulls up another menu to allow the user to select the method of inputting the scan setup data.

SCAN MENU

- 0. Main Menu
- 1. File Input
- 2. Manual Input

ENTER # OF CHOICE ? >

When the file input option is selected, the program will request a setup filename. The setup information will be read from file and displayed for the user to verify that setup information is correct. If the user accepts the setup, then the program will continue by requesting a data file name. Upon entering the file name, the user will be asked to verify that the Unidex III and the multichannel analyzer are ready. After confirming the ready status of the instruments, the program will prepare and load the scan program into the Unidex III stepping motor controller. When the computer is ready, it will prompt the user to press the return key to start the scan. While the interrupt routines are handling the data acquisition, the main program will display the bidirectional scans progress. The scan position is correct for the forward scans but is inverted for the reverse scans. At the end of the scan, the computer will get the data from memory and store it in the specified data file.

If the manual input option was selected, then the user must enter the scan setup information. The following information will be required.

NUMBER OF X POINTS
X POINT SIZE (MICRONS)
TIME per X POINT (SECONDS)
NUMBER OF Y POINTS
Y MOVE (MICRONS)
TIME per Y MOVE (SECONDS)

NUMBER OF ROIs

SPECIMEN SCAN QUADRANT

The NUMBER OF X POINTS is the number of data points that the user wants to collect. The X POINT SIZE (MICRONS) is the area over which the count data will be taken. The total scan length will be the NUMBER OF X POINTS multiplied by the X POINT SIZE. The TIME per X POINT (SECONDS) is the amount of time over which the count data will be acquired for each data point. The total scan time in seconds for one line along the x axis will then be approximately equal to the NUMBER OF X POINTS multiplied by the TIME per X POINT. The NUMBER OF Y POINTS is the number of x axis scan lines. The TIME per Y MOVE is the amount of time the Unidex will take to move the specimen to the next x axis scan position. The NUMBER OF ROIs refers to the number of multichannel analyzer ROI outputs for which data will be collected. The SPECIMEN SCAN QUADRANT provides the x and y axis scan direction information with respect to the present beam location on the specimen.

After the user enters the required information, the program will calculate some additional scan information and ask the user if any changes need to be made. When the user accepts the setup information, the program will ask the user if he wants it saved to a file. If saving the setup is selected, the program prompts the user for a filename and save the setup.

PROGRAMMING

FILE DESCRIPTIONS

The source files used to build the bidirectional scan program are BFSCAN.LNK, BFSCAN.FOR, FISR.MAC, CLEAR.FOR, GETBDS.FOR, GRINFO.FOR, PREPAR.FOR, SAVDAT.FOR, UDXPRG.FOR. The GPIB object files located in the system area are also linked to the scan program. A description of each file is given below.

BFSCAN.LNK This command file is used to link the main program and its subroutines. It is invoked by entering @BFSCAN.LNK at the RT11 System prompt.

BFSCAN.FOR This is the main program. It provides a main menu for the user to select stopping the program, the bidirectional scan menu, or retrieving the last scan's data from memory. When the scan menu is selected, the user is given a choice of returning to the main menu, starting a scan from a setup file, or entering the setup manually to start a

scan.

CLEAR.FOR	This subroutine clears the vt100 terminal screen.
FISR.MAC	This file contains the interrupt service routines and associated subroutines needed to setup the scan. The timer interrupt service routine handles the interrupts for the Unidex stepping pulses. It will generate an overflow pulse which will cause the 4 ROI counters to save their current count, clear their counter, and start counting for the next data point. The counter overflow interrupt routine is used to check for counter overflows. A counter overflow will occur when more than 65535 counts is accumulated in the specified sampling time. The interrupt initialization and the get data subroutines are also included in this file.
GETBDS.FOR	This subroutine gets the bidirectional scan setup data from either a file or the user depending on the user's choice from the scan menu.
SAVDAT.FOR	This routine gets the scan data from memory and puts it in the data file specified by the user when the scan is started. To get the data from memory, this routine calls the initialize and the get point routines which are located in the FISR.MAC file.
UDXPRG.FOR	This routine generates the scan program to be loaded into the Unidex III stepping motor controller. The main program actually loads the program in the Unidex III.
GRINFO.FOR	This routine is used to get the information needed to retrieve the scan data from memory when the retrieve option is selected from the main menu.
PREPAR.FOR	This routine asks the user to prepare the Unidex III and the multichannel analyzer for the scan.
IBUP.OBJ IBVDP.OBJ	These two files were created from the vendor supplied source files. They provide the GPIB commands which are used throughout the software.

COMPILING AND LINKING THE FILES

The source files consist of both Fortran and Macro types. To compile the Fortran source files, use the command "FORT filename"

where filename is the name of one of the Fortran files. To compile the Macro files, use the command "MAC filename" where filename is the name of a Macro file. When all of the source files have been compiled, use the command file BFSCAN.LNK to link them. To invoke the link command file enter the command "@BFSCAN.LNK". The scan program should now be ready to run.

PROGRAMMING/HARDWARE PECULIARITY

The step counter board's ST2 interrupt routine sets up the timer board such that it generates an overflow interrupt on the first step and thereafter an interrupt is generated on every Nth step. Although the software should be more than fast enough to stop the counter and reset it to generate overflow interrupts every Nth step, this approach was used to avoid the possibility that a stepping pulse would be missed due to the speed of software execution. The code in the ST2 interrupt routine which sets up the step counter board is :

```
;
; timer csr must be cleared for the bpr switching to work
;
    clr  @#csrtim
    mov  @andbpr,@#<csrtim+2> ; set bpr for 1st step interrupt
;
    mov  #163,@#csrtim        ; start timer
    mov  @ambpr,@#<csrtim+2> ; set bpr for x scan ( Nth step )
```

This code clears the timer's csr when the begging of scan pulse is received. The BPR register is then loaded with -1 to cause the counter board to generate an interrupt for the first step. After the counter board is started, the BPR register is loaded with the value to cause overflow interrupts every Nth stepping pulse. The counter board will use the initial BPR value for the first overflow interrupt. After the first overflow interrupt, the counter board will generate interrupts using the value of the BPR that was set after it was started.

DETAILED FUNCTIONAL DESCRIPTION

The following detailed functional description of the scan program and its interrupt routines is explained using the block diagram of figure 1, the flow diagrams in Appendix B, and the Unidex program in Appendix D. The following example scan setup will be used to

allow for a step by step description of the interrupt routines.

NUMBER OF X POINTS = 2
 X POINT SIZE (MICRONS) = 2
 TIME per X POINT (SECONDS) = 0.1
 NUMBER OF Y POINTS = 2
 Y MOVE (MICRONS) = 2.0
 TIME per Y MOVE (SECONDS) = 0.1
 NUMBER OF ROIs = 4
 SPECIMEN SCAN QUADRANT = 4

The computer will calculate the following information:

Total # steps for 1 x axis scan = 5
 X axis Feedrate (steps/sec) = 20
 # steps per x axis data point = 2

 Y axis feedrate (steps/sec) = 20
 # steps per y axis move = 2

Using these calculated values, the computer will generate the Unidex program listed in Appendix D with the appropriate values inserted. The scan program will be loaded into the Unidex III by the computer. After loading the scan program into the Unidex, the computer will enable the step counter's ST2 interrupt routine. When the user presses the return key, the computer will start the Unidex scan program running. As shown in the Appendix B main program flow diagram, the main program stays in a loop displaying the scan status until the flag is set by the one of the interrupt routines. Now, lets outline the sequence of events starting with a look at the Unidex program is Appendix D.

Step 1 After the Unidex scan program loads the y points or x axis line scan counter with the number 2, it will output a beginning of scan pulse. As shown in figure 1, this pulse is fed to the step counter board's ST2 input. When the step counter board detects the pulse, it will generate an interrupt causing the step counter's ST2 interrupt routine to execute.

Step 2 The Step counter's ST2 interrupt routine (see the Step counter ST2 flow diagram in Appendix B) will then enable the Step counter board's overflow interrupt while disabling the ST2 interrupts. The step counter board is setup such that the first stepping pulse and then every other stepping pulse causes an overflow interrupt. Since a 200 millisecond delay is present in the Unidex scan program, this step will occur before the scan program

begins moving the specimen.

- Step 3 After the scan program delay, the Unidex program will begin outputting pulses to move the specimen. As shown in figure 1 these stepping pulses are input to the step counter board. The first stepping pulse will cause the step counter board to generate an overflow pulse which will cause the ROI counter boards to start counting. The step counter overflow will also generate an interrupt causing the step counter overflow interrupt routine to execute.
- Step 4 Since this was the first interrupt of the x axis scan, the data from the ROI counter boards will not be saved by the step counter overflow interrupt routine.
- Step 5 When the step counter board receives the next stepping pulse, it will not generate an overflow as explained in the Hardware Peculiarity section.
- Step 6 The next stepping pulse causes the step counter board to generate an overflow pulse which will cause the ROI counter boards to save their present count, zero their counter, and restart counting the data pulses from the multichannel analyzer.
- Step 7 The step counter board overflow also generates an interrupt causing execution of the step counter overflow routine. Since this was not the first overflow of the x scan, the overflow routine will save the data for all 4 ROI counter boards in memory.
- Step 8 The next stepping pulse is detected by the step counter board but does not cause an overflow for this example.
- Step 9 The last stepping pulse of the x scan is detected by the step counter board. The step counter board will output an overflow pulse to the ROI counter boards causing them to save their present count. (This is the reason for the additional x scan step.)
- Step 10 The step counter board overflow also causes the overflow interrupt routine to be run. The step counter overflow interrupt routine will again get the count data from the ROI counter boards and save it in memory. The overflow routine also determines that this overflow was the end of the x axis scan and disables itself while enabling the ST2 interrupt routine again.
- Step 11 The step counter boards ST2 input has been enabled again and the Unidex program has completed the scan in the

forward direction. The Unidex program will now move the specimen up for the reverse scan along the x axis. The delay during this move provides enough time for step 10 to be completed by the software.

- Step 12 After completing the move to the next scan line, the Unidex scan program outputs the beginning of scan pulse and the procedure is repeated from step 1.
- Step 13 When the reverse direction scan is finished, the step counter overflow interrupt routine will again enable the ST2 interrupt routine. Since the ST2 interrupt routine checks for the end of the complete scan, the additional beginning of scan pulse output at the end of the Unidex scan program is required to cause the step counter ST2 interrupt routine to be executed.

Errors which can occur during the scan have not been discussed. Looking at the flow diagrams, there are several errors which can occur that are detected during a scan. The next section defines the meaning for each flag value.

MEANING OF ERROR FLAG VALUES

Flag values	Meaning of flag value
0	Main program looping value while Unidex program is scanning.
100	Set by step counter ST2 interrupt routine to indicate end of scan.
-210	Set by step counter ST2 interrupt routine when an overrun error occurs. An overrun can be caused by either an ST2 or an overflow overrun. Since the Unidex pulses the step counter board's ST2 input at the end of the x axis scans, the ST2 input could only cause the overrun error if noise or stray ST2 input pulses were occurring. The other cause of the overrun error is the overflow rate. If the step counter board is getting stepping pulses and generating overflows faster than the step counters overflow interrupt routine can handle, then an overrun error would occur.

- 10 These values are set by the step counter's overflow
-11 interrupt routine. If either one of the 4 ROI
-12 counter board's ST2 flags are not serviced fast
-13 enough by the step counter overflow routine, then an
overrun error will occur. The other cause of an
overrun error would be the inability of the ROI
counter overflow interrupt routine to quickly
service the ROI counter board overflows. None of
these errors are likely since the scan speeds are
usually low as well as the data pulse rates.
- 20 These values are also set by the step counter's
-21 overflow interrupt service routine. These error
-22 values are used when one of the ROI counter boards
-23 does not have its ST2 flag set. Since the step
counter board's overflow output is the ROI counter
boards ST2 input, the most likely cause of this
error would be a bad connection from the step
counter board's overflow output.
- 30 Both of these values are set by the step counter
-40 overflow interrupt service routine. These values
indicate an overrun of either the step counter's
ST2 flag or its overflow flag. The causes are the
same as error -210.
- 221 These values are set by the ROI counters' overflow
-222 interrupt service routine. These are also overrun
-223 errors which would be caused by either the ST2 or
-224 the overflow bits. If the overrun error was caused
by the ST2 bit, then the step counter's overflow
interrupt service routine would be responsible.

• APPENDIX A LINK PROGRAM COMMAND FILE

• FILENAME: BFSCAN.LNK

R LINK
BFSCAN=BFSCAN//
SY:IBUP
SY:IBVDP
FISR
CLEAR
GETBDS/o:1
savdat/o:1
udtprg/o:1
grinfo/o:1
prepar/o:1
//

APPENDIX B. SOFTWARE FLOW DIAGRAMS

MAIN PROGRAM

Step Counter ST2 Interrupt
(Beginning of Scan) Routine

A pulse on the Step counter's
ST2 input triggers this routine

Step Counter Overflow Interrupt Routine

ROI Counter Overflow
Interrupt Routine

APPENDIX C MAIN PROGRAM AND SUBROUTINE FILES

FILENAME: BFSCAN.FOR

```

C
C THIS PROGRAM IS USED TO PERFORM A FAST SCAN FOR THE X-RAY SYSTEM
C
    BYTE CMDSTG ( 6 )
    BYTE FILENA ( 40 )
    BYTE UPROG ( 512 )
    BYTE CR, LF, NULL, esc
C
    INTEGER*2 IPVAL ( 4 ), IRTC ( 6 )
    INTEGER*2 CSRTIM
    INTEGER*2 CSRCNT
C
    DATA CSRTIM / "170410 /
    DATA CSRCNT / "170420 /
C
    DATA IRTC / "170410, 0, "170420, 0, 0, 0 /
    CALL DEVICE (IRTC)
C
    CR="15
    LF="12
    NULL=0
    esc=27
    IEXST2=0 ! FLAG, NOT YET EXPECTING ST2 INTERRUPT
    IOFCNT=0
C
    CALL IPOKE(CSRTIM,0) ! DISABLE TIMER
    CALL IPOKE(CSRCNT,0) ! DISABLE COUNTER
C
14  call clear
    call mamenu ( iopt )
    if ( iopt .eq. 0 ) stop
    if ( iopt .eq. 1 ) goto 33
    if ( iopt .eq. 2 ) goto 19

```

```

      goto 14
C
19  call grinfo ( filena, ixpnts, iypnts, nrois )
    if (filena(1).eq.0) goto 14
    CALL SAVDAT ( IXPNTS, IYPNTS, NROIS )           ! GET AND SAVE
DATA
    CLOSE (UNIT=1)
    goto 14
C
33  continue
C
C  GET VALUES FOR PROGRAMMING THE UNIDEX III AND ACQUIRING DATA
C
    call sumenu ( iopt )
    if ( iopt .eq. 0 ) goto 14
    CALL GETBDS ( iopt, NROIS, IXPNTS, IYPNTS, XDIR,
1          XFEED, XMOVE, YDIR, YFEED, YMOVE )
C
C  CREATE THE UNIDEX III PROGRAM FOR MAKING THE SCAN
C
    CALL UDXPRG ( IXPNTS, XDIR, XMOVE, XFEED,
1          IYPNTS, YDIR, YMOVE, YFEED,
1          IPRG, NCUP )
C
    CALL PREPAR      ! HAS ORIGIN AND ROIS BEEN SET
C
C
    J=IEUP(4,2)      ! PUT UNIDEX IN REMOTE
C
    DO 543 I=1,100  ! delay loop
      K=I
543  CONTINUE

    IF(C.NE.1) STOP ' ERROR - PUTTING X,Y UNIDEX IN REMOTE'
    J=IEUP(6,1)      ! SERIAL POLL
    WRITE(5,845) J
    IF(J.LT.0) STOP ' ERROR - POLLING X,Y UNIDEX'
    IF(C.NE.0) STOP ' ERROR - SERIAL POLL STATUS'

```

```

C
C  SEND PROGRAM TO UNIDEX III
C
      IDVCE = 2 ! DEVICE # OF X,Y AXIS UNIDEX
      ENCODE(6,174,CMDSTG) CR,LF
174  FORMAT('E 30',2A1)
C
      J=IBUP(0,IDVCE,CMDSTG,6) ! PUT UNIDEX IN EDIT MODE
      IF(J.LT.0) STOP ' ERROR - "FSCAN", PUTTING UNIDEX IN EDIT
MODE'
C
      J = IBUP ( 0, IDVCE, UPROG, NCUP ) ! WRITE THE SCAN PROGRAM
      IF ( J .LT. 0 ) STOP ' ERROR - "FSCAN", SENDING SCAN PROGRAM
'
C
C  OPEN DATA FILE
C
533  write(5,534)
534  format(' Enter filename for data ')
      read(5,535) nc,(filena(i),i=1,40)
535  format(q,40a1)
      if(nc.eq.0) goto 533
      filena(nc+1)=0
'
      OPEN(UNIT=1,NAME=filena,TYPE='NEW')
C
C  FIRST STEP IS USED TO START THE COUNTER
C
      XSPM = 1. ! # OF STEPS PER MICRON OF X AXIS
      INDBPR = -1
      IRNBPR = IFIX ( XMOVE * -XSPM )
'
      SETUP THE INTERRUPT SERVICE ROUTINES AND PASS THE REQUIRED
VARIABLES
C
      iflag = 0
      CALL ISCAN ( IFLAG, INDBPR, IRNBPR, IXPNTS,
1      IYPNTS, IOFCNT, IS2CNT, IEXST2, ICOVER, IROIS )

```

```

C
C  ENABLE TIMER ST2 INTERRUPTS ( 0 100 000 000 000 001 )
C
      CALL IPOKE(CSRTIM,"40001)
      PAUSE ' INTERRUPT ROUTINE ENABLED, READY TO START UNIDEX'
C
      IEXST2=1  ! SET FLAG, EXPECTING ST2 INTERRUPT
C
      CALL STUDX ! START UNIDEX SCAN PROGRAM RUNNING
C
C  WAIT FOR SCAN TO FINISH
C
      I=1
299  continue
C
      REMAIN IN FOLLOWING LOOP UNTIL SCAN COMPLETED
C
      call clear
      write(5,2022)
2022 format(/,' X AXIS BIDIRECTIONAL SCAN ')
      write(5,2023) ixpnts,iypnts,nrois
2023 format('0# X data points = ',i4,'      # Y scan lines = ',i3,
1      '      # ROIS = ',i2)
C
2100 CONTINUE
C
      DO 2344 I=1,20000
      K=I
2344 CONTINUE
C
      WRITE(5,1233) ESC
1233 FORMAT ('+',A1,'[7;1H',$( ! move cursor to line 7
C
      write(5,2088) icover
2088 format (' # of Counter overflows = ',i4,/)
      WRITE(5,2085) IOFCNT, IS2CNT
2085 FORMAT('OPRESENT SCAN POSITION',,,
1      '0Data point ( K ) = ',i4,

```

```

1      '      Scan line ( Y ) = ',i3,/)
C
C THE INTERRUPT ROUTINE WILL CHANGE THE VALUE OF IFLAG WHEN
C THE SCAN IS FINISHED OR AN ERROR OCCURS.
C
      IF ( IFLAG .EQ. 0 ) GOTO 2100  ! LOOP UNTIL FINISH OR ERROR
C
C
      WRITE(5,2115) IFLAG
2115  FORMAT(' FLAG = ',I6)
      if(iflag.eq.100) goto 858
C
      write(5,624)
624   format (' !!! SCAN FAILED !!!',//,
1      ' Press RETURN to Continue')
      goto 14
C
C SCAN FINISHED, SAVE DATA
C
858   WRITE(5,293)
293   FORMAT('SCAN FINISHED, NOW RETRIEVING AND STORING DATA')
C
      CALL SAVDAT ( IXPNTS, IYPNTS, NROIS )      ! GET AND SAVE DATA
C
      CLOSE(UNIT=1)
C
      J=IEUP(6,2)      ! SERIAL POLL
      IF(J.LT.0) STOP ' ERROR - SERIAL POLL'
      WRITE(5,845) J
845   FORMAT(' SERIAL POLL BYTE (OCTAL) = ',O6)
      J=IEUP(6,2)      ! SERIAL POLL
      IF(J.LT.0) STOP ' ERROR - SERIAL POLL'
      WRITE(5,845) J
      J = IEUP ( 5, 2 )      ! PUT IN LOCAL
      IF ( J .NE. 1 ) STOP ' ERROR - RETURNING UNDEFN TO LOCAL '
C
      j=1
      if(j.eq.1) goto 14

```

```

C
999  STOP
      END

```

SUBROUTINE STJDX

```

C
C  START UNIDEX PROGRAM
C
      BYTE CMDSTG(20)
C
      IDVCE = 2
C
      CMDSTG(1)='A'
      CMDSTG(2)='3'
      CMDSTG(3)='0'
      CMDSTG(4)="15
      CMDSTG(5)="12
C
      J = IBUP(0, IDVCE, CMDSTG, 5)      ! WRITE COMMAND
      IF(J.EQ.5) GOTO 7280  ! JUMP IF NO ERROR
      WRITE(5,7182) J
7182  FORMAT ('0ERROR - "FSCAN", WRITING START COMMAND,
             1 IBUP ERROR = ', I4)
      STOP
7280  CONTINUE
C
      RETURN
      END

```

```

      subroutine mainmenu ( iopt )

```

```

      integer*2 iopt

```

```

15  write(5,20)

```

```

20  format ('0Mail Menu',/,/,

```



```

1      ' 0. STOP',/,
1      ' 1. Bidirectional Scan',/,
1      ' 2. Retrieve data from Memory',/,
1      ' Enter # of Choice >')

C
      read(5,30,err=15) nc,iopt
30     format(q,i3)
      if (nc.eq.0) iopt = -1
      return
      end

      SUBROUTINE MENU ( IOPT )
C
C THIS ROUTINE SETS THE USERS CHOICE FOR SETUP INFO. ENTRY
C
17     CALL CLEAR
C
      WRITE(5,18)
18     FORMAT (' MAIN MENU',/,
1          ' 0. Main Menu',/,
1          ' 1. File Input ',/,
1          ' 2. Manual Input ',/,
2          ' ENTER # OF CHOICE ? > ',)
      READ(5,19) nc, iopt
19     FORMAT ( Q, I1 )

      IF ( NC .EQ. 0 ) GOTO 17
      IF ( IOPT .LT. 0 .OR. IOPT .GT. 2 ) GOTO 17

      RETURN
      END

```

FILENAME: CLEAR.FOR

```
      SUBROUTINE CLEAR  
      LOGICAL*1 ESC  
      ESC=27  
      WRITE(5,100) ESC, ESC  
100   FORMAT('+',A1,'[2J',A1,'[1;1H',$)  
      RETURN  
      END
```

FILENAME: FISR.MAC

.title scan initialization routine

;

```

csrtim = 170410      ; timer csr
tofvec = 110         ; timer overflow interrupt vector
tszvec = 114         ; timer st2 interrupt vector

ct1csr = 170420      ; counter 1 csr address
ct1bpr = ct1csr + 2  ; counter 1 bpr address
ct1ofv = 120         ; counter 1 overflow interrupt vector
ct1s2v = 124         ; counter 1 st2 interrupt vector

ct2csr = 170430      ; counter #2 csr address
ct2bpr = ct2csr + 2  ; counter #2 bpr address
ct2ofv = 130         ; counter #2 overflow interrupt vector
ct2s2v = 134         ; counter #2 st2 interrupt vector

ct3csr = 170440      ; counter #3 csr address
ct3bpr = ct3csr + 2  ; counter #3 bpr address
ct3ofv = 140         ; counter overflow interrupt vector
ct3s2v = 144         ; counter st2 interrupt vector

ct4csr = 170450      ; counter #4 csr address
ct4bpr = ct4csr + 2  ; counter #4 bpr address
ct4ofv = 150         ; counter overflow interrupt vector
ct4s2v = 154         ; counter st2 interrupt vector

```

; initialize for mmt

;

```

low    10000000      ; processor status word

```

```
;  
; DEFINE THE KERNEL PAGE ADDRESS REGISTERS  
;  
kpar0 = 172340  
kpar1 = kpar0 + 2  
kpar2 = kpar1 + 2  
kpar3 = kpar2 + 2  
kpar4 = kpar3 + 2  
kpar5 = kpar4 + 2  
kpar6 = kpar5 + 2  
kpar7 = kpar6 + 2  
;  
; DEFINE THE KERNEL PAGE DESCRIPTION REGISTERS  
;  
kpdr0 = 172300  
kpdr1 = kpdr0 + 2  
kpdr2 = kpdr1 + 2  
kpdr3 = kpdr2 + 2  
kpdr4 = kpdr3 + 2  
kpdr5 = kpdr4 + 2  
kpdr6 = kpdr5 + 2  
kpdr7 = kpdr6 + 2  
;  
;  
; DEFINE THE USER PAGE ADDRESS REGISTERS  
;  
upar0 = 177640  
upar1 = upar0 + 2  
upar2 = upar1 + 2  
upar3 = upar2 + 2  
upar4 = upar3 + 2  
upar5 = upar4 + 2  
upar6 = upar5 + 2  
upar7 = upar6 + 2  
;  
; DEFINE THE USER PAGE DESCRIPTION REGISTERS  
;  
updr0 = 177600
```

```

updr1 = updr0 + 2
updr2 = updr1 + 2
updr3 = updr2 + 2
updr4 = updr3 + 2
updr5 = updr4 + 2
updr6 = updr5 + 2
updr7 = updr6 + 2
;

```

```

sr0 = 177572    ; memory management register 0
sr3 = 172516    ; memory management register 3
;

```

```

locan::

```

```

;
;  SETUP KERNEL MODE MEMORY MANAGEMENT REGISTERS
;
;    bic #140000,psw      ; put in kernel mode

    bis #30000,psw        ; set previous mode to user

;    bis #20,sr0          ; enable 22 bit addressing

    mov #0,kpar0
    mov #200,kpar1
    mov #400,kpar2
    mov #600,kpar3
    mov #1000,kpar4
    mov #1200,kpar5
    mov #1400,kpar6
    mov #177600,kpar7

;
    mov #77406,kpar0
    mov #77406,kpar1
    mov #77406,kpar2
    mov #77406,kpar3
    mov #77406,kpar4

```



```

;
    mov #tofisr,@#tofvec ; timer overflow int. service routine
    mov #340,@#<tofvec+2>

    mov #ts2isr,@#ts2vec ; timer st2 int. service routine
    mov #340,@#<ts2vec+2>

; all counter overflow interrupts are handled by the same routine

    mov #cofisr,@#ctlofv
    mov #340,@#<ctlofv+2>

    mov #corisr,@#ct2ofv
    mov #340,@#<ct2ofv+2>

    mov #corisr,@#ct3ofv
    mov #340,@#<ct3ofv+2>

    mov #cofisr,@#ct4ofv
    mov #340,@#<ct4ofv+2>

;
; setup memory management variables
;
    mov #2000,uprmb ; Number of physical memory block
;
; initialize virtual address pointer to the starting address of
; page 0.
; all accesses to addresses in page 0 is remapped to physical
; memory by
; use of the kernel FAR6 register.
;
    mov #14000,vir ; starting virtual addr. of page 0
;
    mov uphmb,#uprmb ; set page 0 relocation constant

return

```

```

;
; variable values and/or addresses are stored here
;

aiflag:    .word 0           ; address of error flag
andbpr:    .word 0           ; address of initial bpr
ambpr:     .word 0           ; address of run bpr
aspnts:    .word 0           ; address of # x points
aypnts:    .word 0           ; address of # ypnts
aofcnt:    .word 0           ; address of overflow count ( x
point )
as2cnt:    .word 0           ; address of st2 count ( y point )
aexst2:    .word 0           ; address of expecting st2 int. flag
acover:    .word 0           ; address of counter overflow count

nrois:     .word 0           ; # of regions of interest
;
nphmb:     .word 0           ; physical memory block pointer
vad:       .word 0           ; address pointer for page 6 access

count1:    .word 0           ; counter 1 bpr value
count2:    .word 0           ; counter 2 bpr value
count3:    .word 0           ; counter 3 bpr value
count4:    .word 0           ; counter 4 bpr value

;
; list of counter csr addresses
;
csra:      .word ct1csr      ; counter 1 csr address
          .word ct2csr
          .word ct3csr
          .word ct4csr
;
; list of counter bpr addresses
;
bpra:      .word ct1bpr      ; counter 1 bpr address
          .word ct2bpr

```



```

        .word ct3bpr
        .word ct4bpr

;
;
        .title Fast Scan Interrupt Service Routines
;
;
; timer overflow interrupt service routine
;
tofisr:
        mov r0,-(sp)          ; save register contents on stack
        mov r1,-(sp)
        inc @aofcnt          ; increment timer overflow interrupt
count
;
; counter service routine
;
; counter st2 flags are caused by the overflow of the timer
board.
; when this interrupt occurs, the data is ready to be read from
the
; counter's bpr register.
;
; test the counter's overrun bit
;
        mov nrois, r0 ; load r0 with # of rois for looping
        mov #ccsra, r1 ; get address of counter csr address list

loop1:
        bit #10000,*(r1) ; check counter overrun bit
        beq 10$          ; jump if not overrun
;
; overrun, stop all iors, set error flag, and exit
;
        add #10., r0 ; calculate error flag
        neg r0

```

```

mov    r0, @aiflag    ; set error flag - counter overrun
jmp    abort

;
clr    @#csrtim    ; disable timer interrupts
clr    @#ct1csr    ; disable counter interrupts
clr    @#ct2csr
clr    @#ct3csr
clr    @#ct4csr
mov    (sp)+, r1    ; restore registers from stack
mov    (sp)+, r0
rti

10$:
;
; test counter ST2 flag, should be set because of timer overflow
;
    bit    #1000000, @(r1)    ; check counter st2 flag bit
    bne    20$    ; jump if ST2 flag set
;
; ST2 flag not set, stop all isrs, set error flag, and exit
;
    add    #20., r0    ; calculate error flag value
    neg    r0
    mov    r0, @aiflag    ; set error flag - counter overrun
    jmp    abort

;
clr    @#csrtim    ; disable timer interrupts
clr    @#ct1csr    ; disable counter interrupts
clr    @#ct2csr
clr    @#ct3csr
clr    @#ct4csr
mov    (sp)+, r1    ; restore registers from stack
mov    (sp)+, r0
rti

;
20$: bic    #1000000, @(r1)    ; clear counter st2 flag for next
interrupt
;

```

```

        sub    r0, loop1 ; loop if not finished
;
; read and save data
;
        cmp    @aofcnt,#1 ; is this the first interrupt of x scan ?
        beq    rdynxt      ; jump if yes, don't save data
;
; no, then save the counter's bpr reading
;
        mov    @#<ctlcsr+2>,count1 ; read counter 1's bpr
        mov    count1,-(sp) ; place bpr value on stack
;
        bit    #1,sr0      ; is mmu on ?
        beq    9$          ; jump if not
        halt
9$:
        bis    #30000,psw    ; set previous mode to user
        inc    sr0          ; turn memory management on
        bis    #20,sr3      ; enable 22 bit addressing
;
; put counter readings on stack, then move to upper memory
;
        mov    nrois, r0    ; put # roi's in r0 for looping
        mov    #cbpra, r1   ; get address of counter bpr address list
;
loop2:
        mov    @(r1)+, -(sp) ; read counter bpr and put on stack
;
        mov    count1,@vad   ; save data in upper memory
;
        mtpi   @vad         ; save data in upper memory
;
        cmp    #157776,vad   ; was this the last addr. of page 6
        bne    11$          ; jump if not
;
; last addr. of page 6, set relocation value for next physical
page
;

```

```

        mov #140000,vad      ; init. address for start of virtual page
6
        add #200,nphmb       ; increment to the next physical page (
128
                                ; memory blocks away )
        mov nphmb,@#upar6    ; set mmu register for next page
        br 20$

11$: inc vad
    inc vad                  ; increment addr. for next data point

20$: sob r0,loop2           ; loop for more rois

        clr sr3              ; disable 22 bit addressing
        clr sr0              ; turn mmu off
;

rdynrt:
    cmp @aofcnt,@axpnts ; is this the end of the X scan ?
    bgt 30$                ; jump if yes
;
; get ready for next interrupt
;
    clr @aext2              ; set flag, no timer ST2 interrupts
expected
;
    bit #10000,@#csrtim ; check timer overrun bit
    beq 27$                ; jump if not overrun
;
; timer overrun, stop all isrs, set error flag, and exit

    mov #-30.,@aiflag      ; set error flag - timer overrun
    jmp abort

    clr @#csrtim           ; disable timer interrupts
    clr @#ct1csr           ; disable counter interrupts
    clr @#ct2csr
    clr @#ct3csr

```

```

        clr    @#ct4csr
        mov    (sp)+,r1    ; restore registers from stack
        mov    (sp)+,r0
        rti
;
27$:
;
; clear the timer overflow bit, ready for next interrupt
;
        bic    #200,@#csrtim
        mov    (sp)+,r1    ; restore registers from stack
        mov    (sp)+,r0
        rti
;
30$:
        bit    #10000,@#csrtim ; test timer overrun bit
        beq    35$          ; jump if no overrun
; overrun, stop all isrs, set error flag, and exit
        mov    #-40.,@aiflag  ; set error flag - timer overrun
        jmp    abort

        clr    @#csrtim    ; disable timer interrupts
        clr    @#ct1csr    ; disable counter interrupts
        clr    @#ct2csr
        clr    @#ct3csr
        clr    @#ct4csr
        mov    (sp)+,r1    ; restore registers from stack
        mov    (sp)+,r0
        rti
35$:
;
; disable timer overflow interrupts and enable timer st2
interrupts
;
        mov    #40001,@#csrtim ; setup counter to int. on st2
        inc    @aenst2        ; flag expected timer st2 interrupt
        mov    (sp)+,r1    ; restore registers from stack
        mov    (sp)+,r0

```

```

        rti

abort:
        clr  @#csrtim  ; disable timer interrupts

        mov  nrois, r0 ; load r0 for looping
        mov  #ccsra, r1 ; get addr. of list of counter csr addr.
abrt1:
        clr  @(r1)+      ; disable counter interrupt
        scb  r0,abrt1    ; loop for each roi

        mov  (sp)+,r1    ; restore registers from stack
        mov  (sp)+,r0
        rti

ts2isr:
;
; timer st2 interrupt service routine
;
; timer st2 interrupts occur when the Unidex III has moved into
position
; for the next x scan ( after y move ).
;
; iflag = 100 when finished
;
; count # interrupts to determine when the scan has finished.
;
; clear flag, st2 interrupt not expected before end of next x
scan
;

        mov  r0, -(sp)          ; save registers
        mov  r1, -(sp)

        clr  @aexst2           ; clear flag, not expecting st2

```

```

incr.
    clr    @aofcnt                ; : scan end, zero timer overflow
;
;
    inc    @as2cnt                ; next y line, incr. timer st2 count
;
    bit    #10000,@#csrtim        ; test timer overrun bit
    beq    20$                   ; jump if no overflow
;
; overflow, stop interrupt routines and set error flag
    mov    #-210.,@aiflag
    jmp    abort

    clr    @#csrtim
    clr    @#ctlcsr
    clr    @#ct2csr
    clr    @#ct3csr
    clr    @#ct4csr
    mov     (sp)+,r1
    mov     (sp)+,r0
    rti
;
;
; timer csr must be cleared for the bpr switching to work
;
    clr    @#csrtim
;
    cmp     @as2cnt,@aypnts        ; has scan finished ?
    ble     40$                   ; jump if not
;
; scan finished
;
    mov     #100.,@aiflag
    jmp     abort

    clr     @#csrtim
    clr     @#ctlcsr
    clr     @#ct2csr

```

```

        clr    @#ct3csr
        clr    @#ct4csr
        mov    (sp)+, r1
        mov    (sp)+, r0
        rti
;
;
40$: ; scan not finished
;
;
; scan not finished, ready and start next scan
;

        mov    r0is, r0          ; load r0 for looping
        mov    #ccsra, r1        ; get addr. of counter csr addr.
list
loopx:
        mov    #20166, @ (r1)+    ; ready counter for next x scan
        sub    r0, loopx          ; loop to setup all counters used

        mov    (sp)+, r1          ; restore registers
        mov    (sp)+, r0

        mov    @andbpr, @#<csrtim+2> ; set timer bpr for interrupt delay
;
;        mov    #153, @#csrtim      ; start timer
;
        mov    #163, @#csrtim      ; start timer
        mov    @ambpr, @#<csrtim+2> ; set timer bpr for x scan
        rti
;
;
cofiscr:
;
; counter overflow interrupt service routine
;
; a counter overflow will only occur when more than 65535 counts
are

```


; taken within the specified count time. if this occurs, then the counter

; overflow flag is incremented to keep count of these occurrences.

;

```
mov r0, -(sp)      ; save registers
mov r1, -(sp)
```

```
mov nrois, r0      ; load r0 for looping
mov #ccsra, r1      ; get addr. of counter csr addr. list
```

loopc:

```
bit  #10000,2(r1)   ; test counter overrun bit
beq  10$            ; jump if overrun bit not set
```

```
clr  @#csrtim      ; disable timer interrupts
clr  @#ct1csr      ; disable counter interrupts
clr  @#ct2csr
clr  @#ct3csr
clr  @#ct4csr
```

```
; calculate error flag to indicate which counter overflowed.
; since r0 is decremented from the # of POIs, the # of the
; counter board can be calculated by the equation
; board# = #POIs + 1 - r0
```

```
neg  r0
inc  r0
add  nrois,r0
add  #220.,r0      ; #220 randomly chosen for overflow error
neg  r0            ; negative # for errors
mov  r0, @aiflag    ; set flag, counter overflow overrun
```

```
mov  (sp)+, r1     ; restore registers
mov  (sp)+, r0
```

```
rti
```

;

```

inc  @acover      ; increment counter overflow count
bic  #200,@(r1)   ; clear counter overflow flag
sdb  r0, loops    ; check all counters

```

```

mov  (sp)+, r1    ; restore registers
mov  (sp)+, r1
rti

```

```

;
; this routine initializes the variables for the get point
routine
;

```

```

iget::

```

```

mov  #0,kpar0
mov  #200,kpar1
mov  #400,kpar2
mov  #600,kpar3
mov  #1000,kpar4
mov  #1200,kpar5
mov  #1400,kpar6
mov  #177600,kpar7

```

```

;

```

```

mov  #77406,kpar0
mov  #77406,kpar1
mov  #77406,kpar2
mov  #77406,kpar3
mov  #77406,kpar4
mov  #77406,kpar5
mov  #77406,kpar6
mov  #77406,kpar7

```

```

mov  #140000,ma
mov  #2000,apara
mov  apara,1#apara

```

```

dis  #30000,paw      ; set previous mode to user

```

```

        bis #30000,psw        ; set previous mode to user

;   bis #20,sr3              ; enable 22 bit addressing
    return

;
;   this routine operates sequentially, after the value of the data
point
;   is passed to the calling routine, it increments a pointer to
the next
;   data point value. "iget" must be called before calling this
routine
;   since it initializes the variables used here.
;

getpnt::
    bis #30000,psw        ; set previous mode to user
    inc sr0              ; turn memory management on
    bis #20,sr3          ; enable 22 bit addressing
    mfpi @vad            ; read value from upper memory to stack
    clr sr3              ; disable 22 bit addressing
    clr sr0              ; turn mmu off

    mov (sp)+,count1

    mov count1,@2.(r5)    ; pass the value to the calling routine

    cmp #157776,vad       ; is this the last addr. on page 6
    bne 14$              ; jump if not

    mov #140000,vad       ; set virtual addr to beginning of page 6
    add #200,nphmb        ; increment memory block to next phy.
page
    mov nphmb,@#upar6     ; setup mmu register for remap
    br 13$

14$:
    inc vad

```

```

19$:
    return

;
;
; this routine initializes the variables for the put point
routine
;

iput::
    mov #0,kpar0
    mov #200,kpar1
    mov #400,kpar2
    mov #600,kpar3
    mov #1000,kpar4
    mov #1200,kpar5
    mov #1400,kpar6
    mov #177600,kpar7

;
    mov #77406,kpdr0
    mov #77406,kpdr1
    mov #77406,kpdr2
    mov #77406,kpdr3
    mov #77406,kpdr4
    mov #77406,kpdr5
    mov #77406,kpdr6
    mov #77406,kpdr7

    mov #140000,vad
    mov #2000,nphmb
    mov nphmb,@#update

    lis #30/30,pow      ; set previous mode to user
    return

;
; this routine operates sequentially, after the value of the data

```

; this routine operates sequentially, after the value of the data point

; is passed to this routine, it increments a pointer to the next
; data point address. "iput" must be called before calling this
routine

; since it initializes the variables used here.

;

putpnt::

bis #30000,psw ; set previous mode to user
mov @2.(r5),count1 ; get the value from the calling routine
mov count1,-(sp) ; put it on the stack

inc sr0 ; turn memory management on
bis #20,sr3 ; enable 22 bit addressing
mtpi @vad ; move value from stack to upper memory
clr sr3 ; disable 22 bit addressing
clr sr0 ; turn mmu off

cmp #157776,vad ; is this the last addr. on page 6
bne 14\$; jump if not

mov #140000,vad ; set virtual addr to beginning of page 6
add #200,nphmb ; increment memory block to next phy.

page

mov nphmb,@#upar6 ; setup mmu register for remap
br 19\$

14\$:

inc vad
inc vad ; increment to next data point address

19\$:

return
.end

FILENAME: GETBDS.FOR

```

      SUBROUTINE GETBDS ( IOPT, NROIS, IXPNTS, IYPNTS, XDIR,
1          XFEED, XMOVE, YDIR, YFEED, YMOVE )
C
C  THIS ROUTINE GETS THE DATA TO PROGRAM THE UNIDEX III FOR A
C  BIDIRECTIONAL
C  SCAN.
C
      LOGICAL*1 FILEA(40),ANS,CHNG
      INTEGER*2 IOPT
C
      XSPM = 1. ! # OF STEPS PER MICRON ON X AXIS
      YSPM = 1. ! # OF STEPS PER MICRON ON Y AXIS
C
C  GET SETUP INFO. FROM FILE IF SELECTED
C
      IF ( IOPT .EQ. 1 ) CALL FILESU ('R', IXPNTS, XMOVE,
1          XFEED, IYPNTS, YMOVE, YFEED,
1          NROIS, IQUAD )
C
      IF ( IOPT .EQ. 1 ) GOTO 141
C
      chng='N'
C
131  CALL CLEAR
132  CONTINUE
C
140  CONTINUE
      IF (CHNG.EQ.'Y') WRITE(5,343) IXPNTS
143  FORMAT(' NUMBER OF X POINTS = ',I6)
      IF (CHNG.EQ.'N') WRITE(5,41)
141  FORMAT(' NUMBER OF X POINTS ( 0 TO 32767 FOR LINE SCAN) : ')
      READ(5,42) NC,NUM
142  FORMAT(I2,I7)
      X POINTS LIMITED TO 512 BUT CAN BE SET TO 32767
      CHANGED TO 32767 ON 11-22-88. DAC.

```

```

IF (NC.EQ.0.AND.CHNG.EQ.'Y') GOTO 20
IF (NC.EQ.0) GOTO 40
IF (INUM.LT.0.OR.INUM.GT.32767) GOTO 40
IXPNTS=INUM

C
20 CONTINUE
IF (CHNG.EQ.'Y') WRITE(5,23) XMOVE
23 FORMAT (' X POINT SIZE ( MICRONS ) = ',F15.1)
IF (CHNG.EQ.'N') WRITE(5,21)
21 FORMAT (' X POINT SIZE ( 0.1 TO 1000 MICRONS ) ?')
READ(5,22) NC,RNUM ! # OF STEPS TO MOVE AXIS FOR NEXT POINT
22 FORMAT(Q,F15.0)
2 MAX. X MOVE IS 2,000,000,000
IF (NC.EQ.0.AND.CHNG.EQ.'Y') GOTO 30
IF (NC.EQ.0) GOTO 20
XSPP = AINT ( rnum * XSPP ) ! CALC. # OF steps IN X MOVE
IF ( XSPP .LT. 1.0 .OR. XSPP .GT. 10000.0 ) GOTO 20
XMOVE=RNUM ! DATA POINT SIZE ( MICRONS )

C
30 CONTINUE
TSMIN = 6.0E-6 ! MINIMUM TIME PERIOD PER STEP
TSMAX = 4000.0 ! MAXIMUM TIME PERIOD PER STEP
TPMIN = TSMIN*XMOVE ! MINIMUM TIME PER DATA POINT
TPMAX = TSMAX*XMOVE ! MAXIMUM TIME PER DATA POINT

IF (CHNG.EQ.'Y') WRITE(5,33) XFEED
33 FORMAT(' TIME PER POINT ( SECONDS ) = ',F15.6)
IF (CHNG.EQ.'N') WRITE(5,31) TPMIN, TPMAX
31 FORMAT(' TIME per X POINT ( ',E15.6,' TO ',E15.6,' SECONDS )
?)
READ(5,32) NC,RNUM ! FEEDRATE FOR MOVES BETWEEN POINTS
32 FORMAT(Q,F15.6)
FEEDRATE LIMIT OF 10,000 CHOSEN BY PROGRAMMER CAN BE CHANGED
IF (NC.EQ.0.AND.CHNG.EQ.'Y') GOTO 50
IF (NC.EQ.0) GOTO 30
XSTIM = RNUM / XSPP ! CALCULATE STEP TIME
IF ( XSTIM .LT. TPMIN .OR. XSTIM .GT. TPMAX ) GOTO 30
XFEED=RNUM

```

```

C
50  CONTINUE
60  continue
C
90  CONTINUE
    IF(CHNG.EQ.'Y') WRITE(5,293) IYPNTS
293  FORMAT(' NUMBER OF Y POINTS = ',I6)
    IF(CHNG.EQ.'N') WRITE(5,91)
91  FORMAT(' NUMBER OF Y POINTS ( 1 TO 512 ) ? ')
    READ(5,92) NC, INUM
92  FORMAT(Q, I7)
C  Y POINTS LIMITED TO 512 BUT CAN BE SET TO 32767
    IF(NC.EQ.0.AND.CHNG.EQ.'Y') GOTO 70
    IF(NC.EQ.0) GOTO 90
    IF(INUM.LT.1.OR.INUM.GT.32000) GOTO 90
    IYPNTS=INUM
C
70  CONTINUE
    IF(CHNG.EQ.'Y') WRITE(5,273) YMOVE
273  FORMAT(' Y MOVE ( MICRONS ) = ',F15.0)
    IF(CHNG.EQ.'N') WRITE(5,71)
71  FORMAT(' Y MOVE ( 0.1 TO 1000 MICRONS ) ? ')
    READ(5,72) NC,RNUM  ! # OF STEPS TO MOVE Y AXIS FOR NEXT SCAN
72  FORMAT(Q,F15.0)
C  MAX. Y MOVE IS 2,000,000,000
    IF(NC.EQ.0.AND.CHNG.EQ.'Y') GOTO 80
    IF(NC.EQ.0) GOTO 70
    YMS = rnum * YSPM  ! # OF steps in Y move
    IF ( YMS .LT. 1.0 .OR. YMS .GT. 10000.0 ) GOTO 70
    YMOVE=RNUM
C
80  continue
C
    TSMIN = 6.0E-6      ! MINIMUM TIME PERIOD PER STEP
    TSMAX = 4000.0      ! MAXIMUM TIME PERIOD PER STEP
    TPMIN = TSMIN * YMOVE  ! MINIMUM TIME PER DATA POINT
    TPMAX = TSMAX * YMOVE  ! MAXIMUM TIME PER DATA POINT

```



```

      IF(CHNG.EQ.'Y') WRITE(5,283) YFEED
283  FORMAT(' Y MOVE TIME ( SECONDS ) = ',F15.6)
      IF(CHNG.EQ.'N') WRITE(5,81) tpmin, tpmax:
81  FORMAT(' TIME per Y MOVE ( ',E15.6,' TO ',E15.6,' SECONDS )
      ?')
      READ(5,82) NC,RNUM ! FEEDRATE FOR MOVES BETWEEN POINTS
82  FORMAT(Q,F15.6)
      IF(NC.EQ.0.AND.CHNG.EQ.'Y') GOTO 100
      IF(NC.EQ.0) GOTO 80
      YSTIM = RNUM / YMS ! CALCULATE STEP TIME FOR Y MOVE
      IF( YSTIM .LT. tpmin .OR. YSTIM .GT. tpmax ) GOTO 80
      YFEED=RNUM
C
100  CONTINUE
110  continue
C
129  CONTINUE
C
3110 CONTINUE
      IF(CHNG.EQ.'Y') WRITE(5,5113) nrois
5113 format(' NUMBER OF ROIS = ',I3)
      IF(CHNG.EQ.'N') WRITE(5,3111)
3111 FORMAT(' How many ROIs ? ( 1 - 4 ) ')
      READ(5,3112) NC,rnum ! # of regions of interest
3112 FORMAT(Q,F15.6)
      IF(NC.EQ.0.AND.CHNG.EQ.'Y') GOTO 3129
      IF(NC.EQ.0) GOTO 3110
      IF(RNUM.LT.1.0.OR.RNUM.GT.4.0) GOTO 3110
      nrois = RNUM
C
3129 continue
C
1344 IF(CHNG.EQ.'N') write(5,1345)
1345 format (
1      ' The initial beam location on',/,
1      ' the specimen is the origin.',/,
1      ' ',/,

```

```

1      ' ',/,
1      '      |',/,
1      '      2 | 1',/,
1      '      |',/,
1      '      -----X-----',/,
1      '      |',/,
1      '      3 | 4',/,
1      '      |',/,
1      ' ',/,
1      ' Enter the # of the specimen',/,
1      ' quadrant to be scanned. ')

C
      IF (CHNG.EQ.'Y') WRITE(5,6333) IQUAD
6333  FORMAT(' SPECIMEN SCAN QUADRANT = ',I3)
C
      read(5,1346) NC,INUM
1346  format(Q,i2)
      IF(NC.EQ.0) GOTO 141
      if(inum.lt.1.or.inum.gt.4) goto 1344
C
      IQUAD = INUM
      xdir = 1.0 ! define x direction for quadrant #1
      ydir = -1.0 ! define y direction for quadrant #1
      if(iquad.eq.2.or.iquad.eq.3) xdir = -xdir
      if(iquad.eq.3.or.iquad.eq.4) ydir = -ydir
C
C
141  CONTINUE
      CALL CLEAR

      WRITE(5,43) IXPNTS, XMOVE, XFEED
43   FORMAT (' NUMBER OF X POINTS = ',I6,/,
1      ' X POINT SIZE ( MICRONS ) = ',F15.1,/,
1      ' TIME PER POINT ( SECONDS ) = ',F15.6)
C
      WRITE(5,93) IYPNTS, ymove, yfeed
93   FORMAT (' NUMBER OF Y POINTS = ',I6,/,
1      ' Y MOVE ( MICRONS ) = ',F15.0,/,

```

```

1      ' Y MOVE TIME ( SECONDS ) = ',F15.6)
C
write(5,3113) nrois, iquad
3113 format (' NUMBER OF ROIS = ',I3,/,
1      ' SPECIMEN SCAN QUADRANT = ',i3)
C
xdir = 1.0 ! define x direction for quadrant #1
ydir = -1.0 ! define y direction for quadrant #1
if(iquad.eq.2.or.iquad.eq.3) xdir = -xdir
if(iquad.eq.3.or.iquad.eq.4) ydir = -ydir
C
XSPP = AINT ( XMOVE * XSPM ) ! CALC. # OF steps IN X MOVE
XSTIM = XFEED / XSPP ! CALCULATE STEP TIME
YMS = AINT ( YMOVE * YSPM ) ! # OF steps in Y move
YSTIM = YFEED / YMS ! CALCULATE STEP TIME FOR Y MOVE
C
XFDR = 1.0 / XSTIM ! X FEED RATE
YFDR = 1.0 / YSTIM ! Y FEED RATE
C
WRITE(5,483) XSPP, XSTIM, XFDR, YMS, YSTIM, YFDR
483 FORMAT ('0CALCULATIONS ',//,
1      ' # X STEPS PER POINT = ',F15.0,/,
1      ' X STEP TIME = ',F15.6,/,
1      ' X FEED RATE = ',F15.3,/,
1      ' # Y STEPS PER MOVE = ',F15.0,/,
1      ' Y STEP TIME = ',F15.6,/,
1      ' Y FEED RATE = ',F15.3)
170 WRITE(5,171)
171 FORMAT('0CHANGES / CORRECTIONS ? ')
READ(5,172) CHNG
172 FORMAT(A1)
IF(CHNG.EQ.'N') GOTO 120
IF(CHNG.NE.'Y') GOTO 170
C
WRITE(5,173)
173 FORMAT('0ENTER NEW VALUE OR LEAVE BLANK TO RETAIN PRESENT
VALUE. ')
GOTO 782

```

```

C
120  CONTINUE
      WRITE(5,121)
121  FORMAT('OSAVE SCAN SETUP ? ')
      READ(5,122) ANS
122  FORMAT(A1)
      IF(ANS.EQ.'N') GOTO 130
      IF(ANS.NE.'Y') GOTO 120
C
C  WRITE SETUP INFO. TO FILE
C
      CALL FILESU ('W', IXPNTS, XMOVE, XFEED, IYPNTS,
1          YMOVE, YFEED, NROIS, IQUAD )
C
130  CONTINUE
C
      return
      end

      SUBROUTINE FILESU ( RWC, IXPNTS, XMOVE, XFEED, IYPNTS,
1          YMOVE, YFEED, NROIS, IQUAD )
C
C  THIS ROUTINE GETS THE SETUP INFORMATION FROM A FILE
C
C  READ THE SETUP INFO. FROM AN INPUT FILE
C
      BYTE RWC  ! CHARACTER TO INDICATE READ OR WRITE ( R OR W ) TO
FILE
      BYTE FILENA ( 40 )
C
      IF(RWC.EQ.'R') GOTO 76
      IF(RWC.EQ.'W') GOTO 126
      WRITE(5,10) RWC
10   FORMAT(' FILESU - INVALID READ/WRITE CHARACTER = ',A1)
      RETURN
C

```

```

76    WRITE(5,4124)
4124  FORMAT('ENTER NAME OF FILE CONTAINING SETUP DATA ? ')
      READ(5,4125) NCFN,FILENA
4125  FORMAT(Q,40A1)
      IF(NCFN.EQ.0) GOTO 76
      FILENA(NCFN+1)=0
      OPEN(UNIT=1,NAME=FILENA,TYPE='OLD',CARRIAGECONTROL='LIST')
C
      READ(1,642) IXPNTS
      READ(1,622) XMOVE
      READ(1,632) XFEED
C      READ(1,652) YDIR
      READ(1,692) IYPNTS
      READ(1,672) YMOVE
      READ(1,682) YFEED
C      READ(1,6102) YDIR
      READ(1,6123) nrois
      READ(1,6130) IQUAD
      CLOSE(UNIT=1)
C
      RETURN
C
C  WRITE THE SETUP INFO. TO THE FILE
C
126   WRITE(5,124)
124   FORMAT(' ENTER FILENAME FOR SAVING SETUP DATA ? ')
      READ(5,125) NCFN,FILENA
125   FORMAT(Q,40A1)
      IF(NCFN.EQ.0) GOTO 126
      FILENA(NCFN+1)=0
      OPEN(UNIT=1,NAME=FILENA,TYPE='NEW',CARRIAGECONTROL='LIST')
.
      WRITE(1,642) IXPNTS
642   FORMAT(I7)
      WRITE(1,622) XMOVE
622   FORMAT(F15.0)
      WRITE(1,632) XFEED
632   FORMAT(F15.6)

```

```
C      WRITE(1,652) XDIR
C652  FORMAT(F15.0)
      WRITE(1,692) XYPNTS
692   FORMAT(I7)
      WRITE(1,672) XMOVE
672   FORMAT(F15.0)
      WRITE(1,682) XFEED
682   FORMAT(F15.6)
      write(1,6123) nrois
6123  format(i6)
      WRITE(1,6130) IQUAD
6130  FORMAT(I3)
C
      CLOSE(UNIT=1)
      RETURN
      END
```

FILENAME: SAVDAT.FOR

```

      subroutine savdat ( ixpnts, iypnts, nrois )
c
c   this routine gets the data from memory and puts it in a data
c   file
c
c      integer*2 isdata ( 4, 512 )      ! data buffer for 1 line
c
c      WRITE(1,833) IXPNTS,IYPNTS,NROIS      ! FIRST LINE OF DATA FILE
833  FORMAT('+',I9,3X,I9,3X,I9)
c
c      CALL IGET ! INITIALIZE "GETPNT" ROUTINE
c
c      LOOP TO GET ALL POINTS FROM UPPER MEMORY
c
200  CONTINUE
c
c      isdir = -1 ! scan direction
c
c      do 305 line = 1, iypnts
c         isdir = isdir * -1      ! calculate scan direction
c
c         if(isdir.eq.-1) goto 133 ! get reverse data
c
c         forward scan data
c
c         do 300 ipnt = 1, ixpnts
c
c            do 202 ir = 1,nrois      ! loop for each region of interest
c               CALL GETPNT ( idp )      ! GET DATA POINT ( INCR. TO NEXT )
c               isdata ( ir, 1 ) = idp      ! put data in buffer array
c            202 continue
c
c            write(1,301) (isdata(ir,1),ir=1,nrois)
c            301 format(1X,I9,3X,I9,3X,I9,3X,I9)

```

```

300  continue
c
      goto 305
c
133  continue
c
c  reverse scan data
c
      do 310 ipnt = 1, ixpnts
c
      do 212 ir = 1,nrois      ! loop for each region of interest
      CALL GETPNT ( idp )      ! GET DATA POINT ( INCR. TO NEXT )
      isdata ( ir, ipnt ) = idp ! put data in buffer array
212  continue
c
310  continue
c
c  file data in reverse order
c
      do 313 ifile = ixpnts, 1, -1
      write(1,301) ( isdata ( ir, ifile ), ir=1,NROIS )
301  format(1x,i9,3x,i9,3x,i9,3x,i9)
313  continue
c
305  continue
c
      return
      end

```


FILENAME: UDXPRG.FOR

```

      SUBROUTINE UDXPRG ( IXPNTS, XDIR, XMOVE, XFEED,
1          IYPNTS, YDIR, YMOVE, YFEED,
1          UPROG, NCUP )
C
C THIS ROUTINE CREATES THE UNIDEX III PROGRAM FOR MAKING THE SCAN
C
C PARAMETEPS ARE CALCULATED FOR THE UNIDEX III PROGRAM
C FOR MOVING TO STARTING POSITIONS AND REMOVING BACKLASH
C
C UPROG - UNIDEX PROGRAM ARRAY
C
      BYTE CR, LF, NULL
      BYTE UPROG ( 512 )
C
      CR = 13
      LF = 10
      NULL = 0
C
      XSPM = 1. ! # OF STEPS PER MICRON OF X AXIS
      YSPM = 1. ! # OF STEPS PER MICRON OF Y AXIS
C
C XTMOVE - THE TOTAL X AXIS MOVE
C
      XTMOVE = XSPM * XMOVE * FLOAT(IXPNTS) ! TOTAL # STEPS FOR
X SCAN
      XTMOVE = XTMOVE + 1. ! + 1 FOR END STEP
      XTMOVE = XTMOVE * XDIR ! SET X MOVE DIRECTION
C
      YTMOVE = YSPM * YMOVE * YDIR ! SET Y MOVE DIRECTION
C
C CONVERT PULSE PERIODS FROM SECONDS TO MICROSECONDS
C
      XFEED = XFEED/ ( XSPM * XMOVE ) * 1.0E6
      YFEED = YFEED/ ( YSPM * YMOVE ) * 1.0E6
C

```

C CONSTRUCT THE BI-DIRECTIONAL UNIDEX PROGRAM

C

ENCODE(512,133,UPROG,ERR=143) IYPNTS, XTMOVE,

1 XFEED, YTMOVE, YFEED, -XTMOVE, XFEED,

1 YTMOVE, YFEED, CR, LF, NULL

C

133 FORMAT ('G91 G662=',I6,'N1100 M-01 M-00 D200 X',

1 F15.0,'F=',F15.0,'* G672 Y',F15.0,'F=',F15.0,

1 'N0 M-01 M-00 D200 X',F15.0,'F=',F15.0,

1 'N0 G672 Y',F15.0,'F=',F15.0,' N>1100 *

1 D100 M-01 M-00 M2%',3A1)

GOTO 150

C

143 STOP ' ERROR - "FSCAN", CREATING UNIDEX PROGRAM '

C

150 IPO=0 ! POINTER TO POSITION FOR CHARACTER PLACEMENT

C

C REMOVE ALL BLANKS AND DECIMAL POINTS FROM UNIDEX PROGRAM

C

DO 250 I=1,512

IF(UPROG(I).EQ.' ') GOTO 250

IF(UPROG(I).EQ.'.') GOTO 250

IF(UPROG(I).EQ.0) GOTO 251

IPO=IPO+1

UPROG(IPO)=UPROG(I)

250 CONTINUE

251 CONTINUE

C

NCUP=IPO ! # OF CHAR. IN PROGRAM STRING

C

WRITE(5,155) NCUP

155 FORMAT(' PROGRAM LENGTH = ',I6)

WRITE(5,160) (UPROG(I),I=1,NCUP)

160 FORMAT(1X,70A1)

C

RETURN

END

FILENAME: GRINFO.FOR

```

      subroutine grinfo ( filena, ixpnts, iypnts, nrois )
c
      byte filena(40)
70  write(5,71)
71  format(' Enter filename for data ( press return to abort )')
      read(5,72) nc, (filena(i),i=1,40)
72  format(q,40a1)
      filena(nc+1)=0
      if(nc.eq.0) return
      OPEN(UNIT=1,NAME=filena,TYPE='NEW')
c
190  WRITE(5,191)
191  FORMAT(' ENTER # X POINTS')
      READ(5,192) IXPNTS
192  FORMAT(2I6)
      WRITE(5,211)
211  FORMAT(' ENTER # Y POINTS')
      READ(5,212) IYPNTS
212  FORMAT(2I6)
      WRITE(5,231)
231  FORMAT(' ENTER # ROIS')
      READ(5,232) NROIS
232  FORMAT(2I6)
c
      WRITE(5,240) IXPNTS, IYPNTS, NROIS
240  FORMAT(' # X POINTS = ',I6,' # Y POINTS = ',I6,' # ROIS = ',I4)
239  WRITE(5,241)
241  FORMAT(' CORRECT ? ')
      READ(5,242) ANS
242  FORMAT(A1)
      IF(ANS.EQ.'N') GOTO 190
      IF(ANS.NE.'Y') GOTO 239
      return
      end

```

FILENAME: PREPAR.FOR

SUBROUTINE PREPAR

C

C THIS ROUTINE PROMPTS THE USER TO SET OR CHECK THE ORIGIN AND
ROIS

C

233 WRITE(5,234)

234 FORMAT (' HAS THE ORIGIN BEEN SET (Y = CONTINUE,
1 N = STOP) ? ')

READ(5,235) NC,ANS

235 FORMAT(Q,A1)

IF(NC.EQ.0) GOTO 233

IF(ANS.EQ.'N') STOP

IF(ANS.NE.'Y') GOTO 233

C

243 WRITE(5,244)

244 FORMAT(' NOTE: IF THE MCA IS ACQUIRING WHEN

1 AN ROI IS DEFINED, IT MUST BE ',/,

1' STOPPED AND RESTARTED FOR IT TO

1 RECOGNIZE THE ROI (PRESS ',/,

1' THE "STOP" BUTTON AND

1 THEN THE "ACQUIRE" BUTTON). ')

245 WRITE(5,246)

246 FORMAT('OHAVE THE ROI(S) BEEN SET (Y = CONTINUE, N = STOP)
? ')

READ(5,247) NC,ANS

247 FORMAT(Q,A1)

IF(NC.EQ.0) GOTO 245

IF(ANS.EQ.'N') STOP

IF(ANS.NE.'Y') GOTO 245

RETURN

END

APPENDIX D EXAMPLE UNIDEX III PROGRAM

IYPNTS = # LINES = 2
 XTMOVE = TOTAL # X STEPS FOR 1 LINE = 5
 XFEED = 1/(X FEEDRATE) = TIME DELAY PER STEP = 1/20
 YTMOVE = # Y STEPS TO MOVE FOR NEXT X LINE SCAN = 2
 YFEED = 1/(Y FEEDRATE) = TIME TO MOVE TO NEXT LINE = 1/20

NOTE: For the example given in this report, the angle bracketed variables below should be replaced with the appropriate values.

```

G91                ! PUT UNIDEX IN INCREMENTAL MOVE MODE
G662= <IYPNTS>      ! SET LOOP COUNTER WITH # X AXIS SCANS

N1100              ! LABEL FOR BEGINNING OF LOOP

M-01               ! SET THE BEGINNING OF SCAN OUTPUT
M-00               ! CLEAR THE OUTPUT
                  ! ( THIS IS ST2 PULSE FOR STEP COUNTER )
                  ! APPROXIMATELY 2 MILLISECONDS LONG

D200               ! 200 MILLISECOND DELAY TO ALLOW FOR
                  ! STEP COUNTER ST2 INTERRUPT ROUTINE TO
                  ! SETUP THE OVERFLOW INTERRUPT ROUTINE

X <XTMOVE>          ! BEGINS X AXIS SCAN
F= <XFEED>          ! WITH THIS TIME PER STEP ( 1/FEEDRATE )
*                  ! PROGRAM WAITS UNTIL X MOVE COMPLETED

G672               ! DECREMENT SCAN LINE COUNT AND JUMP
                  ! FORWARD TO * IF ZERO

Y <YTMOVE>          ! BEGIN Y MOVE TO NEXT X SCAN LINE
F= <YFEED>          ! WITH THIS TIME PER STEP
NO                 ! PROGRAM WAITS UNTIL MOVE COMPLETED

M-01               ! SET THE BEGINNING OF SCAN OUTPUT
M-00               ! CLEAR THE OUTPUT
                  ! ( THIS IS ST2 PULSE TO STEP COUNTER )

D200               ! 200 MILLISECOND DELAY TO ALLOW ST2
                  ! INTERRUPT ROUTINE TO SETUP OVERFLOW
                  ! INTERRUPT ROUTINE

X <-XTMOVE>         ! BEGIN REVERSE X AXIS SCAN
F= <XFEED>          ! WITH THIS TIME PER STEP
NO                 ! PROGRAM WAITS UNTIL MOVE COMPLETED
  
```

```
G672          ! DECREMENT LINE SCAN COUNT AND JUMP
              ! FORWARD TO * IF ZERO

Y <YTMOVE>    ! BEGIN MOVE TO NEXT X SCAN LINE
F= <YFEED>    ! WITH THIS TIME PER STEP

N>1100        ! PROGRAM WAITS UNTIL MOVE COMPLETED AND
              ! JUMPS BACK TO LABEL N1100

*            ! HERE THE SCAN PROGRAM IS FINISHED

D100          ! 100 MILLISECOND DELAY

M-01          ! OUTPUT PULSE TO FOR ST2 INTERRUPT
M-00          ! ROUTINE CHECK SCAN COMPLETION

M2           ! END OF PROGRAM
```

Distribution:

A.K. Lee/DOE-OSTI-9731-MS-8175(2)
S.G. Snow/W.D. Brosey
Y-12 Central Files
9202 File Point

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5 / 16 / 94

END